Getting Off Oil: Recent Leaps and Next Steps

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Originally published in Solutions Journal, Spring 2007

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.

The hardest and slowest sector is cars. But building on 17 years of patient effort, our acupuncture is now driving big and accelerating shifts. The 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 Three firms' CEOs are newcomers to automaking; and Toyota just pulled neck-and-neck with GM as the world's biggest automaker.

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-effcient. Its half-liter flex-fuel engine, tucked under the rear seat, is supplemented by grid electricity via 20 extra kg of batteries. The 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.
Our book urged Detroit to emulate Boeing's breakthrough competitive strategy, based on an efficiency leapfrog integrating ultralight materials, advanced manufacturing, and wholesystem 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 onethird 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. Th 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 designed3 a 67-mpg uncompromised midsized SUV that proved how cheaper tooling, simpler assembly, and smaller powertrain could off set 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 costbusting 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 innovationhungry 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 AutomotiveTM (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 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 electrictraction 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.

This 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 effi ciency, cleanly burning any fuel on the fly, yet with lower cost, size, and weight. Successful development of this

concept could quickly bring internalcombustion 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. Th 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 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 percentmore-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-cropbased 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. They soon discovered that the first 25 percent fuel saving was free. The 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. The 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, I've long urged military leaders to start valuing saved fuel at its delivered value—delivered to platform in theater in wartime. at "fully burdened" cost many times the $13- billion cost of undelivered military fuel in FY2006. e cost in blood is also huge: about half of all U.S. 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. Th 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. Th 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.

This new source of off -oil leadership 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. Th 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 develop@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.