solutions

Forget Nuclear

By Amory B. Lovins, Imran Sheikh, and Alex Markevich

Nuclear power, we're told, is a vibrant industry that's dramatically reviving because it's proven, necessary, competitive, reliable, safe, secure, widely used, increasingly popular, and carbon-free—a perfect replacement for carbon-spewing coal power. New nuclear plants thus sound vital for climate protection, energy security, and powering a growing economy.

Ā ere's a catch, though: the private capital market isn't investing in new nuclear plants, and without financing, capitalist utilities aren't buying. Ā e few purchases, nearly all in Asia, are all made by central planners with a draw on the public purse. In the United States, even government subsidies approaching or exceeding new nuclear power's total cost have failed to entice Wall Street.

Ā is non-technical summary article compares the cost, climate protection potential, reliability, financial risk, market success, deployment speed, and energy contribution of new nuclear power with those of its low- or no-carbon competitors. It explains why soaring taxpayer subsidies aren't attracting investors. Capitalists instead favor climate-protecting competitors with less cost, construction time, and financial risk. Ā e nuclear industry claims it has no serious rivals, let alone those competitors—which, however, already outproduce nuclear power worldwide and are growing enormously faster.

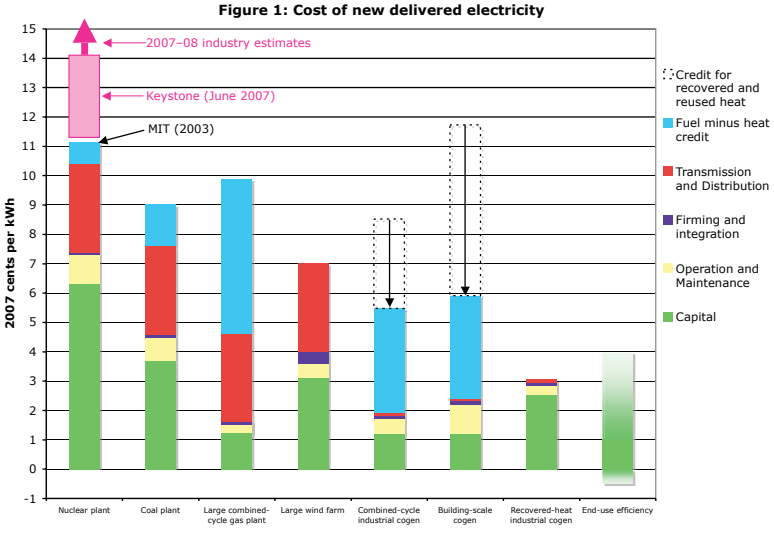
Most remarkably, comparing all options' ability to protect the earth's climate and enhance energy security reveals why nuclear power could never deliver these promised benefits even if it could find free-market buyers—while its carbon-free rivals, which won $71 billion of private investment in 2007 alone, do offer highly effective climate and security solutions, sooner, with greater confidence.

Uncompetitive Costs

Ā e Economist observed in 2001 that "Nuclear power, once claimed to be too cheap to meter, is now too costly to matter"—cheap to run but very expensive to build. Since then, it's become several-fold costlier to build, and in a few years, as old fuel contracts expire, it is expected to become several-fold costlier to run. Its total cost now markedly exceeds that of other common power plants (coal, gas, big wind farms), let alone the even cheaper competitors described below.

Construction costs worldwide have risen far faster for nuclear than non-nuclear plants, due not just to sharply higher steel, copper, nickel, and cement prices but also to an atrophied global infrastructure for making, building, managing, and operating reactors. Ā e industry's flagship Finnish project, led by France's top builder, after 28 months' construction had gone at least 24 months behind schedule and $2 billion over budget.

Figure 1: Cost of new delivered electricity



By 2007, as Figure 1 shows, nuclear was the costliest option among all main competitors, whether using MIT's authoritative but now low 2003 cost assessment,[1] the Keystone Center's mid-2007 update (see Figure 1, pink bar), or later and even higher industry estimates (see Figure 1, pink arrow).[2]

Cogeneration and efficiency are "distributed resources," located near where energy is used.

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In for the Long (and Heavy) Haul

RMI Tackles the Ubiquitous Shipping Container

By Laura Schewel

Like the wires hidden inside my computer as I tap out this sentence, or the billions of neurons that fire before your eyes can blink, global goods transportation—the network of boats, trucks, cars, ports, warehouses, roads, and railroads that get our stuff to us—is a dizzyingly complex system. Also known as "freight," this is a system that must function around the clock for the most simple acts of our daily lives to work: making coffee in the morning, taking notes in class, or reading this *RMI Solutions* after dinner. Figure 1 illustrates the transportation involved in creating and delivering this newsletter to you.

Ā is system is not just complex, it's essential to modern life: in 2005, an average of 68 tons of goods moved 15,310 miles in the United States for each U.S. citizen.[1] And that's only for the goods shipped to, from, and within the nation.

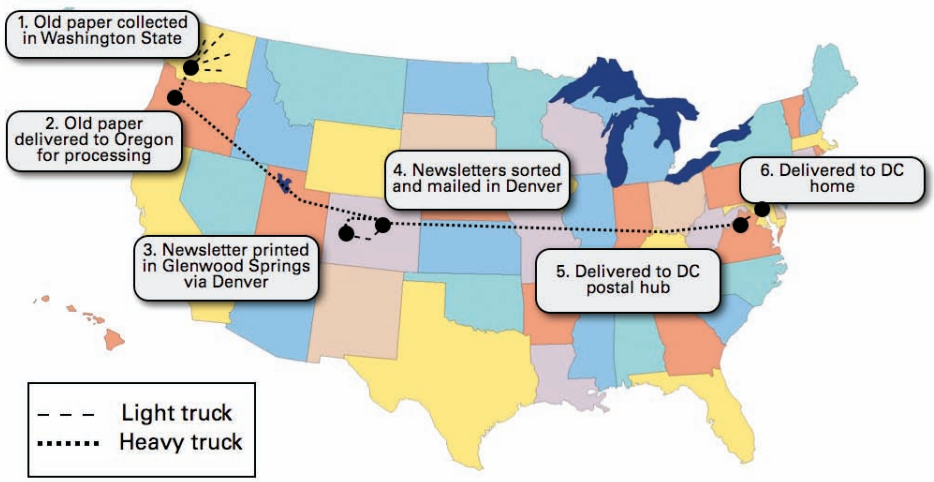


Figure 1: Geographical distribution of freight transport involved in delivering this newsletter to Washington DC

It doesn't include international travel, such as the journey raw materials from South Africa take to reach factories in China where they are processed into electronic goods before being sent to the United States.

Yet while essential, freight comes with a large and growing environmental cost: at least 10 percent of global greenhouse-gas emissions are linked to freight, along with 17 percent of U.S. fuel use and 30 percent of U.S. nitrogen oxide emissions.[2]

While freight has accomplished massive gains in efficiency and productivity in the last hundred years, RMI is researching how we can reduce the 10 percent of greenhouse-gas emissions due to freight by tackling systematic inefficiencies that waste energy and produce unnecessary pollution. Ā e freight system's complexity has derailed many attempts to reduce its energy used and pollution (including some of RMI's own past projects). Based on this experience, RMI recently came up with a new approach: organize the system around one simple, common denominator and see if it can be used as a lever to both better understand and improve the entire system. Fortunately, freight has at least one iconic and ubiquitous rallying point: the shipping container.

The shipping container: thinking inside the box

Ā ree-quarters of all general cargo is transported in shipping containers. Ā ese steel boxes, now familiar sights on massive ships or stacked up in ports, are a relatively recent invention. In 1956 transport mogul Malcolm McLean first developed the shipping container as a way to improve his trucking business. Today, only 50 years later, containerized shipping has enabled globalization, and containerized shipping and port services alone are a $370-billion business.[3]

At first glance, the container seems to directly affect only the shipping industry, which accounts for only 1.5–3 percent of global greenhouse gases. But the shipping container is linked to several other sectors in the transportation system that together represent a large source of environmental degradation (see Figure 2).

So how could a new shipping container help this system? Ā e possibilities are huge, and our research reveals new options every day. One intriguing option would be reducing the weight of the container, which would lead to a variety of benefits including:

- **Lighter loads (and less fuel) for equipment that carry containers:** most containers are filled with low-density products (like Barbies or paper cups) so the weight of the container itself can be 10 to 20 percent of the gross weight. Reducing the container weight would decrease the amount of fuel needed to haul these loads.
- **Ā e ability to put more goods in each container, thereby reducing the total number of containers:** some containers aren't filled to their maximum capacity because they hit weight limits. Reducing the container's weight by 300 pounds means putting 300 more pounds of goods inside each container, which can reduce the total number of containers and save trips.
- **Reduced burden from moving empties:** the trade imbalance between the producing and consuming nations (e.g., China and the U.S.) means that up to 50 percent of container "trips" are empty, and repositioning empty containers to meet cargo requires a lot of truck and barge trips (and money). Reducing the weight of empty containers will reduce engine loads and the amount of fuel necessary for this currently unavoidable inefficiency.

So if lightweighting would be such a great boon for fuel (and hence, cost) savings, why isn't it happening? Ā e problem lies in the financial structure of the container industries. Lightweighting means each container will cost more to build. Ā e chief beneficiaries of better tracking (terminal operators, truckers, rail companies) don't always have a financial role in the design or purchase of containers (where the decision to invest in lightweight materials would be made) and when they do, working together to allocate the benefits would be quite complex. Even though the whole system would save money from reduced fuel use, the incentives aren't properly aligned to push the lightweighting decision forward.

Of course, lightweighting is just one innovation we're exploring. Others include tracking to optimize the use of container-transporting vehicles, improving security

systems to reduce scanning bottlenecks, improving the efficiency of refrigerated containers, and more. Ā ese ideas underscore the most important aspect of RMI's whole-system approach: combining our knowledge of the best environmental options with a detailed understanding of the business, financial, and cultural systems that influence goods transportation—and, working on innovation that incorporates all those systems.

To accomplish this we're seeding the development of a consortium of companies, with one representative from each section of the value chain shown in Figure 2—such as a port operator, a shipping line, a retailer, etc. Using our partners' combined knowledge of their own businesses and technical systems, and their collective wisdom about gaps in the shipping system, we will—during an extensive research phase—develop the environmental and business case for a new kind of container. Ā at will be followed by a consortium-wide Innovation Workshop—RMI's process that we have used to great effect in sectors ranging from semiconductor fabrication to mining and automotive design. Ā e Innovation Workshop will address both technical innovations and business model innovations.

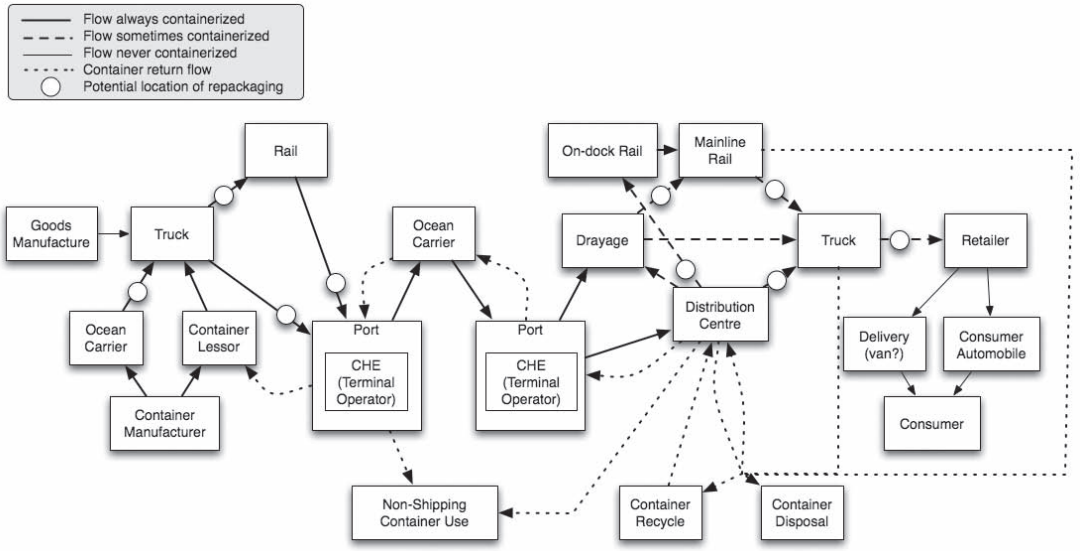


Figure 2: How containers play into the freight system

Conclusion: Putting the (Freight) System in the (Global) System

To fully realize RMI's whole-systems approach with respect to containers, the final step is to consider how the freight system is imbedded in the global system, and how any changes we propose influence that global system. Ā is may allow us to find more hidden benefits of a new container; it also ensures that we watch for unintended consequences.

Let's return to our original example of the newsletter: if we optimized its transportation footprint in a vacuum, by, say, facilitating a system in which all containerized goods were transported as few miles as possible, we would select paper from a mill close to our Colorado printers and one that uses trees logged as close by as possible. We might not use recycled paper, which must be shipped for processing purposes, and we would probably not concern ourselves about the management of the forest from which the pulp was obtained. Ā e unintended consequences of focusing just on the transport footprint are clear: more trees (from a potentially fragile forest) would be cut down leading to all the terrible consequences of deforestation.

Creating an efficient freight infrastructure is necessary, but not sufficient. Ā us, the container is an important leverage point for RMI to make a short-term impact, and an excellent first step towards the ultimate goal: making the entire goods system more sustainable.

Laura Schewel is an analyst with MOVE, RMI's Transportation Innovation Group.

Notes:

1. www.bts.gov/publications/freight_in_america/html/executive_summary.html. Figure represents movement in the U.S. alone, and does not reflect movement that happens overseas involving goods destined for the U.S.

2. Ribeiro, Suzana Kahn and Kobayashi Shigeki. 2007. "IPCC Report Working Group III Chapter 5: Transport and its Infrastructure." Intergovernmental Panel on Climate Change. AR-4.

EIA. 2007. Annual Energy Outlook 2007 with Projections to 2030. Washington (DC): US Department of Energy. Report nr DOE/EIA-0383. Retrieved on 6 August 2007 from www.eia.doe.gov. Tables 2 and 7.

Davis, Stacy and Susan Diegel. 2007. "Transportation Energy Data Book: Edition 26." Office of Planning, Budget Formulation, and Analysis, Energy Efficiency and Renewable Energy. Oak Ridge (TN): ORNL-6978.

3. Datamonitor. For more on the fascinating history of containers, see *Ā e Box* by Mark Levinson or *Ā e Box Ā at Changed the World* by Arthur Donovan.

What can you do to reduce the impact of moving your stuff?

Because freight issues are so complex, there are no 100 percent sure-fire ways to have a smaller impact. However, the following actions can usually reduce your freight footprint:

- Buy locally, and make sure the product is appropriate for your locality (that means don't buy strawberries grown in a hot house in January in Denver, or local wood if your forest can't sustain logging) and that the most efficient vehicle available transports it;
- Combine your errands or arrange for delivery: the trip from a store to your home can have the biggest impact in terms of goods transportation. Fewer trips are better. And a delivery service usually maximizes the efficiency of its deliveries each day;
- Don't buy or send goods via air; and,
- Buy less stuff.

Getting Off Oil: Recent Leaps and Next Steps

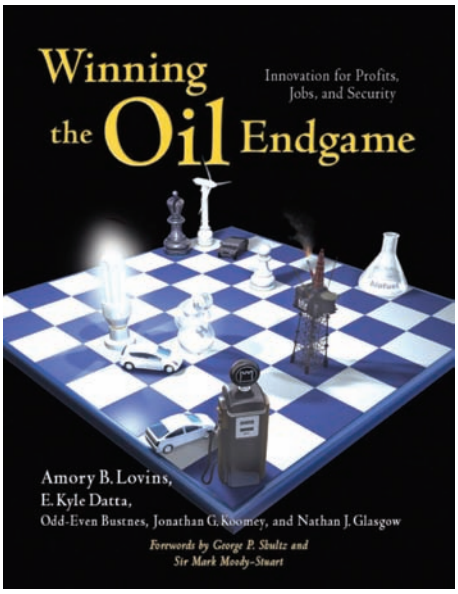
By Amory B. Lovins, Chairman and Chief Scientist

In mid-2005, Rocky Mountain Institute launched a three-year effort to implement *Winning the Oil Endgame* (www.oilendgame.com)—our detailed 2004 roadmap for getting the United States completely off oil by the 2040s, without needing new taxes, subsidies, mandates, or federal laws. We felt this $3.6-million effort could be led by business for profit, because saving or displacing oil would cost only $15 per barrel (in 2000 dollars)—far below oil's price. It might seem foolish to expect to shift such gigantic sectors as oil and cars. But by taking markets seriously, we saw leverage in "institutional acupuncture": find meridians and points where the business logic is congested and not flowing properly, then stick needles into carefully chosen sites to get it flowing.

Some farsighted donors and foundations backed this ambitious experiment. Two and a half years later, it has exceeded expectations. Of the six sectors that must change to set the United States firmly on the journey beyond oil, I believe at least three, perhaps four, have already passed the "tipping point" beyond which the major efforts still required will become ever easier.

Ā e hardest and slowest sector is cars. But building on 17 years of patient effort, our acupuncture is now driving big and accelerating shifts. Ā e tsunami of "creative destruction" we foresaw in 2004 is now breaking over the industry and changing the managers or their minds, whichever comes first. Chrysler, like many leading automotive suppliers, has been bought by a private equity firm; two of the Big Ā r ee firms' CEOs are newcomers to automaking; and Toyota just pulled neck-and-neck with GM as the world's biggest automaker.

Our book urged Detroit to emulate Boeing's breakthrough competitive



strategy, based on an efficiency leapfrog integrating ultralight materials, advanced manufacturing, and whole-system design. Matching our playbook, in September 2006 Ford hired Alan Mulally, head of Boeing Commercial Airplanes, as its new CEO. I now work with Ford's leadership team as a charter member of Chairman Bill Ford's Transformation Advisory Council.

On 10 October 2007, Toyota announced the industry's best-yet Hypercar®-class concept car— the 1/X (pronounced "one-Xth"—see Fig. 1) shown at the Tokyo Motor Show 26 October. Many concept cars never get to market. But a day earlier, Nikkei had reported that Toray, the world's biggest carbon-fiber maker, plans a $0.3-billion factory in Nagoya to mass-produce carbon-fiber body panels and other auto parts for Toyota, Nissan, and others. Together, these two announcements signal strategic intent. Toyota is a proven gamechanger: in the U.S., its Prius hybrid, shown as a concept car in Tokyo in 1995, outsold in 2007 even Ford's Explorer—the top-selling SUV for over a decade. In 2007 alone, U.S. Prius sales soared 69 percent to 181,221, while Explorer sales fell below one-third of their 2000 peak of 445,000.[1] Toyota reported 2007 U.S. hybrid sales totaling 257,760—76 percent of the national hybrid market. Now practically all automakers are selling or urgently developing hybrids to try to catch up with Toyota.

During 1987–2006, the average light-duty vehicle sold in the U.S. got 29 percent heavier; cars alone got 17 percent heavier and 12 percent denser; but only 30 percent of the fleet's weight gain (and none in recent years) was caused by bigger cars or by shifts to SUVs, vans, and pickups. Instead, the obesity came from materials and design. Yet in recent months, strategy has begun to go lean: integrative lightweight design has emerged as an important trend. In November 2007, Ford led by announcing a 250–750-pound weight cut in all cars starting in Model Year 2012 (as soon as production can shift) to capture unexpectedly big design synergies. (Mazda had already been quietly lightweighting.) Two months later, Nissan announced a 15 percent average weight cut by MY2015, and China announced an auto lightweighting alliance aiming to cut 660 pounds out of the average car by 2010. Lightweighting is finally emerging as the hottest strategic trend in the industry.

Unlike traditional improvements, lightweighting can improve fuel economy *and* performance *and* crashworthiness.[2] But this seemingly obvious solution had lacked two key ingredients. First, light materials looked costly. Ā is barrier is rapidly falling due to manufacturing advances, both with familiar light metals and with newfangled carbon-fiber composites (led by RMI's spinoff Fiberforge, www.fiberforge.com, whose high-speed manufacturing technology recently entered industrial service). Second, most automakers still count costs per part or per pound, yet customers care only about cost per car. Since 1991, we've shown how costlier parts or pounds can make cars

cheaper to build. In 2000, our Hypercar® spinoff (later renamed Fiberforge®) and its Tier One industry partners designed[3] a 67-mpg uncompromised midsized SUV that proved how cheaper tooling, simpler assembly, and smaller powertrain could offset costlier materials. *Winning the Oil Endgame* (pp. 61–72) then showed how eliminating 53 percent of that car's weight would be essentially free: the 3.6×-more-efficient SUV would be priced just $2,511 higher (2000 $), a two-year U.S. payback—and would cost more only because it's hybrid-electric, not because it's ultralight.

To support the transition to such cost-busting integrative designs, in summer 2007 RMI led two automotive efforts, either of which could transform the industry—one partnering with a major automaker, another with a consortium of Tier One suppliers. Both turned up trumps, and more are emerging.

Automakers now face relentless and converging pressures from innovation-hungry auto dealers, financial analysts and investors, the United Auto Workers' Union, climate and security concerns, and a 2007 U.S. law requiring 40 percent higher fuel efficiency within 12 years. "Feebates" (*WTOE*, pp. 186–190) will further speed and reward the transition, and a private Feebate Forum RMI led in June 2007 is stimulating strong industry interest. For all these reasons, fundamental rethinking is spreading rapidly, with lightweighting in the vanguard. But lightweighting in turn makes advanced powertrains, especially those using electric traction, cheaper and more advantageous.

In January 2008, RMI joined with powerful industry partners to spin off a new venture, Bright Automotive™ (our third spinoff in addition to two staff startups), focused on PHEV technology development. In 2004, our published menu for tripled-efficiency cars didn't yet include plug-in hybrids, but by 2007, we'd devised technical and

Figure 1. Toyota's impressive 1/X carbon-fiber concept car (2007) has the interior space of a Prius midsize hybrid, but is three times lighter and twice as fuel-efficient. Its half-liter flex-fuel engine, tucked under the rear seat, is supplemented by grid electricity via 20 extra kg of batteries. Ā e plug-in hybrid's remaining curb mass, 400 kg, is exactly what I'd claimed in 1991 (to much industry mirth) a good carbon-fiber four-seater could weigh.

business-model innovations that could often give them a sound business case, at least redoubling cars' potential oil efficiency. To push this further, we're developing the "Smart Garage"—an intelligent interface between electric-traction vehicle, building, and electric grid. Plug-in hybrids' distributed battery storage, or fuel-cell cars' distributed fuel-cell generators, could become important, even dominant, elements of electrical supply, initially for peak loads and later for wider needs—realizing the "vehicle-to-grid" concept I invented in 1991.

Now let's connect the automotive dots. Drive your Prius-class car properly (not the way *Consumer Reports* says to) and you double a typical non-hybrid sedan's miles per gallon. Make it ultralight and slippery and you can redouble its efficiency. Now fuel it with cellulosic E85 fuel (85 percent ethanol, 15 percent gasoline) and cut its oil use per mile by another fourfold, to ~1/16th of the current level. Make it a plug-in hybrid and cut oil use by at least half again, to ~3 percent of the original. Optionally, a hydrogen fuel cell, competitive in such an efficient vehicle,[4] could replace both the engine and its E85 fuel.

Ā is menu doesn't yet count diesel engines, which are more efficient than normal Otto engines and have half the European market today. In 2004, we weren't sure diesels could meet future fine-particulate air standards, so we didn't include them. But in 2007, a small Colorado firm (www.sturmanindustries.com) demonstrated a radically new digitally controlled engine that promises above-diesel efficiency, cleanly burning any fuel on the fly, yet with lower cost, size, and

weight. Successful development of this concept could quickly bring internal-combustion engines to and beyond fuel cells' efficiency range—itself a moving target—revolutionizing both vehicular propulsion and stationary micropower systems. Alternatively, MIT researchers have shown how a tiny, timely squirt of ethanol into the engine can suppress knock even at tripled compression ratio, permitting half-size, same-torque engines about about one-fourth higher efficiency. Ā at could stretch today's modest ethanol supplies to cover the whole fleet.

Of course innovation continues to emerge, encouraged by RMI's continuing conversations with automakers worldwide. More will come from India (p. 12), where Tata just launched the most important clean-sheet car design in decades (the $2,500 Nano) and from China, where Tsinghua University Press will publish *Winning the Oil Endgame* in 2008. But existing technologies are clearly more than adequate to get the world profitably off oil, and they're getting ever better and cheaper, while oil is getting scarcer and costlier.

Meanwhile, the first three sectors to have reached the tipping point are continuing to accelerate their transformations. Let's start with aviation, the fastest-growing oil user. In 2004, Boeing got outsold by Airbus, but launched a bold riposte: the 20 percent-more-efficient, same-price, greatly simplified, easier-to-build-and-run, 50 percent-carbon-composite-by-mass airplane called the 7E7, later renamed the 787 Dreamliner. As we expected, it proved wildly successful. By 24 February 2008, Boeing had sold 885 of these airplanes (892 firm, 38 pending) and 430 options, the fastest order takeoff of any jetliner in history. Production is sold out well into 2017. Boeing now plans to add similar innovations to every airplane it makes before Airbus can catch up. Boeing will also presumably apply its momentum and cashflow to aggressively develop even more efficient designs to consolidate its competitive advantage. So far, Boeing's strategy looks like one of the great turnaround stories in business history: it took only two years (or five years from 2004 start to delayed 3Q09 first delivery) to move Boeing from trouble to triumph. RMI is discussing with airframe makers some ways to accelerate such progress within a profitable competitive and climate strategy. And in February, Sir Richard Branson's Virgin Atlantic Airways successfully tested a novel non-food-crop-based vegetable oil as fuel in an A380.

Winning the Oil Endgame showed how to triple the efficiency of heavy (Class 8, 18-wheel) trucks through an integrated suite of improvements, mainly in aerodynamics and tires, with a juicy internal rate of return around 60 percent. On discovering that major truck buyers didn't know this was possible, we began facilitating conversations between one such firm and its suppliers. Āey soon discovered that the first 25 percent fuel saving was free. Ā e buyer said, "Free isn't good enough: I want to invest for a return. What can you do for me?" Dramatic and lucrative opportunities quickly emerged. In October 2005, the firm announced that its new truck purchases would soon become 25 percent more efficient (it now expects near-completion by late 2008), and that it would double its fleet efficiency by 2015. Āe firm is Wal-Mart (see p. 9), the world's largest company. It will save billions of dollars' net present value and is strongly motivated. Wal-Mart's immense "demand pull" will bring doubled-efficiency trucks into the marketplace where everyone can buy them. In the U.S. alone, that'll save 6 percent of total oil use. Now RMI is working to enroll more buyers, speed suppliers' innovations, and demonstrate tripled-efficiency designs, which Wal-Mart's CEO has also acknowledged as a realistic goal.

Having analyzed and advocated military energy efficiency for two decades and served as an independent member of two U.S. Defense Science Board task forces advising the Secretary of Defense on this issue,[5] I've long urged military leaders to start valuing saved fuel at its delivered value—delivered to platform in theater in wartime.[6] Ā at "fully burdened" cost is many times the $13-billion cost of undelivered military fuel in FY2006. Ā e cost in blood is also huge: about half of all U.S. casualties in theater are related to convoys, which mainly haul inefficiently used fuel. Tying down whole divisions hauling fuel and guarding convoys also diverts and degrades combat capability. Field experience of fuel logistics burdens has created a unique opportunity for switching to efficient platforms that radically trim fuel logistics. *Winning the Oil Endgame* in 2004 estimated a practical long-term scope for tripling the average fuel efficiency of military platforms and installations. Today that estimate looks realistic, perhaps even conservative. Ā e resulting DoD R&D emphasis on light-and-strong materials, advanced propulsion, etc. will help to transform the civilian car, truck, and plane industries toward tripled fuel efficiency, much as past military R&D led to the Internet, the Global Positioning System, and the jet-engine and microchip industries. Ā e Pentagon is thus emerging within the U.S. Government as the leader in getting the nation off oil so nobody need fight over oil.

Ā is new source of off-oil leadership

"*Winning the Oil Endgame* in 2004 estimated a practical long-term scope for tripling the average fuel efficiency of military platforms and installations. Today that estimate looks realistic, perhaps even conservative."

became publicly visible on 13 February 2008 with the release of the Defense Science Board panel's report. Its Appendix E revealed an important policy created 10 April 2007 by the Under Secretary of Defense: "Effective immediately, it is DoD policy to include the fully burdened cost of delivered energy in trade-off analyses conducted for all tactical systems with end items that create a demand for energy and to improve the energy efficiency of those systems, consistent with mission requirements and cost effectiveness." A pilot project is now refining and field-testing this policy. Another new directive, approved by the Joint Staff in 2006, will selectively apply to new weapons systems an Energy Efficiency Key Performance Parameter—a core metric that drives requirements-writing and acquisition. In May 2008 I hope to start helping the Defense Acquisition University, which trains all DoD purchasers, to apply these vital concepts. And as soon as we can find funding, I intend to expand RMI's efforts to help the civilian and uniformed leadership to embed energy efficiency irreversibly in the Services' cultures and processes.

Important changes are also well underway in the fuels and finance sectors. From cellulosic ethanol to butanol to algal oils, a portfolio of exciting new biofuel options is moving from lab to market, including breakthroughs not yet announced. (RMI recently helped the National Renewable Energy Laboratory to redesign a cellulosic ethanol plant to save half its steam, three-fifths of its electricity, and a third of its capital cost; some other emerging advances can cut costs even more drastically.) And the global financial sector made $117 billion of new "clean energy" investments in 2007 alone.

In summary, RMI's "institutional acupuncture" is hitting the right points and starting to elicit potent responses. Ā rough fruitful collaborations with DoD, five Fortune 500 firms, and key business and government players in one state (Hawai'i), plus formation of two new companies and the other actions summarized above, we've already multiplied the $3.6-million received in grants and donations into at least $375 million in measurable benefits. Now we're now seeking another $3 million to build on these successes (see summary on pp. 8–9).

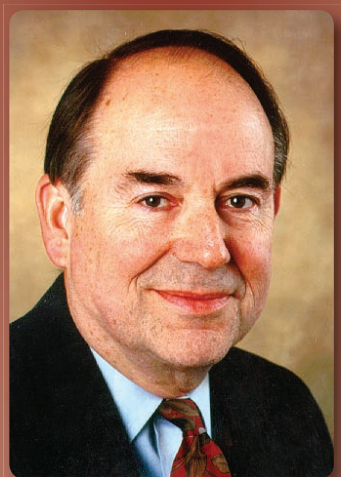
Please contact developers@rmi.org if you'd like to help RMI make oil no longer a strategic commodity—much as refrigeration (notes former CIA Director Jim Woolsey) did to salt. Nations once warred over salt. Now they just use an occasional pinch and pay it no mind. At RMI, we're experiencing a rush of pre-nostalgia just thinking about the richer, fairer, safer world beyond oil.

Notes:

1. B. Simon, *Fin. Times*, London, 10 Jan. 2008.
2. Ā e government analysis previously interpreted as showing that lighter cars will kill people turned out, as we suspected, to be flat wrong: disentangling size from mass in the same database proved that weight kills if size is held constant, and so does smallness at the same weight. (Van Auken and Zellner's 2003 DRI analysis separated size from weight in NHTSA/Kahane's FARS database). Happily, light-but strong materials can make cars both bigger—hence more comfortable and protective—and lighter—hence less hostile and inefficient. Done right, they can even reduce total manufacturing cost. RMI's Laura Schewel reported these and other exciting opportunities at the Society of Automotive Engineers' World Congress in April 2008.
3. RMI Publ. #T04-01, www.rmi.org/images/PDFs/Transportation/T04-01_HypercarH2AutoTrans.pdf.
4. Ref. 3 and 20 Hydrogen Myths, www.rmi.org/images/PDFs/Energy/E03-05_20HydrogenMyths.pdf.
5. Ā e 1999–2001report is at www.acq.osd.mil/dsb/reports/fuel.pdf and the 2006–08 report at www.acq.osd.mil/dsb/reports/2008-02-ESTF.pdf.
6. A public DoD factsheet, noting concurring findings by the Institute for Defense Analyses and SECDEF's JASON scientific advisory group, is posted at www.acq.osd.mil/at/docs/fact_sheets/energy_efficiency_starts_with_the_acquisition_process.pdf.

John E. Abele Joins RMI Board of Trustees

RMI is pleased to announce that John Abele, Cofounder and Director of Boston Scientific Corporation, has joined the Institute's Board of Trustees. A pioneer and leader in the field of "less-invasive medicine," John holds numerous patents and has published and lectured extensively on the technology of various medical devices and on the technical, social, economic, and political trends and issues affecting health care. His major interests are science literacy for children, education, and the process by which new technology is invented, developed, and introduced to society. "I've been a long-time admirer of Amory and RMI," he said. "Ā eir systems thinking, non-partisan practical advice is unique and powerful and a role model for addressing the challenging environmental problems before us." Currently he also serves as Chair of the FIRST Foundation, which works with high school kids to make being science-literate cool and fun. He is also working on the development of Ā e Kingbridge Centre (www.kingbridgecentre.com) and Institute, a conferencing institution whose mission is to research, develop, and teach improved methods for interactive conferencing, including problem-solving, conflict resolution, strategic planning, and new methods for learning, as well as generally helping groups to become "collectively intelligent."



Winning the Oil Endgame, Round Two

In spring 2004, when RMI was writing *Winning the Oil Endgame*—a peer-reviewed roadmap for getting the United States completely off oil by the 2040s—the government forecast that oil in 2025 would cost $26 a barrel. By the time we published the study in September 2004, the actual price was nearly $40. Today, with prices pushing through $110, the solutions to America's oil addiction are worth almost three times as much—conservatively assuming, as *WTOE* did, that oil's hidden costs to security, climate, etc. are worth zero. But the cost of *WTOE*'s solutions still averages around $15 a barrel.

RMI is seeking funding over the next three years to implement many of these solutions. Michael Brylawski, Vice President of MOVE (MObility + Vehicle Efficiency), RMI's Transportation Practice, explains that "With this funding we'll help 'wildcat for efficiency' and find some really big 'negabarrels'." Inspired by the term "negawatt," "negabarrel" simply means oil saved by more efficient use. With this fundraising effort, RMI is kicking off the second portion of the multi-year implementation of *Winning the Oil Endgame*: *WTOE*, Phase II. Ā e Snowmass-based MOVE team is geared up to build on, replicate, and exceed the success of Phase I.

Phase I's Success

In many ways, *WTOE* and its implementation represent what RMI does best: researching, developing, and implementing whole-system solutions led by business for profit. As RMI Senior Development Officer Ginni Galicinao points out, "Ā is work is made possible by individuals and foundations who were excited about the potential of *WTOE*'s Implementation Plan. *WTOE* Phase I's successes were made possible by both long-time and new donors, including a challenge match from an individual donor that sparked additional funding."

RMI has calculated that it leveraged the $3.6 million it received in grants and donations to implement *WTOE* Phase I more than 100-fold through consulting work, technology investments, and oil saved by clients' implementing *WTOE* recommendations. For Michael Brylawski, "It was the biggest social return on investment you could want as a philanthropist."

Ā is support allowed MOVE consultants to break into a variety of high-leverage areas and use radical efficiency solutions to advance the ideas laid out in *WTOE* (see pp. 4–7). But that's not all. *WTOE* donations also financed the development of new technical and business designs that helped RMI start Bright Automotive™, a plug-in hybrid electric development company. Donors supported our pathfinding work with stakeholders on innovative policies, such as revenue-neutral feebates, and on lightweight vehicle safety. *WTOE* funding helped RMI partner with a major automaker to create a "transformational" vehicle that is now being fleshed out by more than two hundred engineers. It allowed RMI to team up with the National Renewable Energy Laboratory and host a charrette to catalyze competitive next-generation cellulosic biofuels. And it helped fund our work with the military, which is now requiring its future platforms to account for the "fully burdened" cost of the fuel transported to the place of use.[1]

Ā is work requires extensive research, documentation, and marketing before a client engagement or commercialization step can occur. Just as much as the initial creation of the intellectual capital, the implementation process requires philanthropic support. *WTOE*'s successes illustrate how RMI's hybrid philanthropy/consultancy funding model allows us to drive environmentally beneficial innovation further, faster, and deeper into the business world.

Overall, *WTOE* Phase I achieved highly gratifying results. Yet the U.S. is still two-thirds dependent on imported oil, and world oil consumption is still rising, especially with growth in India and China, so we must redouble our implementation efforts in *WTOE* Phase II.

Phase II Projects

Phase II will use four main tools: high-level influence, entrepreneurial innovation, corporate engagements, and public outreach. In Phase I, these methods were illustrated respectively by our military work, Bright Automotive, Wal-Mart and a major automaker, and *Forbes* and *Wall Street Journal* articles, among others. For Phase II, we have comparable or better channels in view. Phase II will continue to emphasize the automotive and trucking sectors, the military, and next-generation biofuels, but will expand our efforts in aviation and freight.

In addition, although *Winning the Oil Endgame* was a book about the U.S., RMI wants to expand its outreach beyond our country, especially to the developing markets that increasingly drive growth in global oil use. We are currently finalizing the Chinese translation of the book with Tsinghua University, and looking at tackling selected foreign projects, especially for automaking in India and China. Ā ose two nations have the same percentage of auto ownership that the United States had in 1915. Ā e Chinese auto industry has quadrupled in size in the past six years, and the cars it produces need to be far more efficient. MOVE aims to

get Indian and Chinese automakers, like Mahindra, Tata, and Chery, to leapfrog Western efficiency gains while also accelerating efficiency efforts at U.S. automakers so that they remain at the front of the competition. Early work along these lines is encouraging, but to convince automakers to come on board, MOVE must do significant additional research using philanthropic funding.

As our experience with Wal-Mart showed, integrative design could radically improve heavy trucks' fuel efficiency. Ā e MOVE Team is looking specifically at trailers, which create much of the aerodynamic drag. MOVE aims to raise 6-mpg trucks to 12–14 mpg, roughly the fuel efficiency of a Suburban—not bad for vehicles that regularly carry 50,000–70,000 pounds. Aviation is yet another area where the MOVE Team will apply its growing experience to help make planes 2–3 times as efficient. With airframe makers and other major players now knocking on RMI's door, the MOVE Team will add a senior aviation specialist.

Ā e MOVE Team continues to investigate lightweight shipping containers and how to make them thermally efficient (see p. 2). RMI estimates that containers' refrigeration is responsible for 1 percent of all greenhouse-gas emissions. And the Team continues to work on the electrification and efficient design of ports (see www.rmi.org/sitepages/pid382.php).

MOVE and *WTOE*

Ā e MOVE Team (Michael Brylawski, Lionel Bony, Michael Ogburn, Stephanie Johns, Laura Schewel, Mike Simpson, Schuyler Senft-Grupp, Alok Pradhan, and Laurie Ramroth; www.rmi.org/sitepages/pid56.php#MOVE) practices rigorous program management to assess project impact and allocate resources. Such best-practice process discipline should amplify Phase I's success. In addition, unlike conventional consultancies that seek incremental gains and quick wins, MOVE and RMI seek transformational change. What we do is not easy. But it is vital, urgent, and exhilarating, and we feel we are uniquely equipped for the challenge.

"In implementing *WTOE*, Amory uses the metaphor of 'institutional acupuncture'," Brylawski notes. "I like to combine this metaphor with that of 'efficiency wildcatters.' Acupuncture implies that you know exactly what needs to be done, which is great when you do. But while our desired outcomes and vision for *WTOE* are clear, often the path to get there is not—and we must take risks in how we stimulate industry and other stakeholders into commercializing transformational efficiency. For example, we didn't know when we started looking into plug-in hybrids that bringing together Google and the Turner Foundation with two traditional industrial giants to launch a company (Bright Automotive) was the best way to stimulate the industry, but it turned out to be a good approach with a potentially huge efficiency payoff.

"Similarly, wildcatters know in general where the oil is," Brylawski adds. "Ā ough not specifically where to drill—but the prize is big, so they risk a lot for potentially huge rewards. Ā at 's us. We are efficiency wildcatters drilling for negabarrels. Ā is area is dynamic. It's rapidly changing, and we have ambitious *WTOE* implementation goals for the next Phase. Ultimately, we hope to hit more than a few negagushers."

If you're interested in accelerating the Oil Endgame, please contact developers@rmi.org

Notes:

1. Delivering a gallon to a military vehicle, in theater, in wartime can cost tens of dollars—much more if the delivery must be rapid or to a remote site.

Wal-Mart Foundation Donates to RMI

RMI got a special holiday gift in late December when the Wal-Mart Foundation, the charity arm of the Arkansas-based retailer, donated $250,000 to the Institute. Ā e Wal-Mart Foundation made the donation to support RMI's cutting-edge work on various initiatives that encourage the efficient use of energy and resources.

"We owe a great deal of credit to the staff of RMI," said Tom Mars, Wal-Mart Executive Vice President and General Counsel. "Without the kind of thought leadership the Institute brings to this arena, we wouldn't be as far along in our sustainability efforts as we are."

Rocky Mountain Institute has worked with Wal-Mart for many years, primarily on making Wal-Mart's trucking fleet and large stores more energy efficient.

"I think Wal-Mart is one of the leaders in the corporate sustainability space," said RMI Executive Director Marty Pickett. "Ā ey're genuine in their commitment and this [grant] is evidence of that."

In October 2005, Wal-Mart's CEO Lee Scott announced his company's intention to green up its operations. Wal-Mart's environmental goals include using 100 percent renewable energy, creating zero waste, and selling products that sustain natural resources and the environment.

Pickett noted that this $250,000 will provide significant support for RMI's continued work on fuel-efficient vehicles, high-performance buildings, and utility and industrial energy efficiency.

City of Cambridge Pushes Energy Efficiency to New Level

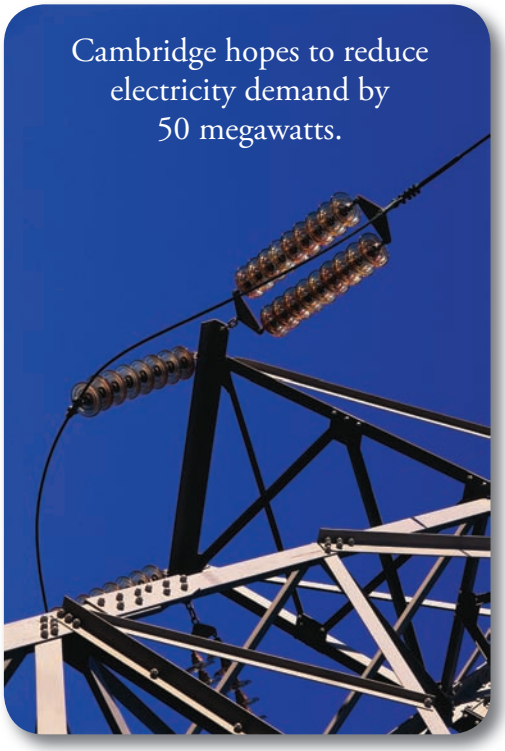
RMI Helps the "City of Squares" Cut Greenhouse-Gas Emissions and Use Less Energy

By Natalie Mims

As the "going green" trend grows, local, state, and big-city governments are joining the movement that smart developers and forward-thinking corporations have been leading. Regional and city climate-change initiatives are mounting, and efforts to cut energy use and greenhouse-gas emissions have become as varied and individualistic as the communities themselves. Recently, RMI worked with one Massachusetts city on its energy and greenhouse-gas reductions efforts.

In March 2006, the City of Cambridge, Mass. announced an ambitious goal: to reduce electricity demand by 50 megawatts and to reduce fossil-fuel consumption by 5 percent in five years. Following the announcement, the City, the Barr Foundation, the Kendall Foundation, and Rocky Mountain Institute began preparing a Design Workshop in which the four organizations could brainstorm ways to meet those goals. One of the first steps the City took was to establish the Cambridge Energy Alliance (CEA), a new non-profit organization to create and implement a cutting-edge program to significantly reduce energy use in Cambridge. Ā e CEA then announced that it would use a new financing model to fund the massive energy-efficiency retrofits necessary to achieve the 50-megawatt peak energy reduction goal.

Ā is innovative financing model relies heavily on the New England Independent System Operator (ISO-NE). Ā e ISO-NE's job is to ensure that adequate electricity supply exists to meet customers' needs. It does so by monitoring the purchase and sale of electricity on the wholesale electricity market. In June 2007, the ISO-NE announced that it would begin offering payment for measures that reduce demand. Ā is will, for the first time in ISO-NE history, allow energy efficiency measures to compete with supply-side resources for capacity payments. Ā e ISO-NE decided to allow demand-side resources to participate in the capacity market because they cost less than traditional supply-side resources. By allowing efficiency into the capacity market, electricity costs to consumers in the ISO-NE region could decline as the cost of the procurement per megawatt decreases (or the value of a negawatt increases). Ā e CEA is poised to earn some of this revenue from the ISO-NE's capacity market through its planned energy-efficiency programs. Ā e CEA plans to fund the energy-efficiency programs 80 percent through private funding and 20 percent through existing energy-efficiency programs.



Cambridge hopes to reduce electricity demand by 50 megawatts.

Ā e City chose to reduce energy demand by 50 megawatts to bring its peak electricity demand down to approximately 300 megawatts. Ā is presented an interesting challenge because in order to reduce the last 50 megawatts of peak demand, the City needs to focus on energy consumption in the summertime, when system demand is highest (see Figure 1).

In addition to the peak energy and fossil-fuel reduction goals, the Barr Foundation also thought it would be interesting to explore what kind of energy challenges could be solved by means of a community competition. Ā e Boston Innovation Challenge, developed by the Foundation, is a new initiative that offers a prize to stimulate the development of new ideas and efforts (rather than reward existing efforts).

After much planning and coordination, a Design Workshop was held in Boston last November. Participants from the Cambridge Energy Alliance, the Kendall Foundation, the Barr Foundation, and RMI, as well as various experts from local institutions met to develop strategies. Ā e Workshop produced many creative and practical ideas as to how the City can meet its energy reduction goals, as well as ideas for other Boston Innovation Challenge topics.

Following the Workshop, RMI compiled the all of the ideas generated, and offered a portfolio of solutions that could be used by the City. RMI recommended that the Cambridge Energy Alliance simultaneously pursue all

available "low-hanging fruit" while working with energy service companies (ESCOs) to implement as many advanced energy-efficiency strategies as possible.

ESCOs develop, install, and arrange financing for projects designed to improve energy efficiency and maintenance costs for facilities over a seven- to twenty-year time period. Some of the specific recommendations included:

- Residential electricity metering and education efforts,
- Energy Star appliance replacement,
- High efficiency central and window air-conditioning units,
- Comprehensive light upgrades,
- High-performance glazing,
- Solar hot water heaters, and
- Boiler or furnace replacement.

While these recommendations are not particularly cutting edge, the challenge for the City of Cambridge will be to implement them widely. For example, if all the residential sector recommendations are implemented at a 7 percent penetration rate, or 35 percent over five years, the City will achieve a 42-megawatt peak energy reduction. Ā is level of penetration is ambitious, but not unachievable, and it will require the City to get more than a third of its residents to adopt significant efficiency retrofits.

Most of RMI's analysis focused on aggressive, comprehensive energy efficiency in the building arena, notably the residential and commercial sectors, but the Design Workshop also generated many ideas for the transportation sector, from closing streets to displaying vehicles' tire pressure. Ā e report is available on the Cambridge Energy Alliances' website for review and comment at (http://ceic.cambridgeenergyalliance.org/).

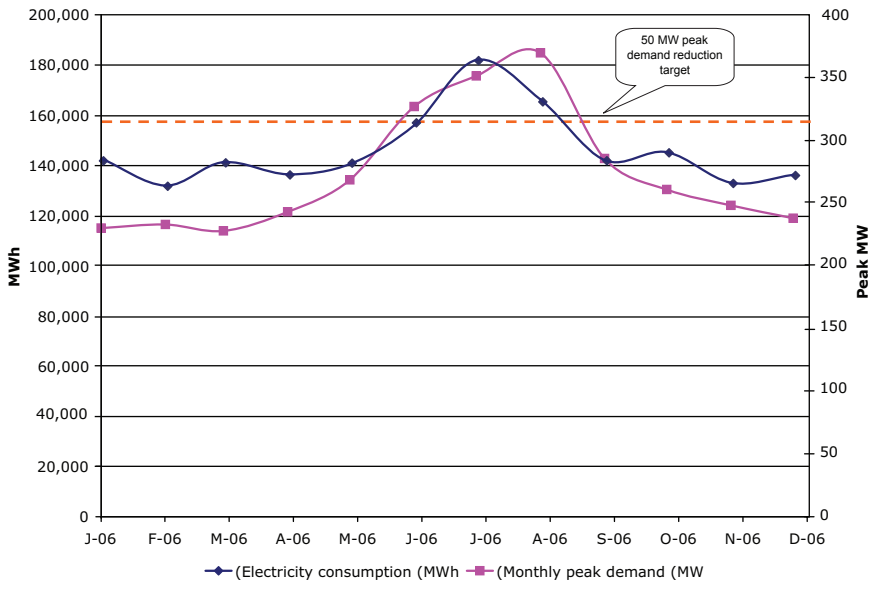


Figure 1: Cambridge Electricity and Demand, 2006

Many other interesting ideas for the Boston Innovation Challenge were discussed, including:

- Enhancing the financial model that the Cambridge Energy Alliance is using by lengthening the payback period for energy-efficiency measures by using carbon cost accounting or on-bill financing;
- Creating super-efficient rooftop air-conditioning systems for smaller commercial applications in humid climates; and
- Retrofitting all buildings in the city with real-time energy consumption information to allow consumers to make their energy use decisions based on real-time information.

Technology breakthroughs and products were mentioned many times during the Innovation Challenge, and while some of these ideas offered great opportunities, the lead-time necessary for implementation may be beyond the City's five-year goal. RMI recommended that the first Boston Innovation Challenge be based on behavioral, financial, or social changes to encourage a high penetration of energy efficiency. Moving forward, future Boston Innovation Challenges could build on ideas generated at the workshop or they could develop new technology challenges.

Ā e Cambridge Energy Alliance has already begun chipping away at energy consumption and plans to move forward aggressively to achieve its goals. Ā e CEA is hoping the example they set will ultimately become a model that other cities can use to reduce their energy consumption without taxpayers bearing a financial burden.

Natalie Mims is a Consultant with RMI's Energy & Resources Team (www.rmi.org/sitepages/pid48.php).

> "Ā is timely and ambitious project provides an opportunity to apply highly innovative new approaches to energy efficiency in terms of advanced technology, integrated building design, novel business models, and creative policy mechanisms to capture the full potential for efficiency, our cleanest, cheapest, and most secure energy resource."
>
> —Amory Lovins, Rocky Mountain Institute

OCS Update

Ā e past few months have been exceptionally busy for Amory and his staff.

Alex Markevich joined RMI in October. As Vice President of the **Office of the Chief Scientist (OCS)**, he'll oversee this six- to nine-person team, foster external partnerships, and strengthen integration between OCS and the rest of the Institute. His keen strategic insight is already making its mark. Alex comes to RMI with 13 years of strategic consulting experience, most recently on Bain & Company's management team in London and Moscow, and previously at Cannon Associates and LEK Consulting. His three years at Hewlett-Packard included technical and marketing work, emphasizing computer systems performance. He holds a Ph.D. in physics from Stanford.

Ā ree OCS staff are completing an intensive half-year update to our best-selling 1999 business book *Natural Capitalism*. Aaron Westgate, Maria Stamas, and Noah Buhayar have been revising the text, reassembling worthy overflow material, and updating old and adding new case-studies. All will be published later this year as optional hypertext at www.natcap.org, which also contains, by permission, the original book edition and our *Harvard Business Review* overview of it, "A Roadmap for Natural Capitalism"—one of *HBR*'s most reprinted articles. A long-awaited French edition is also in press at Editions Scali in Paris.

Over the past year, RMI's original (1982–) headquarters building has undergone extensive renovations and improvements to physical fabric, superwindows (now R-14, or in one case R-19—insulating like 19 sheets of glass), lighting, daylighting, wiring, and other systems. Ā e new interior jungle, designed *pro bono* by EDAW landscape architects Greg Hurst and David Sachs and by our staff's project manager Aaron Westgate (who largely installed it), saw inch-a-day banana-tree growth last summer; the trees should go bananas (and papayas, guavas, mangoes, etc.) this summer. In April, the OCS team moved back into its much-improved workspace.

In late 2007, Amory Lovins did a 38-day round-the-world trip, supported in stages by Alex Markevich, Michael Brylawski, and Lionel Bony. In New York, Amory received the *Popular Mechanics* Breakthrough Leadership Award and addressed a J.P. Morgan utility conference. He and Judy then flew to Tokyo to receive the Blue Planet Prize (www.af-info.or.jp/eng/honor/honor-e.html), where, in the presence of Prince and Princess Akishino and many other dignitaries, he invited Japan to lead the global energy transition. He also lectured at Tokyo University, Ministry of Environment, Foreign Correspondents' Club, and National Institute for Environmental Studies, which has shown how to cut Japan's 2050 carbon emissions by 70 percent below the 1990 level despite robust economic growth.

In Delhi, Amory addressed a leading global business-strategy conference keynoted by the Prime Minister, then continued to Mumbai for Mahindra & Mahindra and the Indian Institute of Technology. Our hosts were excited by his two national industry seminars on superefficient ultralight cars and by integrative design for radical energy efficiency.

Next, in Gothenburg and Stockholm, Amory addressed the Volvo group, Chalmers Institute of Technology, U.S. Embassy, and Royal Swedish Academy of Engineering Sciences, which later elected him a Foreign Member. He received the Volvo Environment Prize from HRH Prince Carl Philip (see www.environment-prize.com/pressRelease.e) as the fifth person in the world to win both of these top environmental awards, and the first to win both in the same year. Volvo later made a special 60-second spot on our work (see www.rmi.org/sitepages/pid41.php), carried 60 times on the Volvo-sponsored global telecast of the Nobel Prize ceremonies.

Via London for meetings with senior business leaders, Amory flew on to Boston to co-lead a charrette for the Kendall and Barr Foundations on accelerating Cambridge's electric efficiency, then a San Antonio financial-industry keynote, then home. But the next month saw trips to Atlanta for another utility finance conference, Michigan (to receive the Goff Smith Prize, U. Mich.'s top external award in engineering), Syracuse U., Perth in Western Australia (helping redesign two radically efficient mines with Rio Tinto), Big Sur, and Florida. Ā ere his keynote (www.rmi.org/sitepages/pid444.php) to the Institute for Healthcare Improvement about analogies between health and energy, and a side-seminar on designing superefficient healthcare facilities, sparked breakthrough thinking on which we'll report later.

Busy though 2007 was, 2008 looks even busier, but differently so. In a two-week period in early 2008, Amory helped redesign an oil refinery, a data center, a famous big building, and an auto company; each project should strongly steer its industry toward advanced resource efficiency. Ā e carbon saved by his work enormously exceeds the amount emitted by his travel, but Amory is thrilled that a more thoughtful strategy led by Alex and Judy will help him travel less, and more virtually—moving only the electrons while leaving the heavy nuclei at home at the passive-solar banana farm.

Farewell to Dale Levy

By Ginni Galicinao

With the 1 July 2000 arrival of Dale Levy as RMI's Development Director, fundraising at RMI would never be the same. RMI was fortunate to have him at the helm of its Development Department until he retired at the end of December 2007.

During his tenure, Dale challenged RMI to explore new ways of building relationships with our supporters and offering our donors new ways and opportunities for giving.

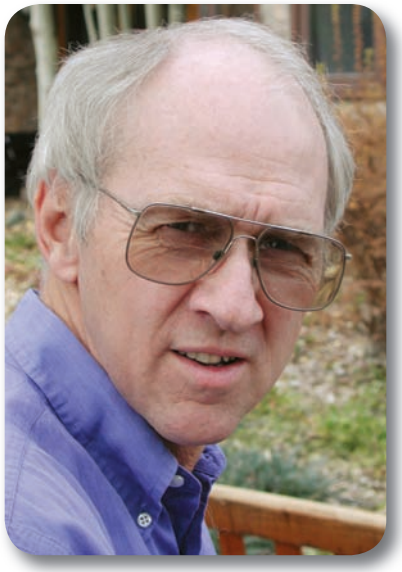
During Dale's tenure, RMI's contributed income grew from $2 million in FY2000 (total FY2000 operating revenues and support was $4.9 million) to $4.7 million in contributed income for FY2006 (total FY06 operating revenues and support was $9.6 million).

Dale was particularly instrumental in cultivating RMI's relationship with the William and Flora Hewlett Foundation, whose giving rose from $500,000 over three years in 1998 to a $750,000 three-year grant. He also took the lead in the Sandler Family Foundation's matching grants campaign. Ā rough the generosity of the Sandler Family, RMI was able to considerably leverage those grants.

Some of the important work that RMI was able to fund as a result of Dale and the Development Team's work include:

• ***Winning the Oil Endgame*** **(WTOE):** Published in 2004, *WTOE* clearly represents one of the most important and ambitious pieces of work ever undertaken by RMI. Ā is independent, peer-reviewed detailed roadmap for getting the United States completely off oil by the 2040s drew on the skills and time of everyone at the Institute.

• **National Energy Policy Initiative (NEP Initiative):** In February 2002, RMI and the Consensus Building



Institute convened a bipartisan group of the nation's best energy thinkers to craft a stakeholder-based national energy policy that meets security, economic, and environmental needs simultaneously and without compromise. Ā e result integrated creative win-win opportunities in transport and mobility, electrical services, energy security, and climate. Endorsed by 33 leading private- and public-sector energy leaders, the NEP Initiative received wide praise and was presented to Congressional leaders of both parties and houses in the hope of reshaping how legislators responded to the nation's unresolved energy policy issues.

• ***Small is Profitable: Ā e Hidden Economic Benefits of Making Electrical Resources the Right Size*****:** Ā is definitive work describes 207 ways in which optimizing the size of "electrical resources"—devices that make, save, or store electricity—increases their economic value. *SIP* showed that "distributed" (decentralized) electrical resources are typically worth about tenfold more than previously assumed. Although directed at the electricity sector, over the years *Small is Profitable* has proved to have a much broader audience.

• **Sustainable Settlements:** RMI joined forces with Dr. Eric Rasmussen and an array of relief organizations to rethink refugee and displaced persons settlements from scratch. Ā e study yielded fascinating results, some of which immediately influenced aid and humanitarian work.

Other important work funded under Dale's leadership includes: teaching National Capitalism at the University of Peking, RMI's *Design Recommendations for High-Performance Data Centers*, *Ā e New Business Climate: A Guide to Lower Carbon Emission and Better Business Performance*, the Community Energy Opportunity Finder, the Greening of Greater Boston's Health Care Systems and Facilities, RMI's Energy Resource Investment Strategy, and the Biomimicry Database.

Dale and his wife, Linda, plan on having fun during this next phase of their lives. Ā ey have relocated to Oklahoma to be closer to their families. All of us RMI wish them the very best, and are grateful to Dale for his invaluable leadership role at RMI. Ā ere is no question that Dale's contributions to RMI will have an effect long after his departure.

RMI Legacy Society

Esther and Francis Bligh
Jill Bolduc
Joanne and Michael Caffrey
Virginia Collier
Anne Cooke
Richard Ford
Marcia and John Harter
Stanton Klose
Erika Leaf
Susan and Arthur Lloyd
Margaret Wurgel and Keith Mesecher
David Muckenhirn
Judith and Mark Schaffer
Joan Semmer
Joel Shapiro
Jane Sharp-MacRae
Anonymous (7)

Water, Water...But Not Everywhere

RMI Helps Design an Environmental Center Near Atlanta

By Jim Nicolow

Rocky Mountain Institute has collaborated with numerous design firms over the years, but efforts with design firm Lord, Aeck & Sargent (LAS) have been particularly fruitful. RMI worked with LAS on the Blue Ridge Parkway Visitor's Center, the Southface Energy Institute Eco Office, the Great Smoky Mountains National Park's Twin Creeks Science and Education Center, the National Estuarine Research Reserve's Grand Bay Visitor's Center, and a handful of other buildings. Recently, RMI helped LAS with the design of a remarkable new building in Georgia, the Gwinnett [County] Environmental + Heritage Center (GEHC), which was awarded one of *Environmental Design + Construction* magazine's 2007 Excellence in Design Awards.

Gwinnett County is one of the fastest growing counties in the country, and, although the Atlanta area gets 50 inches of rain per year, the water table lies deep within the area's granite bedrock, making it inaccessible to users. Atlanta area suburbs thus rely on surface water. Recognizing that the County's fast-paced growth would place tremendous strain on water resources, County officials established the Center to improve education about the critical role that water plays in daily life. Ā e two-story, 59,000-square-foot facility blends indoor and outdoor classroom spaces, exterior trails and exhibits, a collection of permanent and rotating displays, and interactive learning opportunities. Ā e Center is projected to use 76 percent less potable water and 35 percent less energy than a conventional building of the same size, and the GEHC achieved LEED Gold-level certification in the U.S. Green Building Council's LEED system. RMI's role was to analyze glazing, daylight, shading, and energy use.

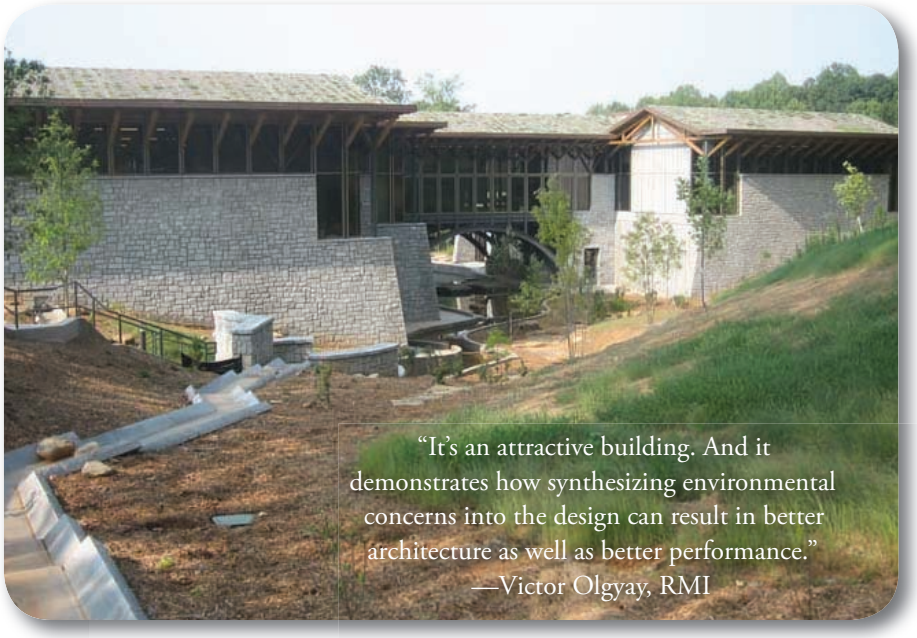
Ā roughout the design process, charrettes were conducted with the entire design team, the owner's team, and various user groups and stakeholders. Ā e facility's signature integrated design feature—a unique cooling shoals water feature[1]—sprang directly from the charrettes. Ā e landscape architect proposed a water feature, the owner suggested re-using non-potable water from the adjacent treatment plant, and the architect envisioned using the feature to condition the building. Ā ese wonderful synergies can only happen when everyone is at the table.

Ā e project's environmental goals and strategies were developed specifically to respond to regional environmental challenges. Ā e three major challenges identified are: limited potable water supply (the Atlanta Regional Commission predicts that water will be the resource that limits the region's growth); polluted stormwater; and poor air quality (due to urban heat-island effect and air pollution from coal-fired power plants in the area).

A green roof was anticipated from the project's inception to reduce urban heat-island effect as well as naturally controlling and treating stormwater. Ā e building is fully capped with an extensive green-roof system planted with six species of conventional drought-tolerant sedums. An 800-square-foot portion of the roof is planted with native granite outcrop plants, providing a test plot for developing a native palette of plants for use on green roofs in the local Piedmont region. Four different types of porous paving are featured, and runoff from the green roof and paving is directed into bioswales as well as two detention areas planted with native wetlands species. After the building was completed, the amount of stormwater running off the site remained the same—in both quality and volume.

All site plantings are native to the region and are grouped according to appropriate existing plant communities and onsite micro-climates. Non-potable water from the facility's water treatment plant is used for irrigation via a drip irrigation system and for toilet flushing (the first such installation in the state). Waterless urinals and low-flow (0.5 gallon-per-minute), automatic lavatory faucets were used throughout.

Ā e building was elongated on an east–west axis to maximize passive heating and cooling, and daylight modeling, solar geometry analysis, and energy modeling were utilized to optimize



"It's an attractive building. And it demonstrates how synthesizing environmental concerns into the design can result in better architecture as well as better performance."
—Victor Olgyay, RMI

the design. Daylighting is abundant throughout the building, and the clerestory monitors are equipped with operable louvers for the exhaust of hot air during fan-assisted passive ventilation mode.

"It's an attractive building," said RMI's Victor Olgyay, AIA. "And it demonstrates how synthesizing environmental concerns into the design can result in better architecture as well as better performance."

ED+C's award judge Peter Levasseur said, "Seventy-six percent water usage reduction and 35 percent energy usage in such a great-looking facility demonstrate that care was placed in both the architectural and systems design of this facility. Ā e interior, exterior, and site design show an integration of aesthetic with performance that shine above other submissions in this category. Coupled with an intent to educate the public, this Environmental and Heritage Center is a space I would not want to miss visiting."

Notes:

1. Designed to span a ravine, the shoals will function like a heat exchanger and be an integral part of the building's mechanical system.

Ā is article was adapted from "2007 Excellence in Design Awards: Gwinnett Environmental + Heritage Center," provided by Jim Nicolow, AIA, LEED AP, and published in Environmental Design + Construction *magazine. Jim leads the Sustainability Initiative at Lord, Aeck & Sargent. Last year he was named one of* Building Design & Construction *magazine's "40 Under 40" up-and-comers.*

Different Ways of Giving

Long-time National Solutions Council member **Christopher H. Smith** will be remembered for his environmental devotion and commitment to Colorado's Roaring Fork Valley communities. One of Chris's dreams was to develop energy-efficient buildings and a sustainable farm at his ranch in the Gunnison area. Because of his commitment to the sustainable and efficient use of energy and resources, Chris sponsored the production of RMI's award-winning film High-Performance Building: Perspective & Practice, which was first shown in November 2007 at the U.S. Green Building Council's conference in Chicago, Ill. After his untimely death, his family and friends chose to recognize and honor Chris's dream by asking that donations be directed to RMI.

For more than twenty years **Joseph Ā omas, IV and Etel Ā omas** generously and consistently supported RMI. Such longstanding commitment spoke volumes of their high regard for RMI and spanned the growth of the Institute from its early days into the world-changing organization it has become. Joe and Etel (founding members of RMI's Legacy Society) left a lasting legacy when they remembered RMI as beneficiaries of two charitable remainder trusts. Ā r ough their trusts, Joe and Etel ensured that the support they provided to RMI for more than two decades will continue on in perpetuity. What was particularly exceptional about their generous gift was that they shared their planned gift intentions with RMI staff, enabling us to thank them for their generosity while they were still with us.

RMI was saddened by the passing of Chris Smith and Joe and Etel Ā omas yet grateful to be the beneficiaries of their years of support (both past and future) and the generosity of their friends and family. RMI's work fostering the efficient use of resources was enhanced as a result of these individuals and we thank them deeply.

Good Car, Bad Car

RMI Holds the Nation's First Feebate Forum

Ā e centerpiece of the policy recommendations made in Rocky Mountain Institute's (RMI) most recent book *Winning the Oil Endgame* is the "feebate."

A feebate is a policy that provides a one-time rebate on fuel-efficient vehicles and places a surcharge on vehicles that are inefficient. New light vehicles that exceed a defined fuel economy benchmark, called the "pivot point," qualify for a rebate. Ā e logic is that people who choose to drive more efficient vehicles deserve a rebate because they are helping reduce social problems, such as pollution, oil dependence, congestion, health problems, and climate change.

Ā e amount of the rebate would depend on where the vehicle's fuel economy falls in relation to the pivot point for all vehicles in that class. A Honda Civic, for instance, would qualify for a rebate because it's more efficient and consumes less fuel than comparably sized vehicles. Conversely, new vehicles that are less fuel-efficient than others in the same class would be subject to a fee.

"Feebates are truly a market-oriented solution to improving automobile fuel economy," said Natalie Mims, a Consultant with RMI's Energy & Resources Team. "State governments should consider feebates as an opportunity to create incentives to improve vehicle fuel economy and help get the United States off oil without federal leadership. Ideally, the federal government could use the feebate as an alternative to CAFE, and shift to a national incentive-based system instead of the current command-and-control system."

Many public policy experts believe offering a rebate for the purchase of efficient vehicles is justified because efficient vehicles reduce social costs. A feebate is a better approach to regulating the automotive industry because it allows manufacturers to install as much fuel economy technology as is cost-effective as opposed to requiring manufacturers to install technology regardless of the cost. Feebates also help consumers to consider the long-term impacts of a vehicle's fuel economy when they purchase a car. Better yet, a well-designed feebate can be self-financing. Fees could pay not only for the rebates but also the administrative costs of running the program.

Last year, RMI organized and hosted the first Feebate Forum in the United States in Snowmass Village, Colo.[1] Twenty-seven diverse stakeholders from across the United States and Canada attended the two-day Forum, which was funded by the Smith Richardson Foundation. Ā e purpose of the Forum was to encourage an open, off-the-record discourse between the auto industry and policymakers about feebates.

Subsequently, RMI produced a white paper on feebates (www.rmi.org/images/PDFs/Transportation/Feebate_final.pdf), which analyzed the effect that the number of size classes and the variety of size attributes used to divide the feebate classes would have on a new 2005 vehicle. Ā e research had two major findings. First, as the number of vehicle size classes increases the range in the volume of vehicles in each class decreases; the range of fuel economies in each class gets smaller; and the differences in size of the fees or rebates decreases. Second, regardless of the size attribute used to divide a vehicle class (interior volume, exterior volume, footprint and rectangular shadow), there is not a significant impact on automobile manufacturers.

In addition to providing this additional research, the report also provides an in-depth look at feebates and recommends that they include the following characteristics:

Constant rate: Ā e rate is the component of the feebate that determines how much the fees or rebate for each vehicle will be. It is measured in dollars per gallons per mile. It is critical that the rate remains the same for every vehicle to ensure that all gallons of fuel saved are equally valued.

Self-financing: Ā e policy should be revenue neutral or slightly revenue generating (to pay administrative costs). Ā is is achieved by resetting the pivot point regularly and accurately.

Preserve consumer choice: Ā e policy should not interfere with consumer freedom of choice. Creating size classes with separate pivot points is one way to achieve this.

Continuous fuel improvement: Ā e policy should be dynamic and require constant innovation by a given vehicle manufacturer for them to continue to receive rebates on vehicles. Ā is can be achieved by regularly evaluating the pivot point, which also ensures the policy is self-financing.

Optimize size classes: Ā e current six passenger-car class system and six light-duty truck class system under CAFE may be the easiest way to introduce the feebate policy.

In principle, feebates are gaining acceptance. Canada has had a feebate law in effect since 2007. Last year, several European countries adopted feebates. Finland and Ireland changed their automobile tax structure to vary based on greenhouse-gas emissions, and France just implemented what's being called the "bonus-malus" law in January. California's State Assembly recently considered a feebate bill to reduce vehicle greenhouse-gas emissions after the EPA denied the state a waiver to regulate tailpipe emissions.

Notes:

1. In October 2006, feebates were discussed as part of the 7th Annual Global Conference on Environmental Taxation on Ottawa, Ontario.

Life at RMI

Celebrating Solutions for 25 years

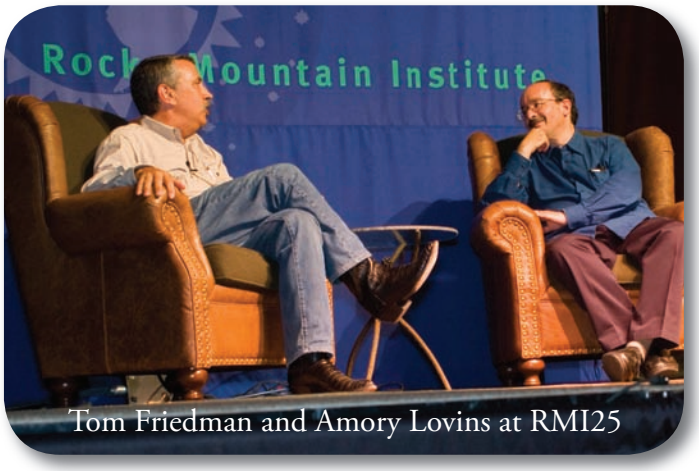
By Marty Pickett

One of the most significant events since our last newsletter—in fact, one of the most significant events of RMI's lifetime/existence—was RMI25: Celebrating Solutions in August. We are delighted that we met our goals, which included convening influential luminaries, engaging RMI's network of friends, supporters, and colleagues, encouraging development of meaningful collaboration and actions for the future, inspiring and motivating a new audience to become part of the solution, raising funds for cutting-edge initiatives, and having fun!

Master of Ceremonies Tom Friedman, keynote speaker President Bill Clinton, panel moderators, and other luminaries (who donated their time and in most cases, their travel expenses) were impressive and inspiring. New levels of conversation and engagement have begun as a result of some of the connections made during that weekend. Our website includes a video about RMI's work and staff that was shown at the gala, as well as videos of the RMIQ and Symposium panel discussions on "A Convenient Truth: Profitable Business-Led Climate Solutions; Corporate Leadership: How Smart Firms are Making the World Better and Safer;" "Venture Philanthropy and Entrepreneurial Nonprofits: Transformational Change Agents with Business Tools and Social Goals;" and "Building Real Security: Harnessing Resource Efficiency to Create Freedom from Fear of Privation or Attack." The highlight of the weekend was Amory's amazing and moving speech entitled "Imagine a Future" about RMI's past and next 25 years—and yes, it's on our website. Even if you were there to hear it, listen again. It highlights RMI's solutions-oriented approach and is full of hope for the future.

The event raised more than $500,000 in net revenues plus more than half that amount of in-kind donations. We welcomed guests from all over the country and had a total of 500 attendees at the RMIQ, 500 at the Symposium, and 782 at the Gala. Many thanks to all of you, friends old and new, who joined us for RMI25. It was truly a transformational event for RMI in many ways.

But you won't have to wait another 25 years to visit us again. We are already planning our annual National Solutions Council weekend, which will be held in Denver this year. It promises to be stimulating, informative, and fun. Stay tuned for more details and we hope to see you then.



Tom Friedman and Amory Lovins at RMI25

At the RMI25 gala, RMI trustee Adam Albright and friend and supporter Jesse Fink offered a spontaneous challenge to match the membership fees of all new RMI National Solutions Council members who joined as a result of the event. We're pleased to announce that 32 new members joined the NSC as a result. Thank you Adam and Jesse for offering this added motivation for new NSC memberships!

RMI25
CELEBRATING SOLUTIONS

We extend a warm thank you to the many voluneteers, including the following people, who helped RMI pull off its biggest event yet, RMI25: Celebrating Solutions.

Lonnie Bones
Vicki Brooks
Don Chaney
Jill Cohen
Jackie Daly
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B. Wu and Eric Larson
Linda Yates and Paul Holland
Margaret and Martin Zankel
Toni Zurcher
Anonymous (6)

Peter Boyer Joins Doug Weiser as Co-Chair of National Solutions Council

After helping found the National Solutions Council (along with Kathy Finley) in 2003, Elaine LeBuhn is stepping down from her role as Co-Chair of the NSC. RMI is pleased to welcome Peter Boyer as our new Co-Chair. Peter will be serving with Doug Weiser, who has served as NSC Co-Chair for the last two years.

Who is Peter Boyer? After hearing a talk by Amory Lovins in 1992 at San Francisco's Commonwealth Club, Peter Boyer was convinced that he had heard a voice that demanded much closer attention. Indeed, Peter has gone on to become an avid student of RMI publications, and a sort of Johnny Appleseed for *Winning the Oil Endgame*, carrying 10 copies around in his car and giving them out to people who seem interested (or should be).

Peter and his wife Terry's family, in conjunction with their family foundation (Ā e Ayrshire Foundation), have gone on to help raise funds for various RMI projects, most recently the short film *High-Performance Building: Perspective & Practice*.

Peter is an artist by profession and maintains a studio in San Francisco, where he lives with his wife and two children, both of whom are militant recyclers.

Who is Doug Weiser? As our world continues to become more crowded and the pace of life quickens, we are confronted with mounting challenges that our ancestors never had to face. Doug believes "wholeheartedly in, and supports RMI's constructive efforts to partner with and guide, rather than to blame and undermine, the corporations, institutions, and other entities that are positioned to meet these challenges and effect significant, immediate positive changes in our society and in the world at large."

A member of the Florida Bar Association, Doug is a hotel developer and owner (Ā e Ritz-Carlton Hotel, Key Biscayne, Florida). He currently resides in Snowmass, Colorado with his wife and two children, writing and producing screenplays and serving as a volunteer firefighter.

NSC Co-Chairs
Doug Weiser and Peter Boyer

Q&A with a Donor:

Rachel and Adam Albright

How did you first learn of RMI's work?

Rachel: "Environmentalist network."

Adam: "Ralph Cavanagh, a brilliant and witty person has worked for decades leading NRDC's demand side management initiatives. Ralph holds Amory in highest regard and I hold Ralph in highest regard, so the connection was made."

What attracts you to RMI's work?

Rachel: "It's, 'You can make a profit and help the Earth.' Ā is will appeal to many powerful polluters, most of whom think not of their fellow men or even, apparently, of their children's future."

Adam: "I remember in the early '90s learning of Paul Erlich's IPAT equation (environmental Impact = Population x Affluence x Technology) and thinking that it made a bunch of sense. When Rachel and I founded the ARIA Foundation we decided to search for organizations with the potential to move one of those factors in a real way. I got very excited when I read some of Amory's articles on the Hypercar and the more I learned about his vision for revolutionizing the way we get and use energy, the more I felt RMI would fill the bill in shifting the 'T'."

You've been on the Board of RMI since 1998, what are you most proud of during your tenure?

Rachel: "Adam and a few other functioning board members and staff pulling together excellent board and staff teams."

Adam: "As a board member I look for ways to make a difference and it was clear to me (and to Amory) that change needed to happen if RMI was going to have the level of impact that was clearly possible. You think about potential for impact and RMI to my eyes was like a huge boulder resting at the top of a hill being blocked by a few small rocks. Ā ere were a lot of good people and good work being done at that time, but the level of influence was not anywhere close to what it should have been. Ā e board really was not functioning at a high level and good staff people weren't sticking around. I knew I could help change the dynamic, so working with key board and staff members we rolled up our sleeves and got those little rocks out of the way. Today it's 'look out below!'"

Is there any one area of RMI's work that gets you really excited?

Rachel: "Getting business people to realize there is profit in 'greening'—hopefully our pathetic government will follow suite."

Adam: "I am fixated by how we use energy in this country. It is so rare that we can find such an obvious huge win-win on so many levels and RMI is right in the middle of it. It continually amazes me how difficult it is to do something that is so clearly good for the environment, job creation, and our wallets. Finally things are beginning to shift, and it's no small credit to RMI."

What are your hopes for RMI's future?

Rachel: "RMI's team will get more into 'greening' government sectors as well as keep growing its 'environmentalizing' businesses."

Adam: "Al Gore wrote in the forward to the Earth in Balance that one of the main reasons he said he was writing the book was that it was what he really knew and felt, and that he hoped that if he ever ran for office again his friends would remind him of what he had written. He did run for office and never spoke what he knew and what he felt about the environment. Ā at was a huge disappointment but it woke me up to the huge limitations on even the best national political leader to truly lead. Ā at leaves it largely to the non-profit sector to hold government accountable (which NRDC does so effectively) and mobilize the private sector to play more of a leading role. RMI sits at a unique and powerful nexus of charity and business. Ā ere is no other organization like it, and I think its potential to shift the way we think and live are unmatched.

You and Jesse Fink played a huge impromptu role at RMI25 … what motivated you to jump on stage and challenge everyone to join the NSC?

Rachel: "Success breeds success."

Adam: "It was such a great gathering and from my view really was the Coming Out Party for RMI. As a group we were basically saying 'we're going to play on the bigger stage now and we're going to make a bigger difference, so get on board.' Jesse and I are both long-time, dedicated environmentalists and we both know that energy builds upon itself. What a great opportunity to encourage so many people who were perhaps just learning about the issues and learning what a great organization RMI is, to step up in a real way, support the work, and make a difference."

What got you interested in the non-profit world?

Rachel: "Maturation, along with realizing the world, and particularly the United States, is too tilted toward materialism, leaving nonprofit groups—which are generally underfunded—as the main

societal watchdog."
Adam: "I had met John Adams, the founding President of NRDC, in the early '80s and we hit it off. He decided he would like a younger non-lawyer on the board, and so it came to pass. In 1990 I became actively involved in their strategic planning process and saw the dedication and knowledge that then board member, now President, Frances Beinecke brought to the table and realized that this non-profit volunteer stuff was a something I could get serious about. I must have done a good job on the Strategic Planning Committee because after the process was over John asked me if I'd be willing to Chair either the newly formed Program or Fundraising Committee. I said I'd love to do the Program Committee, as that was clearly the sharp edge of the sword. John said 'Great, I'm sure you'd do a good job, but you should realize that you can do the most good for the organization if you would head up the Fundraising Committee.' Ā at was an eye-opener for me and one of the main things I try to do with any organization I'm involved with is help build a 'value-added board.' Different boards need different things at different times, and over the years I've held pretty much every board leadership position, usually multiple times, always looking to where I personally can make the biggest contribution to the organization."

You're (Adam) on the board or have been on the boards of several organizations (Natural Resources Defense Council, Conservation International, Worldwatch Institute, Redefining Progress, Population Communications International, Futures for Children, and, of course, RMI). How about you, Rachel? What other organizations do you support and why?
Rachel: "I support all organizations our Foundation supports—it is a partnership."

Why are you so involved with these particular organizations and how do they complement each other?
Rachel: "Ā e environment and certain underdog groups of people need someone championing their causes. Ā ey 're both elements of the Earth that are too often ignored and left to fend for themselves. What do they have in common? Ā ey are more important than most people realize."
Adam: "Our support for various issues usually starts with our priorities, which may be quite strategic (as in the case of the environment) or quite personal (as in the case with indigenous peoples). We then research the groups in the field looking for those that are particularly effective in their work and which have a unique and powerful approach to addressing the issues. For instance, Amazon Conservation Team's support of indigenous peoples would be far less compelling to us if they did not teach them to use GPS systems to map their traditional lands, file a formal claim for them, and thereby gain the right to continue to manage them sustainably and evict illegal miners and loggers. We also try to support only one group in a sub-sector at a time. For instance, in the environmental arena we are active with and support NRDC (policy, advocacy, litigation, etc.), Redefining Progress (economics and environmental justice), Worldwatch Institute (environmental research and public education), Global Greengrants (support for a wide variety of international initiatives), Environmental Working Group (media and the environment), Berkshire Natural Resources Council (local land conservation), and Amazon Conservation Team (tropical biodiversity protection and empowerment of indigenous peoples).

Are there organizations that you, Rachel, have an interest in other than those mentioned? Any other interests of note?
Rachel: "I am on the board of Amazon Conservation Team (ACT). My work with indigenous peoples has made me want to give back."

RMI works on efficiency in transportation, buildings, and infrastructure, and energy generation. Do you think RMI needs to apply its efforts in other areas? If so, what areas?
Rachel: "Let me say, if you truly tackle those four subjects you will change the world (and be very, very busy)."
Adam: "I strongly feel RMI is at a time in its organizational evolution when it needs to be strongly focused on really making a difference with a few priority issues, and the ones mentioned above would all make my short list. If this country were to truly shift the way it approaches any one of these priorities it would have a huge ripple effect throughout all sectors of our economy. To take on all of them in a meaningful way should keep us busy for a while."

What could RMI do better?
Rachel: "Periodically ask yourselves—both board and staff—is the rubber hitting the road?"
Adam: "Making sure that its brilliant ideas actually get adopted. I think it's now time to build more systematic and serious follow-through into RMI's operations to ensure that its thought leadership becomes implementation leadership."

Save The Date!

Denver, Colorado
Ā e 4th Annual National Solutions Council Weekend
Friday, September 19 through Sunday, September 21, 2008

Join us for a unique opportunity to learn more about RMI's work. Take part in stimulating discussions with staff and explore global projects in which RMI is playing an influential role. Ā ere will be plenty of time for socializing, special field trips, and fascinating conversations. Ā is is a unique opportunity to expand your knowledge and understanding of key issues—and to discover new and vital ways to be part of the solution!

For more information, call Liz Bauer at (970) 927-7218 or email lbauer@rmi.org. Be sure to visit our up-to-the-minute website at www.rmi.org/NSCweekend.

A Hearty Thanks!

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1 September 2007 and 31 March 2008

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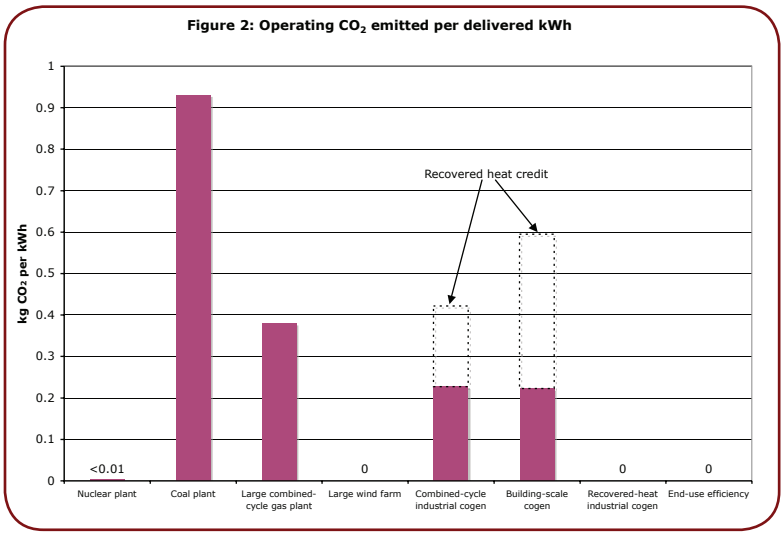


from page 1

Ā erefore, they don't incur the capital costs and energy losses of the electric grid, which links large power plants and remote wind farms to customers.[3] Wind farms, like solar cells,[4] also require "firming" to steady their variable output, and all types of generators require some backup for when they inevitably break. Ā e graph reflects these costs.

Making electricity from fuel creates large amounts of byproduct heat that's normally wasted. Combined-cycle industrial cogeneration and building-scale cogeneration recover most of that heat and use it to displace the need for separate boilers to heat the industrial process or the building, thus creating the economic "credit" shown in Figure 1. Cogenerating electricity and some useful heat from currently discarded industrial heat is even cheaper because no additional fuel is needed.[5]

End-use efficiency lets customers wring more service from each kilowatt-hour by using smarter technologies. As RMI's work with many leading firms has demonstrated, efficiency provides the same or better services with less carbon, less operating cost, and often less up-front investment. Ā e investment required to save a kilowatt-hour averages about two cents nationwide, but has been less than one cent in hundreds of utility programs (mainly for businesses), and can even be less than zero in new buildings and factories—and in some retrofits that are coordinated with routine renovations.

Wind, cogeneration, and end-use efficiency already provide electrical services more cheaply than central thermal power plants, whether nuclear- or fossil-fuelled. Ā is cost gap will only widen, since central thermal power plants are largely mature while their competitors continue to improve rapidly. Ā e high costs of conventional fossil-fuelled plants would go even higher if their large carbon emissions had to be captured.

Uncompetitive CO_2 Displacement

Nuclear plant operations emit almost no carbon—just a little to produce the fuel under current conditions.[6] Nuclear power is therefore touted as the key replacement for coal-fired power plants. But this seemingly straightforward substitution could instead be done using non-nuclear technologies that are cheaper and faster, so they yield more climate solution per dollar and per year. As Figure 2 shows, various options emit widely differing quantities of CO_2 per delivered kilowatt-hour.

Coal is by far the most carbon-intensive source of electricity, so displacing it is the yardstick of carbon displacement's effectiveness. A kilowatt-hour of nuclear power does displace nearly all the 0.9-plus kilograms of CO_2 emitted by producing a kilowatt-hour from coal. But so does a kilowatt-hour from wind, a kilowatt-hour from recovered-heat industrial cogeneration, or a kilowatt-hour saved by end-use efficiency. And all of these three carbon-free resources cost at least one-third less than nuclear power per kilowatt-hour, so they save more carbon per dollar.

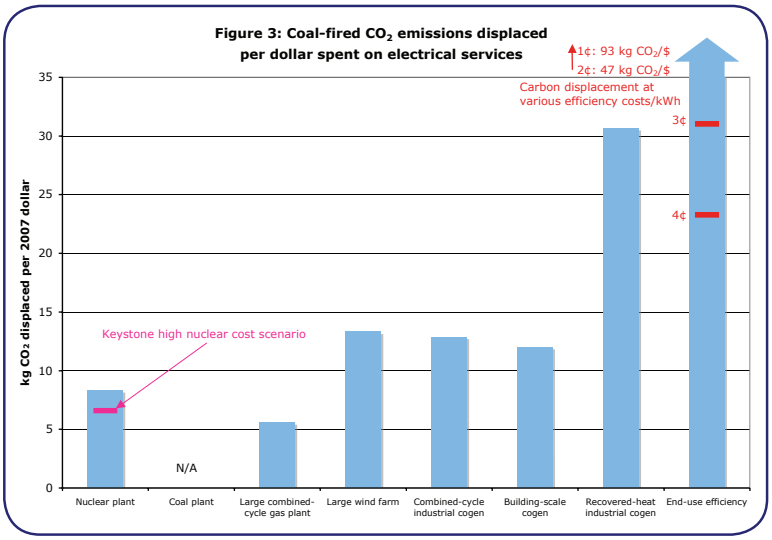
Combined-cycle industrial cogeneration and building-scale cogeneration typically burn natural gas, which does emit carbon (though half as much as coal), so they displace somewhat less net carbon than nuclear power could: around 0.7 kilograms of CO_2 per kilowatt-hour.[7] Even though cogeneration displaces less carbon than nuclear does per kilowatt-hour, it displaces more carbon than nuclear does per dollar spent on delivered electricity, because it costs far less. With a net delivered cost per kilowatt-hour approximately half of nuclear's, cogeneration delivers twice as many kilowatt-hours per dollar, and therefore displaces around 1.4 kilograms of CO_2 for the same cost as displacing 0.9 kilograms of CO_2 with nuclear power.

Figure 3 compares different electricity options' cost-effectiveness in reducing CO_2 emissions. It counts both their cost-effectiveness, in delivering kilowatt-hours per dollar, and their carbon emissions, if any.

Nuclear power, being the costliest option, delivers less electrical service per dollar than its rivals, so, not surprisingly, it's also a climate-protection loser, surpassing in carbon emissions displaced per dollar only centralized, non-cogenerating combined-cycle power plants burning natural gas.[8] Firmed windpower and cogeneration are 1.5 times more cost-effective than nuclear at displacing CO_2. So is efficiency at even an almost unheard-of seven cents per kilowatt-hour. Efficiency at normally observed costs beats nuclear by a wide margin—for example, by about ten-fold for efficiency costing one cent per kilowatt-hour.

New nuclear power is so costly that shifting a dollar of spending from nuclear to efficiency protects the climate several-fold more than shifting a dollar of spending from coal to nuclear. Indeed, under plausible assumptions, spending a dollar on new nuclear power *instead* of on efficient use of electricity has a worse climate effect than spending that dollar on new coal power!

If we're serious about addressing climate change, we must invest resources wisely to expand and accelerate climate protection. Because nuclear power is costly and slow to build, buying more of it rather than of its cheaper, swifter



rivals will instead reduce and retard climate protection.

Questionable Reliability

All sources of electricity sometimes fail, differing only in why, how often, how much, for how long, and how predictably. Even the most reliable giant power plants are intermittent: they fail unexpectedly in billion-watt chunks, often for long periods. Of all 132 U.S. nuclear plants built (52 percent of the 253 originally ordered), 21 percent were permanently and prematurely closed due to reliability or cost problems, while another 27 percent have completely failed for a year or more at least once. Even reliably operating nuclear plants must shut down, on average, for 39 days every 17 months for refueling and maintenance. To cope with such intermittence in the operation of both nuclear and centralized fossil-fuelled power plants, which typically fail about 8 percent of the time, utilities must install a roughly 15 percent "reserve margin" of extra capacity, some of which must be continuously fuelled, spinning ready for instant use. Heavily nuclear-dependent regions are particularly at risk because drought, a serious safety problem, or a terrorist incident could close many plants simultaneously.

Nuclear plants have an additional disadvantage: for safety, they must instantly shut down in a power failure, but for nuclear-physics reasons, they can't then be quickly restarted. During the August 2003 Northeast blackout, nine perfectly operating U.S. nuclear units had to shut down. Twelve days of painfully slow restart later, their average capacity loss had exceeded 50 percent. For the first three days, just when they were most needed, their output was below 3 percent of normal.

Ā e big transmission lines that highly concentrated nuclear plants require are also vulnerable to lightning, ice storms, rifle bullets, and other interruptions. Ā e bigger our power plants and power lines get, the more frequent and widespread regional blackouts will become. Because 98–99 percent of power failures start in the grid, it's more reliable to bypass the grid by shifting to efficiently used, diverse, dispersed resources sited at or near the customer. Also, a portfolio of many smaller units is unlikely to fail all at once: its diversity makes it especially reliable even if its individual units are not.

Ā e sun doesn't always shine on a given solar panel, nor does the wind always spin a given turbine. Yet if properly firmed, both windpower, whose global potential is 35 times world electricity use, and solar energy, as much of which falls on the earth's surface every ~70 minutes as humankind uses each year, can deliver reliable power without significant cost for backup or storage. Ā ese variable renewable resources become *collectively* reliable when diversified in type and location and when integrated with three types of resources: steady renewables (geothermal, small hydro, biomass, etc.), existing fuelled plants, and customer demand response. Such integration uses weather forecasting to predict the output of variable renewable resources, just as utilities now forecast demand patterns and hydropower output. In general, keeping power supplies reliable despite large wind and solar fractions will require less backup or storage capacity than utilities have already bought to manage big thermal stations' intermittence. Ā e myth of renewable energy's unreliability has been debunked both by theory and by practical experience.

Large Subsidies to Offset High Financial Risk

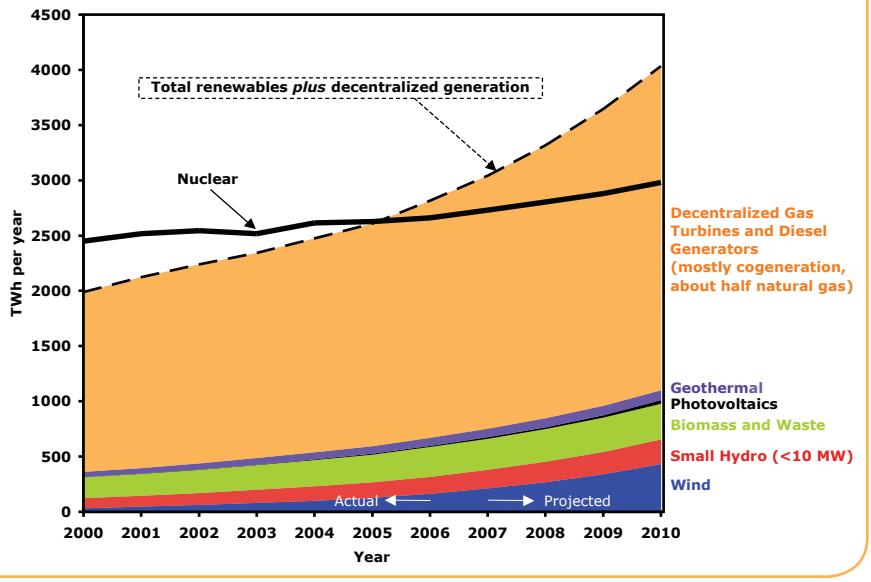
Ā e latest U.S. nuclear plant proposed is estimated to cost $12–24 billion (for 2.2–3.0 billion watts), many times industry's claims, and off the chart in Figure 1 above. Ā e utility's owner, a large holding company active in 27 states, has annual revenues of only $15 billion. Such high, and highly uncertain, costs now make financing prohibitively expensive for free-market nuclear plants in the half of the U.S. that has restructured its electricity system, and prone to politically challenging rate shock in the rest: a new nuclear kilowatt-hour costing, say, 16 cents "levelized" over decades implies that the utility must collect ~27 cents to fund its first year of operation.

Lacking investors, nuclear promoters have turned back to taxpayers, who already bear most nuclear accident risks and have no meaningful say in licensing. In the United States, taxpayers also insure operators against legal or regulatory delays and have long subsidized existing nuclear plants by ~1–5¢ per kilowatt-hour. In 2005, desperate for orders, the politically potent nuclear industry got those subsidies raised to ~5–9¢ per kilowatt-hour for new plants, or ~60–90 percent of their entire projected power cost. Wall Street still demurred. In 2007, the industry won relaxed government rules that made its 100 percent loan guarantees (for 80 percent-debt financing) even more valuable—worth, one utility's data revealed, about $13 billion for a single new plant. But rising costs had meanwhile made the $4 billion of new 2005 loan guarantees scarcely sufficient for a single reactor, so Congress raised taxpayers' guarantees to $18.5 billion. Congress will be asked for another $30+ billion in loan guarantees in 2008. Meanwhile, the nonpartisan Congressional Budget Office has

concluded that defaults are likely.

Wall Street is ever more skeptical that nuclear power is as robustly competitive as claimed. Starting with Warren Buffet, who just abandoned a nuclear project because "it does not make economic sense," the smart money is heading for the exits. Ā e Nuclear Energy Institute is therefore trying to damp down the rosy expectations it created. It now says U.S. nuclear orders will come not in a tidal wave but in two little ripples—a mere 5–8 units coming online in 2015–16, then more if those are on time and within budget. Even that sounds dubious, as many senior energy-industry figures privately agree. In today's capital market, governments can have only about as many nuclear plants as they can force taxpayers to buy.

Figure 4: Low- or no-carbon worldwide electrical output (except large hydro)



Ā e Micropower Revolution

While nuclear power struggles in vain to attract private capital, investors have switched to cheaper, faster, less risky alternatives that *Ā e Economist* calls "micropower"—distributed turbines and generators in factories or buildings (usually cogenerating useful heat), and all renewable sources of electricity except big hydro dams (those over ten megawatts). Ā ese alternatives surpassed nuclear's global capacity in 2002 and its electric output in 2006. Nuclear power now accounts for about 2 percent of worldwide electric capacity additions, vs. 28 percent for micropower (2004–07 average) and probably more in 2007–08.

An even cheaper competitor is end-use efficiency ("negawatts")—saving electricity by using it more efficiently or at smarter times. Despite subsidies generally smaller than nuclear's, and many barriers to fair market entry and competition, negawatts and micropower have lately turned in a stunning global market performance. Micropower's actual and industry-projected electricity production is running away from nuclear's, not even counting the roughly comparable additional growth in negawatts, nor any fossil-fuelled generators under a megawatt (see Figure 4).[9]

Ā e nuclear industry nonetheless claims its only serious competitors are big coal and gas plants. But the marketplace has already abandoned that outmoded battleground for two others: central thermal plants vs. micropower, and megawatts vs. negawatts. For example, the U.S. added more windpower capacity in 2007 than it added coal-fired capacity in the past five years combined. By beating all central thermal plants, micropower and negawatts together provide about half the world's new electrical services. Micropower alone now provides a sixth of the world's electricity, and from a sixth to more than half of all electricity in twelve industrial countries (the U.S. lags with 4 percent).

In this broader competitive landscape, high carbon prices or taxes can't save nuclear power from its fate. If nuclear did compete only with coal, then far-above-market carbon prices might save it; but coal isn't the competitor to beat. Higher carbon prices will advantage all other zero-carbon resources—renewables, recovered-heat cogeneration, and negawatts—as much as nuclear, and will partly advantage fossil-fueled but low-carbon cogeneration as well.

Small Is Fast, Low-Risk, and High in Total Potential

Small, quickly built units are faster to deploy for a given total effect than a few big, slowly built units. Widely accessible choices that sell like cellphones and PCs can add up to more, sooner, than ponderous plants that get built like cathedrals. And small units are much easier to match to the many small pieces of electrical demand. Even a multi-megawatt wind turbine can be built so quickly that the U.S. will probably have a hundred billion watts of them installed before it gets its first one billion watts of new nuclear capacity, if any.

Small, quickly built units also have far lower financial risks than big, slow ones. Ā is gain in financial economics is the tip of a very large iceberg: micropower's more than 200 different kinds of hidden financial and technical benefits can make it about ten times more valuable (www.smallisprofitable.org) than implied by current prices or by the cost comparisons above. Most of the same benefits apply to negawatts as well.

Despite their small individual size, micropower generators and electrical savings are already adding up to huge totals. Indeed, over decades, negawatts and micropower can shoulder the entire burden of powering the economy. Ā e Electric Power Research Institute (EPRI), the utilities' think-tank, has calculated the U.S. negawatt potential (cheaper than just running an existing nuclear plant and delivering its output) to be two to three times nuclear power's 19 percent share of the U.S. electricity market; RMI's more

detailed analysis found even more. Cogeneration in factories can make as much U.S. electricity as nuclear does, plus more in buildings, which use 69 percent of U.S. electricity. Windpower at acceptable U.S. sites can cost-effectively produce at least twice the nation's total electricity use, and other renewables can make even more without significant land-use, variability, or other constraints. Ā us just cogeneration, windpower, and efficient use—all profitable—can displace nuclear's current U.S. output roughly 14 times over.

Nuclear power, with its decade-long project cycles, difficult siting, and (above all) unattractiveness to private capital, simply cannot compete. In 2006, for example, it added less global capacity than photovoltaics did, or a tenth as much as windpower added, or 30–41 times less than micropower added. Renewables other than big hydro dams won $56 billion of private risk capital; nuclear, as usual, got zero. China's distributed renewable capacity reached seven times its nuclear capacity and grew seven times faster. And in 2007, China, Spain, and the U.S. each added more windpower capacity than the world added nuclear capacity. Ā e nuclear industry does trumpet its growth, yet micropower is bigger and growing 18 times faster.

Security Risks

President Bush rightly identifies the spread of nuclear weapons as the gravest threat to America. Yet that proliferation is largely driven and greatly facilitated by nuclear power's flow of materials, equipment, skills, and knowledge, all hidden behind its innocent-looking civilian disguise. (Reprocessing nuclear fuel, which the President hopes to revive, greatly complicates waste management, increases cost, and boosts proliferation.) Yet acknowledging nuclear power's market failure and moving on to secure, least-cost energy options for global development would unmask and penalize proliferators by making bomb ingredients harder to get, more conspicuous to try to get, and politically costlier to be caught trying to get. Ā is would make proliferation far more difficult, and easier to detect in time by focusing scarce intelligence resources on needles, not haystacks.

Nuclear power has other unique challenges too, such as long-lived radioactive wastes, potential for catastrophic accidents, and vulnerability to terrorist attacks. But in a market economy, the technology couldn't proceed even if it lacked those issues, so we needn't consider them here.

Conclusion

So why do otherwise well-informed people still consider nuclear power a key element of a sound climate strategy? Not because that belief can withstand analytic scrutiny. Rather, it seems, because of a superficially attractive story, an immensely powerful and effective lobby, a new generation who forgot or never knew why nuclear power failed previously (almost nothing has changed), sympathetic leaders of nearly all main governments, deeply rooted habits and rules that favor giant power plants over distributed solutions and enlarged supply over efficient use, the market winners' absence from many official databases (which often count only big plants owned by utilities), and lazy reporting by an unduly credulous press.

Isn't it time we forgot about nuclear power? Informed capitalists have. Politicians and pundits should too. After more than half a century of devoted effort and a half-trillion dollars of public subsidies, nuclear power still can't make its way in the market. If we accept that unequivocal verdict, we can at last get on with the best buys first: proven and ample ways to save more carbon per dollar, faster, more surely, more securely, and with wider consensus. As often before, the biggest key to a sound climate and security strategy is to take market economics seriously.

Mr. Lovins, a physicist, is cofounder, Chairman, and Chief Scientist of Rocky Mountain Institute, where Mr. Sheikh is a Research Analyst and Dr. Markevich is a Vice President. Mr. Lovins has consulted for scores of electric utilities, many of them nuclear operators. *Ā e authors are grateful to their colleague Dr. Joel Swisher PE for insightful comments and to many cited and uncited sources for research help. A technical paper preprinted for the September 2008* Ambio *(Royal Swedish Academy of Sciences) supports this summary with full details and documentation (www.rmi.org/sitepages/pid257.php#E08-01). RMI's annual compilation of global micropower data from industrial and governmental sources has been updated through 2006, and in many cases through 2007, at www.rmi.org/sitepages/pid256.php#E05-04.*

Notes:

1. Ā is is conservatively used as the basis for all comparisons in this article
2. All monetary values in this article are in 2007 U.S. dollars. All values are approximate and representative of the respective U.S. technologies in 2007. Capital and operating costs are levelized over the lifespan of the capital investment.
3. Distributed generators may rely on the power grid for emergency backup power, but such backup capacity, being rarely used, doesn't require a marginal expansion of grid capacity, as does the construction of new centralized power plants. Indeed, in ordinary operation, diversified distributed generators free up grid capacity for other users.
4. Solar power is not included in Figure 1 because the delivered cost of solar electricity varies greatly by installation type and financing method. As shown in Figure 4, photovoltaics are currently one of the smaller sources of renewable electricity, and solar thermal power generation is even smaller.
5. A similar credit for displaced boiler fuel can even enable this technology to produce electricity at negative net cost. Ā e graph conservatively omits such credit (which is very site-specific) and shows a typical positive selling price.
6. We ignore here the modest and broadly comparable amounts of energy needed to build any kind of electric generator, as well as possible long-run energy use for nuclear waste management or for extracting uranium from low-grade sources.
7. Since its recovered heat displaces boiler fuel, cogeneration displaces more carbon emissions per kilowatt-hour than a large gas-fired power plant does.
8. However, at long-run gas prices below those assumed here (a levelized 2007-$ cost of $7.72 per million BTU) and at today's high nuclear costs, the combined-cycle plants may save more carbon per dollar than nuclear plants do. Ā is may also be true even at the prices assumed here, if one properly counts combined-cycle plants' ability to load-follow, thus complementing and enabling cleaner, cheaper variable renewable resources like windpower.
9. Data for decentralized gas turbines and diesel generators exclude generators of less than 1 megawatt capacity.

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