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ROCKY MOUNTAIN INSTITUTE
NEWSLETTER

TUNNELING THROUGH THE COST BARRIER

Why Big Savings Often Cost Less than Small Ones

There is an ordinary-looking tract house in Davis, California that defies conventional wisdom. It has no furnace. Despite temperatures of up to 113°F, it has no air conditioning system. It uses 67 percent less energy than comparable houses in the area, saving $490 annually.

It cost more to build because it was a one-off demonstration, but if it were built in the same quantity as other tract houses it would cost $1,800 *less* than they do.

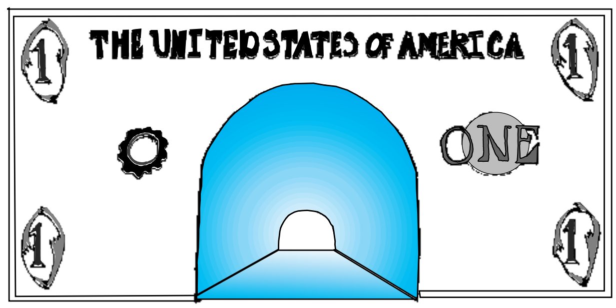
The house, part of an experimental program sponsored by Pacific Gas & Electric, illustrates an important principle: *big savings can be easier and cheaper to achieve than small ones* if you combine the right ingredients in the right way.

The usual way to redesign a product is to analyze its components or subsystems separately and optimize the cost-effectiveness of each in isolation. But components interact in ways that aren't obvious when you're looking at them separately, and optimizing one part may "pessimize" the whole. Often you can reduce the total cost of a technical system by spending extra on certain components.

That's what happened, many times over, with the Davis house. To give just one example: having reduced the building's cooling requirements by two-thirds with various cost-effective measures, the designers found that other measures, previously screened out because they didn't save enough *energy* to pay for themselves, were now worth doing because they could together eliminate the remaining cooling requirement. That saved $1,500 on the *capital* cost of air conditioning and ductwork.

The Davis house may be the shape of things to come. It points toward a future in which engineering designs become simpler rather than more complex, cheaper rather than costlier, uniquely optimized rather than formulaic, and radically more efficient rather than incrementally so.

As RMI's research is demonstrating, huge opportunities exist for re-engineering not



only buildings but also cars, lights, motor systems, electric utilities, industrial processes, and almost anything that uses energy.

UNDIMINISHING RETURNS

Most of us view efficiency as a process of diminishing returns. Let's say you're trying to make an office building more efficient. You prioritize all the things you could do, from the highest return on investment down to the lowest. You work your way down the list until either your budget for improvements is used up, or the return on your investment is so small that you'd be better off spending the money on something else. You've reached what we call the cost barrier (see figure 1 on the next page).

This is a fine way to identify simple, cost-effective improvements, but it's limited in

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what it can do. This approach would have eliminated two-thirds of the Davis house's cooling load, for instance, but it would have left the remaining third, which would have necessitated retaining the cooling system, leaving the whole house costing more, not less. And if this approach comes unstuck with something as simple as a house, imagine how inadequate it is for redesigning a skyscraper or a car.

The fact is that our major technologies are getting so complex that they're outstripping our traditional methods for designing them. Even with CAD workstations, designers tend to simplify the process by optimizing just one or two variables at a time. Moreover, designers are now so specialized that they rarely understand all the workings of an entire system, and tend to confine themselves to optimizing their particular component or subsystem.

For decades, industry has preferred to keep design *processes* relatively simple while allowing *products* to become devilishly complex. It will take a revolution in design sophistication to make products simple and efficient again.

Electronics and personal computers may be both harbingers and enablers of the coming changes. Other enabling technologies such as photovoltaics, advanced polymer composites, and fuel cells have the potential, as they reach critical price points, to cause dramatic technological shifts.

INSPIRED DESIGN

Back to that cost barrier. Conventional wisdom says you've got to stop when you get to your cost-effectiveness limit. But as the Davis house demonstrated, there are times when, by allowing yourself to exceed that threshold temporarily, you can tunnel *through* the cost barrier and drop back down the other side for even greater savings at lower total cost (figure 2).

Such breakthroughs happen all the time, usually thanks to new technologies. But what we're finding is that inspired design and whole-system engineering can often accomplish the same thing, even with old technologies.

Here's another example. An industrial process in the manufacture of carpet involves melting bitumen by means of a hot-oil pumping loop. The engineers who design these loops typically optimize the pipe size in isolation by comparing the extra cost of fatter pipe with the pumping energy it can save.

Designing a system for a new Shanghai carpet plant, Dutch engineer Jan Schilham decided to optimize for total lifecycle cost, which includes capital as well as operational costs. Since pipe friction falls as the fifth power of diameter, he used *bigger* pipes to reduce friction. The pipes cost more, but the smaller pumps and motors to circulate the oil cost much less to buy and to run. Schilham's other innovation was to lay out the pipes first, then the equipment they connect, not vice versa. That resulted in straight pipe runs, further reducing friction, saving even more construction costs, and making it cost-effective to insulate the pipes more heavily, saving 72 kilowatts of heat.

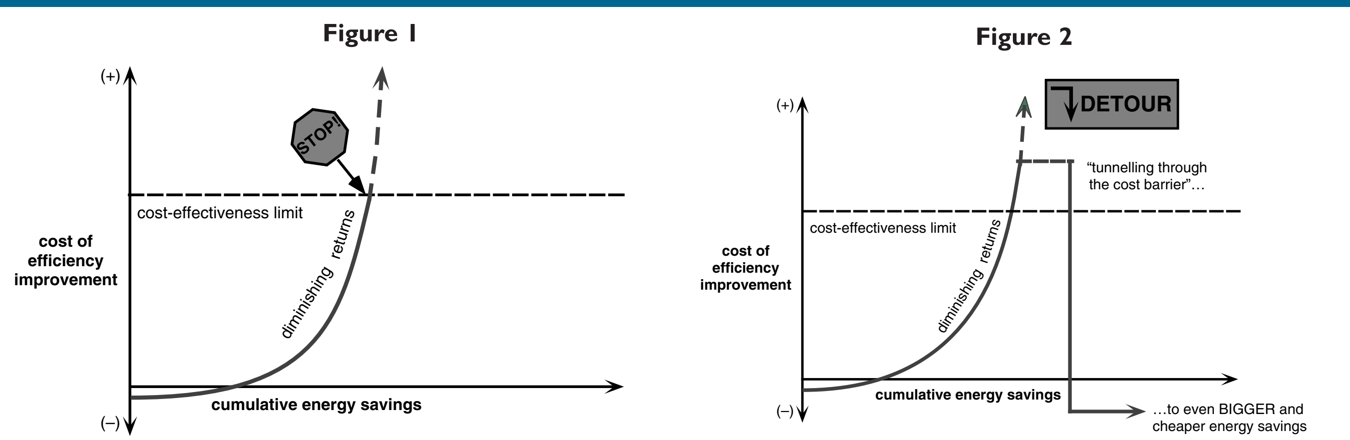
Schilham's loop is expected to reduce pumping energy by an amazing 92 percent, compared to a standard system designed earlier for the same plant by a top engineering firm. Capital cost and construction time went down; reliability, controllability, and maintainability went up.

FOUR PRINCIPLES

Tunneling through cost barriers is as much an art as a science. There's no formula for doing it, but here are four principles that we at RMI find helpful:

Capture multiple benefits from single expenditures. This might seem obvious, but the trick is properly counting all the benefits. It's easy to get fixated on optimizing for energy savings, say, and fail to take into account reduced capital costs, maintenance, risk, or other attributes (such as mass, which in the case of a car, for instance, may make it possible for other components to be smaller, cheaper, lighter, and so on). Another way to capture multiple benefits is to coordinate a retrofit with renovations that need to be done for other reasons anyway. Being alert to these possibilities requires lateral thinking and an awareness of how the whole system works.

BEYOND THE LIMIT



Brett Williams

When prioritizing efficiency measures, the standard method is to pursue those that pay the highest rates of return first, then work down the list until the "cost-effectiveness limit" is reached (figure 1). But by considering the whole system, rather than just components in isolation, it's often possible to tunnel through the cost barrier and achieve even bigger savings at lower total cost (figure 2).

Start downstream to turn compounding losses into savings. Think pipes again. An engineer looks at an industrial pipe system and sees a series of compounding energy losses: the motor that drives the pump wastes a certain amount of electricity converting it to torque, the pump and coupling have their own inefficiencies, and the pipe, valves, and fittings all have inherent frictions. So the engineer sizes the motor and pump to overcome all these losses and deliver the required flow.

But starting downstream—at the pipe instead of the pump—turns these losses into compounding *savings*. Make the pipe more efficient, as Jan Schilham did, and you reduce the cumulative energy requirements of every step upstream. You can then work back upstream, making each part smaller, simpler, and cheaper, saving not only energy but also capital costs. And every unit of friction saved in the pipe saves about *nine* units of fuel and pollution at the power station.

Get the sequence right. Achieving big energy savings is a process of multiplying little savings. That means breaking the task down into many steps and tackling them in the right sequence.

Amory Lovins has created a list of six guidelines for doing this, which he's reduced to sound-bite brevity: people before hardware; shell before contents; application before equipment; quality before quantity; passive before active; and load reduction before supply.

We don't have enough space here to explain each of these best-buys-first principles, but here's an example that illustrates some of them. Suppose you're considering making your office lighting more efficient. First you should improve seating and surface configurations (people before hardware), reduce glare (quality before quantity), harness natural light (passive before active) through better window and building design (shell before contents), and only then improve the technical efficiency of your lights and how thoughtfully they're used and maintained.

Optimize the whole system, not parts. Optimizing an entire system takes ingenuity, intuition, and close attention to the

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CORPORATIONS, ARISE!

By L. Hunter Lovins, Executive Director

Corporate hatchet men are the poster boys of the business press…investors hardly look beyond next quarter's profits…foreign policy bows to global free trade. When the business of the world is business and consumption is king, talking about sustainability might seem like an exercise in futility.

But where others see problems, RMI seeks opportunities. As corporations gain power, they're more able than ever to lead the transition to a sustainable society. And the status quo is breeding its own counterculture: many executives know they're part of the problem, and long to be part of the solution.

PERSPECTIVES

It's too soon to label it a trend, but there's something like an awakening in the handful of companies we're working with. Interface, led by visionary CEO Ray Anderson, is undergoing probably the most thorough corporate transformation to date.

The company's April sales conference on Maui (see page 4) was almost like an AA meeting—you know, where someone gets up and says, "Hi, my name's Joe and I'm an alcoholic" and everyone cheers—except in this case it was carpet salespeople pledging to reduce waste and close materials loops. One staid-looking fellow came up to Amory after one of our talks and proclaimed, "I want to be an eco-warrior!"

Don't laugh. That guy can probably do more to change the way we're headed than I can. There's enormous leverage in working within the system.

One of the other speakers at the Interface retreat was Paul Hawken, whose book *The Ecology of Commerce* largely launched the corporate sustainability movement. Paul says he's seeing the same phenomenon in dozens of companies, as their executives realize that downsizing and cutthroat tactics have spread fear and squashed morale. For them, a commitment to more sustainable practices doesn't just save money and confer competitive advantage—it enables them and their employees to regain pride in what they're doing.

I sense that this is a movement whose time has come. At a recent gathering of renewable-energy advocates in Santa Barbara, I happened to use the word "epiphany" to describe the new interest in sustainability among corporations. The whole meeting came alive with excitement, and that word became common parlance for the rest of the day. These were people who traditionally viewed corporations with suspicion. Some still did, but a new spirit of cooperation was in the air.

Corporations may seem like monolithic, impersonal entities, but they're still run by people. Their leaders make mistakes, but they can learn. Just like everybody, they want to be liked. And when they know they're doing something wrong, they do what everybody does—they stonewall. It takes time to break the walls down. We all have to be given appealing, face-saving openings through which we can begin to make change, and that's what RMI is trying to do.

Is it healthy for corporations to have so much power? Maybe not, but it's the reality now. Centralized government, for a variety of reasons, has largely abdicated its role as an agent of change. Washington is slow and indecisive, and its mandates are no match for the market. We're witnessing a triumph of economics over politics—nowadays we wield more power as customers than as citizens.

Corporations, not governments, have the combination of skills, resources, agility, and motivation (profit) to make things happen. One way or another, they will. It ain't democratic, but when Ray Anderson stands up and says his company is going to become sustainable, a thousand people get right to work on it.

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way technical systems really work. It requires a sense of what's on the other side of the cost barrier and how to get to it by selectively relaxing your constraints, as the designers of the Davis house did when they decided to pay extra for better windows.

Whole-system engineering is back-to-the-drawing-board engineering. It doesn't rely on rules of thumb, which are typically based on single components, operating costs only, old prices, and very high discount rates. Nor does it rest on theoretical assumptions (for instance, that efficient components must cost more—they often don't). And, importantly, it incorporates "feedback" to make the design process intelligent, cyclical, and capable of continuous improvement based on *measured* performance.

THINK BIG

One of the great myths of our time is that technology has reached such an exalted plateau that only modest, incremental improvements remain to be made. The builders of steam locomotives and linotype machines probably felt the same way about their handiwork.

The fact is, the more complex the technology, the richer the opportunities for improvement. There are huge systematic inefficiencies in our technologies; minimize them and you can reap huge dividends, for your pocketbook and for the earth.

Why settle for small savings when you can tunnel through to big ones? Think big!

CORPORATE PRACTICES

SUSTAINABILITY ISLAND

How a Corporate Retreat Transformed a Hawaiian Resort

Last fall, Interface, the world's leading carpet-tile manufacturer, began planning its 24th-anniversary party—a six-day blowout for 1,000-odd employees at Maui's Grand Wailea Resort, one of the most opulent hotels in the world.

For a company building a reputation as a paragon of sustainable practices, the Grand Wailea was not the greenest of choices. This is a resort that uses $1.5 million worth of electricity annually just to run its "water features." Occupying (let alone flying to) one of its 800 rooms for a week causes more than a ton of carbon dioxide to be emitted.

So Interface CEO Ray Anderson convened a "dream team" of consultants, including RMI's Bill Browning and Amory Lovins, to turn the April convention into what architect Bill McDonough called a "design problem"— and a full-on exercise in corporate sustainability. The guests themselves would demonstrate the potential for improvement at Grand Wailea. That experience would serve as a metaphor for the company's own transformation, and for wider opportunities in the world.

The resort's management and staff, no less than Interface's employees, were enthusiastic about reducing their environmental impact as well as cutting costs. The venue, which at first had seemed so inappropriate, actually illustrated the opportunities of sustainable practices better than an already-"green" resort ever could.

Grand Wailea Resort

Maui's Grand Wailea Resort—what better place to demonstrate the potential for reducing waste?

FEEDBACK

Perhaps more than anything else, the exercise demonstrated the importance of feedback—that is, information that's fed back into a system to improve its performance. Normal consumption patterns were measured on the first full day of the conference to establish baseline metrics. After that, the attendees received daily reports on how much energy, water, and other resources they were using. In between plenary sessions, the guests heard presentations on the implications of their resource use and voluntary measures they could take to reduce it.

Seeing daily improvements spurred the group on, but what engaged them even more was a sudden *increase* in water consumption of 100,000 gallons on the fourth day. Finding the cause of that blip became a sort of treasure hunt for the rest of the week. A maintenance worker was later discovered to have only *estimated* water consumption for that day—a reminder that decisions are only as good as the numbers they're based on. ("In God we trust; all others bring data.")

By the final day, the resort was using 21 percent less electricity, 48 percent less propane, and 48 percent less water, and generating 34 percent less solid waste. That translates into a potential annual operational savings of slightly over $1 million.

Those reductions were due entirely to behavioral and operational changes by guests and resort staff. Grand Wailea's management now intends to pursue a host of longer-term changes to the facility's physical plant—lighting and window retrofits, more efficient pumps and motors, water-efficient landscaping, conversion of vehicles to run on recycled cooking oil—that an earlier "eco-audit" revealed could reduce resource use (and the resort's $7-million annual utility bill) by far more.

SETTING AN EXAMPLE

Despite tourism's normally conspicuous consumption, resorts like Grand Wailea are in a position to educate tens of thousands of guests each about the latest green technologies and practices. Many technological innovations—central heating, air conditioning, telephones, elevators, and toilets—first appeared in hotels and resorts, and only later moved to residential construction.

Extending its influence still further, the Grand Wailea teamed up with Interface and a community group called Maui Tomorrow to host "Sustainable Hawaii." Led by dream team members Lovins, Browning, McDonough, David Brower, Paul Hawken, and John Picard, and with support from several other RMI staff, the seminar drew 300 business and community leaders from around the state.

The Interface event was only the latest of several recent RMI involvements in Hawaii (see also the spring and summer 1996 newsletters). Is this trend the result of the islands' being more attuned to their physical limits than the mainland is? Or just a symptom of a struggling economy? Either way, several surf-minded staffers have bravely volunteered to scout locations for an "RMI West." Hunter suggests that maybe we should just help the people of Hawaii find their own solutions.

Valuing Nature

You could say that everything RMI does comes down to correcting market failures. That's why we were particularly pleased to see an article in the 15 May issue of *Nature*.

Following the logic of Gretchen Daily's important new book *Nature's Services*, economist Robert Costanza and colleagues calculated the value of 17 major functions provided by the world's ecosystems—water filtration by wetlands, air filtration by plants, nitrogen fixing by soil microbes, and so on—to be worth $16–54 trillion a year. By comparison, gross global product is $18 trillion annually.

The numbers are only approximations, but they're an important first step toward forcing markets to count the true marginal costs of degrading the environment.

Ask RMI

I'm building a new home. How can I make it energy-efficient?

—Sam Bushman, Delta, Utah

If you're building a new home, you have the chance to do it right from the start. This makes it easier and cheaper to achieve really big savings through a whole-system design approach (see cover story).

Obviously we don't have room to go into a lot of detail here, but we can focus on one aspect of energy-efficient home-building that's particularly important in sunny Utah: passive-solar design. The key elements to bear in mind are windows, thermal mass, and superinsulation.

Because of their generally low insulative properties, windows are a major source of heat loss in most houses—but the right kind of windows, correctly oriented, can instead contribute a net heat *gain*. The first order of business is to orient your home so that it faces within 15 degrees of true south, and put most of the windows on the south side. Second, buy the right kind of windows. Standard double-panes, required by most local building codes, have an insulation value (excluding frame losses) of only R-2. High-performance windows with special heat-reflecting films and filled with argon or krypton gas get R-4.5 to R-8.1 or better. Face them south in a sunny climate and you're guaranteed to get big net solar gains, which will directly offset the need for heat from a furnace. (High-performance windows are designed for specific climates, so make sure to get the right kind.)

But how to store that solar gain? That's where thermal mass comes in. A conventional "stick-built" house has relatively little thermal mass—its wood, drywall, and other lightweight materials don't store much heat. For this reason, passive-solar houses often use unconventional materials such as adobe or rammed earth, where the walls themselves provide the thermal mass, storing up heat (or "coolth" in the summer) and keeping daily temperature swings to a minimum.

Concrete, rock, brick, or plaster interior and cavity walls are another approach, as are thermal storage walls (also known as trombe walls), which are positioned just inside south-facing windows to capture solar gain directly. Some solar homes use water, which stores heat twice as effectively as masonry; 55-gallon drums or commercially available "water walls" work well.

It's important to get the ratio of glass to thermal mass right, because a house with too much south-facing glass will overheat. The Passive Solar Industries Council recommends that south-facing glass account for 7–12 percent of a house's total floor area, depending on thermal mass. The lower figure is for a conventional frame house with no extra mass; for each additional square foot of glass above 7 percent, PSIC recommends an additional six square feet of exposed thermal mass, optimally four inches thick.

Surprisingly, an 18-inch adobe wall only has an R-value of about 4.5. How can it be energy-efficient? Unless insulated, it's not. Common practice is to fix rigid polystyrene board to the *outside*, then stucco, "trapping" the mass inside. This approach can be used to superinsulate frame houses as well. It's almost always cost-effective, in cold climates, to insulate beyond what's required by local building codes, whether or not you live in a passive solar house. As a benchmark, Rocky Mountain Institute has R-40 walls and an R-80 roof.

Alternative construction is often the best way to achieve high R-values at similar cost to conventional framing with standard insulation. Straw bales, foam panels, and foam forms filled with concrete are increasingly popular building materials.

Passive solar design is simple and elegant, but it's only part of whole-system design. Work with a knowledgeable architect or builder to make sure you address all the details.

For more information, see *The Passive Solar House* by James Kachadorian (Chelsea Green, 1997) or *Homemade Money* by Richard Heede (RMI, 1995), or contact:

- Passive Solar Industries Council, 202/628-7400, www. psic.org.
- Energy-Efficient Building Association, 612/851-9940, www.eeba.org.

MISSION SUSTAINABLE

Two Strategies that Complement RMI's

RMI is lucky enough to work with many other nonprofit organizations that share the goal of sustainability. Two that have come onto our radar recently are Redefining Progress and the Corporation for Enterprise Development's Common Assets Project.

Redefining Progress emphasizes realigning taxes and other economic signals to ensure that social, fiscal, and environmental debts aren't unfairly passed on to future generations. Founded in 1994 by Ted Halstead, it promotes policies that increase economic opportunity, social cohesion, environmental conservation, and fiscal responsibility.

Common Assets, founded in 1996, is concerned with what has come to be known as the "tragedy of the commons"—the degradation of assets, such as the atmosphere or the gene pool, that are commonly owned and overused. Founder Peter Barnes, who also started the long-distance company Working Assets and happens to sit on RP's board, advocates charging for the use of these common goods and distributing the "rent" to all citizens as a means of redistributing wealth.

The missions of Redefining Progress, Common Assets, and RMI are neatly complementary. Perhaps the most prominent common concern is climate change.

Redefining Progress scored a major coup in February when it released a statement signed by more than 2,000 economists, including six Nobel laureates, acknowledging climate change as a "significant environmental, economic, social, and geopolitical" challenge and urging action in the form of market-based policies. Such an approach, according to the statement, would "slow climate change without harming American living standards, and…may in fact improve U.S. productivity in the long run."

Common Assets is concerned enough about global warming to choose the atmosphere as the asset it considers most imperiled. Barnes presented a paper on the subject, "The Sky as a Common Asset," at The Other Economic Summit, a conference on sustainable development held in parallel with the Summit of Eight in Denver in June.

RMI, for its part, has long maintained that actions to mitigate global warming make economic sense regardless of whether scientific concerns prove correct. The Institute will release new work on least-cost climate stabilization before the Kyoto Conference on Climate Change this December, showing how climate stabilization, far from being costly, is a major business opportunity.

Like RMI, both Redefining Progress and Common Assets believe that market forces are the key to change. To that end, Redefining Progress in April published its first monograph, *Tax Waste, Not Work: How Changing What We Tax Can Lead to a Stronger Economy and a Cleaner Environment*. Since basic economics tells us that we'll have less of what we tax and more of what we don't, RP argues we should reduce taxes on productivity, innovation, and work (payroll and income taxes), and increase levies on pollution and resource depletion through either direct taxes or the sale of transferable permits. The result would be revenue-neutral—meaning a tax *shift*, not an increase.

Common Assets is looking at pollution permits too, but with an eye toward who owns the sky. According to the Tenth Amendment as interpreted by Peter Barnes, we the people do. Barnes would therefore like to see the government set limits on carbon emissions and auction the limited quantity of permits to polluters. The revenues would go to a national trust fund with dividends payable to all Americans, probably as restricted individual savings accounts with money earmarked for education, retirement, job training, or first-home purchase—all long-term investments.

Barnes argues that auctioned permits are preferable to carbon taxes because the permits, being limited in number, would only go up in value as they become more scarce (as they must do if pollution is to be reduced). That would mean higher dividends for all citizens, creating a powerful constituency for pollution reduction. Carbon taxes, on the other hand, would yield less revenue as pollution decreased—and the money would disappear into a general fund, giving citizens no sense of ownership.

Of course, legislated policy changes like those advocated by Redefining Progress and Common Assets aren't necessarily how RMI would approach all environmental problems. In many cases, we believe tech-

Factor Four Endorsed

Factor Four: Doubling Productivity, Halving Resource Use, Amory and Hunter Lovins's collaborative book with Ernst von Weizsäcker (see the spring newsletter), is starting to influence debate in Europe.

In an April statement on behalf of the European Union, Environment Minister Margaretha de Boer said: "There are studies which indicate that the magnitude of necessary changes, to be achieved by the middle of the next century, can roughly be estimated to an average 10-fold increase of the resource productivity, as compared to the current level. As an intermediate step, an increase in resource productivity, for example by a factor of four in the next two or three decades, seems to be within reach.…Industrialized countries will have a special responsibility and must take the lead in this respect. Such an increase does not happen by itself; we should commit ourselves to make it happen."

In May, the environment ministers of the Organization of Economic Cooperation and Development endorsed the concept of factor-10 increases in resource productivity as a prerequisite for long-term sustainability. The World Business Council for Sustainable Development is urging *factor 20*. Do we hear factor 100? Sold! To the lean- and clean-cut organization in the back row…

nology can tap market forces with little or no government intervention—hypercars, for example, may take over the market simply because consumers prefer them and manufacturers win with them. Still, many organizations pursuing multiple solutions form a robust and creative approach to problem-solving. We wouldn't want it any other way.

- Redefining Progress, 415/781-1191, www.rprogress.org.
- Corporation for Enterprise Development, 202/408-9788, www.cfed.org.

FORESTS

BLAME IT ON THE SYSTEM

Challenging Conventional Wisdom About Deforestation

What causes perfectly knowledgeable people and industries to extract natural resources unsustainably?

Why do the traders and processors of resources get so much of the profits, while the producers—farmers, loggers, fishers, miners—get so little?

And why are commodity prices so notoriously volatile?

If you blame "the system," you're right—though not in the sense you're probably thinking.

"These questions are not about morals, they are about *systems*," writes Donella Meadows in a forthcoming paper for the Systems Group on Forests, a panel convened by RMI to address the root causes of global deforestation (see the spring 1996 newsletter). "They recognize that well-meaning people can collectively produce results that no one intends. Perverse results at the macro-level can arise from rational decisions made at the micro-level.…

"There must be something *systematic* going on, something that arises from overarching institutions, prices, contracts, policies, and practices that cause people to use resources in such a way that both resources and people are degraded."

A co-author of *The Limits to Growth* and *Beyond the Limits*, Meadows is one of the world's leading authorities on system dynamics, an analytical approach that influences all the work of the Systems Group on Forests (as its name suggests). Her paper, written with four colleagues from MIT's System Dynamics Group, proposes a generic computer model of how commodities are harvested, processed, traded, and returned to nature. The team plans to develop this into more detailed models of specific commodity systems for timber, sugar, and bauxite.

A FIRST STEP

Almost everyone has an opinion about how to stop deforestation: green labeling, ecotaxes, land reform, regulations on extraction rates and practices, and many other ideas all have their champions. But who really knows which would produce the greatest effect at the least cost, and which would shift what benefits, costs, and risks to whom? Nobody, says Meadows, because the behavior of commodity systems is far too complex for us to track by intuition alone.

That's where system dynamics comes in. Computer-model the interworkings of the system—the feedback loops, bottlenecks, time lags, and so on—and you begin to understand the root causes of its behavior, and to reveal hidden leverage points for creating effective change. Armed with that knowledge, you can then craft policies to minimize the unsustainability, inequity, and instability alluded to at the start of this article.

Though Meadows's generic model is only a first step, it's a big one. Even at this stage, it offers some potentially profound insights that aren't obvious from mental models. (Meadows is careful to point out that these are only "hunches" until confirmed by later simulations.)

HUNCHES

How the model actually works is a long story best saved for an academic journal, but here are some hunches to ponder:

- The longer the value chain between producers and consumers, the greater the tendency for price and production instabilities. Small variations at the consumer end of the chain tend to become amplified back along the chain and felt most strongly at the producer end, making stable profits and secure livelihoods difficult at that end.
- Market instabilities can exacerbate tendencies toward unsustainability because they make all price signals, including signals of scarcity, harder to read and trust. On the other hand, they may slow resource depletion by idling harvest and processing capacity and discouraging investment.
- Natural resources are depleted because of failures in the market's ability to signal scarcity by raising prices fast enough or definitively enough to reduce demand. Even when the price of the raw commodity does increase because

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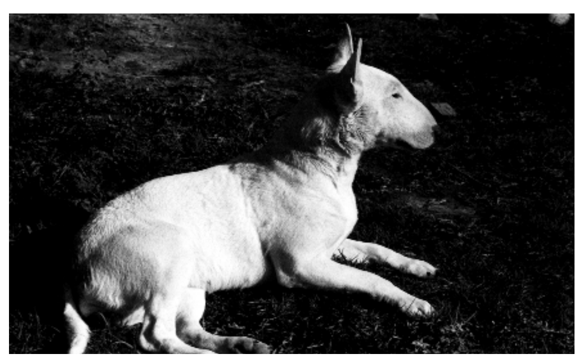
Nanuq the Beastoid, 1982-1997



Hunter Lovins

Hunter and Amory's "dogter" Nanuq, an English bull terrier, died peacefully of old age on 2 July. Only two months younger than the Institute, she was beloved for her gracious dignity, keen intelligence, and gentle patience with our imperfect domestication.

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of scarcity, the system has enough slack that production is not cut back until long after the stock of the resource has declined.

- Low desired income (or little opportunity for alternative income) leads to a high number of harvesters and rapid depletion of the resource. This gives support to those who believe that poverty in developing countries is a factor in unsustainable resource use. Minimum desired income seems to be a leverage point not only for equity but also for sustainability; however, it's a variable that no one has much control over.
- Technological advances that greatly lower the cost of harvest and/or processing make it much harder for the system to find and settle on sustainable extraction rates.
- Depletion is forestalled when minimum desired income of producers is high, price aggressiveness of producers is high, and upstream technology improvements are low—or when a sustainable harvest quota is imposed on the system.
- Some of the most sensitive variables in the system—and therefore possible policy levers—are interest rates (lower ones increase stability but also unsustainability), minimum desired income of producers, and cost-cutting changes in harvest/processing (which mask signals of resource scarcity and enhance unsustainability).

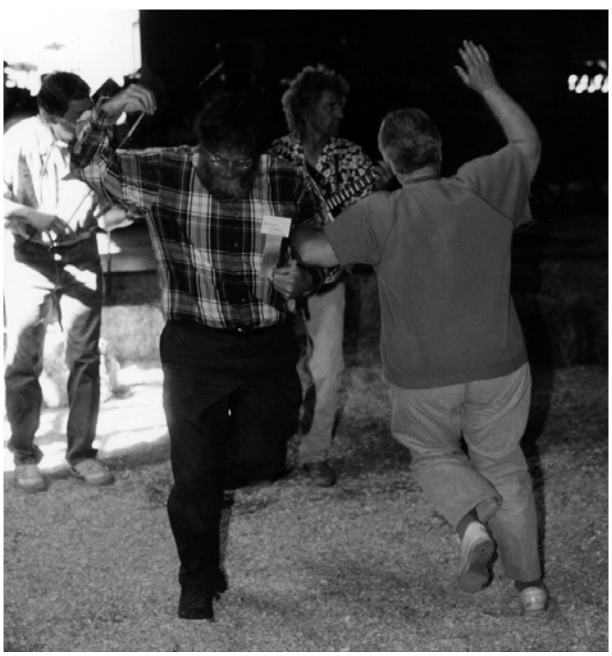
IMPROVING THE MARKET

Meadows and her team don't know what this exercise will finally reveal. It may tell us something we don't want to hear. Or it may enable certain parties to manipulate the system more skillfully to their own short-term advantage. These are occupational hazards in the quest for knowledge.

Ultimately, though, better information can only improve the workings of what is now a decidedly imperfect marketplace. The specific commodity models are intended to be policy tools for industry, government, environmentalists, and indigenous peoples, and especially for negotiation processes involving all these parties. With refinement, the generic model should serve as a useful "flight simulator" for students of system dynamics.

Other members of the System Group on Forests have written draft papers on wood reduction opportunities, green accounting, incipient "surprises" related to deforestation, the economic value of biodiversity, optimal forest management principles, global trends in raw materials demand, Southern perspectives on deforestation, and "intergenerational commerce" mechanisms. Watch this space.

Dancing for Dollars



Tony O'Rourke

RMI Board Chairman Michael Stranahan whoops it up with a friend at the Second Annual Solstice Celebration, held 22 June at a ranch near RMI as a fundraiser to create a $1-million endowment for the Windstar land. Huge thanks to the many volunteers who helped make the celebration such a delightful event—and to all those who have contributed to the campaign (see page 14).

TRANSPORTATION

FUEL FOR THOUGHT

Hypercars, Fuel Cells, and the Coming Hydrogen Economy

Energy can be stored and moved around in many ways. But in the future RMI is helping to invent, two essential energy carriers will probably do most of the work: electrons and hydrogen atoms.

Electrons aren't new—they're the stuff of electricity. Electricity is an enormously versatile power source, but producing it traditionally is a messy and inefficient business, and it can't be stored in large quantities. Hydrogen can change all that.

Fuel cells—devices that produce electricity by chemically combining hydrogen with oxygen—look certain to be the enabling technology of this "hydrogen economy." They convert fuel into electricity two or three times more efficiently than combustion engines, produce no emissions or noise, and permit the storage and distribution of energy in the form of hydrogen.

Fuel cells currently cost at least 10 times more than equivalent internal-combustion engines, but they're expected to become competitive within a decade or two. As explained in last summer's cover story, RMI's "hypercar" concept may play a key role in the transition. Being so much more efficient than comparable conventional cars, hypercars could run on smaller, cheaper fuel cells, thus making fuel cells viable candidates for vehicles much earlier in their development cycle. The price reductions needed for that can come from high-volume uses in buildings.

Several major manufacturers are already experimenting with fuel-cell cars (see box). Various technologies seem promising, but one huge question has yet to be resolved: how to supply the hydrogen to the fuel cell?

ANSWERS

There's a lot more to that question than meets the eye. But first let's consider the possible answers.

Answer No. 1 is that cars have always run on gasoline, and always will. Pigs will fly before the petroleum industry allows its gas stations to be replaced by hydrogen-dispensing competitors, and before motorists willingly switch to a gaseous fuel. Fuel-cell cars, therefore, will have to be designed to run on gasoline. That means they'll have to tote around an extra system, known as a reformer, to "reform" the gasoline into hydrogen onboard.

The second answer is a variant of the first. We'll never abandon our liquid fueling infrastructure, runs this line of thinking, but it would be relatively easy to switch from gasoline to another liquid fuel, such as methanol. Methanol is an improvement over gasoline, particularly when used in fuel-cell vehicles, because it can be more easily reformed into hydrogen.

Yet a third view is that, for a whole host of technical and societal reasons, it's loony to reform other fuels into hydrogen *onboard* the vehicle. Do the reforming offboard, where it can be done more efficiently and cheaply, and give the car's fuel cell the pure hydrogen it wants. If that means changing the entire fueling infrastructure, so be it.

Most in the auto industry are hitching their wagons to either of the first two views. The Department of Energy, which sets the course of hydrogen research through its funding priorities, has been very kind to onboard reformer development. The hydrogen industry, backed by such research institutions as Princeton University and Directed Technologies, Inc., takes the latter view.

RMI sides with the hydrogen folks on this one. In a paper delivered to the National Hydrogen Association in March (see page 12), hypercar researcher Brett Williams stated RMI's findings in favor of *offboard* reforming, and urged DOE to shift its research funding to offboard reformers and alternative fuels infrastructure.

TRADEOFFS

Here's why RMI believes offboard reforming is better—and why all this technical stuff matters.

First, a reformer is quite a complicated chemical system that will be difficult to manufacture cheaply, let alone squeeze into a car. Doing so increases the mass and purchase price of the vehicle, and adds to maintenance and repair costs.

Then it takes energy to run a reformer—energy robbed from the fuel cell. Fuel cells produce waste heat, but alas, not enough to drive the reactions in a reformer. So the fuel cell has to be sized bigger and requires more fuel to run it.

There's more. An onboard reformer has to be able to crank out hydrogen on demand, from the moment the driver stomps on the "gas" pedal. Storing hydrogen for later use won't do—that would require a pressurized storage container, which is one of the things you were trying to avoid with onboard reforming. So your reformer must be either very sophisticated (and thus expensive) or oversized (and thus heavy and bulky, as well as expensive).

(continued on next page)

NEXT YEAR'S MODELS

Our feature last summer on fuel cells in cars seemed like science fiction, but it's rapidly becoming fact. Several major car companies have recently announced plans to build fuel-cell models:

- Last October, Toyota unveiled a prototype sport utility vehicle retrofitted with a fuel-cell system, though it said production vehicles wouldn't be ready till "the first part of the next century." The vehicle's metal hydride storage is heavy and limits driving range. Industry watchers were underwhelmed, but Toyota is a company to be watched—it's allegedly committed to spending a phenomenal $800 million a year on alternative-fuels research.
- Chrysler announced plans in February to build a "proof of concept" fuel-cell car by 2000 that would be 50 percent more efficient than a comparable car powered by an internal-combustion engine. The car will reform gasoline onboard: Chrysler adamantly believes that the market isn't ready for hydrogen refueling. The company acknowledges that there are still plenty of technical issues to be resolved before its gasoline reformer is viable, but that's what the concept car is for.
- Ford's P2000 prototype, announced in March, is the most hypercar-like of the bunch. It's a "validated" (i.e., crash-tested) aluminum-body car that weighs about 2,000 pounds—nearly as light as what RMI believes is possible with advanced composites—and two of three designs being readied will have hybrid-electric drivesystems. Ford later announced that it would work with Ballard Power Systems (the world's leading fuel cell developer) to adapt the P2000 platform for a pure-hydrogen fuel cell powerplant to be prototyped by 2000.
- In April, Daimler-Benz and Ballard announced a $330-million joint venture—a serious chunk of money that should bankroll much of the development of the next generation of more affordable fuel cells for cars. Daimler was the first major carmaker publicly to embrace fuel cells (in 1995); its next prototype, expected to be shown by year-end, will be a fuel-cell version of the new Mercedes A-Class subcompact, which should really test the manufacturer's ability to miniaturize its technology. Daimler is designing its fuel-cell cars for onboard-reformed methanol, although it's not writing off pure hydrogen in the future. It vows to make 100,000 fuel-cell cars by 2005.

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Wait, we're still not finished. Because of cost and time constraints, an onboard reformer can't produce pure hydrogen gas. That means the fuel cell has to be designed to tolerate higher levels of carbon monoxide and other gases, further reducing its efficiency and increasing its size, complexity, and above all, cost.

By the time you've made all these tradeoffs for the sake of the reformer, you've lost most of the increased system efficiency that the fuel cell was supposed to deliver.

Yet fuel reforming is not a function that needs to be mobile. Hauling the reformer around is like, say, bringing fresh food and a freeze-dry unit on a backpacking trip instead of just carrying freeze-dried food.

REFRAMING THE QUESTION

How you frame a question helps determine its answer. The car companies and the DOE are basically asking, how can we put a fuel cell in a conventional (read gasoline) car? It's a good question, but it doesn't consider anything outside the car. The fueling infrastructure is assumed to be beyond the scope of the question.

RMI is concerned with optimizing the fueling infrastructure as well as the car. Reframing the question to include both, it turns out, reveals vast potential synergies.

There's no doubt that the transition from liquid to gaseous fuels would be expensive, but this could prove to be a profitable opportunity rather than a cost. If fuel cells are used in buildings before they're used in cars, as most hydrogen folks expect, efficient building- or neighborhood-sized fuel reformer "appliances" will be mass-produced and relatively inexpensive. The marginal cost of equipping such a reformer to route spare hydrogen to vehicles as well would be minimal.

This scenario, which faces far fewer technical hurdles than onboard reforming, offers multiple benefits. Cars would benefit from the efficiencies and economies of scale of stationary reformers, so they'd use less fuel. Buildings would receive both electricity and heat extremely efficiently from fuel cells. Fuel cells in parked cars could even be used to send back electricity to the grid (see the summer 1996 newsletter). The use of both stationary and mobile fuel cells would facilitate the transition to hydrogen reformed from methane (natural gas)—so, as Princeton's Bob Williams points out, carbon dioxide thus separated at the wellhead could be cheaply sequestered by reinjection into old gas fields (boosting methane recovery). Hydrogen could be electrolyzed by renewable generators, and ultimately by direct solar processes, paving the way to a sustainable solar-hydrogen economy.

Ultimately, onboard reforming is a waste of an extremely versatile energy carrier. Hydrogen can be created in many ways, and, thanks to fuel cells, it can be used to do almost anything. The engineers designing cars with onboard reformers are harnessing it for only a split second in a single process. It should be the backbone of the entire economy, carrying energy from the point of production to the point of use in a myriad processes, each doing what it does best.

WATER

SOFT PATH, HARD FACTS

Needed: A Vision for Radically Increased Water Efficiency

Water efficiency? We're onto it! We've got low-flow showerheads and toilets, we've got efficient irrigation and lawn-watering techniques, we're plugging leaks.

How much can we save? Oh, 10, maybe 20 percent. That's per capita, mind you—we're expecting our population to double here in the next couple of decades, so overall water use will keep growing. We'll still need a few more dams, no getting around it…

To give them their due, North American water utilities have come a long way in a short time. Only a decade ago, supply-side thinking ruled. Whatever the question, the answer was another dam, diversion, or well. Now, with the cost of creating new supplies skyrocketing, utilities are increasingly embracing water efficiency as a way to reduce demand.

But are they going far enough?

Not if they're setting their sights on 10- or 20-percent decreases in per-capita water use (which is about as aggressive as most utilities are prepared to get). That won't even offset population increases in most places, and even if it did, it wouldn't be enough. In fact, many communities are already drawing unsustainable amounts of water from the environment—depleting aquifers, degrading rivers and wetlands. Slowing the rate of increase is a good start, but they're still heading in the wrong direction. If anything, they need to *reduce* their *overall* use.

That's the backdrop for RMI's new Soft Water Path program, a multi-year effort modeled after Amory Lovins's pioneering work in energy efficiency.

Back in 1976, Lovins coined the phrase "soft path" to refer to an energy strategy favoring efficient end-use and right-sized renewable energy sources, as contrasted with the conventional "hard path" of apparently endless increases in overcentralized supply.

The parallels with water are obvious. Society can't afford—neither environmentally nor economically—to keep building dams and sinking wells any more than it could have afforded to carpet the earth's surface with nuclear power plants. Efficiency isn't just better for the environment, it's plain cheaper.

RMI has been promoting water-efficient technologies and programs since its inception. With the Soft Water Path program, though, researchers Richard Pinkham and Scott Chaplin plan to articulate a broader vision of what's needed to achieve radical improvements in water efficiency and a long-term decline in total water use.

As they see it, current efforts fall short for three main reasons.

First, water decision-makers don't have a clear sense of the technical potential of water efficiency. Nobody does, really. How much less water would Americans use if proven, cost-effective technologies and practices were fully implemented? Fifty percent (like RMI)? Seventy?

Water is a localized resource, so the potential of water efficiency—and the need for it—will depend on location: what's cost-effective in the desert Southwest might not be in the moist East. Still, there are good reasons to believe that 20 percent is too timid a target. The researchers' first task will be to establish a baseline for what's achievable, and encourage water providers to aim even higher.

A second problem is that nobody is fully accounting for all the economic benefits of being more efficient with water. Sure, saving water can mean deferring supply or treatment expansions—that sort of direct benefit is easy enough to see. But what about the economic value of the energy "embodied" in the transportation, heating, and treatment of water and in pressurizing water distribution systems? What about the reduced financial risk that comes with avoiding or deferring big projects? And what about the waste-treatment costs that are avoided when aquatic ecosystems are supplied with enough water to perform their ecological services (see page 5)?

In this task, Pinkham and Chaplin will be able to adapt much of the work RMI has already done on valuing the hidden benefits of small-scale, distributed electricity supplies (spring 1997 newsletter). They'll be asking about water and wastewater systems the profoundly simple question: what's the right size?

Finally, there's a glaring lack of policies that encourage investments in water efficiency. Although RMI doesn't lobby, it can help shape policy by creating model programs in selected communities, publicizing case studies of the best policies and programs, documenting barriers to efficiency, and identifying the opportunities and pitfalls as the water industry privatizes and restructures itself in the coming years.

At the end of the day, it may be even more critical to forge a soft path for water than for energy. Though renewable, water is being used up faster in many places than it's being renewed, and it's likely to prove a more drastic limiting factor for human civilization than coal or oil.

PROTOCOL UPDATE

Last summer's newsletter reported on a national "protocol" being put together by the Department of Energy (especially RMI alum Gregory Kats) that promises to do for energy-efficiency financing what standardized FHA rules did for mortgages. The protocol makes it easier for lenders to bundle and resell energy-efficiency loans by standardizing how the savings from efficiency are measured and verified.

As originally drafted, the protocol only addressed energy savings. However, the latest version, expected to be released in August and promoted internationally, also takes into account water efficiency, thanks to the work of a task force that included RMI researcher Scott Chaplin.

"This protocol will make it much easier to finance water- and energy-efficiency projects for large buildings," says Chaplin.

RMI NEWS

DEAR ROCKY

An RMI Outreach Specialist's Journal

Auden Schendler, RMI's newest outreach specialist, keeps a journal of his contacts. Here's an excerpt:

Yogurt, perpetual motion, conflict resolution: these are not topics typically associated with Rocky Mountain Institute. But my job, responding to questions from the public, requires a broader base. Besides addressing boilerplate topics—energy, green architecture, transportation—I work in the Institute's curiosity shop of ideas: a place musty with oddities and treasures.

One recent series of calls involved the yogurt industry. Because RMI's logo appeared for a time on the lids of one brand of yogurt, some people thought we were the manufacturer. One person called to demand a recall of a moldy batch: apparently the raspberries had gone bad. Another wanted us to explode an urban myth: "My friend tells me yogurt cultures come from putting worm poop in milk. Is that true?"

Confusion mitigation is part of the job. We receive letters from kids addressed to "Rocky." As in: "Dear Rocky, Please send me some information on the mountains. Like are they dangerous." In some child's mind, Rocky is a high-altitude bruiser who named an institute after himself to study mountains.

"Rocky" at work.

We as a species are always thinking, trying to figure out the world, maybe find a way to defeat the laws of physics and get a free lunch in the process. Two approaches I often hear: perpetual motion machines and improbable inventions. A hydrodam where the fallen water is frozen, floats back to the top, melts, and flows down again. A photovoltaic electricity-generating facility in the Arctic, where (the caller believed) it's light all the time. Black solar rafts off the coast of Africa. Energy generated from the rails of trains, from water, from the movement of growing trees.

This quest for answers is a noble and profoundly hopeful pursuit, and really the thrust of RMI's work. As good teachers say,

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there is no such thing as a dumb question. For all I know, the next Einstein might be holding on line two with an idea no one else will listen to. And I'm happy to lend an ear. (After all, the most prominent of the free-lunchers is our own Amory Lovins, who calls energy efficiency a meal you're *paid* to eat.)

Questions often spawn internal debate and research. What *are* the hazards of outgassing from foam building forms and kitchen countertops? The jury is still out—foam and plastics outgas, but how much? And is it more or less a concern than outgassing from plywood and carpeting? Adequate studies haven't been done.

Though I often get stumped by specific questions, the general ones create the most ripples. The most common query is about energy-efficient construction (see this issue's "Ask RMI" column). Curious builders not only put up good houses, but invariably become converts and proselytizers, and we hear from their friends.

Sometimes we receive pleas for help in areas where we may not be the best contact. Some monks in Nova Scotia asked for help with non-confrontational tactics and sound arguments to prevent a clearcut near their wilderness monastery. The point is that once you start dealing in hope, your field of work broadens considerably. The world becomes small. From Indonesia, a young woman wished that God would always bless us, and give us strength to save the world. That letter, like most of the other notes and calls we receive, makes it seem altogether possible.

New Staff

Dave Reed

Summertime, and the staff is growing… Front row (L–R): Windstar summer intern Julia Kertz, development secretary Charmaine Boudreaux, publications coordinator Alaine Seastrom, and visiting scholar J. Baldwin. Not pictured: Windstar volunteer Steve Atterby, Economic Renewal coordinator Amy Seif, summer intern/Konheim Fellow Gregg Osofsky, visiting scholar Karen Kho, maintenance man John Roberts, development specialist Lee Novak, and land management worker Nathan Child. And a fond farewell to Trevi Burkholder, Donna Fischer, André Lehmann, and Lisa McManigal.

New Publications

TRANSPORTATION

HEV Control Strategy: Implications of Performance Criteria, System Configuration and Design, and Component Selection. Technical discussion for IEEE of design issues and strategies for optimizing hybrid-electric vehicle control systems. T97-7. 5 pages, free

Speeding the Transition: Designing a Fuel-Cell Hypercar. Paper modeling a conceptual six-seat fuel-cell hypercar and discussing some of the wider implications of powering hypercars with fuel cells, presented to the National Hydrogen Association in March (see page 8). T97-9. 15 pages, $8.00

Don't Shortchange Advanced Composites. Rebuttal to an article in *Technology Review*. T97-10. 2 pages, $1.50

ANNUAL REPORT

RMI's 1996 annual report is now available. It highlights the Institute's work in 1996, profiles several staff members, describes the special niche we fill in the nonprofit world, and summarizes our finances. If you would like a free copy, please contact Alicia Bell-Sheeter in Development.

TAKE AN RMITE OFF THE ROAD

In 1986, loans to RMI enabled it to buy its 11-person staff housing complex next door for the then-princely sum of $250,000. Now that loan is nearly paid off—and we're doing it again.

A house within walking distance, big enough for eight staff, is now being purchased for $599,000 to replace four trailers that incur costly ground rent and are 10–15 minutes' drive away. We've swung a one-year bank loan, but will need to replace it with long-term notes (preferably 10–20 years) at more affordable interest rates.

As with our Facilities Improvement Fund, we can pay you more than a bank CD but less than the bank charges us. (Some lenders prefer zero, or just CPI, rates of interest.) Our 40-plus private noteholders enjoy a perfect repayment record, and this new financing will bring RMI's debt service, all for capital purposes, up to only about 6 percent of total income.

If you have $10,000 to $100,000 or more that we can give a nice home to, please call Comptroller Christy Otis or Treasurer Amory Lovins at 970/927-3128 to discuss details. And the time those RMItes used to devote to fighting traffic can be redeployed to saving resources.

RMI GETS ITS EARTH SHARE

RMI's corporate experience is paying off in its fundraising through Earth Share, the environmental workplace-giving program.

Through contact with the Institute, Andersen Consulting, one of the nation's largest consulting firms, has agreed to host a campaign for its employees. For recruiting Andersen, RMI earns a finder's fee equal to a declining percentage of contributions made by the company's employees for three years.

Separately, Earth Share's board has elected RMI researcher Ross Jacobs as an alternate member, which effectively puts him on deck for the next available voting seat. Ross's election recognizes RMI's many connections with environmentally conscious companies.

If your company, government agency, or institution hosts an Earth Share fundraising campaign, you can contribute to RMI, or more than 40 other selected nonprofit groups, by payroll deduction. If your workplace doesn't participate in Earth Share, please contact Ross Jacobs at RMI to find out how to sign up your employer.

WINDS OF CHANGE

RMI already gets much of its electricity from the sun. Now it's investing in wind power. Along with thousands of other Colorado households, the Institute will soon begin buying "blocks" of electricity from a $10-million wind farm to be built this fall by Public Service Company of Colorado and other utilities.

The Institute has signed up to buy 33 blocks of 100 kilowatt-hours per month, for a premium of $2.50 per block per month. Displacing that much conventional electricity with wind power avoids the emission of nearly 40 tons of air pollution annually, equivalent to planting about 13 acres of trees.

Aspen's Community Office for Resource Efficiency, led by former RMI staffer Randy Udall, was instrumental in putting the so-called Windsource program together. Unlike other renewable-energy facilities that were required by regulators, Udall notes, this one will be supported entirely by consumers choosing wind power on its merits.

"In the long term, customer demand is going to send a stronger signal to utilities than any mandate by regulators," he says, especially given the restructuring of the electricity industry.

CORRECTION

If you saw a June wire-service report that RMI had received $2 billion from industry to develop hypercars…don't believe everything you read in the newspapers. The number is right, but it represents firms' estimated worldwide commitments to their own *internal* ultralight-hybrid car development efforts, not ours. (We wish!)

INSTITUTE SUPPORTERS

Our sincere appreciation is offered to these friends who have contributed to RMI. 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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Rocky Mountain Institute is an independent, nonpartisan, nonprofit research and educational foundation with a vision across boundaries.

Seeking ideas that transcend ideology, and harnessing the problem-solving power of free-market economics, our goal is to foster the efficient and sustainable use of resources as a path to global security.

Rocky Mountain Institute believes that people can solve complex problems through collective action and their own common sense, and that understanding interconnections between resource issues can often solve many problems at once.

Founded in 1982, Rocky Mountain Institute is a §501(c)(3) /509(a)(1) public charity (tax-exempt #74-2244146). It has a staff of approximately 40 full-time, 45 total. The Institute focuses its work in seven main areas—corporate practices, community economic development, energy, real-estate development, security, transportation, and water—and carries on international outreach and technical-exchange programs. Its E SOURCE subsidiary (1033 Walnut, Boulder, CO 80302-5114, 1-800-E SOURCE, esource@esource.com, www.esource.com) is the leading source of information on advanced techniques for electric efficiency.

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