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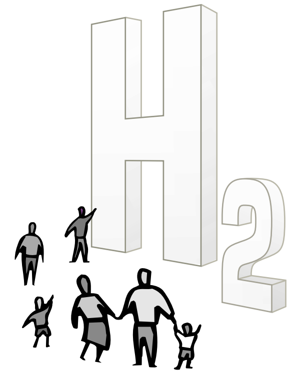
RMI Solutions

NEWSLETTER

AMORY B. LOVINS'S

Hydrogen Primer



If there were no oil in Iraq, would we have just fought a war there? The Administration cited weapons of mass destruction as the main *casus belli*, but it cannot be denied that U.S. interest and policies in the region are influenced, and perceived to be influenced, by our interest in oil. Yet, just as our transportation fuels have transitioned from clunky, awkward solids to easy-to-store liquids (coal to oil) during the past two hundred years, they are likely to transition again, from liquids to gases. The most likely candidate to power our transportation devices of the future is the simplest, most abundant gas—clean, efficient hydrogen.

Author's note: This article is a highly condensed version of "Twenty Hydrogen Myths," a detailed paper correcting many errors recently published about hydrogen. For the full article, please visit www.rmi.org in late June. This work was partially supported by The Rose Family Foundation and the Harold Grinspoon Foundation.

The chairs of eight major oil and car companies have said the world is entering the oil endgame and the start of the Hydrogen Era. A Shell planning scenario in 2001 envisaged a radical, China-led leapfrog to hydrogen (now clearly underway), making world oil use stagnate until 2020 and then fall. President Bush's 2003 State of the Union message further emphasized the commitment to developing hydrogen-fuel-cell cars he'd announced a year earlier (FreedomCAR).

Yet many diverse authors have lately criticized hydrogen. Some call it a smokescreen to hide White House opposition to raising car efficiency using conventional technology, or fear that working on hydrogen would divert effort from rather than complement renewable energy deployment/adoption. Some simply presume that if this President believes something, it must not be true. Most reflect errors meriting a tutorial on basic hydrogen facts. But before I discuss the transition to hydrogen, here are four key points about H_2 that are not always articulated:

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Photo: courtesy LRC

What's Inside

Four key points about H_2

1) **Hydrogen makes up about 75 percent of the known universe, but is not an energy source like oil, coal, wind, or sun.** Rather, it is an energy carrier—a molecule that, like electricity, can carry useful energy to users. Hydrogen is an especially useful carrier because like oil and gas, but unlike electricity, it can be stored in large amounts.

2) **The reason hydrogen isn't an energy source is that it's almost never found by itself, the way oil and gas are.** Instead, it must first be freed from chemical compounds in which it's bound, using heat and catalysts to "reform" hydrocarbons or carbohydrates, electricity to "electrolyze" water, or other methods, including experimental processes based on light, plasmas, or microorganisms. All devices that produce hydrogen on a small scale, at or near the customer, are collectively called "hydrogen appliances."

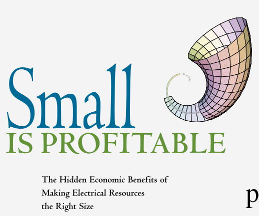
3) **Over two-thirds of the fossil-fuel atoms burned in the world today are hydrogen.** The debate is about whether getting rid of the last third (the carbon), and even its combustion ("uninventing fire"), could be more profitable and attractive than burning both the carbon and the hydrogen.

4) **Hydrogen is the lightest molecule, eight times lighter than natural gas.** Per unit of energy, it weighs 64 percent less than gasoline or 61 percent less than natural gas: 2.2 pounds of hydrogen has (within two percent) the same energy as one U.S. gallon of gasoline, which weighs 6.2 pounds. Conversely, hydrogen is bulky—per unit volume, hydrogen gas contains only 30 percent as much energy as natural gas, and even at 170 times atmospheric pressure (170 bar), only six percent as much energy as gasoline.

RMI *in the news*

SIP Introduces Itself to the Energy Sector

In the spring issue of *RMI Solutions*, we told you how *SIP* had been named a Book of the Year by the *Economist* magazine. It has also been winning praise in many energy and electricity journals.



"[T]he mere publication of this work catapults it onto the shelf of texts that will be referenced for decades.... In 400 pages, 119 figures and 782 footnoted references, the authors lay out a veritable smorgasbord of information to explain why smaller, more localized energy production and management systems proffer a whopping 207 benefits on society. Two hundred and seven quantifiable benefits. For those of us toiling in the daily trenches of power regulation, very few individual efforts could be as timely, or as helpful. We know how to change out coal plants for photovoltaic panels and gas-fired turbines; changing hearts and minds has proven to be much harder."

—Anne-Marie Borbeley-Bartis (Advisor, U.S. Department of Energy) and Shimon Awerbuch (recently moved from the International Energy Agency to the University of Sussex), in *Energy Policy*, in press.

"[T]he benefits enumerated are genuine, often substantial and in many instances hitherto unacknowledged. Certainly they have never before been so comprehensively and coherently presented to policymakers.... The case it makes is well-nigh unanswerable. No present or prospective player in the electricity game can afford to ignore it.... *Small Is Profitable* must be the definitive commentary on the first phase of transition away from traditional electricity, not only in the US but around the world. If it receives the close attention it deserves, it will accelerate and ease this phase, and hasten the arrival of the next.... As the electric transition gathers momentum, look to Amory Lovins and RMI to stay in the vanguard."

—Walter C. Patterson, Associate Fellow, Royal Institute of International Affairs, London, in *Modern Power Systems*, 30 April 2003, p. 13.

To order your own copy of *SIP* or to read other reviews, please visit www.smallisprofitable.org.

So much for the basics. Now for the currently prevalent myths:

1. A whole hydrogen industry would need to be developed from scratch.

Wrong. Hydrogen manufacture and use is already a large and mature global industry. At least five percent of U.S. natural gas output is currently converted into industrial hydrogen, half of which is used in refineries—mainly to make gasoline and diesel fuel. Globally, about 50 million metric tons of hydrogen is now made for industrial use, about 3–5 times America's consumption. Nearly all hydrogen is extracted ("reformed") from fossil fuels, mainly natural gas, because that's cheaper than electrolysis unless you have extremely cheap electricity (generally well under two cents per kilowatt-hour), or unless the hydrogen is a byproduct (about two percent comes from electrolytic chlorine production).

2. Hydrogen is too volatile and explosive to use as a fuel.

Wrong. Although all fuels are hazardous, hydrogen's hazards are different from and generally more easily managed than those of hydrocarbon fuels. It's 14.4 times lighter than air, four times more diffusive than natural gas, and 12 times more diffusive than gasoline—so leaking hydrogen rapidly rises away from its source. Also, it needs at least four times the concentration of gasoline fumes to ignite, it burns with a nonluminous flame that can't scorch you at a distance, and its burning emits no choking smoke or fumes—only water.

Hydrogen-air mixtures are hard to make explode. Hydrogen does ignite easily, with only a tenth as much energy as natural gas, which a static spark can ignite. However, unlike natural gas, ignited hydrogen burns at lower concentrations than can explode, and it can't explode in open air. The 1937 *Hindenburg* disaster was investigated by NASA scientist Dr. Addison Bain in the late 1990s. He found that probably nobody aboard was killed by a hydrogen fire; the 35 onboard who died as a result of the fire were killed by jumping out or by the burning propeller-engine diesel fuel, flammable furnishings, and dirigible itself, which—coated with a paste containing aluminum powder and chemically similar to rocket fuel—was easily set alight by a spark. The clear hydrogen flames swirled harmlessly above the 62 surviving passengers as they rode the flaming dirigible safely to earth.

3. Making hydrogen uses more energy than it yields, making it impractical.

It would violate the laws of physics to convert *any* kind of energy into a larger amount of another kind of energy. Hydrogen is no exception, and neither are today's energy forms. Converting gasoline from crude oil is generally 75–90 percent efficient from wellhead to retail pump and electricity from fossil fuel is only about 30–35 percent efficient from coal to retail meter. Hydrogen is typically converted at efficiencies around 72–85 percent in natural-gas reformers (thermochemical devices that separate hydrogen from carbon) or around 70–75 percent in electrolyzers. (These efficiencies are all reduced by 15 percent because a different definition of the hydrogen's energy content, called "Lower Heating Value," is appropriate for its use in fuel cells than is used to measure sales of fossil fuels.) But hydrogen's greater end-use efficiency can more than offset its conversion loss. From wellhead to car tank, oil is typically 88 percent efficient (the lost energy mainly fuels refining and distribution). From car tank to wheels, gasoline is typically 16 percent efficient. The average contemporary vehicle is thus about 14 percent efficient well-to-wheels. A hybrid vehicle like the Toyota *Prius* nearly doubles the gasoline-to-wheels efficiency to 30 percent and the total to 26 percent. But an advanced fuel-cell car's 70 percent natural-gas-well-to-hydrogen-in-the-car-tank efficiency, times 60 percent tank-to-wheels efficiency, yields 42 percent—three times higher than the normal gasoline car or one and a half times higher than the gasoline-hybrid-electric car. Thus the energy lost in making hydrogen is more than made up by its extremely efficient use, saving both fuel and money.

4. Delivering hydrogen to users would consume most of the energy it contains.

Wrong. Two Swiss scientists recently analyzed the energy needed to compress or liquefy, store, pipe, and truck hydrogen. Their net-energy figures are basically sound—but their widely quoted conclusion that because hydro-

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Energy Facts

If the hydrogen now used by U.S. refineries were instead fed into fuel-cell vehicles as efficient as Hypercar, Inc.'s *Revolution* concept SUV, it would displace one-fourth of all U.S. gasoline—twice as much as comes from Persian Gulf oil.

This recent update, and others on pp. 4 & 37, to RMI's "Energy Security Factsheet" (www.rmi.org/sitepages/pid533.php) were added as we went to press with its booklet edition, available free from RMI Publications (phone 970-927-3851 or email orders@rmi.org).

gen is so light, "its physical properties are incompatible with the requirements of the energy market" is not. In fact, their paper, published by the competing Methanol Institute, simply catalogues certain hydrogen processes that most in the industry have *already* rejected, except in special niche markets, because they're too costly, including pipelines many thousands of kilometers long, liquid-hydrogen systems (except for rockets and aircraft), and delivery in steel trucks weighing more than one hundred times as much as the hydrogen carried.

The authors also focus almost exclusively on the costliest production method—electrolysis. They admit that reforming fossil fuel is much cheaper, but reject it because, they claim, it releases more CO_2 than simply burning the original hydrocarbon. That ignores the hydrogen's more efficient use: even under conservative assumptions about car design, a good natural-gas reformer making hydrogen for a fuel-cell car releases between forty and sixty-seven percent less CO_2 per mile than burning hydrocarbon fuel in an otherwise identical gasoline-engine car, because the fuel cell is 2–3 times more efficient than the engine.

Even more fundamentally, the Swiss authors analyzed only costly centralized ways to make hydrogen. Most industry strategists suggest—at least for the next couple of decades—decentralized production at or near the customer, using the excess off-peak capacity of existing gas and electricity distribution systems instead of building the new hydrogen distribution infrastructure whose costs the Swiss analysis finds so excessive.

Energy Facts

The potential cost-effective windpower in the Dakotas could make as much hydrogen as the world now uses—enough, if used in efficient fuel-cell vehicles, to displace all oil now used by U.S. highway vehicles.

5. Hydrogen can't be distributed in existing pipelines, requiring costly new ones.

Wrong. If remote, centralized production of hydrogen eventually did prove competitive or necessary, existing gas transmission pipelines could generally be converted by adding polymer-composite liners, similar to those now used to renovate old water and sewer pipes, plus a hydrogen-blocking coating or liner, and by converting the compressors. Even earlier, existing pipelines could carry a mixture of hydrogen, up to a certain level, to "stretch" natural gas; users of fuel cells could separate the two gases with special membranes. Some newer pipelines already have hydrogen-ready alloys and seals, and all future ones should be made hydrogen-compatible, as Japan intends for its big Siberia-China-Japan gas pipeline. As for gas distribution pipes, many older systems are already largely or wholly hydrogen-compatible because they were originally built for "town gas" (synthetic gas that's up to sixty percent hydrogen by volume), although burner-tips, meters, and other minor components could require retrofit.

6. We don't have practical ways to use hydrogen to run cars, so we must use liquid fuels.

Wrong. Turning wheels with electric motors has well-known advantages of torque, ruggedness, reliability, simplicity, controllability, quietness, and low cost. Heavy and costly batteries have limited battery-electric cars to small niche markets, although the miniature lithium batteries now used in cellphones are severalfold better than those used in battery cars. But California regulators' initial focus on battery cars had a huge societal value because it greatly advanced electric drivesystems. The question is only where to get the electricity. Hybrid-electric cars now on the market from Honda and Toyota, and soon from virtually all auto-makers, make the electricity with on-board engine-generators, or recover it from braking. This gives the benefits of elec-

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RMI *in the news*

RMI Work to Influence United Nations Discussions

Once again, RMI's work is helping the United Nations. Recently, RMI prepared a strategic scoping paper to inform discussions about consumption and production around the world. The Danish Ministry of Environment commissioned and funded the paper, which it has now forwarded to the UN. The paper includes recommendations for eliminating or reducing the impacts of unsustainable practices.

The paper grew out of the 2002 World Summit on Sustainable Development in Johannesburg, which created the so-called "Plan of Implementation"—the summit's delegates' recommendations for global sustainable development.

Inventing the Low-Power, High-Performance Data Center

TAKING A BYTE OUT OF HEAT

By Cameron M. Burns

Please visit www.rmi.org/sitepages/pid626.php to download the Data Center Charrette Report.

Last year, an English computer enthusiast who uses the online alias Trubador pulled his PC apart, removed the fans, attached a bundle of coins to the top of the Athlon XP1500+ chip (to store and conduct heat), and turned the machine on. After the device had warmed up, he placed a folded aluminum tray on top of the coins, cracked an egg into the tray, and began cooking. Eleven minutes and a dollop of brown HP Sauce later, breakfast was served.

"The heat transfer was not up to the quantities of a normal frying pan," Trubador reported in the English computer magazine, *The Register*, "and it was a tedious task waiting for the egg to cook, but eleven minutes later it was lovely."

This little story illustrates not only the wonderful eccentricity of English computer enthusiasts, but also the highly concentrated energy use in modern computer chips.

Although computers and Internet-related equipment don't and probably never will swallow the massive amounts of energy estimated by Peter Huber and Mark Mills in their 1999 *Forbes* fantasy "Dig More Coal: The PCs Are Coming,"[1] scientists on the leading edge of computer technology do worry about the *intensity* of the energy they use.

Many computer experts expect that by the year 2010, a single computer chip might contain more than a billion processors producing up to 1,000 watts of heat—enough to cook a London broil, not just an egg. In fact, some chips get so hot they actually threaten to melt themselves. Individual computers are one thing; now imagine the concentrated heat being generated by millions of chips all thrumming contentedly away in a big data center, one of those immaculately-clean perfectly-chilled white rooms seen in sci-fi movies.

The obvious problem with computers and computing is that they have traditionally focused on speed and power (calculations per second) and are, in the words of server pioneer Chris Hipp, a lot like muscle cars in the 1960s—power at any price; cost, reliability, and energy consumption be damned!

RMI Gets Into the Data Center Business

In February 2003, Rocky Mountain Institute staffers dug into their encyclopedic Rolodexes and invited a broad cross-section of smart engineers, computer experts, and real estate professionals to come talk openly and candidly about data-center design. The event, dubbed *Low Power Data Centers: An RMI Charrette*,[2] was held 2–5 February 2003 in San Jose, in the heart of Silicon Valley. About ninety industry experts took part in the rich discussion whose aim, ultimately, was to chart a new course for data centers. Certainly, if a single computer chip producing 1,000 watts of heat is stacked among thousands of other chips producing the same, and many of them contain vital national security, military, academic, telecommunications, and financial information, someone should be mulling over the perplexing issues of heat and power in data centers.

As the charrette unfolded, attendees broke into four main groups and six or seven subgroups to examine everything from the main electricity supply system to options for removing heat from individual chips, from system architecture to software and compilers. Perhaps the most important thing that came out of the three-plus days of discussion was an awareness of the unintended disconnections that permeate data centers—the event became something of a happy confession, where participants tell of their small realm's troubles. While hundreds of ideas were exchanged, rather than list them all here, I'll touch on a few of the highlights.

First of all, it turns out that most chips don't need to gobble nearly as much electricity as they now do. In fact, many chipmakers are finding that efficiency is as important to customers as computational muscle, and they are starting to design their CPUs to be less consumptive. One group of engineers at the charrette explored this idea further, and created—at least on paper—

"The heat transfer was not up to the quantities of a normal frying pan and it was a tedious task waiting for the egg to cook, but eleven minutes later it was lovely."

Trubador
describing his CPU cooker in *The Register,*
www.handyscripts.co.uk/egg.asp

LBNL's Dale Sartor asks charrette attendees to envision the future.
Photo: Cameron M. Burns

the Hyperserver. The Hyperserver's disk drives and fans were set apart from the CPU, its operating system was installed on chips, and its power supplies were efficient and "right-sized"; the entire assembly ran on dynamically-allocated resources—or, in lay parlance, it powered up only the components it needed at any moment.

While that group was looking at moving the components of servers around, another group of engineers and architects looked at the way servers are stacked and stuffed into tiny, hot places, and wondered what an optimal design for housing servers might look like. Hipp, who has developed blade servers and installed them in all sorts of lilliputian rabbit warrens, gave a presentation showing thick braids of power cords strung between overloaded server racks, in turn stacked among jumbles of "useless" sheet metal, all cooled by a guy wheeling a small electric fan around. Clearly, most server technicians are afraid of removing old equipment—justifiably, they fear something will break—so they prefer to pile new equipment on top of the old, which leads to hotter and hotter spaces. Cooling fins, fans, and exhaust systems are often suboptimally located, so this "cooling group" created a variety of naturally ventilating designs for rooms that might house server racks. They also suggested sticking servers' power supplies on top—an incredibly simple idea but one not regularly practiced. In another room, a subgroup of the cooling group sketched out several server racks designed with liquid cooling elements—after all, despite the sector's fear of mixing water and electricity, they can be kept well apart, and water is a 3,500-fold better heat carrier than air per unit volume.

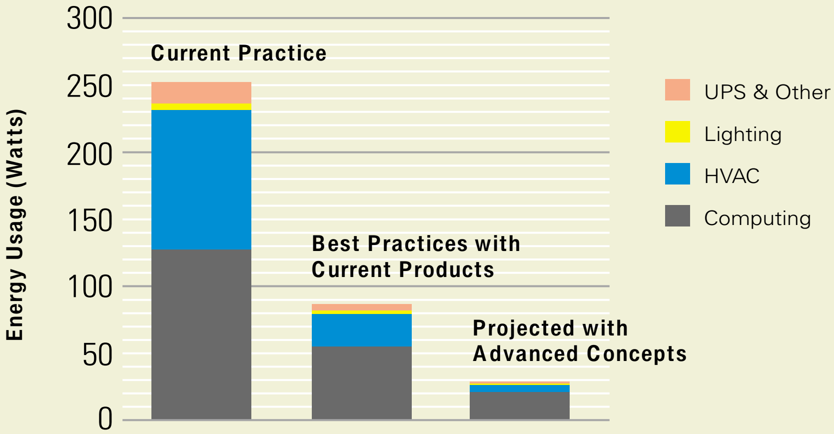
Meanwhile, a "power supply" group looked at the power supply coming into the building, and redesigned it for efficiency and reliability. One of the not-surprising-but-rarely-addressed aspects of data centers is that *intermittent* savings of energy aren't as valuable as *continuous* power savings. This idea—akin to RMI's "tunneling through the cost barrier" thesis—could permeate all aspects of data center design. Even though computers and their cooling systems might power down when not used, often they have other systems—uninterruptible power supplies (UPSs), for example—that remain active. In fact, according to information presented at the charrette, power continuously saved is worth roughly $10 per watt over a three-year period—several times as much as power saved intermittently. Power supplies aren't designed to be nearly as efficient as they should be to match this value. (An additional ironic twist: many computers' energy requirements are bumped up so the machine can run more complex applications, with very fancy graphics, faster—usually unnecessarily. As Lawrence Berkeley

RMI *in the news*

NewCars.com Supports RMI

NewCars.com, a car referral service that helps consumers get quotes from dealers in their areas, recently chose RMI as one of three nonprofits it will support each month. NewCars.com selected RMI because of the Institute's efforts to advance auto efficiency and to move the industry away from a reliance on fossil fuels. The company plans to donate twenty percent of its profits to nonprofit organizations that work to mitigate the effects of automobiles.

In the graph below, "Best Practices" refers to implementation of a recommendation with technology that exists today, and "Advanced Concepts" refers to implementation of a recommendation with new technology that must either be invented or put into common practice.



Source: Lewis, M., cited in "Design Guide for Low Power Data Centers," www.rmi.org/sitepages/pid626.php

Labs' Dr. Jon Koomey asked at one point, "Who here uses more functions in Microsoft Word now than you did ten years ago?"—and not many hands went up.)

A fourth group looked at "future trends," which included a broad range of concerns—the meatiest of which was the misalignment of incentives. For example, the immature real estate model for data centers calls for charging tenants by the square foot and not by the energy consumed, even though—all things being equal—the watts (and taking away heat) cost much more than the space. As one attendee noted, "Cramming 'free' watts into 'costly' square-footage creates uncoolably concentrated heat, hence vastly more cost and unreliability."

The ideal situation, group members noted, is when incentives are aligned and all involved are working together—a new real estate model now starting to emerge. Like other attendees, the "future trends" group also called for benchmarking, education, and energy ratings on chips, servers, and racks.

As several RMI staffers compiled the elements of the discussion, a report about the charrette quickly began to organize itself around recommendations—over fifty, all told. Some recommendations merely urged the search for a solution to a problem. Other recommendations were so specific they included engineering schematics. All of them seem best applied in unison.

Soon complete and downloadable at www.rmi.org/sitepages/pid626.php, the report, although comprehensive, should be seen only as a starting point, a document that will infuse creative thinking into all high-tech sector activities, and point toward smarter use of fewer watts.

Possibly the most encouraging part of the report is one graph. At the end of the final day's discussion, Malcolm Lewis, of Constructive Technologies Group, outlined the results of the charrette. His summary graph (above) depicts an eighty-nine percent potential energy reduction for the whole data center—from CPU to everything else—at lower total capital cost and with improved reliability.

The graph tells a remarkable story and could have far-reaching consequences: by using more efficient CPUs and designs ("advanced concepts"), it might be possible to drop the required computing power to one-sixth of the amount needed in the business-as-usual ("Current Practice") approach. When that happens, the rest of the hardware can drop its requirements in a similar fashion (in fact, the heating, ventilation, and air conditioning requirements can be dropped to less than one-twentieth their current energy requirements). This bodes well for anyone interested in processing data affordably, reliably, and efficiently—and brings to mind thoughts of servers in cars, desks, and backpacks.

How quickly will the Data Center of the Future be realized? The late 1990s dot-com bubble bust and the economic lull of the past several years have provided all who work with data centers, computers, and high-tech real estate a chance to do data centers right.

As Dr. Wu-chun Feng, co-creator of the Green Destiny computer at Los Alamos National Laboratory and charrette keynote speaker, observed, "Bigger and faster machines are not good enough anymore. Size, power consumption, reliability, and ease of maintenance will be *the* issues of this decade." And, need we add, cost.

1 RMI's quest for a Low Power Data Center and the argument that Huber and Mills were making are not antithetical arguments. Mills and Huber stated that electricity consumption by the Internet would consume half of the electric grid's available power within a decade of May 1999, but technical review by Lawrence Berkeley National Laboratory, the Center for Energy and Climate Solutions, RMI, and others found they'd overstated computer-related electricity use by at least eightfold (See "Debunking an Urban Legend," *RMI Solutions*, Spring 2003). RMI's concern for data centers is not the amount of energy—which overall is rather small—but its *concentration* in a small space.

2 A charrette is an intensive, multi-stakeholder, transdisciplinary design workshop. It is not a conference, but a hands-on, solution-generating, working event with ambitious deliverables.

Kanzi Gets a New Home

RMI's First Interspecies Design Project

By Jenny Constable

Kanzi's like many young folks. He loves to eat M&Ms, climb trees, play in water, drive a golf cart, and go camping, where he builds the fire and toasts marshmallows. He loves to make music, play video games, and watch movies. He sometimes gets jealous of his little sister, although they're nice and soon make up. If you ask him about his latest meal, he might complain about the way it was cooked—unless he cooked it himself. And he enjoys such games as chasing his buddies around wearing a scary gorilla mask…which he eventually strips off to reveal a big grin.

Early next year, Kanzi will be moving from his current home in Georgia to a new home in Iowa. The designers have been taking his and his family's needs into consideration as they plan the building. None of this is particularly remarkable, except that Kanzi is not human—he is a bonobo, an endangered species (*Pan paniscus*) of great apes formerly known as pygmy chimpanzees (the normal chimp is called *Pan troglodytes*). Tests have confirmed that the chimps' functional DNA is 99.4 percent the same as human DNA—and bonobos are more like us than like chimps, making them our closest living relatives. In fact, some scientists think they're best considered in the same genus as humans, so as a paper in the *Proceedings of the National Academy of Sciences* just recommended, they should be *Homo paniscus*. (See "Bonobos in the Wild" [p.11] for more on these remarkable creatures.)

Lexigram: courtesy Language Research Center (LRC)

Twenty-two-year-old Kanzi is one of eight bonobos residing at the Georgia State University Language Research Center (LRC, www.gsu.edu/~wwwlrc/) near downtown Atlanta. Its researchers have been studying bonobos' ability to comprehend human language for over twenty years. The work began in 1980 with Kanzi's adopted mother, Matata, who was born in the wild and had already reached puberty when researchers began to teach her English. After many attempts spread over five years, Matata recognizes only six food names.

But serendipitously, Matata's adopted baby Kanzi—*hidden treasure* in Swahili—was with her continuously during the first few years of her training. Thinking him too young to learn language, the researchers focused all of their efforts on Matata. While his mother was put through a rigorous course of words, expressions, and abstract ideas, Kanzi played and scampered around like a normal baby bonobo. Yet remarkably, he learned far more language than she probably ever will, and he did it through immersion, just as human children do, because language is a cultural phenomenon.

Kanzi's abilities have taken off since those first "accidental" lessons in language. Researchers taught the apes to use lexigrams to communicate. Each lexigram is an abstract symbol representing a single English word. Kanzi and his relatives who have learned English (most impressively his young nephews) use electronic keyboards, touching a series from among 350 keys to "speak" English sentences in a computer voice. Their understanding of spoken English is clearly great. Some bonobos even draw lexigrams rather than using the keyboard.

Bonobos aren't just good with words. They are also athletic, musical, dexterous, and creative. They like jam

RMI *in the news*

RMI Opens Boulder Office

RMI has opened a new office in downtown Boulder, Colo. The office will be home base for our Energy and Resources Services team, led by Joel Swisher, Ph.D., P.E. Initially, four staff members will be based in the office, including new Energy and Resources Services staff member Kitty Wang, who holds B.S. and M.S. degrees in civil and environmental engineering from Stanford University. The Boulder satellite office offers an opportunity for RMI to have greater visibility on Colorado's Front Range, as well as better access to an international airport.

Photo: © 2003 courtesy LRC

If you build it, the bonobos will come.

sessions (and have played music with Peter Gabriel and Paul McCartney), they can make tools (taught by Indiana University's flint-knapping paleoanthropologist Nick Toth) and, like most apes, they are discerning consumers. When chimps at the Copenhagen zoo were offered organic bananas, they munched the entire fruit. When given non-organic bananas, they peeled them before eating the inside.

"What separates bonobos is their intelligence," noted researcher Sue Savage-Rumbaugh, Ph.D. "It is not that other apes are less intelligent but the bonobo expression of social intelligence is most human-like."

It's also likely they can learn gardening, as other apes do. When RMI's CEO Amory Lovins recently visited an orangutan and a gorilla, both fluent in sign language, and the apes were told Lovins grew bananas in his home, the orangutan grew quite excited at the idea of growing his own food. According to the orangutan's human keeper, he had grown flowers and corn as a youngster. Why should bonobos be any different?

"Bonobos and humans are basically Lucy, the Rift Valley hominid, plus 3.5 million years," said Lovins. "It's tempting to think of them as furry versions of smart eight-year-old kids, but, as an ex-linguist, the more I learn about them, the less reason I see to assume they're any more limited than we are."

In short, these are compassionate, sensitive, careful, brilliant creatures whose potential we are just starting to learn.

Designing a new facility for Kanzi

Thanks to the Iowa Primate Learning Sanctuary (IPLS) in Des Moines, Kanzi and his bonobo and researcher friends will be moving to a new facility designed especially for them. The sanctuary was founded by Des Moines businessman Ted Townsend for three reasons: to be a home for great apes, a place to conduct noninvasive research, and a facility for Des Moines-area residents to learn about great apes.

The idea for IPLS grew out of a project by Townsend's Iowa Child Institute, which plans to conduct intensive immersion training for environmental educators. Iowa Child is building an artificial rainforest near Iowa City, and had originally hoped to include primates. Further research revealed that the apes deserved dedicated space, so Townsend founded IPLS.

IPLS will be built on a 137-acre abandoned gravel quarry about five miles southeast of downtown Des Moines. The site has been neglected for many years, but that will change as IPLS grows and restores the natural ecosystem. The building for the bonobos will be located on an island surrounded by a lake, which provides a natural barrier that will keep overly-curious humans out.

Construction will start on the IPLS later this year; it is scheduled to open in March 2004. The first building will boast enough space for the eight bonobos currently housed at LRC to live, learn, and play, as well as a visitors' center that will also serve as an educational facility. Other areas are planned to accommodate other species of great apes.

Townsend founded IPLS with the natural world in mind and planned for a green facility from the start. Since great ape habitat is often destroyed for building materials, IPLS' directors thought it important to design the facility without any such materials. They also want to maximize energy efficiency. Overall, they want a healthy, comfortable indoor space that makes for happy bonobos and successful researchers.

IPLS officials retained RMI's Green Development Services (GDS) to help them design the facility. Bill Browning, founder of GDS, has already worked on facilities for other species, including a new building at the National Aquarium in Baltimore and a master plan for the Bronx Zoo, but never before has he known of a project in which people are communicating with another species.

To share the news of a new home with the bonobos, Savage-Rumbaugh shot a video of the new site when she visited several months ago. When she returned to LRC, she showed the video to the bonobos, who often watch television and will rewind a

Kanzi Gets a New Home

Designing a facility for another species can be quite challenging.

tape to see their favorite parts over again. Upon seeing the location, the bonobos said they wanted to play in the water and climb the trees there. Kanzi's younger sister, Panbanisha, was more reflective and project-oriented than the others: "[Need] bricks." Then, wrote Savage-Rumbaugh: "When I commented that the [sanctuary] might be like the baseball stadium in the movie *Field of Dreams*, and that after it is built it it might attract bonobos from all over the world, they responded with huge excited 'Waaa' calls. I was surprised that they would make the connection, but they do like that movie very much, and they have heard us repeatedly talking about a building in Iowa."

The designers have sought to include features to enhance the bonobos' comfort and creativity throughout the facility. A large greenhouse, extensive climbing space, heavily-windowed towers where the apes will live, a courtyard that is open to the outside, and a unique space that allows the primates to interact with visitors are all planned.

According to Browning, designing a facility for another species can be quite challenging. "You have to think about different comfort considerations," said Browning. "For example, the bonobos will have direct skin contact with many surfaces in the facility," suggesting the incorporation of gentle radiant heat. Because bonobos are susceptible to many human diseases, project designer Peter Hind of the Omaha-based firm Leo A Daly has planned airtight doors and positive air pressure. A visiting area has also been designed to allow the bonobos to see and communicate with visitors without direct contact.

In mid-January, the humans involved in the design process got together to generate other ideas on "greening" the facility. RMI's Browning and Lovins (a longtime student of orangutans) led a design charrette and brought together representatives from various disciplines, including officials from IPLS, Leo A Daly, construction contractor the Hansen Company, Inc. of Johnstown, Iowa, and consulting firm Conservation Design Forum, of Chicago. RMI also brought in endangered species experts, zoo designers, and primatologists, as well as researchers from the LRC to explain the needs of the animals.

The charrette produced ideas for heating, cooling, and energy efficiency in the facility, and reduced operating costs will mean more funds for research. Refinement of the design continued in April, when Hind visited RMI.

As designed, one of the facility's buildings will have four towers, each with two living areas for apes. Two of the towers will be living quarters for the eight bonobos from LRC. An open research area joins the towers to researcher offices. In the center, a large open greenhouse will allow apes to move from one side of the facility to the other across a year-round garden, somewhat like RMI's headquarters "jungle."

A living "green roof" will cover the complex (see p. 13) and help it blend into the surrounding forest. The designers have called for building materials that have photovoltaic cells built into them, so exterior walls and windows will generate some of the electricity needed in the facility while solar panels will heat the water.

Local building codes require that ventilation systems in animal dwellings pass air through only once, and then send it outside. Designers have separated the heating and cooling system from the ventilation system to save energy, and heat exchangers will transfer energy out of the warm air as it leaves the building. Radiant floors and walls will be incorporated throughout. Hind is planning to include a closed-loop system running through the nearby lake to send summer heat into the water.

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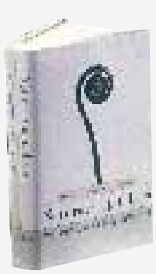
RMI *in the news*

Clinton Still Plugging *Natural Capitalism*



As most *RMI Solutions* readers know, President Clinton is a big fan of *Natural Capitalism*. Last fall, he embarked on a speaking tour that included many big Western universities. RMI Associate and former staff member Brett Williams caught Clinton's presentation at the University of California at Davis last fall and found the former president is still plugging *Natural Capitalism*.

"During the question and answer period he was asked about energy," Williams noted. "His answer was heavily influenced by *Natural Capitalism*. Indeed, the only specific reference he made in his answer was to 'Amory and Hunter Lovins and Paul Hawken's book, *Natural Capitalism*,' which he used to explain that we already knew how to grow the economy while reducing greenhouse gases."

The apes will have access to water both inside (where there'll be ponds in the greenhouse) and outside (where there'll be a lagoon). Outside the apes' living space, wastewater will be filtered through an artificial wetland created with native species. The design allows the wetland's plants to grow deep roots and spread out over a large area. Biological processes slow down during cold periods, so the wetland needs to be big to process wastewater adequately in winter.

Probably the most important outcome of this facility's creation will be a new understanding of how to design buildings for humans. Designers working on the IPLS are keenly aware that apes didn't evolve in square, sterile, hard-surfaced boxes, so they are looking at forest floors and muddy bogs as models. "What we might not realize," said Lovins, "is that they might prefer to walk, or scramble, on logs—or on some other surface."

So as we design for bonobos, it reminds us that humans also didn't evolve in square, sterile, hard-surfaced boxes.

Kanzi and his clan will move into his new home when the first building of the IPLS is complete next year. Ultimately, sanctuary officials plan to build enough space to house all four species of great apes. They hope to bring greater learning opportunities to their community while attracting researchers from around the world. Kanzi and the other bonobos are excited about the upcoming move. And we at RMI who are familiar with this project are excited to see what he and his bonobo buddies learn next—not to mention what he might teach us humans about how to evolve.

Jenny Constable (jenny@rmi.org) is RMI's Media Relations Director.

Bonobos in the Wild

If you were going to design a building for members of another species, how would you start? The assumptions that architects and designers make for human-only buildings don't apply when a building will have residents who like to swing athletically through three dimensions, climb everything in sight, and eagerly apply muscles that are, pound for pound, five times stronger than a human's. A space that's roomy for us can be cramped for them.

For the IPLS design charrette, RMI invited primatologists from around the world to help them understand what bonobos need in a habitat.

Jo Thompson

As it turns out, one of RMI's neighbors has been studying bonobos in the wild and helping to preserve their habitat for over a decade. Jo Thompson, Ph.D. of Snowmass Village, Colo., is founder and director of the Lukuru Wildlife Research Project, a nonprofit group dedicated to the research and conservation of and research on wildlife, particularly bonobos, in an area of the Democratic Republic of Congo (DRC).

Bonobos are native only to the Congo Basin, which lies to the south of the Congo River in the DRC. They generally live in jungles with trees that reach 130 feet and are more arboreal than common chimpanzees, with whom they are often compared. Their stance is more upright than the chimpanzee's, and their skeletal structure has many similarities to those of ancient hominids.

Some of Thompson's research might play a role in the design process. For example, she and other researchers have often observed wild bonobos walking upright, sometimes for long distances. Walking frees their hands, and they have been known to carry sugar cane and other objects.

Thompson has also observed bonobos wading in water in their natural habitat. Apes cannot swim because their bodies are too dense, but bonobos have an affinity for shallow water.

Thompson's research has also shown that bonobos use various types of habitat; in fact, while they spend most of their time in forests, they often venture onto nearby grasslands to eat fruit. This bodes well for their adaptability in the face of climate and habitat changes. According to some estimates, fewer than 20,000 bonobos are left, making them the rarest of the great apes. In addition to the stresses that affect many ape species, such as disease and the presence of humans, wild bonobos—already hunted for meat—have been living in a war zone for several years. It is unknown how many may have been killed or displaced, and researchers like Thompson have only recently been able to return to the region since fighting intensified in 1999. In her reports, Thompson stresses that the presence of foreign researchers is often the most effective way to protect bonobos.

For more on Thompson's work or to support her research, visit her website at http://members.aol.com/jat434/index.htm. For more on the bonobos of IPLS, visit www.iowagreatapes.org.

—Jenny Constable

An Introduction to Green Building

Part 3: Other Green Building Considerations

By Alexis Karolides, AIA

As mentioned in the first part of this series, green building design is an integrated, holistic process with a greater goal than the sum of its individual components' tasks. More important than the greenness of each and every material is the way that the parts work together to become wonderful, healthy spaces that offer humans contact with the natural environment while not over-using resources. It is difficult in such a short space to describe all the complex and symbiotic ways facets of green building interconnect. Experience and collaboration with the basic principles, elements, and systems is important for any green designer or builder—so is a lot more reading. In Part One you read about Resource Efficiency; in Part Two, about Environmental Sensitivity with Building Materials. To conclude this series, I will mention several other important areas, including site, water, and building envelope issues. Although they appear to be separate considerations, they are as interconnected in the green building process as anything yet discussed.

On the Site

On any site, native vegetation should always be a priority over pavement. If paving is necessary, use porous pavement when constructing new paved areas or replacing existing ones. Porous paving products include reinforced grass paving (a pervious load-bearing surface with voids for grass to grow in, good for intermittently parked areas) and gravel (for low-traffic areas), block interspersed with gravel, and porous asphalt.

While retention and detention ponds do one thing—manage stormwater—constructed wetlands can manage stormwater while providing multiple human and environmental benefits. When designed after natural models, wetlands become a diverse ecosystem of plants and animals that filter polluted runoff and provide habitat (which may be threatened by development elsewhere). Unlike engineered ponds, which often come with steep concrete sides and barbed-wire "keep out" fences, constructed wetlands are shallow, vegetated amenities that don't require fences.

Controlling erosion is essential to protecting air and water quality and avoiding loss of topsoil on any site. An erosion plan should ensure that topsoil is stockpiled, that soil is not carried away by stormwater runoff or wind, and that particulate matter from construction activities does not cause sedimentation in receiving waterways. Unless local standards are strict, some good basic management practices are outlined in the EPA's *Storm Water Management for Construction Activities*.

Water Water Everywhere

The Western World's practice of using huge amounts of drinking-quality water to transport sewage is unsustainable. This is increasingly evident

RMI *in the news*

Bronx Zoo Getting a Green Master Plan

RMI is helping green up the Bronx Zoo. The Wildlife Conservation Society (WCS), which manages the world's largest system of urban wildlife parks, including the Bronx Zoo, has retained RMI to examine transportation patterns, landscape, and hydrology issues, energy use and production, and green building techniques at the zoo as part of a new master planning process.

The 265-acre zoo is now over 100 years old, and the current master planning process is aimed at improving guest experience and encouraging conservation. One issue is the zoo's tangled 9.5 miles of pathways, which make visitor circulation cumbersome. Also, zoo officials want to encourage more visitors to use public transportation to get to and from the zoo. They also hope to use energy efficiency and distributed generation of electricity to meet the zoo's growing energy needs.

In late February, RMI's Bill Browning, Alexis Karolides, and Joel Swisher led an intensive design workshop on sustainability, attended by WCS architects and planners, curators, and administrative staff, as well as city and state officials. Various green building ideas were explored, as were larger community issues, such as eliminating stormwater runoff and restoring the Bronx River.

Drawing: © 2003 courtesy Leo A Daly

as the population grows in the dry regions of the United States. Plumbing fixtures that use little water or no water are available from various manufacturers. They include composting toilets, waterless urinals, low-flow toilets (various models using 1.6 gallons per flush or less, including standard gravity-flush and pressure-assist models), low-flow showerheads (various models using less than 2.5 gallons per minute), low-flow faucets (using less than 2.5 gallons per minute), metered faucets (to ensure that faucets in public bathrooms will not be left on), and shut-off valves for kitchen faucets and showerheads that enable the temperature setting to be "saved" while the water is temporarily shut off.

Treating graywater from showers, sinks, washing machines, and other appliances as if it were blackwater from toilets and garbage disposals is not the most efficient strategy. Graywater can often be reused directly for toilet flushing or subsurface irrigation depending on regional codes. Graywater can also be used on [non-edible] plants after treatment with a commercial filter or site-built sand filter. Graywater waste-heat recovery systems can capture the heat from showers or other fixtures as it goes down the drain and transfer that heat to incoming water. These systems are especially effective in high-use shower areas, like locker rooms.

Capturing rainwater for irrigation greatly reduces the demand for treated water, and collected rainwater—oxygenated, non-mineralized, and non-chlorinated—is much better for plants. Rainwater can also be used around the house, even as drinking water. Typically a building's roof and gutters can double as its rainwater collection device. For potable water collection, it is critical that the roofing not leach lead, copper, asbestos, petrochemicals, or other nasty things. Modern steel roofing is likely to be the safest option as long as the coating doesn't contain heavy metals: old metal roofs with toxic coatings and lead fastening systems should never be used to collect drinking water. Cisterns for rainwater storage can be made out of metal, concrete, or plastic. The first step in water treatment is to remove large pieces of debris with gutter screens and roof washers; sediment can be allowed to settle within the tank or it can be removed with cartridge filters. If disinfection is needed to ensure human potability, the options include chlorine, iodine, ultraviolet light, and—more expensively—ozonation.

Light and Heat

Even in mild climates, the sun can cause roofs to reach extremely high temperatures. A reflective roof will stay significantly cooler, last longer (by reducing heat and UV damage), and reduce heat-island effects. Multiple studies of buildings in hot climates (*e.g.*, in California, Texas, and Florida) have documented ten to fifty percent energy savings when roofs were painted with reflective coatings. Reflective coatings can bounce away as much as eighty-two percent of total sunlight; non-petroleum water-based reflective coatings are best. Green roofs (built with soil and native plants, and mimicking natural topography) UV-protect the roof membrane while providing habitat for flora and fauna, insulation, stormwater management, clean air, and natural beauty—excellent for habitable roofs or roofs visible from above.

If renewable energy is a priority, the marginal costs of upgrading to PV-integrated roofing panels or PV shingles when installing a new roof or replacing an old one should be considered, because this will be cheaper than installing stand-alone PV panels in addition to a roof.

With thousands of door and window products on the market, selecting the right ones might seem like a daunting task (see Other Voices, p. 26). Your goal when selecting windows is to specify a product that has the climatically appropriate insulating

ADDITIONAL REFERENCES FOR WINDOW INFORMATION:

- National Fenestration Rating Council www.nfrc.org
- Efficient Windows Collaborative www.efficientwindows.org
- Energy STAR Windows www.energystar.gov/products/windows/index.html
- *Glazing Design Handbook* (1997), AIA
- LBNL—Window Technology http://windows.lbl.gov/technology/highly_insulating.htm
- Selecting Windows for Energy Efficiency (512 KB) http://windows.lbl.gov/pub/selectingwindows/window.pdf

As with many products, it is worthwhile to ask window manufacturers whether their products contain recycled materials. Even if the manufacturer does not use recycled content, knowing that customers are requesting it helps to move the marketplace toward recycled products.

value, lets in a high percentage of visible light for daylighting, and provides the appropriate solar heat gain coefficient (SHGC). Because there are many options and manufacturers, it is possible nowadays to "tune" glazing for specific orientations and conditions. The best windows can be essentially perfect in letting in light without heat.

In the coldest climates you'll want "low-e" windows that also offer high visible light transmittance, insulating gas fill (argon or preferably krypton), good edge seals, insulated frames (with thermal breaks if frames are metal), and airtight construction. Instead of applying low-e coatings directly to glass, several window manufacturers apply it to a suspended plastic film between the panes of glass. Triple-pane windows are also an option, although they're heavier and costlier.

Several new glazing products may become common in the future. One is a gel, inserted between glazing layers, that turns from clear to reflective white when exposed to a preset amount of heat, sunlight, or electric current. This gel can be used in skylights to provide full daylighting on cloudy days while avoiding glare and overheating on hot sunny days (in its light-blocking white form, it still admits ten percent of incident solar energy—potentially enough for glare-free daylighting). Another product that could become revolutionary for window technology is Aerogel, a silicon solid (the world's lightest—like "solidified smoke") that transmits over seventy percent of visible light but blocks heat three to four times better than common insulation products like rigid foam and fiberglass. Aerogel was developed in the 1930s and used by NASA for space exploration, but could have many building applications.

Insulation

Insulation is important to keep heat in or out, depending on the climate. There are many considerations when choosing an insulation material. When researching insulation types and brands, ask yourself the following questions: Which type will provide the best R-value within a reasonable thickness? Does it allow airflow? As with other building materials, will it release gaseous pollutants into the building interior? Will it pose potential health risks to installers or manufacturers, and if so, can precautions be taken to prevent these risks? Finally, does the insulation contain ozone-depleting chemicals?

These are only a few of the considerations you'll need to evaluate in your green building. Thinking about them should spark ideas in other aspects of design and construction. Most important, they should be considered as part of a whole system. For instance, the amount of shading that the landscaping around a building provides will have implications for the type of glazing needed; both landscaping and glazing will affect the heating and cooling requirements; if rainwater is to be captured for drinking, only certain roofing materials should be used. All these issues are interconnected. Besides approaching green building as a whole system, remember also to question the status quo and to think creatively.

About the Author

RMI's Alexis Karolides, a former Richter Fellow, holds a Master of Architecture degree from Rice University. A registered architect with six years' commercial experience, she was previously the sustainability manager for the architectural firm Sussman Tisdale Gayle. This three-part series on the basics of green building is adapted from the recently released book Green Building: Project Planning & Cost Estimating, *coauthored by Karolides. It is available from the publisher at 1-800-448-8182 or at www.rsmeans.com, in the website bookstore under "New Releases."*

RMI and Shell Explore the "Stackless Refinery"

By Cameron M. Burns

During a recent interview with RMI's CEO Amory Lovins, I threw out the question, "Why is carbon dioxide so important and why should anyone care?" I thought I knew the answer, but I wanted Amory to state it—you know, for the record.

He looked up for a moment, and then tilted his head as if he trying to decipher a muffled airport announcement. He held out his right hand, and then gently raised it through the air while pinching at invisible little objects. He was simply, he explained, grasping tiny imaginary price tags—attached to the carbon atoms—floating up and away on a warm exhaust.

"Every carbon dioxide molecule going up a smokestack costs you money, notably your fuel bill," he said. "If you figure out how to do its task without generating those waste carbon dioxide molecules, you save a lot of money." I knew waste was superfluous, but his visualization clinched it—heck, I can easily picture those little price tags drifting away in the wind.

Now, think about those little price tags a moment and ponder, if you will, the mobility fuels business. If selling fuels to move vehicles that use one percent of their energy to move the driver, and then send all the resulting carbon dioxide out tailpipes, were a big chunk of your income, what do you think your number one business strategy would be?

In October 2001, Royal Dutch/Shell Group released a remarkable pair of long-term energy scenarios called "Dynamics as Usual" and "The Spirit of the Coming Age" (www.shell.com/home/media-en/downloads/scenarios.pdf). The latter describes society's coming shift from hydrocarbon-based energy to hydrogen, and it envisions the shift happening quickly: "By 2025, a quarter of the OECD (Organisation for Economic Cooperation and Development) vehicle fleet already use fuel cells," the scenario reads. "Less than a five percent increase in [natural] gas production is sufficient to meet demands. The global auto industry rapidly consolidates around the new platform…. By 2025 China—with huge and growing vehicle use—faces an unacceptable dependence on oil imports. Unease about the sustainability of regional gas resources and fears about the reliability of external gas suppliers push towards the use of indigenous coal. But this is becoming logistically and environmentally problematic…. Meanwhile the growing demand for gas and hydrogen is supported by—and spurs—advances in low cost and unobtrusive *in-situ* extraction of methane and hydrogen from coal and oil shales. Carbon dioxide sequestration is feasible and enhances productivity…."

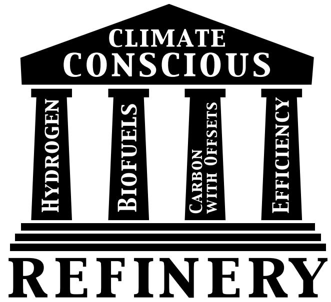
Although they sound a bit like excerpts from an Arthur C. Clarke novel, the documents are solidly based in fact, and they are part of Shell's ongoing effort to figure out what our energy future looks like—not only so the firm can remain profitable, but so it can also do what society wants (and thus, in turn, remain profitable). Most accepted forecasts for oil output have it dipping someplace around 2020 to 2050, and they don't—not the credible forecasts, anyway—have it coming back up, ever, so a gentle, graceful transition is pretty important.

In mid-February 2003, RMI and Shell Global Solutions combined talents to hold a joint "Innovation Laboratory" at a Shell refinery in Northern California. Such events are designed to challenge existing practices and generate ideas about the business. In this case, participants pondered the

Stackless Refinery

The Four Pillars of Climate-Conscious Refining:

1. **Carbonless energy carriers (notably hydrogen)**
2. **Carbon-containing-but-climate-safe biofuels (which mimic the carbon cycle that occurs in photosynthesis)**
3. **Carbon-containing fuels with offsets or sequestration**
4. **Carbon-efficient refineries (which need offsets or sequestration because they still emit carbon)**



Refinery of the Future—or as meeting chair Dr. Jan Verloop termed it, the *Stackless* Refinery. RMI consultants and staff members at the event included Kyle Datta, Catherine Greener, Jason Denner, Joel Swisher, Amory Lovins, and Sara Weiss.

"This was a hypothetical facility," noted Lovins. "Shell is interested in thinking through a future refinery that would make nothing but value—no *muda* [Japanese for waste, purposelessness, or futility], nothing that nobody wants. Everything it made would be something useful you could sell. And it would probably accommodate not only crude oil feedstocks but also biomass feedstocks to produce a range of valuable products. 'Stackless' was specific shorthand for 'no carbon dioxide,' but it could go much further than that."

As I pointed out at the beginning of this story, if you focus on the carbon dioxide and follow the money, you might save not only the climate, but a few shekels as well.

There are numerous options for eliminating or reducing carbon dioxide, ranging from carbon-free fuels to providing access services in which the fewer gallons used, the more profit a company makes to deliver the service the customer wants (counterintuitive to say the least, but in reality what some smart businesspeople are doing). The workshop's lively discussion was framed by what Lovins calls the "Four Pillars of Climate-Conscious Refining": carbonless energy carriers (notably hydrogen); carbon-containing-but-climate-safe biofuels (which mimic the carbon cycle that occurs in photosynthesis); carbon-containing fuels with offsets or sequestration; and carbon-efficient refineries (which need offsets or sequestration because they still emit carbon). Of course, the Four Pillars represent a kind of smorgasbord and they can easily be mixed to taste (Lovins smacks his lips when he tells this part of the story), depending on the end-use technologies and social patterns using the refinery's output.

In more concrete terms, RMI and Shell experts brainstormed techie stuff like advanced energy efficiency and radically improved process technologies. Increasing the use of biomass as a refinery fuel or feedstock, sequestering carbon dioxide rather than releasing it into the atmosphere, and using low-carbon fuels such as hydrogen and natural gas were also part of the mix.

Attendees also spent quite a bit of time in open conversation, swapping anecdotes on refinery design in general and how to improve it. In one of Shell's most efficient refineries at a Factor 4 workshop led by RMI two years ago, attendees found retrofit opportunities to save over two-fifths of the fuel at very attractive prices, while if designing a new facility from scratch, they estimated they could make a refinery "many, many" times more efficient.

"You could, for example, greatly improve the structure and function of controls," Lovins said. "One of the Shell experts from Europe told us that at another major oil company, the average molecule of refined product was being reboiled and recondensed an average of thirty-five times. Why? When the roast is done, you take it out of the oven. One can design refineries in a completely different way that minimizes wasteful superfluity."

Electrical loads for pumping could be far better designed at most refineries (think fat, short, straight pipes rather than skinny, long, crooked pipes), as could the reuse of waste heat. And some Shell and RMI experts think it's possible to design refineries with no stack gas, no waste, and no wastewater. All this bodes well for the Refinery of the Future, the so-called Stackless Refinery.

Although no hard and fast refinery diagrams were drawn up, Shell Global Solutions and RMI enjoyed drilling deep into the—pardon the analogy here—Gray Matter Formation to find rich ideas about cutting carbon dioxide, while providing the world's citizenry with mobility when it's necessary and freedom from the need for mobility where possible.

And one thing is for certain: next time you drive past a Shell refinery, you can be assured that those clever engineers are trying to cut the carbon dioxide molecules rising out the smokestacks—those are, after all, attached to tiny, imaginary price tags. Now, there's a concept anyone can grasp.

Carbon Disclosure Project Looks at Businesses and Climate Change

If you think the hubbub over climate change is some kind of oddball creation dreamed up by critics of the corporate world, then think again. Businesses that emit a lot of carbon dioxide and other climate-changing compounds (like NO_x, CFCs, and methane) are coming under a great deal of scrutiny. Mainstream institutional investment organizations are starting to warn their clients—and the emitters themselves—about the financial risks of turning potential profits into costly pollution.

The reason is simple: not only sending money up the stack (see p.15), but business risk. Industries that emit a lot of bad stuff tend to see pretty strict limits imposed on what they do (remember the tough restrictions imposed on the tobacco industry in the United States during the '90s?). Even if the Kyoto agreement doesn't go into force this year, there is a range of restrictions that various organizations still want to see adopted to halt the flow of climate-damaging molecules out the top of smokestacks. Indeed, in January 2003, attorneys general in Maine, Massachusetts, and Connecticut announced plans to sue the U.S. Environmental Protection Agency to force it to regulate carbon dioxide emissions. And many have read the recent articles about shareholders' meetings erupting into boisterous protests over corporate emissions.

"With all the talk of potential shareholder lawsuits against industrial emitters of so-called greenhouse gases (GHGs), Zurich-based insurance powerhouse Swiss Re is considering denying coverage, starting with directors-and-officers liability policies, to companies it decides aren't doing enough to reduce their output of the gases," wrote Jeffrey Ball of the *Wall Street Journal* in a 7 May 2003 article.

Limits on the number of climate-altering molecules you can exhaust aren't the only threat to businesses. There are also threats that come as a result of the climate change made by emitting GHGs—weather extremes, for example. Weather extremes have never been good for business, whether you're a fisherman off the coast of Chile, the banker in New York who made the loan for the fishing fleet, or the insurer who pays if it sinks.

About two years ago, a group of thirty-five large institutional investors, representing more than $4.5 trillion, created the Carbon Disclosure Project (CDP), an effort "to assess and provide hard data on a company's exposure to climate change through impacts of both extreme weather events and regulation of greenhouse gas emissions."

In 2002, the London-based CDP surveyed the chairs of the world's 500 largest companies. "The CDP study found that while eighty percent of respondents acknowledge the importance of climate change as a financial risk, only 35–40 percent were actually taking action to address the risks and opportunities," states a 17 February 2003 press release. "The Carbon Disclosure Report reveals that the financial impact of climate change extends well beyond the obvious, emissions-intensive sectors such as oil and gas and electric utilities," states a project press release. "Companies in the financial services, transportation, semiconductor, telecommunications and electronic equipment sectors, among others, will also be significantly affected. Further, industry sectors vary widely in their degree of risk exposure and the levels to which companies, in response, develop their risk management capabilities. Those at greatest risk were not necessarily those with the strongest risk management architecture."

The report also explained that firms that are quick to reduce greenhouse gas emissions "stand to gain competitive advantage, in terms of both cost and market risk management." One example cited is British Petroleum, which has, according to the CDP, cut carbon dioxide emissions at the company's plants by ten million metric tons, saving BP an estimated $650 million in ten-year net present value.

This really is quite remarkable: greenhouse gas emissions and what firms do about them might affect your retirement portfolio, your kids' inheritance, or your company's ability to stay in business. Certainly, smart investors are starting to look at their investments through a new lens: what's coming invisibly out of a firm's smokestack or that of the energy plants that power it.

"Emissions reductions are going to be required. It's pretty clear," Christopher Walker, managing director for a unit of Swiss Re told the *Wall Street Journal* recently. "So companies that are not looking to develop a strategy for that are potentially exposing themselves and their shareholders." For more information, see http://194.242.156.103/cdproject/index.asp.

—Cameron M. Burns & Brian C. Adams

Biomimicry in Communities

Shared Resources Work

By Onno Koelman

In the previous two articles ("Building the Future of Buildings," *RMI Solutions*, Fall/Winter 2002, and "Biomimetic Buildings," *RMI Solutions*, Spring 2003) I explained what biomimicry is, its enviable properties, what it means for buildings, and how nature can help inform some of our process design (*e.g.*, natural ventilation systems). But biomimicry's ultimate promise goes well beyond better material and process design in individual buildings. If we kept the focus there, we would miss an essential point of biomimicry: rewarding cooperation and making symbiotic relationships work. This third and final article in the series describes syntheses found in nature and how not only can we use them as models in site selection and the physical construction of the building, but also nature can provide a model for designing communities.

Nature: (1) rewards cooperation and makes symbiotic relationships work, (2) fits form to function efficiently, (3) develops diverse possibilities to find the best solution and survival, (4) recycles and finds a use for everything, (5) requires local expertise, (6) avoids excesses and "overbuilding," (7) taps the power of limits, (8) runs on the sun and other natural sources of energy, and (9) uses only the energy and resources that it needs.

Nature can provide a model for designing communities.

If our buildings are to help us flourish on this earth, it is essential that they follow the above precepts. Until now our industrialized society has prospered through a process of constant expansion: enter a new locale, exploit virgin resources, and leave your trash behind. But as the planet fills and people demand higher standards of living, this short-sighted strategy will fail us, just as it fails the prairie grasses that grow rapidly in the wake of a fire but only last a few short months before a diverse, cooperative, long-term mix of species takes its place and creates a forest.

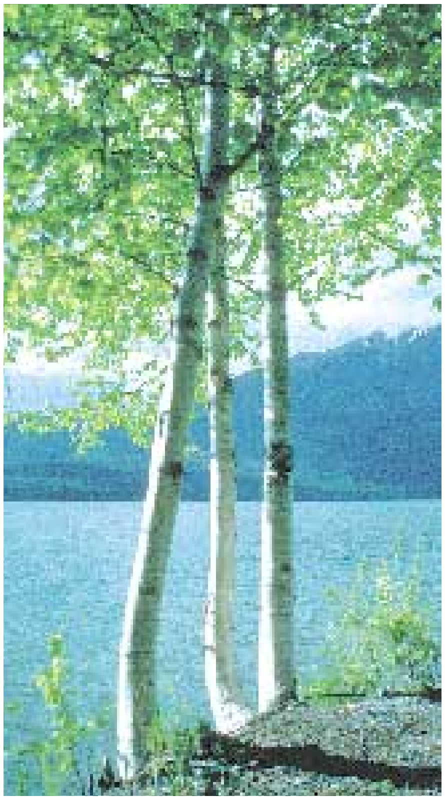
This "type III" ecosystem (a developed forest) is replete with interlocking and interdependent systems, and encompasses a staggering diversity of animal, fungal, bacterial, and plant life—each uniquely attuned to local environmental pressures and niches. Trees and animals have developed customized attributes to help them thrive in these niches. Thicker bark, more or fewer leaves, deeper roots, water-storing strategies, and other characteristics all vary from place to place.[1] Aspen trees only grow in certain climes with snowy winters and hot summers. Similarly, other species have adapted to their conditions, suggesting that each climate and location inspires an optimal design, and that the practice of planting tropical species in, for example, temperate zones doesn't work for trees—nor does it work to take a Florida house and put it in New York. Today's architects are beginning to realize that their designs can leapfrog standard comfort levels and efficiencies if they take into account sun paths and local weather patterns and build to maximize the benefits offered by a house's location.

RMI *in the news*

RMI's Kinsley Advises British Groups on Community Development

In late February, RMI's Michael Kinsley spoke at the Creating Enterprising Communities conference in Nottingham, England and provided guidance to the New Economics Foundation (NEF) and the East Midlands Development Agency (EMDA) on their Local Alchemy program.

NEF and EMDA hosted the conference to examine how communities can best respond to development and employment needs. After the conference, Kinsley stayed on to work with the organizations on the joint Local Alchemy program, a community project aimed at promoting community-based enterprise. Kinsley, who co-founded RMI's economic renewal program, has extensive experience in teaching communities around the world how to develop their economies.



Trees constantly exercise flexibility in their building philosophy.

When nature grows something new (for example, a tree in a forest) this growth is an *exercise in flexibility*. The tree doesn't grow up and bulldoze everything out of its path, nor does it have a larger footprint (*i.e.*, resource drain) than its root system can sustain. (Indeed, the tree is the above-ground, light-gathering expression of mycorrhizal funghi.) When we go to an existing urban community and put up a new building, we should be sensitive to existing buildings and community functions, and design accordingly. When we go to a greenfield (undeveloped land) we should design around existing landscapes.[2] Given that we are running out of land to build on, and that a large percentage of the buildings we built so hastily after World War II need more than just a facelift today, now is the perfect time to get our community design and building philosophies right. Who knows, it might even help to bring in a coral reef specialist to share knowledge of how that successful community works and what balance of features and players (species) is required.
It certainly will help to examine communities that already work, and buildings—like the Capers Building (p. 21)—that succeed. In terms of industrial development, it might help to take a closer look at the EcoPark in Denmark, a community of industries that process each other's "wastes" to the benefit of all.

The Capers Building is one of the best examples of biomimicry in the world. It exemplifies the principles of the discipline by rewarding cooperation, requiring local expertise, and avoiding overbuilding. As a mixed-use building, it has also had a marked effect on the local community—able to act as a focal point for residents, businesses, *and* retailers—all at once. In essence, the building was successfully designed for a niche. The developer, Harold Kalke, spent a year studying the local community and asking what residents felt was needed in a new development. His gentle probing overcame initial skepticism and gained him the support of neighborhood residents. With their help and his intuition about what a community needs, he created a building that now acts as a magnet for all of Kitsilano (a suburb of Vancouver), and Kalke's unique, sensitive development process has become the standard for all Vancouver. The Capers Building includes offices, retail stores, and homes, all coexisting side by side. Much like a tree that houses myriad species under one "roof," this building provides a healthy balance of diversity and cooperation.

In industry there is also room for cooperation. Humans have coined a popular maxim to describe how

Biomimicry's nine principles:

1. Reward cooperation and make symbiotic relationships work

2. Fit form to function efficiently

3. Develop diverse possibilities to find the best solution and survival

4. Recycle and find a use for everything

5. Require local expertise

6. Avoid excesses and "overbuilding"

7. Tap the power of limits

8. Utilize the sun and other "natural sources" of energy

9. Use only the energy and resources that are needed

Examples in this article include:

The Capers Building, Vancouver, BC

Principles 1, 2, 3, 5, 6

The developer spent a year studying the local community, and asking what residents felt was needed in a new development. The resulting building promotes a healthy balance of diversity and cooperation among the offices, retail stores, and homes.

EcoPark, Kalundborg, Denmark

Principles 1, 3, 4, 7, 9

Resources are exchanged between tenants in a manner that is mutually beneficial and that saves on landfilling, generates revenues from previously unusable by-products, and improves their corporate images.

Village Homes, Davis, California

Principles 2, 3, 6, 8, 9

This residential community promotes solar energy use in the homes, uses natural drainage systems (saving infrastructure cost to finance amenities), and uses narrow streets to reduce the amount of pavement needed. Edible landscapes, walking paths, and bike trails are also popular and create exceptional value.

If modeled on nature, our industrial sectors can churn out the material goods we demand, yet do so in a way that encourages product responsibility and does not drain our dwindling natural resources.

nature operates: waste for one species is food for another. One place where such coexistence and waste-sharing is already happening is an "Eco-industrial park" in Kalundborg, Denmark. A cluster of industries and businesses has formed what might be called an island of sustainability, based on the principles of a natural ecosystem. Flows of waste from one process become food for another process. The participants (a coal-fired power plant, a refinery, a pharmaceutical and industrial enzyme plant, a wallboard company, and the town's heating facility) exchange a variety of resources (steam, hot water, gypsum, sulfuric acid, biotech sludge, and other "wastes") in a manner that is mutually beneficial so all the companies save on landfilling, generate revenues from previously unusable byproducts, and improve their corporate reputations.

A more happenstance eco-industrial network was recently "discovered" in the province of Styria, Austria. There, a researcher (Eric Schwarz) learned of a large industrial recycling network that had sprung up largely without organized guidance, one company at a time. In fact, when asked about this "industrial symbiosis," the plant managers weren't aware that they were part of a network. Each individual firm had made micro-decisions to take "waste" from others and use it as raw material for their own processes; in some cases, these byproducts were of higher quality than available primary materials.

The implications of these eco-industrial parks are enormous. If modeled on nature, our industrial sectors can churn out the material goods we demand, yet do so in a way that encourages product responsibility and does not drain our dwindling natural resources. If we can do it right, we will have a workable system that can be exported all over the world to bring previously unreachable levels of material wealth, comfort, and health to the billions who now lack it. This must be what our industrial society strives for. It cannot afford any longer to devalue its richest resource—natural capital—and it must learn to fit in with existing limitations and structures (see Principle No. 7, "taps the power of limits"). The prior model of expansion—always reaching for the next resource and leaving a wake of trash—is fundamentally unsustainable, but we can abandon it at a profit.

Other wastes caused by the inefficient design of cities can also be eliminated with a holistic, biomimetic approach. For example, cities where people do not need to commute by car have less pollution, less noise, less stress, and fewer automobile deaths—and people know their neighbors better. Surveys show that people in these communities (*i.e.*, Village Homes in Davis, Calif.) are happier, healthier, and feel safer than the average homeowner. Mixed-use dwellings are a great stride

RMI *in the news*

Kiwi MP and Associate Energy Minister Visits RMI

Harry Duynhoven, New Zealand MP and associate minister of energy and of transport, visited RMI briefly this May, during a whirlwind tour of Europe and the United States. According to the *Daily News* (of New Plymouth, New Zealand), Duynhoven was "swotting up on maritime security, accident investigation, and energy sources of the future."

In Holland, he met with the Dutch Minister of Transport to discuss maritime security, and in France he attended the International Energy Agency (IEA) conference. New Zealand leaders are concerned about the country's mature oil and gas reserves as its Maui field (located in the Tasman Sea, and supplying about seventy percent of the country's hydrocarbons) is running out. Duynhoven is exploring various nations' energy strategies, and was interested to learn about the U.S. hydrogen strategy—with its $1.7 billion commitment—released at the conference. His final stop was—where else?—RMI, where he spent an afternoon and evening chatting with cofounder and CEO Amory Lovins, one of the world's leading energy and hydrogen strategists.

"For us, [the IEA conference] was interesting because we had already been doing some work on this issue," Duynhoven told the *Daily News*. "In the future, the world might not have the resources in terms of oil and gas, but with hydrogen, we could use wind power or solar power to separate hydrogen from water. It would provide a fuel that would be transportable. I'm looking forward to New Zealand being part of that initiative. It doesn't solve anything today, but it does give a pointer to what is ahead."

The Capers Building, 2211 W. 4th St., Vancouver, BC.
Photo: © 2003 courtesy Harold Kalke

in the direction of sustainability in urban settings: if the true price of mobility is ever accurately revealed, we will realize that the mixed-use dwellings created in the 1920s were sensible, not stylistic. And if we combine new technology with a complete understanding of energy flows and architecture, we will create buildings that, like trees, only use resources proportional to their footprints.

Tying together everything we have explored in this series offers a vision for how buildings can enhance our lives *and* our economies. Individually, a fully biomimetic building would be made from local materials with little energy input. It would be naturally ventilated and illuminated and use a minimum of energy for moving air and water. Composting toilets and Living Machines™ would be standard. The building would not draw from the electricity grid—instead, it might sell back surplus solar energy. And most if not all of the materials would be reusable at the end of their lives. Landscaping would be attractive to animals and plants from local ecosystems and could also provide food for building occupants. And on a community level, buildings would work together, each performing complementary functions for the benefit of all, with enough redundancy so that, like a tropical forest, if one species or building fails temporarily, the web of others can support the flourishing neighborhood until it gets back on its feet.

RMI's former Minerals Acquisition Partners Research Fellow, Onno Koelman, is now pursuing an engineering career with a start-up company that uses Nature's design wisdom in creating efficient fluid-moving systems, PAX Scientific (see www.paxscientific.com and www.rmi.org/sitepages/art7036.php).

1 Interestingly, the physical shape of the community (not just the individual tree itself) also has influenced its effectiveness. In high, windy altitudes, Krummholz trees form themselves into a tear-drop-shaped copse in order to minimize damage from the wind and maximize protection.

2 As surprising as this sounds, whole developments have been erected without destroying a single tree (for example, Dewees Island in South Carolina).

RMI *in the news*

RMI to Help Massachusetts Improve State's Green Building Program

MASSACHUSETTS TECHNOLOGY COLLABORATIVE

RMI recently entered into a partnership with the Massachusetts Technology Collaborative (MTC) to promote the design and construction of highly efficient buildings.

MTC functions as the state's development agency for renewable energy and the "innovation economy." It manages the Massachusetts Renewable Energy Trust, a $150-million fund created by the state legislature in 1998 as part of electric utility industry restructuring. Last year, MTC launched a $35-million green building program. The program awards funds to builders if they use renewable energy technologies in their buildings. More than ninety projects have received funds to date. RMI was selected to assist MTC because of the Institute's reputation and experience as a world leader in green building design and construction.

Institute Generating Important Work

Marty Pickett, Executive Director

In past issues of *RMI Solutions*, I have emphasized some of the great projects we are working on, and this issue is no different. During this spring and summer, RMI will be focusing on a number of projects, but I'd like to bring to your attention three energy-related items rich with research and analysis.

One of RMI's highest priorities over the coming months is a project we're calling "Out of the Oil Box: A Roadmap for U.S. Mobilization." The Principal Investigator on the project is RMI's CEO Amory Lovins, who is leading a team including Kyle Datta, RMI's Managing Director of Research & Consulting; Dr. Jonathan Koomey, who is contributing to this work while on professional leave from the Lawrence Berkeley Laboratory; RMI's Energy & Resources Team Leader Dr. Joel Swisher, PE; and RMI consultant Odd-Even Bustnes, as well as Jamie Fergusson, an intern who holds a Bachelor's degree from Cambridge and is a candidate at Yale for a joint Master's degree in Business and Environmental Management. This business-oriented white paper will synthesize new efficiency and substitution opportunities, policy innovations, and implications. The paper will integrate answers to these critical questions: What is the potential for profitable demand- and supply-side substitutions for oil? What policy instruments and packages are best suited to capturing this potential? What is the potential for combined economic effects from policy packages? What next steps are recommended for policymakers in the public and private sectors? We have targeted 20 October 2003 for completion and release of this important synthesis. This release date is the thirtieth anniversary of the start of the Arab oil embargo against the United States. The finished product will be sent to leaders in business, the military, government, and civil society, to inform the rapidly growing conversation about energy futures that yield security *and* prosperity.

RMI also recently produced "Energy Security Facts," a little booklet studded with facts about energy sources—notably oil, uses, wastes, and solutions. For example, did you know that if, at the time of President George W. Bush's Inauguration, the U.S. had resumed its 1977–85 pace of saving oil, it could have displaced Persian Gulf imports by now? To download a copy, visit www.rmi.org/images/other/S-USEnergySecurityFacts.pdf.

Finally, as you'll see on the cover of this issue, Amory has penned a lengthy white paper countering many of the factual and conceptual errors recently published about hydrogen and fuel cells. Although you can sample the article in this newsletter, I recommend you visit www.rmi.org to read the full, roughly 36-page version of the paper, containing complete explanations and documentation. I think you'll agree that these projects reflect the continually growing credibility of RMI's voice and expertise in energy—a reputation that's attracting even more collaboration from leading energy companies and policymakers.

Editor's Notes

Institute Planning Summer Alumni/ae Event

Cam Burns, Editor

One of the always impressive things about RMI is the high level of community involvement by its staff members.

While you can read all about many RMI staff members' community-minded pursuits in the newsletter (the next two pages feature Jen Seal and former RMI employee Auden Schendler), whenever any of us go out into the world and track down former RMI staff members, we're always amazed by what they're up to—locally and internationally.

Locally, former RMItes have worked and continue to work part- or full-time on transportation, environmental, and political issues of all sorts—while serving on dozens of boards. Farther afield, they have led and continue to lead government and private agencies; promote grassroots-level changes in society; and consult with global corporations on energy and resource efficiency. Whatever they're doing, RMI's message of sustainable resource use is being shared widely and effectively.

We are now planning an alumni/ae get-together event for a weekend in August. Bill Browning and I are heading up a group to organize the event, which we plan to announce on the website as soon as it's organized.

So if you're a former RMI staffer, and would like to come see some old friends, make some new ones, and catch up on the Institute's latest work, let us know (at newslet@rmi.org) and we'll put you on the list to receive an invitation.

It'll involve a tremendous amount of relaxed fun!

Auden Schendler, Aspen Skiing Company

Editor's note: In this and coming issues of RMI Solutions, *we will profile former RMI staff members.*

Auden Schendler has a whimsical request for his epitaph. The former RMI research associate and outreach coordinator, now environmental affairs director for Aspen Skiing Company, wants his headstone to commemorate his struggle to complete an energy-efficient lighting retrofit in the parking garage of the company's Little Nell Hotel.

"It took me three years to accomplish the Little Nell retrofit," Schendler said, "coming up against obstacles I had never considered. I want my headstone to say, 'He pulled off the Nell retrofit.'" Replacing the existing metal halide lamps, fixtures, and wiring with a new fluorescent lighting system cost $19,000. But the retrofit saves the company $11,000 annually in energy and labor and keeps 150 tons of carbon dioxide (from coal-fired power plants) out of the atmosphere every year.

Schendler started working at RMI in 1996 as outreach coordinator, answering questions on sustainability telephoned or emailed in by the public. He became a research associate in corporate sustainability issues and helped research *Natural Capitalism*, the landmark book authored by Amory Lovins, Hunter Lovins, and Paul Hawken. He also managed an environmental audit for the World Bank.

In 1999, Schendler was hired by Aspen Skiing Company as environmental affairs coordinator to assist Chris Lane, who was ASC's first environmental affairs director. He was promoted to director of environmental affairs when Lane left in 2000. Guided by Schendler and his predecessor, and with the leadership of visionary CEO Pat O'Donnell, Aspen Skiing Company has become an environmental leader in the recreation industry and, indeed in the wider corporate world.

When Schendler started, ASC was in the middle of planning the new Sundeck restaurant and day lodge atop the Aspen Mountain ski area. Guidelines for green building were just coming into being, and the Sundeck became a sort of pilot project for development of the U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED) building standards. As a result, the second version of the guidelines, LEED 2.0, contains many changes inspired by the Sundeck project—light pollution reduction methods, for example.

Schendler has had a hand in changes in various aspects of the way the company conducts its day-to-day business. All ASC snowcats, used for grooming the snow on ski slopes every night, now run on biodiesel, a mixture of petroleum diesel fuel and a soybean-based fuel. The company goes through about 260,000 gallons of fuel each year, so the resulting cuts in the emission of particulates, carbon monoxide, unburned hydrocarbons, and sulfates are significant.

ASC's Environmental Department oversees small projects as well, but they all have significant effects. Providing an efficient car for the company's mail delivery saves thousands of dollars a year and reduces exhaust emissions.

More projects are under way. Schendler and Randy Udall, another former RMI employee who directs the Community Office for Resource Efficiency (CORE) in Aspen and Carbondale, are preparing to install a micro-hydroelectric turbine in a snowmaking system at ASC's Snowmass ski area. This small power plant has the potential to generate as much as 250,000 kilowatt-hours annually, using energy provided by water that's flowing downhill through the snowmaking pipes. If this project is as successful as anticipated, every ski area with a snowmaking system could emulate it, at a profit.

"I think we've helped create an environmental arms race. We set the standard, and we're in the crosshairs because we're so far in front."

Another Schendler project, one that isn't expected to be so profitable, involves energy efficiency in a new ski village at the base of the Snowmass ski area. The village will have 600 residential units and 100,000 square feet of commercial space, and it's expected to cost more than $200 million. But the company plans to maximize the efficiency of each building's mechanical system and to engineer every building to exceed the local energy code by thirty percent.

Schendler doesn't have to think up all the ASC's projects. ASC employees have started thinking green, and they share their ideas. The micro-hydroelectric generator was the brainchild of Snowmass General Manager Doug McKenzie; using windpower to run the gondola on Aspen Mountain was Event Marketing Director John Rigney's idea; the idea of putting a spill-mitigation kit in each snowcat came from a cat driver.

Aspen Skiing Company's efforts in sustainability are not going unnoticed outside the industry, either. Articles written by Schendler have appeared in the *Journal of Industrial Ecology* and *Harvard Business Review*, and the company's green work has been the subject of stories in *Business Week*, on *The News Hour with Jim Lehrer,* and elsewhere.

—Jeremy Heiman

Staff Spotlight

Jen Seal, RMI Green Development Services

Among the important values RMI staff members develop while delving deep into energy policy, green buildings, water efficiency, and other resource issues, arguably the most important is community service. RMI staff members have long been known for serving on public boards, as community mentors, and as hardworking volunteers. All RMI staff get two paid hours' leave per week for such community work.

Jenifer Seal, a principal architect with RMI's Green Development Services (GDS), has taken volunteering to a high level. She serves on the board of a local philanthropic organization, volunteers with an adult literacy program, and helps an outdoors group build trails around her adopted hometown, Basalt, where she serves on the town's planning commission and volunteers for even more organizations.

Jen started her RMI career in 1994, working with the GDS team, first on a green development primer, then on green building case studies, and later on the book *Green Development: Integrating Ecology and Real Estate* and its companion CD-ROM *Green Developments*. The CD-ROM has gone on to become one of RMI's most popular publications ever.

A few years ago, Jen left RMI to pursue a graduate degree. She returned to work in GDS in late 2002 with her master's degree from MIT and a year's experience as an officer in a nonprofit dedicated to land preservation. Since returning to RMI, she has led a design charrette for a sustainable grocery store, helped manage RMI's highly successful Data Center Charrette (see p. 5), and worked on many aspects of the progressive California Academy of Sciences project (below). She is also involved in GDS's ongoing biomimicry research.

As busy as she is at RMI, Jen is just as booked up in her free time, with volunteer work. Volunteering, she says, is an essential part of her life. As a member of Roaring Fork Outdoor Volunteers, Jen spends some summer weekends building or repairing trails in the Colorado mountains. In summers past, she worked alongside other volunteers to restore wetlands on the Windstar Land Conservancy, and she teamed up with other RFOV workers and a group from Volunteers for Outdoor Colorado to repair the Capitol Creek trail.

RMI *in the news*

RMI Advises California Academy of Sciences

150 ANNIVERSARY CELEBRATION CALIFORNIA ACADEMY of SCIENCES Since 1853

RMI's Green Development Services is helping the California Academy of Sciences with the rebuilding of its headquarters in San Francisco's Golden Gate Park. The Academy, the oldest scientific institution in the West, opened in its current location in 1916 and is currently housed in twelve separate buildings throughout the park. The new building will bring the entire organization, including the Steinhart Aquarium and Morrison Planetarium, under one roof. The Academy's new building is one of the City of San Francisco's green building pilot projects. As such it must achieve at least a Silver rating in the U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED) rating system, which RMI's Bill Browning helped to design. Both the Academy and the design team expect it will earn top Platinum rating from LEED. Probably the most visible feature of the new building will be its 2.5 acre "green" roof (see below). Green roofs—which include various types of vegetation and natural topography—help keep buildings cool, manage stormwater better than traditional roofs, and provide habitat for wildlife. The designers have described the effect as "lifting a portion of the park and putting a building under it." Other highlights of the design include daylighting, natural ventilation, innovative ways to save water, and renewable energy systems. The design team includes Renzo Piano Building Workshop, Gordon H. Chong & Partners, and Arup.

Drawing: courtesy California Academy of Sciences

For Jen, helping people is as important as restoring trails. Jen volunteers for the Adult Literacy Program which, with sponsorship from the Aspen Valley Community Foundation, arranges one-on-one literacy tutoring for adults. The Program's tutors use both formal and experiential learning methods, ranging from grammar texts to field trips, to help the students acculturate. Jen is currently helping a Japanese woman— who came to Basalt because her husband was employed nearby—to master English.

"Getting involved locally has given me new perspectives on how to make my work at RMI more effective. I love getting to know my valley neighbors and working together to hopefully create an even better place to live and work."

"It opens up a whole new world for people," Jen said. Indeed, her student, once a virtual shut-in, has now become a teacher herself, and instructs students at Glenwood Springs's Yampah Mountain High School in Japanese. She has advanced far beyond her modest goal of being able to take care of daily business in Basalt.

Jen's not scared of the political arena, either. Basalt, with a population of around 3,000, is rapidly growing from a bedroom community into a town with a self-sustaining economy. But with growth comes a new set of problems: Where should commercial interests be concentrated? What can be done to preserve open space? What should be done to provide affordable housing? How should traffic be handled? Jen, a seven-year resident of the town, was asked to become a planning and zoning commissioner because of the diverse skills and experience she could bring to the post.

"I have an overall interest in how Basalt will unfold," she said. The planning commission, which advises the Town Council (on which Dr. John Fox-Rubin serves—he migrated from RMI and now leads its spinoff Hypercar, Inc.), is working on a major revision of the town's master plan and a river master plan that will govern management and conservation of the two rivers that flow through the town. The P&Z meets twice a month, with additional time required for site visits.

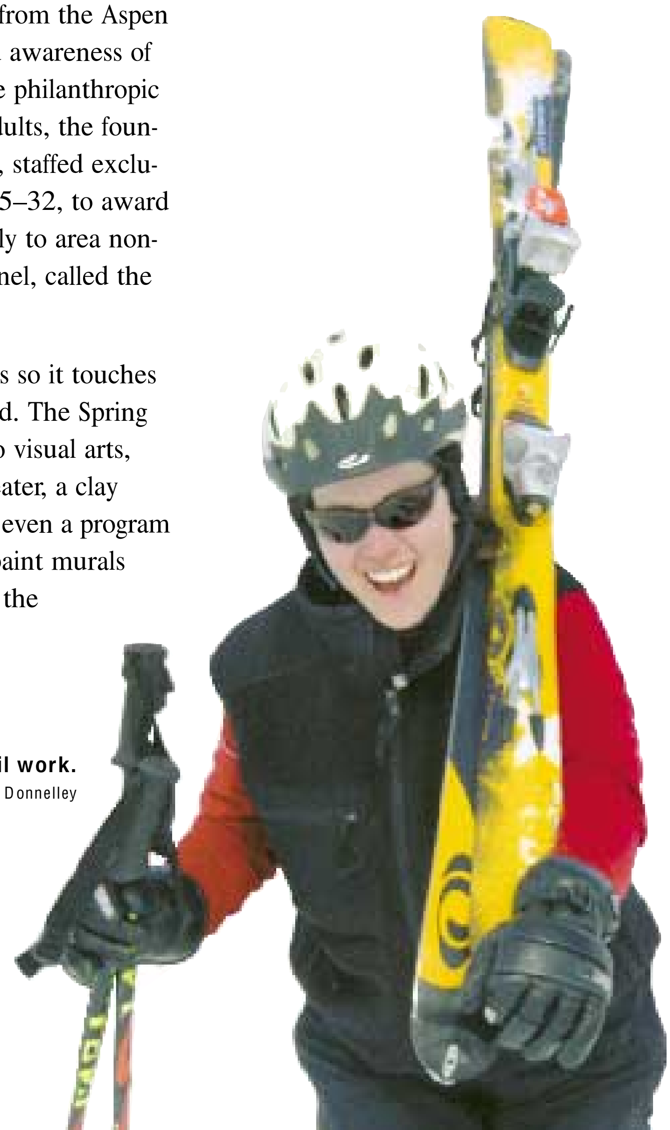
While the P&Z is focused on Basalt, Jen advises another organization that works in communities from Aspen to Parachute, a span of roughly 80 miles. Aspen Valley Community Foundation funds projects intended to strengthen communities, drawing on foundation grants and some funding from the Aspen Skiing Company. To build awareness of philanthropy and promote philanthropic attitudes among young adults, the foundation assembled a board, staffed exclusively with people aged 25–32, to award $50,000 in grants annually to area non-profits. Jen sits on this panel, called the Spring Board.

"We're trying to focus this so it touches the whole valley," she said. The Spring Board directs funding into visual arts, music programs, local theater, a clay program for children, and even a program that arranges for kids to paint murals on buildings. "It enlivens the community," says Jen.

All of Jen's volunteer work enlivens the community. Regardless of whether she's working her day job at RMI or out rebuilding trails, whether she's leading a working group designing a green building or teaching adult literacy, you can be sure that all her efforts will be of great service.

Jen is optimistic that the efforts she makes will ultimately have an effect for good. One of her favorite quotes, by David Brower: "We can no longer afford the luxury of pessimism. Despair is a sin. Hope is more fun. So is rethinking. We can rethink progress, sustainability, mobility, design, conservation, preservation, restoration. And we must."

—Jeremy Heiman



Trail work.
Photo: courtesy Owen M. Donnelley

Issues in Materials Selection

By Wayne Trusty,
President,
Athena Sustainable
Materials Institute

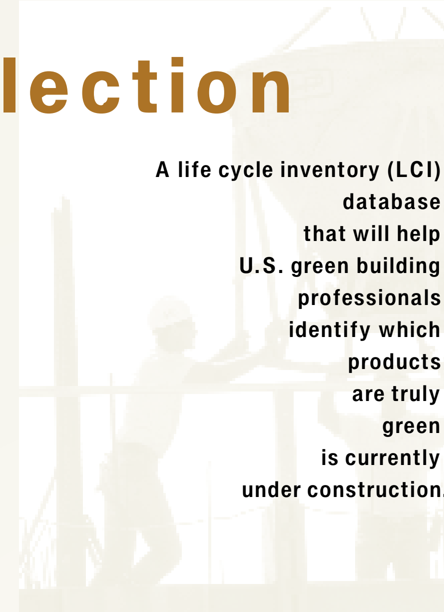
Everyone involved in creating green buildings or products would appreciate having simple guidelines that would make selecting building materials easy. Unfortunately they are hard to come by, if they exist at all. We are constantly forced into a balancing act, trading off a good outcome here with a not-so-desirable effect there. Our ability to judge depends upon the availability of good information about the issues.

When I read Alexis Karolides's article "An Introduction to Green Building" in the Spring 2003 issue of *RMI Solutions*, I was reminded how easily oversimplified and confusing these issues can be—even when correctly explained by knowledgeable professionals.

My organization, the Athena Institute, is a not-for-profit dedicated to furthering sustainability. We focus on making complex information readily available to professionals who do not have the time or resources to pursue details about building materials, and who appreciate the dangers of oversimplification. The tool of choice for these processes is life-cycle assessment. Athena has performed life-cycle assessments on more than a hundred building materials and has created tools such as the Athena *Environmental Impact Estimator* software to facilitate use of that information. The *Estimator* helps architects, engineers, and researchers assess the integrated environmental implications of building designs at an early stage in their projects.

Life cycle assessment (LCA) is a highly specific methodology that is carefully defined in the ISO 14000 series of standards for better understanding the environmental implications of products and processes (for more information see www.iso.org/iso/en/iso9000-14000/tour/meet14k.html). Its rigid accounting framework is essential to the credibility and consistent international practice of LCA. Its methodology encompasses the full range of environmentally significant flows from and to nature.

It is important, however, to distinguish between general cradle-to-grave and cradle-to-cradle assessments and LCAs with much more stringent methodologies. While issues of efficiency, reusability, and recyclability may indirectly affect the outcome of



A life cycle inventory (LCI) database that will help U.S. green building professionals identify which products are truly green is currently under construction.

an LCA, they are not explicitly included in the methodology. For example, the *recycled content* of a product is of direct concern and is explicitly taken into account, but the *recyclability* of that product is not. This does not mean recyclability is not important—it clearly is and it should be considered, but not in the LCA.

The answers for specific materials are seldom as clear-cut as we would like. That's precisely why LCA (or some comparable assessment method) is essential. Whether we are talking about the relative merits of plastic, wood, or concrete, we must take all factors into account. For example, the production and disposal of resins used in the manufacture of plastic wood have to be evaluated if that product is

RMI *in the news*

RMI Advises International Building Materials Company

In mid-February Bill Browning, founder of RMI's Green Development Services, traveled to Paris to meet with representatives from Lafarge Group, a leading building materials manufacturer. Lafarge is the biggest maker of cement on earth and has a strong interest in reducing the impacts of its product. Cement production is responsible for five to eight percent of annual world carbon dioxide emissions.

Browning spoke to Lafarge representatives about green architecture and the company's future. Other experts at the meeting with Lafarge included RMI board member Ray C. Anderson, Chairman of Interface Corp. (via teleconference); Michael Braungart of McDonough Braungart Design Chemistry; and representatives from the World Wildlife Foundation's UK division.

to be considered a superior alternative to wood treated with toxic chemicals or to wood from old growth forests.

Concrete is a particularly important example because it is the most widely used of all construction materials. It seems to be subject to an unusual level of myth and misunderstanding among members of the green building community. Carbon dioxide releases from the manufacture of cement are unquestionably high. It is important to recognize, however, that cement is simply one component of concrete, accounting for roughly fifteen to twenty percent of its mass, depending on the strength. Concrete is the building material and cement is one ingredient in the recipe. This important distinction is too often ignored.

Depending on the efficiency of the cement kiln, more than half (and often considerably more) of the carbon dioxide releases from cement manufacturing are not the result of fuel combustion. They are "process emissions" resulting from the calcination process through which carbon is driven out of limestone. On the other hand, the same chemical processes that result in these carbon dioxide releases can be made to capture other combustion emissions, such as sulfur dioxide and nitrogen oxides. The cement industry has achieved tremendous progress in fuel efficiency and emission control in recent decades, but there is little the industry can do about the constraints imposed by nature. Limestone is an abundant naturally-occurring resource that can be converted into very useful building materials; making it into cement, however, entails some unavoidable chemical reactions.

This brings me to the issue of reducing the proportion of cement used in concrete. Alexis's article mentions replacing up to seventy percent of Portland cement with fly ash from power plants. The reality is complex and needs further explanation.

Fly ash comes primarily from power plants that burn coal. The quality of fly ash depends on several factors, such as the efficiency of the furnace and the type of coal burned. The exact make-up of fly ash is a critical factor in the mix. Substitution at levels above twenty-five percent require very careful batch testing of the concrete. We have worked on buildings constructed with concrete that went to the fifty-percent fly ash substitution level, but testing is critical or serious problems can arise. Substitution of up to seventy percent is not possible with fly ash, but may be possible using blast furnace slag, a waste from steel production that is itself a cementatious material when appropriately treated.

All green building professionals would welcome simple methods to tell us which products are truly green, taking all factors into account over the product's whole life cycle. The reality is this requires formal life cycle assessment or some equally thorough approach to produce those answers. In the absence of that kind of scrutiny, we should regard seemingly easy answers with caution.

The good news is that we have the necessary tools, and soon we will have the data. Athena is currently leading a project, under contract to the National Renewable Energy Laboratory, to develop publicly available life cycle inventory (LCI) databases. RMI has been supporting this project as a member of its advisory committee. Over the past decade the Athena Institute has generated a similar Canadian LCI database that serves as a starting point for the U.S. project.

Life cycle assessment (LCA) is a highly specific methodology encompassing the full range of environmentally significant flows from and to nature.

This public/private research partnership will produce regionally specific, publicly available LCI databases for commonly used materials, products, and processes to support various efforts to develop environmentally-oriented decision support systems and tools; to provide regional benchmark data for generating or assessing company, plant, or technology data; and to provide a firm foundation for subsequent life-cycle assessment tasks such as characterization, normalization, and impact assessment.

The project enjoys strong support from organizations in the industrial, academic, and consulting sectors, including NGOs such as the World Resources Institute and the U.S. Green Building Council, government agencies such as the USEPA, and private sector interests such as manufacturers from Canada, the United States, and Mexico. All recognize that a high quality, public LCI database will be a valuable source of information, one that is needed for assessing future efforts to build a more sustainable world and product systems.

Life cycle assessment, with its system focus, is the tool of choice.

About the Author

The Athena Institute's web site is www.athenaSMI.ca. Mr. Trusty can be reached at 1-866-520-6792. Athena Sustainable Materials Institute is a Canadian not-for-profit corporation. Its affiliate, Athena Institute International, is a U.S. not-for-profit corporation.

Janine Benyus

Janine Benyus lives in Stevensville, Montana, on the edge of the Selway-Bitterroot Wilderness. Nature is right outside her door. It's a perfect location for a nature-lover, and an ideal place to carry out her work as a writer and her work with biomimicry, the art of using nature's breakthroughs to guide mankind's design work.

With an English literature degree and another in forest ecosystem science from Rutgers, Benyus is a natural sciences writer—"basically, an interpreter of the natural world," she said. She is author of six books, three on wildlife adaptation and animal behavior. These three are what she describes as "ecosystem-first field guides"—you look up the ecosystem type and the book tells what you'll find there and provides information on how animals and plants in that particular ecosystem interrelate. Writing these books led Benyus into a way of thinking that has much in common with, and has fundamentally informed, RMI's teaching.

"That was my training in whole systems thinking," she said, "consciously trying to emulate organisms that are that exquisitely adapted to their places."

But the book that caught the attention of other important thinkers was *Biomimicry: Innovation Inspired By Nature*, published in 1997. It was built on the premise that nature, through evolution, has 3.8 billion years of research and development experience in solving the very same problems humans face, and that we can benefit from this rich R&D heritage by not only learning *about* nature, but learning *from* it.

> **"RMI will be a great guide when it comes to distributed manufacturing. RMI's job is to start 'daylighting' the possibilities there, just as Amory did with hydrogen."**

Amory Lovins and other respected sustainability leaders "grabbed the book, saying 'we need these ideas'." Benyus said. "Their reaction was we've kissed a lot of frogs, and biomimicry is kissing the right frog."

Paul Hawken, Amory Lovins, and Hunter Lovins adopted biomimicry as the second of four principles of business design in the 1999 book *Natural Capitalism*.

"Nature's designs are inherently sustainable," Benyus said. But in the materials she had been reading, she didn't see a lot of biologists involved in sustainability. One of her goals now is to try to bring biologists and ecologists—scientists who know how life works—to the design table, to begin to allow nature's strategies to inform the design of products and the human environment.

Benyus joined RMI's Board of Directors in September 2001. She's on the Blue Sky Sessions Steering Committee—she and board member David Orr organize discussion of a topical, provocative subject that provides over-the-horizon radar for issues RMI needs to stay ahead of. She's also a member of the Executive Committee.

"I'm happy to be on the Board, to try to look beyond the headlights and see what kind of issues are arising in the world," she said.

Benyus has several goals for RMI's immediate future. She would like to see the charrette process, perfected by RMI as a tool for implementing change in institutions, used more frequently in RMI's work. She would also like to see RMI become more adept at analysis to determine where sustainability is needed, using a system similar to the "gap analysis" technique used in the study of biodiversity. Gap analysis is used to identify gaps in biodiversity protection that might be filled by the establishment of new biodiversity preserves or changes in land-use practices. She also believes RMI's work in designing sustainable settlements and refugee camps is extremely important.

For the longer term, Benyus would like to see RMI's work with small-scale distributed electrical generation translated into studies of distributed small-scale manufacturing.

"RMI will be a great guide when it comes to distributed manufacturing," she said. "RMI's job is to start 'daylighting' the possibilities there, just as Amory did with hydrogen."

Besides her work with RMI, Benyus is also President of the Board of Directors of Living Education, a small nonprofit concerned with kindergarten through grade twelve education. Living Education advocates learning about and through the place where the student lives. "The place informs all the subjects—it's place-based learning," she said.

Living where she does, in the mountains of western Montana, Benyus feels at home. She spends her spare time rowing on Montana's mountain lakes or backpacking in the warm months, and backcountry skiing in the wilderness or skate skiing on prepared trails in the winter.

"I spend as much time as I can here," she says. "I don't really need to travel."

True. Her gifted thinking and writing travel for her, resounding through the world.

—Jeremy Heiman

Maine Man Pushing *NatCap* and its Principles

"I did it [started the *NatCap* library service] mostly because I wanted certain people I respect to read the book. And the little pressure I applied worked in most cases."

Natural capitalism's first principle (advanced resource productivity) is practiced by people and organizations in many different ways. Jonathan Archer, a biomedical researcher who lives just outside Bar Harbor, Maine, has his own way of advancing resource productivity: he shares his copies of *Natural Capitalism* with anyone he thinks will read them, using each copy continuously and intensively.

Jon owns three copies of *Natural Capitalism*, which his wife Carolyn describes thus: "one is a tattered and worn copy, which he uses when reciting chapter and verse to non-believers; the two other copies he loans to people."

When he loans out a book, Jon enters the names of the borrower in his Palm Pilot and then sets the device to alert him two weeks later. When the two weeks have passed, he calls the borrower to see if he or she has finished reading the book—and if not, why not.

"He will, if you have good reasons for not finishing the book (*i.e.*, something short of death), let you have the book another two weeks," Carolyn explained. "Or he will take the book and loan it to someone else. If you have read it, then he discusses the book with you."

Jon doesn't know how much water, energy, and paper his modest library service has saved—that wasn't his goal. "I did it mostly because I wanted certain people I respect to read the book," he said. "And the little pressure I applied worked in most cases."

Jon estimates he has loaned *NatCap* to between ten and fifteen people, meaning that each copy of the book has been read (to date) three to five times.

Running a *Natural Capitalism* library service is just one of Jon's many environmentally-minded activities. He bicycles whenever possible, and even purchased an electric bike so he can ride farther and longer; he lives with a modest solar power system; and he sails a catamaran to his job at Jackson Laboratory, where he is studying aging in mice. The four-mile trip by boat means a huge savings in vehicular carbon emissions—when he doesn't sail, he has to drive his diesel *Jetta* forty-four miles around the water to his office. When he reaches the "work side" of the harbor, Jon rides a bicycle the last mile to lab—avoiding tourist-generated congestion, saving time, and of course, saving more fuel and emissions.

Jon is also a low-impact sheep farmer. "We are trying to preserve an old tradition of keeping sheep on islands off the coast of Maine," he explained. "There, we have seventy sheep on a 100-acre island and are practicing low-impact organic agriculture"—more natural capitalism in action.

Jon admits there are a few tardy readers from whom he's had to "pull" *Natural Capitalism*, but said they didn't mind because they knew others wanted to read it, and most vowed to get their own copies.

So how many times has Jon read *Natural Capitalism*? "I'm on my third reading," he said proudly. Clearly, advanced resource productivity takes many interesting and unusual shapes and forms, but "advanced book productivity" is a new one for us.

The official Bar Harbor *NatCap* library. Closed holidays.

Photo: © 2003 courtesy Jonathan Archer

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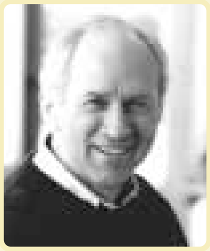


Dale Levy, Development Director

To each individual who contributed recently, I say a hearty thank you. You are really special people. Even in the midst of a declining economy, a roller-coaster stock market, and preparations for and then a war in Iraq, our donors have come through.

For the first nine months of FY2003 (July 2002–March 2003), RMI received $916,604 from individuals, compared to $828,732 received during the same period a year earlier. Much of this increase was stimulated by the all-or-nothing challenge grant made by the Sandler Family Supporting Foundation in July 2002. The Sandler Family committed to giving us $100,000 if RMI could find $200,000 in gifts or grants, from brand new donors by 31 December 2002.

By early December, we were a long way from our goal. We requested and were granted an extension to 31 March.

Because of factors beyond our control—including the war in Iraq—we weren't able to make much progress in the first two and a half months of 2003. But as the second deadline neared, people and foundations considering contributions to RMI—realizing their gifts could be leveraged by an additional fifty percent—started saying "yes." On 31 March (the last day), two new donors committed $60,000.

The total raised through the Sandler challenge came to a whopping $270,600! Many thanks and welcome to our new donors.

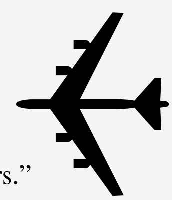
The RMI Board and staff owe a large debt of gratitude to the Sandler Family Supporting Foundation for its foresight in encouraging and enticing us to work harder at developing new donors who have the capacity to give $10,000 or more. This, the third Sandler Family challenge grant, brings the total raised from first-time donors of $10,000 or more to over $676,000 in three years.

In addition to the above good news, we learned in mid-April that the William and Flora Hewlett Foundation approved a $250,000 general support grant and the Joyce Foundation approved a $92,670 grant for a collaborative project with the Cuyahoga Valley Initiative in Cleveland, Ohio.

> **"I don't generally support U.S. groups or causes. I have many great choices 'up here' in Canada. However, the RMI team consistently surprises, delights and amazes me with their depth of commitment, knowledge and ability to bridge cultures, generations, life styles, governments and many other 'criteria' we live by."**
>
> Michael Ballard

RMI *in the news*

Battle for Military Energy Efficiency: Winning the Opening Skirmish



During the recent Iraq war, the U.S. military burned through an estimated 417 million pounds of jet fuel—enough, noted RMI's CEO Amory Lovins, to "keep a Boeing 737-300 airliner aloft for 11.9 years."

Partly aided by RMI's involvement, in early January 2003, a Defense Science Board (DSB) special task force unanimously recommended prompt (within five years) re-engining of the whole B-52H fleet to make those aircraft 35 percent more efficient. RMI has long advocated a fast, smart, responsive military, and has worked over the past eight years to deploy efficiency in both buildings and platforms. In early 2001, this involvement led to the completion of an important DSB report, *More Capable Warfighting Through Reduced Fuel Burden*, which points out numerous areas ripe for saving. For example, properly accounted for, fuel (during midair refueling) costs $17.50 per gallon, not counting the cost of the new tankers now starting to be procured. In the past, the military had ignored the delivery cost and counted fuel at just $1 per gallon. After the report was complete, RMI's Lovins emphasized its importance to a key panel member (a close adviser to the Secretary of the Air Force), and also accelerated its delivery into Defense Secretary Rumsfeld's hands when he entered office. Reportedly, on hearing about the report's findings, Rumsfeld's reply was, "Sounds great. Give me a one-pager on what we can be doing right now while we're reading the report." Adoption of this re-engining recommendation is, according to Lovins's contacts in the Administration, considered "highly likely," and is projected to save $6–9 billion.

Our sincere appreciation is offered to these friends who have contributed to RMI between 1 January 2003 and 30 April 2003. Numbers in parentheses indicate multiple donations. Please let us know if your name has been omitted or misspelled so it can be corrected in the next issue.

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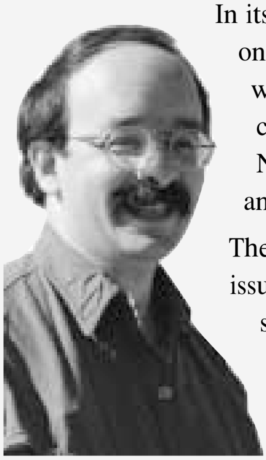
RMI *in the news*

Esquire Names Lovins to "Best and Brightest" List



In its December 2002 issue, *Esquire* magazine named RMI cofounder and CEO Amory Lovins one of America's "Best and Brightest." Dubbed one of "43 people who will revolutionize the world," Lovins was recognized for his contributions to business, along with the CEOs of innovative companies Expedia, Tyco, and Xcorp. Others listed include Baltimore Mayor Martin O'Malley, NASA's Mars specialist Dave Lavery, genetic scientist Eugene Chan, and actors Samantha Morton and Ryan Gosling.

The "Best and Brightest" represents, as former President Bill Clinton writes in his foreword to the issue, the "deep well of greatness" that exists in America. The list is divided into four categories: society, culture, business, and science. For more than a year, *Esquire* editors researched, interviewed, discussed, and identified scores of pioneers who are blazing the trail to a better world.

The table of contents for the magazine is available at www.esquire.com/themagazine/2002/021200_mtc_best01.html.

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RMI *in the news*

Hypercar, Inc. Receives Hewlett Investment

HYPERCAR INC.

Hypercar, the RMI for-profit spin-off developing lightweight automotive technologies, recently received a $2 million Program-Related Investment from The William and Flora Hewlett Foundation.

According to Hypercar's President and CEO Dr. Jon Fox-Rubin, the investment will help Hypercar develop its patent-pending Automotive Volume Advanced Composite Solution (AVACS™) technology. AVACS is a design and manufacturing system that will allow the creation of autobody structures in advanced composites (like carbon fiber) at costs comparable to traditional steel, aluminum, and magnesium techniques (www.hypercar.com/pdf/Hypercar_EVS19.pdf). Economic and scalable production of advanced composite autobody structures is considered one of the biggest challenges in the widespread use of composites in automobiles.

"Reducing the environmental impacts of the automobile is perhaps the premier environmental challenge of our time," said Hal Harvey, Environment Program Director at the Hewlett Foundation. "Hypercar has demonstrated visionary but realistic concepts to that end, and they have backed them up with detailed and sophisticated engineering analyses. We are delighted to be partners in this venture."

The investment brings to approximately $9 million in equity finance the amount Hypercar has secured to develop, design, and commercialize its technologies. "We are thrilled that the Hewlett Foundation shares our vision for more environmentally sustainable automobiles and has faith that we can put cars on the road to a sustainable tomorrow," said Fox-Rubin.

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Wills

Below is suggested wording for including RMI in your will. But we suggest you consult with your attorney.

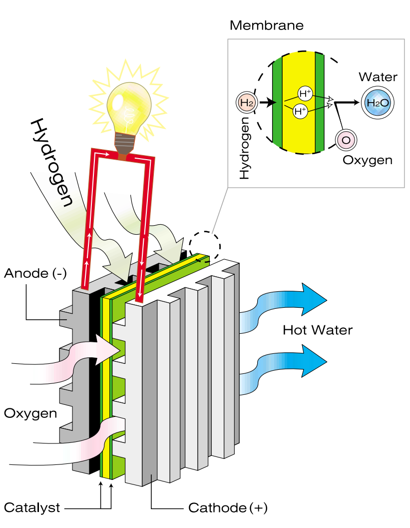
"I hereby leave _____ percent of my estate (or a fixed amount, specific property or the remainder of my estate) to Rocky Mountain Institute, a Colorado nonprofit corporation, whose purpose is to foster the efficient and restorative use of resources to make the world secure, just, prosperous, and life sustaining."

Myths about H_2 (continued from p. 4)

tric propulsion without the disadvantages of batteries. Still better will be fuel cells—the most efficient (50–70 percent from hydrogen to direct-current electricity), clean, and reliable known way to make fuel into electricity.

Fuel cells reverse the high-school chemistry experiment—splitting water with an electric current so hydrogen and oxygen bubble out of the test-tube—by chemically recombining hydrogen and oxygen on a special membrane, at temperatures as low as 160–190˚F (much higher in some types), to produce electricity, pure water, heat, and nothing else. Invented in 1839, fuel cells have been widely used for decades in aerospace and military applications. Breakthroughs since the early 1990s mean that, even in this decade, they'll start becoming affordable. As for most other manufactured goods, real cost should fall by about 15–30 percent for each doubling of cumulative production. Used in the right place and manner, even today's hand-made fuel-cell prototypes can compete in many buildings.

A typical proton exchange membrane (PEM) fuel cell.



Source: www.rmi.org/sitepages/pid537.php

Testing of vehicular fuel cells is well advanced. Already, many manufacturers have tens of fuel-cell buses and over a hundred fuel-cell cars on the road; a German website (www.hydrogen.org/h2cars/overview/main00.html) reports 156 different kinds of fuel-cell concept cars and sixty-eight demonstration hydrogen filling stations; Honda and Toyota are leasing fuel-cell cars; six other automakers plan to follow suit during 2003–05; many kinds of military vehicles are demonstrating more advanced fuel cells; ship, boat, scooter, and recreational uses are emerging; and Fedex and UPS reportedly plan to introduce fuel-cell trucks by 2008. A Deutsche Shell director predicted in 2000 that half of all new cars and a fifth of the car fleet will run on hydrogen by 2010, while the German Transport Minister forecast ten percent of new German cars.

Some automakers formerly assumed that they must extract hydrogen from gasoline (or methanol) aboard cars, using portable reformers, for two reasons: tanks of compressed hydrogen would be too big because hydrogen has so much less energy per unit volume than liquid fuels, and it would be too hard or costly to shift today's fueling infrastructure from gasoline to hydrogen. Both these problems have now been solved, so few automakers still favor onboard gasoline reformers. That's good, because they're very difficult and problematic, and would cut gasoline-to-wheels efficiency to or below that of a good gasoline-engine car. Since almost all automakers now agree that reformers should be at or near the filling station, not aboard the car, there's no longer any reason to reform gasoline: natural gas is much cheaper, and is easier to reform. Hydrogen will thus displace gasoline altogether, without spending the energy and money to make gasoline first. There is similarly little reason to "bridge" with methanol, except perhaps to run fuel cells in very portable devices like vacuum cleaners, cellphones, computers, and hearing aids.

7. We lack a safe and affordable way to store hydrogen in cars.

Wrong. Such firms as Quantum (partly owned by GM) and Dynetek now sell filament-wound carbon-fiber tanks lined with an aluminized polyester bladder. They are extremely rugged and safe, unscathed in crashes that flatten steel cars and shred gasoline tanks. The car isn't driving around with highly pressurized pipes, either, because the hydrogen is throttled to the fuel cell's low pressure before it leaves the tank. That pressure reduction is done inside the carbon shell, eliminating external high-pressure plumbing. Such aerospace-style tanks operating at up to 700 bar and tested above 1,656 bar have been tested by GM in fuel-cell cars and have been legally approved in Germany; U.S. authorities, who've licensed 345-bar tanks, are expected to follow suit shortly. The carbon-fiber tanks could be mass-produced for just a few hundred dollars, and can hold 11–19 percent hydrogen by mass, depending on pressure and safety margin.

A 345-bar tank is nearly ten times as big as a gasoline tank holding the same energy. But since the fuel cell is 2–3 times more efficient than a gasoline engine, the hydrogen tank is only 3–5 times bigger for the same driving range. Lighter, stronger, more efficient cars and their more compact propulsion systems can largely make up that difference. The result works so well in all respects that further advances in hydrogen storage, or costly work-arounds like liquid hydrogen, simply aren't necessary.

8. Compressing hydrogen for automotive storage tanks takes too much energy.

Wrong. Filling tanks to 345 bar takes electricity equivalent to about 9–12 percent of the hydrogen's energy content. However, most of that energy can then be recovered aboard the car by reducing the pressure back to what the fuel cell needs (~0.3–3 bar) through a turboexpander. Also, the compressor's externally rejected heat can be put to use. And compression energy is logarithmic—it takes about the same amount of energy to compress from 10 to 100 bar as from 1 to 10 bar, so using a 700-bar instead of a 345-bar tank adds only one percentage point to the energy requirement. Modern electrolyzers are therefore often designed to produce 30-bar hydrogen, halving the compression energy required for tank filling. The latest electrolyzers can cut it by three-fourths.

9. Hydrogen is too expensive to compete with gasoline.

Wrong. Using fuel-cell cars 2.2 times as efficient as gasoline cars, onsite miniature reformers made in quantities of some hundreds—each supporting at least a few hundred fuel-cell vehicles—and using natural gas at $5.69 per gigajoule or $6 per million British thermal units could deliver hydrogen into cars at well below $2 per kilogram. That's as cheap per mile as U.S. untaxed wholesale gasoline ($0.90 per U.S. gallon or $0.24 per liter). Other countries often pay more for both natural gas and gasoline, so miniature reformers tend to retain their advantage abroad.

Only a tiny fraction of hydrogen is made electrolytically, because this method can't compete with reforming natural gas unless the electricity is very cheap or heavily subsidized, or the electrolysis is done on a very small scale (a neighborhood with up to a few dozen cars). However, mass-produced (around one million units) electrolyzers each serving a few to a few dozen cars could beat taxed U.S. gasoline even using three cent per kilowatt-hour off-peak electricity, so household-to-neighborhood-scale electrolyzers could be a successful niche market if enough units were made. Yet such units, even initially using fossil-fueled electricity that might increase net carbon output per car, would be small enough to create little electrical load or climatic concern. Their market role would be temporary, or they would switch to using electricity from renewable sources.

Energy Facts

If the performance and weight of U.S. cars and light trucks had stayed constant since 1981 (instead of increasing 93% in horsepower, 29% in acceleration, and 24% in weight), their fuel economy would have improved 33%—enough to displace Persian Gulf imports 2.5 times over.

10. We'd need to lace the country with ubiquitous hydrogen production, distribution, and delivery infrastructure before we could sell the first hydrogen car, but that's impractical and far too costly—probably hundreds of billions of dollars.

Wrong. RMI's 1999 hydrogen strategy (see www.rmi.org/images/other/HC-StrategyHCTrans.pdf) shows how to build up hydrogen supply and demand profitably at each step, starting now, by interlinking deployment of fuel cells in buildings and in hydrogen-ready vehicles, so each helps the other happen faster. Such linkage was adopted in November 2001 by the Department of Energy and is part of the business strategy of major auto and energy companies.

Extensive analysis by the main analyst for Ford Motor Company's hydrogen program indicates that a hydrogen fueling infrastructure based on miniature natural gas reformers, including sustaining their natural gas supply, will cost about $600 per car *less* than sustaining the existing gasoline fueling infrastructure, thus saving about $1 trillion worldwide over the next forty years. In absolute terms, a filling-station-sized gas reformer, compressor, and delivery equipment would cost about $2–4 billion to install in an adequate fraction (10–20 percent) of the nation's nearly 180,000 filling stations. Even a small (twenty cars per day) reformer would cost only about a tenth as much as a modern gasoline filling station costs (about $1.5 million, not counting the roughly threefold larger investment to produce and deliver the gasoline to its tanks—a far more capital-intensive enterprise than for natural gas).

Although more work is needed to pin down the numbers exactly, other analysts are also starting to conclude that switching from oil to hydrogen could be not costly but profitable. For example, Mary Tolan, who leads Accenture's $2-billion energy practice, estimates that a one-time $280-billion investment in hydrogen and the natural gas capacity to make it could save a roughly comparable oil-industry investment, plus $200 billion in oil imports *every year* by 2020.

CONTINUED ON NEXT PAGE

Myths about H_2 (cont. from previous page)

11. Manufacturing enough hydrogen to run a car fleet is a gargantuan and hugely expensive task.

Wrong. Current worldwide production of industrial hydrogen, about fifty million tons per year, if it fueled a global quintupled-efficiency[1] car fleet, *would displace two-thirds of today's entire worldwide consumption of gasoline.* About a third of that hydrogen production is currently being used to make gasoline and diesel fuel. If that U.S. refinery usage were diverted into direct fueling of quintupled-efficiency vehicles, like Hypercar, Inc.'s *Revolution* concept SUV, it could replace one-fourth of U.S. gasoline—equivalent to twice as much as is made from Persian Gulf oil.

12. Since renewables are currently too costly, hydrogen would have to be made from fossil fuels or nuclear energy.

Hydrogen would indeed be made in the short run, as it is now, mainly from natural gas, but when the hydrogen is used in fuel cells, total carbon emissions per mile would be cut by about half using ordinary cars (equipped with fuel cells) or about eighty-plus percent using quintupled-efficiency vehicles. That's a lot better than likely reductions without hydrogen, and is a sound interim step while zero-carbon hydrogen sources are being deployed.

Remember that long-term, large-scale choices for making hydrogen are not limited to costly renewables-or-nuclear-electrolysis *vs.* carbon-releasing natural-gas reforming. Reformers can use a wide range of biomass feedstocks which, if sustainably grown, don't harm the climate. With either biomass or fossil-fuel feedstocks, reformers can also sequester carbon (already being tested in the North Sea, and looking promising). If sequestration doesn't work, the Victorian carbon-black process for making hydrogen, with zero carbon emissions into the air, is also 50+ percent efficient, offering a good backstop technology.

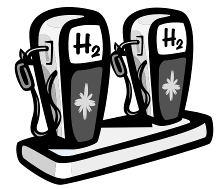
12a. A hydrogen economy would require the construction of many new coal and nuclear power stations.

This fear of many environmentalists is unfounded. New nuclear plants would deliver electricity at about 2–3 times the cost of new windpower, 5–10 times that of new gas-fired cogeneration in industry and buildings, and 10–30+ times that of efficient use, so they won't be built with private capital, with or without a hydrogen transition. The 207 "distributed benefits" recently described in *Small Is Profitable* further increase nuclear power's disadvantage, often by as much as tenfold.

Electricity from any source is rarely competitive with natural gas for producing hydrogen. Just the operating cost of existing nuclear plants is barely competitive with that of other traditional power plants or with the *full* cost of gas-fired cogenerated electricity or windpower—even less so when hydrogen or electricity delivery costs are included. New nuclear plants are forever uneconomic. Indeed, hydrogen fuel cells will join their toughest competitors. The hydrogen future, long touted by nuclear enthusiasts as the savior of their failed technology, is just another nail in its coffin.

12b. A hydrogen economy would retard the adoption of renewable energy by competing for R&D budget, being misspent, and taking away future markets.

This concern is partly prompted by allegations—probably unprovable



either way—that the Department of Energy may have diverted funds that Congress voted for renewable R&D into fossil-fuel hydrogen programs. Such diversion would be illegal and unwise. Unfortunately, such a reallocation is proposed in the President's 2004 budget. Both many renewables *and* many hydrogen programs are worthwhile and important for national prosperity and security, so we should do both, not sacrifice one for the other. Fortunately, hydrogen creates important new economic opportunities and advantages for many renewable energy sources, so a well-designed hydrogen economy should speed up renewables' wide adoption.

12c. Making hydrogen from natural gas would quickly deplete our gas reserves.

At least five percent of U.S. natural gas is currently used to make industrial hydrogen. Natural gas is more abundant and widely distributed than oil. Making enough hydrogen to run an entire U.S. fleet of quintupled-efficiency light vehicles would take only about one-fifth of current U.S. gas production. But gas use wouldn't actually increase by nearly that much if at all.

In fact, the sort of integrated hydrogen transition that RMI recommends and GM (among others) assumes may even *decrease* net U.S. consumption of natural gas by saving more gas in displaced power plants, furnaces, boilers, and refinery hydrogen production than is made into hydrogen. In other words, a well-designed hydrogen transition may well reduce U.S. consumption of oil *and* natural gas *simultaneously.*

13. A viable hydrogen transition would take 30–50 years or more to complete, and hardly anything worthwhile could be done within the next 20 years.

Quintupled-efficiency vehicles, under development since 1991, could in principle ramp up production as soon as 2007 with aggressive investment and licensing to manufacturers. Such vehicles could make the hydrogen transition very rapid. Although very long transition times have been reported as inevitable according to unnamed experts, many other experts feel the transition could take off quickly. Accelerated-scrappage feebates could turn over most of the U.S. car fleet in less than a decade if desired. The scores of hydrogen refueling stations in Japan, Europe, and the U.S. could grow rapidly: Deutsche Shell has said hydrogen could be dispensed from all its German stations within two years if desired.

14. The hydrogen transition requires a big (say, $100–300 billion) federal crash program, similar to the Apollo Program or the Manhattan Project.

Many political leaders and activists cite such large, round numbers to symbolize the level of investment and commitment they consider appropriate. However, it's not clear that a federal crash program is the right model when there's plenty of skill and motivation in the private sector to introduce hydrogen fuel-cell vehicles rapidly—if they can compete fairly. This is difficult when, for example, the latest tax law makes up to $100,000 spent on a *Hummer* (bought ostensibly for business purposes) deductable in new tax breaks, federal funds for automotive innovation virtually exclude innovation-rich small businesses, global and state initiatives to make carbon costs visible are opposed by the federal government (disadvantaging U.S. businesses), and feebates aren't yet on the agenda.

Coherent private- and public-sector policy could go a long way toward a rapid and profitable hydrogen transition. There are signs of smarter policy emerging in the Department of Energy's recent restructuring to integrate hydrogen, vehicle, building, and utility programs. On the other hand, a senior DOE official, when told in January 2002 that the just-announced FreedomCAR program hoped to develop over the next 10–20 years a car that had already been designed (by Hypercar, Inc.) in 2000, replied, "Well, then, we'd better not try to help you, because we'd just slow you down." That might be true, but if we want a vibrantly competitive rather than a failed automotive industry, we'd better make it as untrue as possible.

The total cost of a hydrogen transition is probably a lot more than the $1.7 billion proposed by President Bush over the next five years, but is probably far less than $100 billion. It may not be much bigger than the billions of dollars that the private sector has already committed to pieces of the puzzle—if the money is intelligently spent on an integrated buildings-and-vehicles transition that bootstraps its investment from its own revenue and earns an attractive return at each stage. And evidence is emerging that this future will be more profitable, not only for customers and the earth, but even for oil companies.

Amory B. Lovins is cofounder and CEO of RMI.

[1] Such as the Hypercar®. These are super-lightweight vehicles that reduce power requirements roughly threefold by reducing weight and drag. In round numbers, these cars' efficiency is tripled if they run on a conventional engine, quadrupled if they're powered by a hybrid electric-drivetrain, and quintupled if they run on a fuel cell.

RMI*Solutions*

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Letters to the Editor

We want to hear your comments. Please address all correspondence to:

Cameron M. Burns, Editor
Rocky Mountain Institute
1739 Snowmass Creek Road
Snowmass, CO 81654-9199
tel: (970) 927-3851
fax: (970) 927-3420
newslet@rmi.org
www.rmi.org

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RMI Solutions

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