Amory and Judy Lovins' Response to Jeffrey Ball's article in *The Wall Street Journal*, "The Homely Costs of Energy Conservation"

Note: Amory and Judy Lovins wrote this response to Jeffrey Ball's August, 2009 article about the design, construction, and renovation of the Lovins' home. This response was posted in the Comments section of the online article. The Lovins' comments draw economic conclusions opposite to Mr. Ball's. The original article, along with a video and interactive drawing of the house, can be found at http://online.wsj.com/article/SB124959929532112633.html#articleTabs%3Darticle

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Our superefficient house demonstrates the opposite of Jeff Ball's conclusions that its radical energy efficiency bore a "hefty upfront cost" and that its wide replication would need "huge investment and sweeping changes to governmental policy." Lest those claims confuse some readers, let's ensure that the original 1982–84 house doesn't get muddled with its major 2007–09 renovation.

The original house saved about 90% of household electricity and 99% of space- and water-heating energy (not 90% of total energy as reported) at an extra 1983 cost of just $6,000 ($1.50/sq ft), counting all donated or discounted elements at fair market value. The total construction cost on that basis equaled the local median for custom houses at that time. The $6,000 (1%) cost premium was repaid from total energy savings (not just "heating and cooling" savings) in ten months.

What had a "hefty...cost" is not that original construction but instead the recent renovation, which commingled mainly deferred maintenance, upgraded esthetics, and an elaborate energy monitoring system with modestly increased energy efficiency. We upgraded to today's state-of-the-art not to save money—little energy was left to save, and retrofitting an existing masonry building is especially difficult—but to measure and demonstrate 25 years' remarkable advances and flip the house's carbon footprint from tiny to negative. Jeff's article rightly says we make no economic claims for these custom "bleeding-edge" items. But they're costly only because they're handmade; normal production scaling should make them market winners too. Thus inferring that superefficiency is costly would be as wrong for 2009 technologies in later mature markets as it was for their 1983 versions in our original house.

The house's biggest, but unmentioned, lesson is integrative design (http://www.rmi.org/rmi/Stanford+Energy+Lectures). Insulating to twice "cost-effective" levels—which are normally but wrongly compared only with saved energy cost, not also with avoidable capital cost—lowered construction cost $1,100 by eliminating the even costlier heating system, so that important part of the initial energy savings bore a negative cost premium. Throughout the building, most components do many jobs for one expenditure: the atrium, for example, collects energy in five different ways (heat, hot air, hot water, light, and photosynthesis), and the arch supporting it has twelve functions but only one

cost. Please see the detailed description of the original building at http://www.rmi.org/Content/Files/Locations_LovinsHome_Visitors_Guide_2007.pdf and the virtual tour at http://www.rmi.org/rmi/Amory's+Private+Residence. These will be updated online as we get data and time to write up the performance of the renovation. We'll also try to draw some conclusions about costs, although it will be very hard and may be impossible to disentangle energy from other purposes.

If all houses—of whatever style, size, and climate—were designed in the same integrative way ours was, they'd save upwards of 80% of their energy at comparable or lower capital cost. Over 20,000 "passive houses" in Europe do that today, requiring no heating but costing the same (or sometimes a bit less) to build, because their superinsulation, better glazings, and ventilation heat recovery are offset by the avoided capital cost of the eliminated heating system (en.wikipedia.org/wiki/Passive_house). These innovations are promoted by the Passivhaus Institut in Germany (www.passiv.de) and its US offshoot (www.passivehouse.us/passiveHouse/PHIUSHome.html). The first such house, by Dr. Wolfgang Feist in Darmstadt in 1990–91, was much influenced by ours, although we had the advantage of superwindows that weren't available in Germany.

Such opportunities apply to hot climates too. The Davis and Stanford Ranch tract houses in PG&E's ACT2 experiment in the '90s (http://www.pge.com/pec/resourcecenter/ see “Related Links” on right sidebar) had original design savings of ~80% of what the strictest US code allowed (or ~90% vs. the US average) but, in reasonable quantities, would cost less than normal to build. Or in steamy Bangkok, Professor Suntoorn Boonyatikarn applied our house's integrative design principles to save ~90% of his home's air-conditioning energy at no extra construction cost.

In short, a new house needn't look like ours, use our materials, or be in our severely cold-and-dry climate in order to work like ours and yield compelling overall economics. Similar principles and technologies are partly applicable to retrofits (e.g. see ACT^2 Walnut Creek house), though performance and economics will vary widely. Large savings are available even in historically listed buildings, such as half-timbered Elizabethan houses retrofitted with superinsulation in Europe, or the Greening of the White House (which converted historic glass into the outer lites of superwindows), though this takes special skills and can be costly.

Integrative design isn't just for houses. It has demonstrated expanding, not diminishing, returns to efficiency investments—very big energy savings cheaper than small or no savings—in thousands of buildings, various vehicles, and over $30 billion of diverse industrial plants that RMI has helped redesign. This revolution, less in technologies than in how they're combined, will make global climate and oil solutions not costly but profitable (www.scientificamerican.com/media/pdf/Lovinsforweb.pdf).

Let's also take this opportunity to clear up a few other points of possible confusion:

• Our ~4,000-sq-ft multipurpose building is only about a 1,910 sq ft "house": ~474 sq ft for two bedrooms and a bathroom, ~1,166 sq ft in the entryway/kitchen/pantry/living/dining area, and ~270 sq ft in the laundry/utility room. The building also includes ~930 sq ft of banana jungle (with two crops currently ripening), fishponds, and circulation through them. Most importantly, the whole east wing is a ~1,000–1,200-sq-ft office, donated for use by as many as 30+ employees of Rocky Mountain Institute for its first ~25 years (it was RMI's original headquarters) and now containing Amory's ~10-person RMI office.

• The office uses the great bulk of the building's electricity. When last measured in the 1980s, the household used only ~$5 a month worth of electricity (~110–120 average watts). Thus the article's statement that our 9.7-kW photovoltaic array is "enough for the house's needs" might lead some to suppose that "house" means "household" when in fact it includes a smaller-than-normal house, a big jungle/aquaculture system, an industrial-strength monitoring system, and (most importantly) a sizeable office. The current consumption split is unknown—many things have changed, in both directions—but we're commissioning a ~200-point Johnson Controls monitoring system that will show what each area and system is now using. We expect the household use still to be very small, needing well under 1 kW of PVs. Once the monitoring system is commissioned, we intend to post real-time data on the Web.

• As shown in Jeff's nice online illustrations, the 16" walls are not solid stone, but sandwich a 4" foam core with an aged insulation rating of R-33. The effective performance of the sandwich wall, averaged over orientations, is ~R-40, and the roof is ~R-80.

• The recently upgraded "multiple-pane windows" have two lites of ordinary glass, two double-sided Heat Mirror(R) films, and xenon fill, for a center-of-glass R-12.5 (vs. ~9–10 for the previous units). The operable sashes are pultruded fiberglass, often with nanogel fill. The three best glazing units (in the north loft and east "Frostcork" door) have low-E glass too, for a center-of-glass R-20.

• The Swiss cooktop, from nuveco.ch, uses a new conduction design, integrated with very innovative pots and digital controls, so it uses ~60% less energy than a good induction cooktop.

• The building's fifth lighting retrofit now uses nearly all LEDs of exceptional color quality and efficiency, often in luminaires with unusual optical properties optimized to the building's unique architectural requirements. Both the sources and the fixtures are naturally expensive, but their combination of nice color and high luminous efficacy (often ~5x halogen or better) should become commoditized within a few years. Some LED

lamps are already at Wal-Mart, and in due course others as pretty as ours will be too. But for now, this technology changes weekly. Some of Jeff's photos showed certain vacant areas as unlit because they were turned off while he was photographing other areas, but the whole house can now be beautifully lit with very little energy.

• The house was earth-sheltered for esthetic and microclimatic reasons peculiar to the site. Earth-sheltering does temper the north wall's heat loss somewhat, but earth is good at storing heat, not at insulating against its flow. The construction materials (e.g., ~200 tons of Dakota sandstone retrieved from the adjacent hillside) and style were likewise matched to the site, local style and culture, and owners' esthetic preferences. If you prefer a New England saltbox, that's fine too.

• The flat roof collects snow that helps insulate. The roof was designed for ultimate earth-sheltering (250 lb/sq ft), so it easily supports the snow load. In our high-desert climate at 7100', snow seldom overtops the bottom of the solar heat and PV panels, and generally slides off them soon after a storm.

• The original house had no controls except light-switches, operable vents and windows in the atrium (opened and closed once a day in the short summer), and one humidistat (controlling the main air-to-air heat exchanger). The renovated version adds six zonal thermostats to control active solar heat distribution to 11 radiant coils that were cast into the floor slabs in 1983 but first activated only in 2009. They are meant to provide the last 1% of the space heating, thereby displacing the two woodstoves; the other 99% remains passive, gained from the windows, people, lights, and appliances, and formerly a 50-watt dog. Running the house does not require tweaking controls, although currently we're doing that to complete the commissioning of the new systems, check everything is working right, and set up the automatic monitoring system to support our and others' research.

• Our original water-heating system was 99% active-and-passive solar, with a ~1500-gallon stratified quasi-seasonal-storage water tank. The renovation doubled the solar input and added a second secondary heat exchanger to run the slab coils. We changed the 1% backup from a modulating solar-backup Aquastar (now Bosch) propane demand heater to an electric boiler in order to minimize carbon footprint.

• If the new boiler ever turns on (which we hope it won't), it won't release carbon, because the building runs on 100+% solar electricity in the daytime and 100% additional purchased windpower at night. We tweaked the expanded photovoltaic system to maximize carbon savings on the grid, and do not store solar electricity for nighttime use (as one of Jeff's labels might imply) because we'd rather displace coal-fired electricity than lose energy going in and out of the batteries. The new PV system is also "islandable"—it works with or without the grid. Part of the old system could do that too,

enabling us to offer battery-recharging to local emergency services when the grid went down in a flood a few years ago.

• My comment that "If it looks pretty, it probably doesn't save energy" referred only to piping layout—not to the house, which most people consider beautiful. We see no conflict whatever between efficiency and esthetics; quite the contrary. We want and get both.

• Jeff's belief that "adopting some of the house's innovations on a wide scale would require huge investment and sweeping changes to governmental policy" is his, not ours. We think it refers to the current cost of bleeding-edge, tiny-volume, handmade technologies, but does not describe what is necessary to move those technologies to volume, nor is it the approach we would recommend for innovative public policy. Specifically, we do not agree that superefficiency requires technology subsidies or government mandates. We got neither. RMI advocates neither. And whatever your income, a ten-month payback is about the highest riskless return in the whole economy. Today, the economics of a design like the original (especially with today's even better technologies) would be even better: the ten-month payback could well be less than zero.

• For those unfamiliar with Rocky Mountain Institute (which Amory cofounded in 1982), it's an independent, entrepreneurial, public-benefit (i.e., nonprofit) think-and-do tank that creates abundance by design. Its mission is to drive the efficient and restorative use of resources. It works chiefly with the private sector, gets 30–70% of its $13 million annual revenue from private-sector consulting, is very technology- and market-oriented, and has spun off five for-profit firms. We, not RMI, paid for the house and nearly all its energy retrofits; some firms, wishing to partner in the building's continuous improvement, kindly donated equipment.

• The building contains much cement and rebar, but was built extremely durably and designed for low maintenance. We haven't calculated its embodied energy, but also saved a good deal of that by materials-conscious design, especially in the retrofit. (ABL is well aware of these issues from having codeveloped the "generally accepted accounting principles" for net energy in the 1970s.)

• Our building has had over 100,000 visitors in 27 years and far more online visitors, so we suspect it has had significant outreach influence, although we can't tell how much. Over a decade ago, the Department of Energy put the building on its poster of the most energy-efficient buildings in the United States.

Amory B. Lovins and Judy Hill Lovins