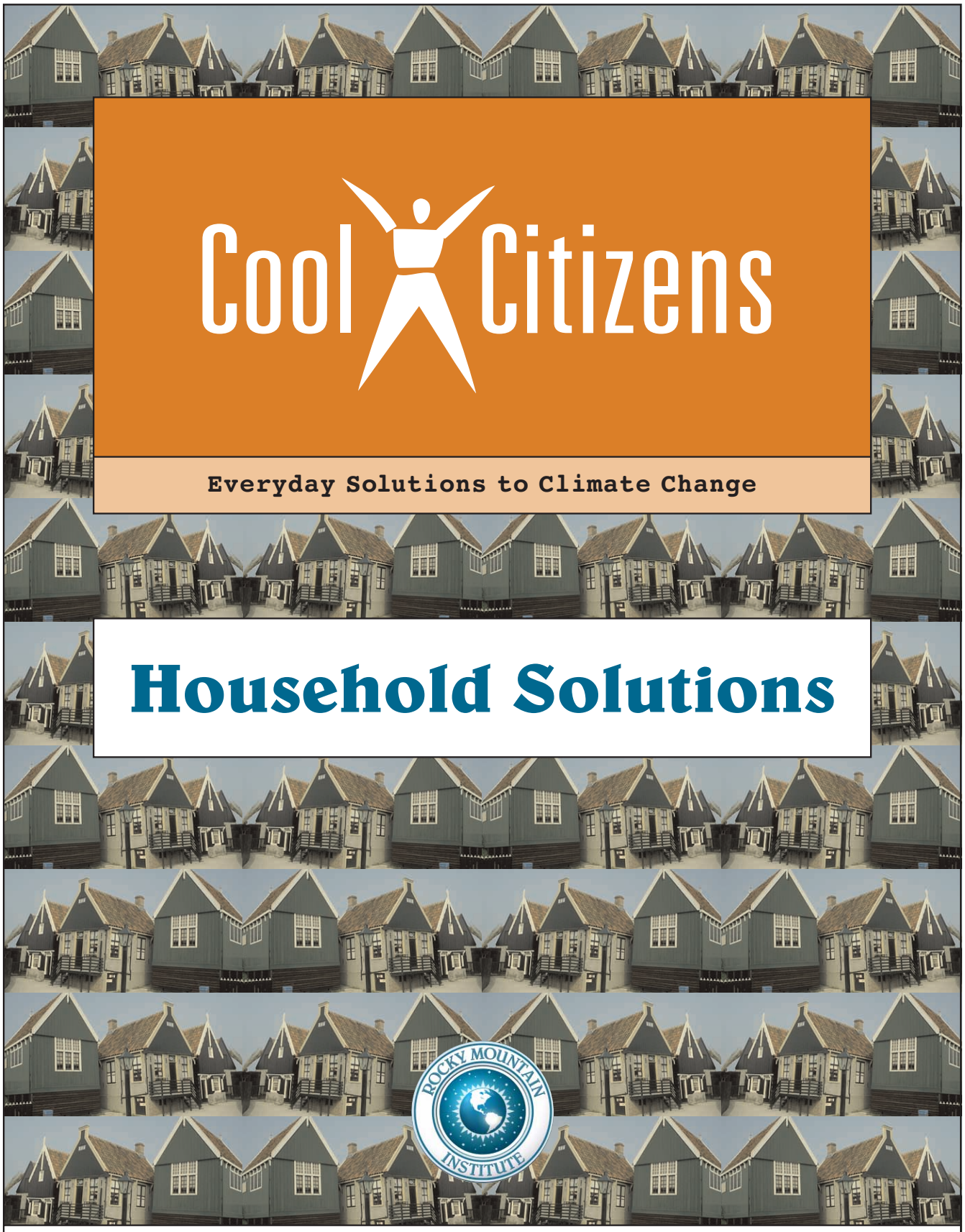

09 April 2002

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This work is supported by the Richard and Rhoda Goldman Fund, Winslow Foundation, and Sun Hill Foundation

Jonathan Foley brings his work home. As a leading climatologist at the University of Wisconsin, Jonathan understands the perils of rising greenhouse gases emissions. In 1998 he and his wife Andrea decided to reduce their family's carbon dioxide emissions by 50 percent (their home's carbon budget was then 26,730 lbs CO_2 annually—quite typical for a suburban home).[1] They have since moved to a smaller house in town, sold their cars (they bought a fuel-efficient Toyota Prius and walk or bike to work most days), and renovated their new home with numerous energy- and carbon-saving lights and appliances. The result: much smaller utility bills, and their carbon emissions reduced to 10,540 lbs CO_2—saving nearly *60 percent* of their emissions and easily meeting their goal.[2] The Foleys also reduced gasoline consumption from 1,000 gallons to 208 gallons per year and saved a bundle of money. A March 2001 article in *Audubon* magazine discusses the Foleys' adventure in reducing the size of their climate footprint.

Most homeowners can't readily move into a smaller home to achieve the dramatic savings the Foleys did. Yet all homeowners can, through smarter purchasing and gradual and profitable investments in our homes, easily equal the Foleys' success. And we can do it, as the Foleys did, without freezing in the dark. We can do a lot for free, saving enough on utility bills to pay for further improvements that cost a bit more but lead to even greater savings.

This brief describes how we homeowners can lighten our impact on the earth's changing climate by reducing emissions of greenhouse gases from our households. Some of the measures save money fast enough (or are mobile, in case you move) to make sense for renters, too. Most of the recommendations pay for themselves in reduced energy bills in six years or less, and many in less than two years. For a discussion of the greenhouse gas emissions from household vehicles and suggestions on how to trim household transportation emissions (which average 21,490 lbs of carbon dioxide per year), see the forthcoming *Cool Citizens* brief on Transportation Solutions.[3]

Household carbon dioxide emissions baseline

For the typical American family, keeping our shelter warm and comfortable leads to the emission of thirteen tons of carbon dioxide annually from the direct combustion of natural gas or fuel oil in boilers, furnaces, and water heaters and indirectly from fossil-fueled power plants.

We analyzed the data on energy consumption in America's 73.7 million single-family homes (which, of course, vary widely in age, location, size, heating fuels used, carbon-intensity of the electricity supply, solar income, thermostat settings, and climate) and developed a profile of the "typical" home.[4] We estimate that such a single-family home, mixing all regions and fuel consumption patterns, uses $1,441 of energy annually, and emits 26,028 lbs of carbon dioxide per year. This typical home is 2,280 square feet in floor area, with annual energy costs of $0.63 per square foot, has under-insulated walls and roof, and has air leakage equivalent to a small window open year-round. A typical house also has 1.27 middle-aged refrigerators, 2.6 occupants, and no extra insulation around the water heater. Most have a clothes washer, dryer, dishwasher, and central air conditioning, just to name a few characteristics.

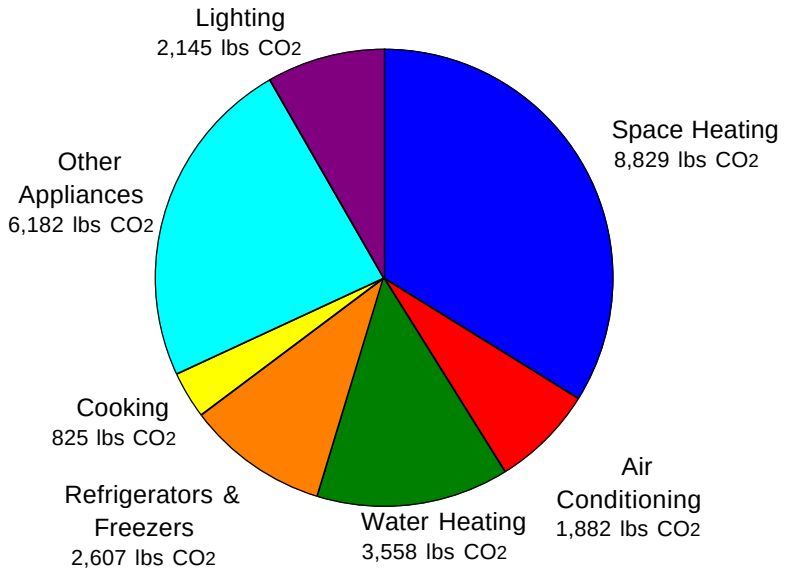
Some homes use no air-conditioning energy, while others have little need for heating, and many do not use exterior lighting, clothes dryers, or computers. But *on average* a single-family home

uses 11,278 kWh of electricity per year for all end uses, plus 81.7 million Btu for heating and cooling, and 27.8 million Btu for water heating.[5] Burning a kitchen match releases about one Btu (British Thermal Unit) of heat. The operation of the average American household requires the annual consumption of 195 million Btu either at home or at the power plant. If we were burning matches to run it, 195 million Btu per year is equivalent to lighting over six matches per second, every second, all year long. Burn your fingers yet?

Fortunately, our home energy fuels are cleaner than burning matches. Still, refineries, coal mines, and power plants spew tens of millions of tons of sulfur dioxide, particulates, and other pollutants into the atmosphere every year in order to meet residential energy demand. In terms of greenhouse gas emissions, all of the nation's 101.5 million homes emit 1,187 *million* tons of carbon dioxide, or 14.4 percent of all U.S. greenhouse gas emissions. This does not count the household vehicle emissions, travel and recreation, the climate impacts of our food choices, manufacturing of our consumed goods, or emissions from landfills and agricultural operations that are discussed in other briefs in this series.

Fuel used for space heating and electricity used for appliances are the largest sources of residential emissions of greenhouse gases. See the chart and the table below for the breakdown of energy and emissions by end-use. Rocky Mountain Institute has posted lots of information on household energy use, cost, and carbon dioxide emissions on its website (www.rmi.org).[6]

CO_2 Emissions per Household, 1997



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Distinct regional differences in climate and electric utility resource mix make the information in the following table merely indicative of your household's emissions (using the worksheet at the end of this brief will give you a good estimate of your total emissions). A large home in the Sunbelt may have air conditioning emissions from its utility's power plants exceeding 14,000 lbs CO_2 per year, for example, whereas total emissions for a small all-electric house in Seattle would be near zero because of Seattle City Light's low carbon emissions (0.196 lbs CO_2 per kWh consumed, or one-seventh the U.S. average of 1.43 lbs CO_2/kWh). The Sunbelt resident can achieve significant emissions reductions by improving the home's thermal performance, and Seattle residents would look to transportation and landfill savings to take a bite out of their overall emissions budget.

CO_2 per Single-Family Home, 1997

	Cost $/yr	Energy 10^6 Btu/yr	CO_2 lbs/yr	Percent of CO_2
Space heating	$476	68.1	8,829	33.9%
Air conditioning	$105	13.6	1,882	7.2%
Water heating	$202	27.8	3,558	13.7%
Refrigerator, freezer	$146	18.9	2,607	10.0%
Cooking	$46	6.5	825	3.2%
Other Appliances	$346	44.7	6,182	23.8%
Lighting	$120	15.5	2,145	8.2%
Total	**$1,441**	**195.1**	**26,028**	**100.0%**

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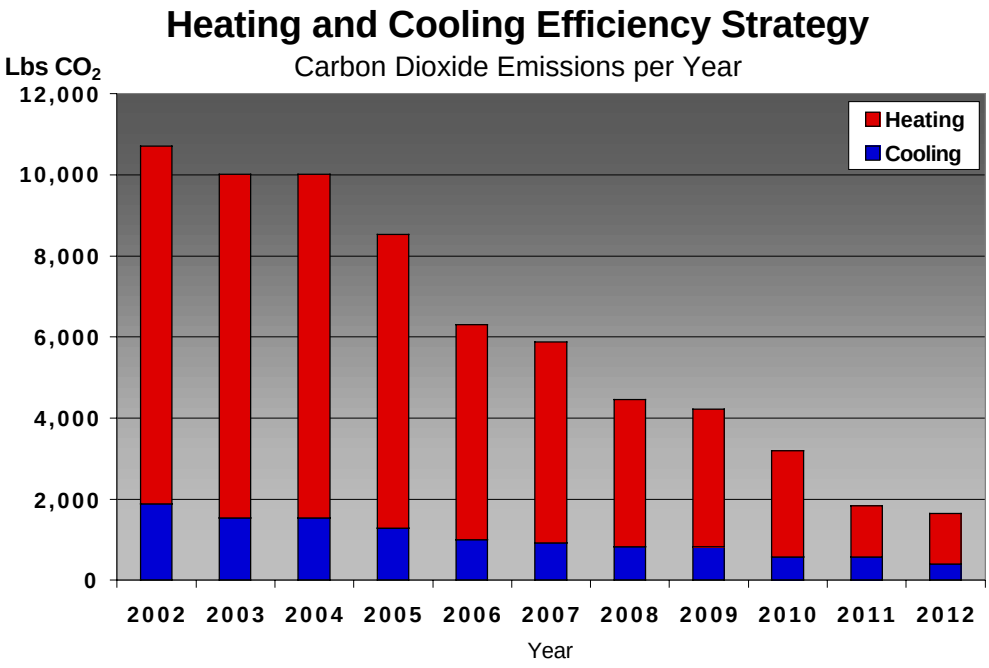
Household carbon dioxide saving measures

Using the emissions profile table above, we can analyze and prioritize the most important and cost-effective ways to *reduce* those emissions. (Bear in mind that not all of these measures apply to your house, or even if they do, the paybacks and priorities will certainly differ.) We have posted estimated savings, investment costs, payback periods, cost of saved carbon (which we use to prioritize the sequence of measures), and emissions reduction for 36 energy-saving measures and equipment upgrades on our website. Also, RMI's book: *Homemade Money: Saving Energy and Dollars in Your Home,* and ACEEE's *Consumer Guide to Home Energy Savings* discuss many more opportunities to reduce energy bills profitably, give lots of how-to advice, help you resolve radon and moisture issues, and show you how to determine your own priorities.

The analysis starts with "free stuff:" savings that cost nothing but reap big returns, accomplished by such easy measures as lowering the temperature of your water heater to 120°F, air drying clothes in the summer, and turning off computers, lights, and electronic equipment when not in use. Easy stuff. Total zero-cost measures reduce emissions by a healthy 3,605 lbs CO_2 per household per year. In terms of carbon dioxide emissions, this is equivalent to *not* driving the average 19.6-mpg family car 3,600 miles.[7]

Space heating and cooling measures focus on improving the performance of the building's exterior envelope first, *then* on reducing the energy losses of delivering the heat or coolth to where it is needed (for example, by sealing and insulating the heating or cooling ducts), and finally on improving the efficiency of heating and cooling equipment. This strategy minimizes cost by getting the best bang-for-the-buck, and allows the homeowner to use the greatest savings to help pay for the next set of energy- and greenhouse gas-saving measures. Furthermore, we can reduce the overall need for heat or coolth (because the building has been made more comfortable with less energy input), which not only means lower energy bills, but enables us to install a much smaller heating and cooling unit when the old beast fails. This reduces the installation cost, and allows us to buy a more efficient unit with the saved money, which in turn leads to additional savings. Instead of a vicious circle, this is a fortuitous spiral. We'll talk more about making a strategic plan at the end of this brief.

In a cold climate, focusing on improving the building's envelope typically means sealing large air leaks, adding attic insulation, and weatherizing windows and doors. These are good measures for reducing cooling costs, too, but in a hot climate we'd add a radiant barrier and upgrade windows to reject unwanted solar gain. Adding wall insulation or upgrading windows to super-insulating or low-e units have higher costs per unit of energy or CO_2 saved; we estimate these measures can reduce emissions by 860 and 970 lbs CO_2 per year, but due to their relatively high cost we do not put them high on the priority list. As with all of these measures, however, it's much more effective and far less costly to do it right the first time—when you are building a new house. RMI has an excellent book on new home design and construction, *A Primer on Sustainable Building.*



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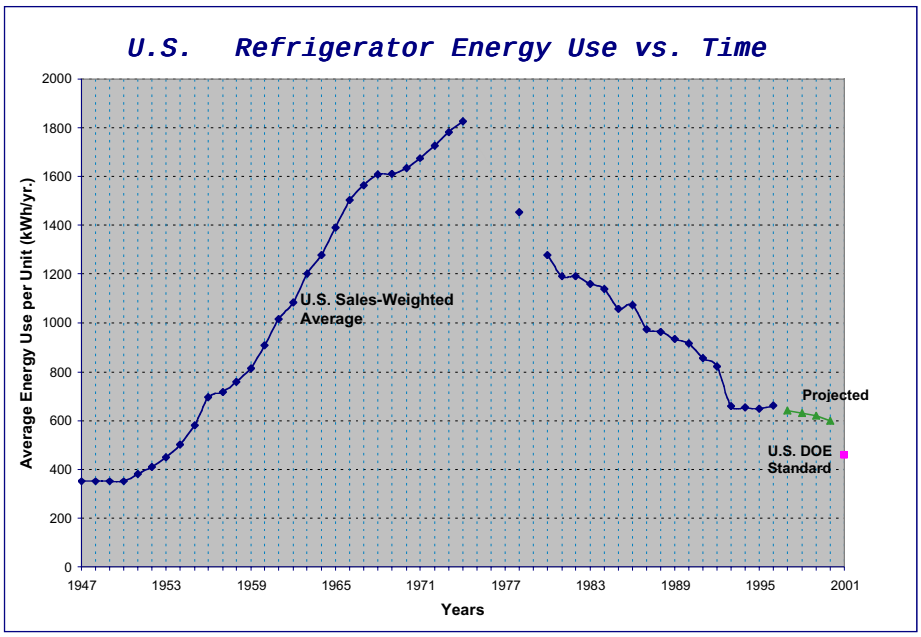
All in all, we estimate that careful attention to and investment in measures to improve the efficiency of your home's envelope will reduce space heating and air conditioning emissions by 5,370 lbs CO_2, or 50 percent of the HVAC emissions budget of 10,711 lbs CO_2 per year. Subsequent

implementation of several heating and cooling equipment energy-saving measures—such as installing a programmable thermostat, sealing and insulating heating and cooling ducts, and improving the efficient operation of the heating and cooling equipment—save an additional 1,763 lbs CO_2 per year. Total heating and cooling savings are thus 7,133 lbs CO_2, and we've reduced space conditioning emissions from 10,711 lbs to 3,578 lbs CO_2 and costs from $581 to $195 per year. Moreover, these improvements are cost-effective, and most of the measures have simple paybacks of less than five years. Replacing furnaces and air conditioners with more efficient equipment is typically *not* cost-effective based on cost-savings alone. But it's certainly worth installing much more efficient equipment once the old units are due for replacement. Both the strategy discussion at the end of this brief and the detailed tables posted on our website touch on this subject and estimate the value (dollars and carbon dioxide savings) of such upgrades. The table above shows all of the heating and cooling measures implemented over a ten-year period.

Water heating savings are among the cheapest, easiest, and most cost-effective to implement. Simple stuff such as adding an insulating wrap around water heater storage tanks, and installing great new energy- and water-saving showerheads and faucet aerators all have simple paybacks shorter than three years (less than two years as a package of measures), guaranteeing that bill-savings stay in your pocket for several years thereafter. We use conservative and field-tested energy-savings in our analysis, in contrast to a number of sources that tend to over-estimate actual savings. All in all, the cost of our recommended water-efficiency investments total $92 compared to savings of $47 per year. Annual savings from such simple measures total 824 lbs CO_2, or 23 percent of pre-measure emissions. The strategy is to reduce the end-uses first (the amount of hot water used at the tap), *then* improve the efficiency of distribution systems (pipes), and *lastly* to improve the efficiency of the supply (water heater), including options to switch fuels for water heating. We also estimate the large potential, worth 1,494 lbs of CO_2 in our typical household, to reduce fossil fuel water heating by installing solar thermal water heating. Solar systems work well in nearly all of America's climates—including Portland and Cleveland—but at a cost not justified by financial savings alone.[8] More than half a million homeowners have installed solar water or space heating systems in the U.S.

Saving energy in refrigeration is easy, but the largest savings lie in replacing the old inefficient unit, since the best new models use half as much electricity as older units. Also, unplugging the really inefficient extra fridge that eighteen million households have in the garage to store extra beer and whatnot is an easy move. Upgrading to a new refrigerator saves an estimated 830 lbs CO_2 per year, but only if you get a model that uses less electricity. Shopping carefully is essential and rewarding; a list of the most energy-efficient appliances is available from American Council for an Energy-Efficient Economy at www.aceee.org. We can also improve the performance of the typical in-use refrigerator, which consumes 1,140 kWh per, by keeping it fairly full but not crammed. This means less cold air drains onto your kitchen floor when you open the door;

crammed too full, on the other hand, and chilled air movement is obstructed and the compressor has to work longer. The refrigerator's coils might be gummed up with dust, and vacuuming these coils would improve heat transfer, thus improving its mechanical efficiency. Our personal behavior makes a difference, too, if we're in the habit of thinking about what to make for dinner with the door open.



Source: Joe Betts-LaCroix, San Francisco, personal communication, December 2001.

Cooking consumes about three percent of household energy. There are many ways we can cut energy waste and greenhouse gas emissions. Many of these are free: putting lids on pots, cleaning the pan under the burner so it reflects more heat onto the bottom of the cooking vessel, using a Crockpot or microwave instead of turning on the oven when appropriate, and putting the extra coffee in a thermos instead of keeping the coffee pot plugged in all morning. We estimate that simple changes in cooking habits and equipment used can easily save 165 lbs CO_2 per year. Using the toaster for one slice of bread at a time, for example, can put as much carbon into the air (from its use of fossil-fueled electricity) as the bread contains in carbon as *carbo*hydrate.

Appliances in our typical household use 6,955 kWh, cost $538 for energy, and emit 9,614 lbs of CO_2 per year. Our homes are bursting with new widgets in the kitchen and gadgets throughout the house and garage. Big appliances tend to be big energy users, too, but the explosion of VCRs and satellite TV and Dustbusters™ and home office equipment has brought two new energy saving measures to the table:

- Many appliances use electricity even when they're turned off: TVs with instant on, telephone answering machines, VCRs, and plug-in tools all use ~2-6 watts. Researchers at the Lawrence Berkeley National Laboratory estimate that such "phantom" or stand-by loads consume an average of 67 continuous watts in the typical home, and waste 587 kWh, $47, and 840 lbs of CO_2 per year.
- Home computers, printers, scanners, copiers, fax machines, lights, TVs, stereos, fans, and other widgets are often left on when not being used. Some 35 million computers, 11 million

printers, 7 million fax machines, and 4 million copiers call home "home." We estimate that if the forty percent of American households that do have computers would reduce electricity consumption of such equipment by such measures as (1) turning them off at night (nearly three million users keep their computers, and, presumably, other home office equipment, on 24/7/52: *one* computer on all year uses 1,230 kWh costing $98 per year and emits, needlessly, 1,460 lbs of CO_2 for the on-time of 20 hrs beyond the ~4 hrs of use-time per day for the typical home computer), (2) upgrade to electricity-saving laptops when buying a new computer (laptops use about 15 w compared to 140 w for typical desktops), (3) buy EnergyStar office equipment and enable associated software, and (4) plug computers, printers, and desk lights into an occupancy-sensing control strip that turns selected equipment off when you're not around. If we dilute such savings for the 40 percent of households that have home office equipment (and use 808 kWh/hh/yr) across all single-family households, we can, on average, save 96 kWh, 137 lbs of CO_2 and $7.68 per household per year. As with all of the measures discussed in this brief, savings are higher in households that have such equipment, and the difference is especially high for equipment that is not ubiquitous, or for households that use energy-breathing equipment more intensively than "typical." Interested folk may wish to read the extensive comments posted on our website and in the footnotes of the downloadable analysis document.

Major appliances provide additional opportunities for savings. Simply air drying our clothes during the summer months saves 779 lbs of CO_2 per year, washing half our clothes washer loads in cold water instead of hot water saves 327 lbs of CO_2, and using energy-saving features on our dishwashers, dryers, and refrigerators save an estimated 769 lbs CO_2 per year. Conventional clothes washers are energy hogs: they use lots of water, indeed, lots of *hot* water, and we estimate that recycling the old tub and buying a water-saving horizontal-axis machine will cut emissions by 326 lbs CO_2 per year and shave $18 off your utility bill (not including the $9 and 166 lbs CO_2 saved by your dryer because the new washer spin-dries your clothes more thoroughly, and uses less water and detergent, to boot).

Lighting efficiency is often on the top of the to-do list because replacing bulbs is so easy, and it saves on shopping for new bulbs every few weeks. Incandescent bulbs are actually little toasters that also give off a little light and a lot of waste heat (~90 percent of the electricity they consume is converted to heat), increasing your air conditioning bill, too. Compact fluorescent (CFL) bulbs typically last 7,000-10,000 hrs and use three-quarters *less* electricity than incandescents with the same light output. We estimate that replacing six of your most-used incandescent light bulbs with CFLs will reduce emissions by 566 lbs CO_2 and lower your electric bill by nearly $32 per year. One-third of homeowners keep one or more exterior lights on all night, every night, and we estimate savings of 210 lbs CO_2 and $12 annually from replacing one such light per household with a CFL. The simple paybacks for these two measures are 1.9 and 1.5 years, respectively.

Green power purchases. A growing number of attentive electric utilities around the country are investing in wind power farms or photovoltaic installations or other certified forms of environmentally responsible electricity supply (electricity generation from methane captured at landfills often qualify, as do some small hydropower projects). Such electricity costs more to generate—even though new efficient wind turbines can deliver electricity at prices very competitive with dirty coal and semi-clean natural gas plants. In any case, those utilities that offer customers green power typically do so at a price premium of about 2.5 cents per kWh more than regular juice (a premium of ~30 percent above the normal dirty electricity). Homeowners who sign up for this option help to finance and build new clean electricity generation capacity and can claim zero emissions for the zero-carbon electricity thus purchased. For the typical pre-efficient household that uses 11,278 kWh per year, buying green power for the whole lot increases the electric bill by $283 annually (from $904 to $1,187 per year). This is too high a premium to expect most families to pay for zero emissions from electricity consumption. As we'll suggest in the strategy section below, there's a better way: invest in reasonable, easy, and cost-effective ways to reduce electricity demand and *then* buy green power for the kilowatt-hours that remain.

Summary of savings. Our analysis suggests that gradual implementation of the twenty-five most cost-effective energy-saving measures (plus eight no-cost measures) will cut energy bills by *57 percent* (from $1,441 to $617) and reduce emissions by 14,942 lbs of carbon dioxide per year (from 26,028 to 11,086 lbs CO_2/yr). The total cost of the analyzed measures is $5,006, which means an overall simple payback of 6 years. Many of the measures cost very little and have paybacks of two years or less. It is these measures we'll start with when we discuss greenhouse gas reduction *strategy* in the next section.

If a solar water heating system is added, the greenhouse gas emissions reductions increase to 16,436 lbs of carbon dioxide, or total emissions savings of *63 percent*. We have taken the analysis even further by estimating savings from measures that are too costly in their own right (such as replacing air conditioning and heating equipment) yet save a lot of energy and emissions once a replacement is needed anyway. Such measures increase savings to *68 percent* below current emissions in our hypothetical household (shown in the bar chart below), and are included in the most aggressive strategy discussed in the following section, namely, a plan to achieve *climate neutrality* by 2012.

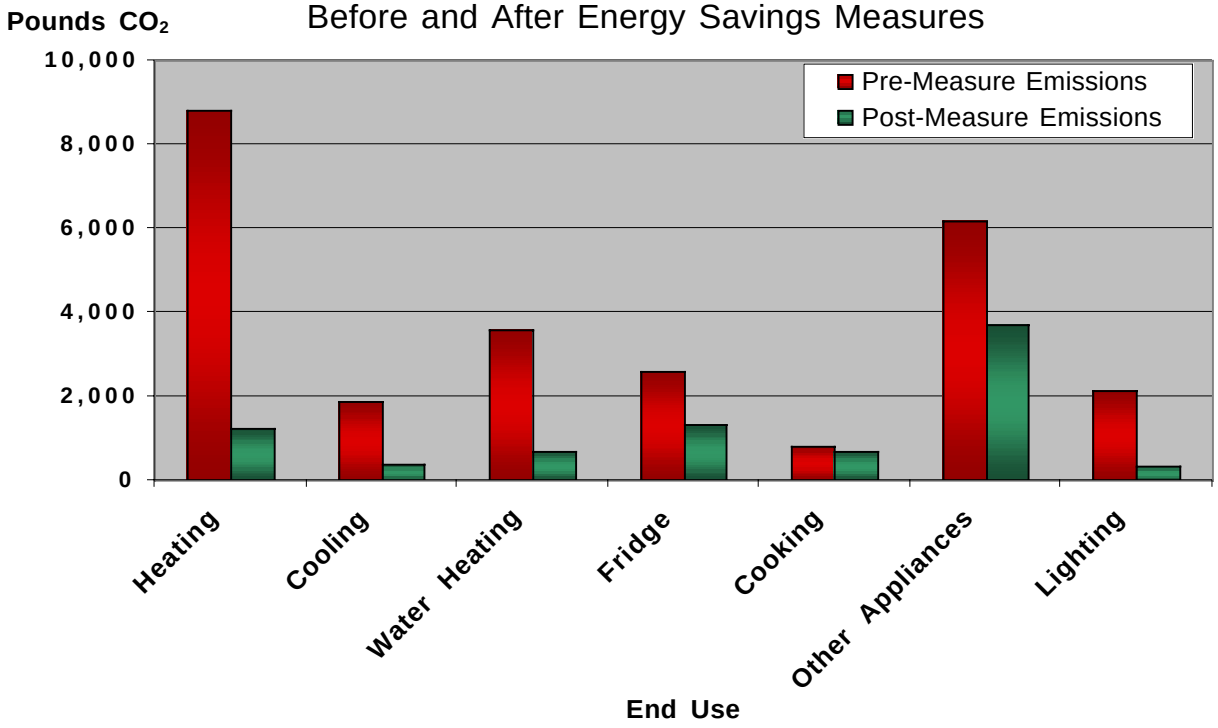
Let's see how we can accomplish it.

Household CO_2 Savings
All Measures

	Energy (10^6 Btu/yr)	CO_2 Saved (lbs/yr)	$ Saved ($/yr)	CSC life ($/ton CO_2)
Total prior to measures	195.10	26,028	$1,441.00	
Total free stuff	26.61	3,605	$201.36	$0.00
Total building shell	41.05	5,370	$290.85	$46.82
Total heating/cooling equipment	13.47	1,763	$95.87	$48.97
Total water heating	6.44	824	$46.81	$18.59
Total appliances	14.30	1,936	$108.57	$49.08
Total lighting	10.46	1,444	$80.80	$33.21
Total household savings	**112.33**	**14,942**	**$824.26**	**$34.82**
Remaining after measures	**82.77**	**11,086**	**$616.74**	
Savings fraction	**57.6%**	**57.4%**	**57.2%**	
Add solar water heating, save:	11.67	1,494	$84.80	$117.14
Total savings after solar water heating	**124.00**	**16,436**	**$909.06**	**$45.61**
Remaining after all measures	**71.10**	**9,592**	**$531.94**	**na**
Savings fraction after solar water heating	**63.6%**	**63.1%**	**63.1%**	**na**

Carbon Dioxide Emissions By End Use

Before and After Energy Savings Measures



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A greenhouse gas reduction plan

While the priorities and the actual savings in our homes will no doubt differ from the measures discussed in this brief, there are a lot of opportunities to reduce emissions of greenhouse gases. In some cases we can do even better than the Foleys did in their home. In fact, we estimate that doing the eight no-cost measures, then implementing the ten or more low-cost measures, and investing in a few costly measures such as replacing the old refrigerator and adding wall-insulation will allow the typical homeowner to reduce their emissions by an impressive 57 percent. This increases to 63 percent when we add the solar water heating system. Adding the most expensive measures—replacing the heating and cooling system—will improve our savings to 68 percent. Of course, these improvements will take time and money, but we'll save both in the short run *and* the long run. Also, we'll lead our communities into climate stewardship *at a profit.*

The three most important resources in our favor are (1) new efficient technology, (2) implementation smarts, and (3) sufficient time to implement the measures in a rational, optimal, and cost-effective sequence. It makes no sense to dive into a crash program this year, for example, because we want to wait for some of the existing equipment to fail before replacing it. Nor does it make good financial or climate sense to wait ten years, when the nations of the world will meet to discuss the success of U.S. and international efforts to reduce emissions of the six Kyoto greenhouse gases, and *then* start an emergency program to catch up to missed emissions reduction opportunities. That the United States under President Bush is taking this latter approach is no reason we citizens should follow such a wasteful "strategy." As we'll see below, homeowners can take a measured approach to emissions reduction, gradually saving and investing small amounts of capital, and far exceed the U.S.'s Kyoto Protocol commitment to reduce all emissions of greenhouse gases to 7 per cent below 1990 emissions by 2012.

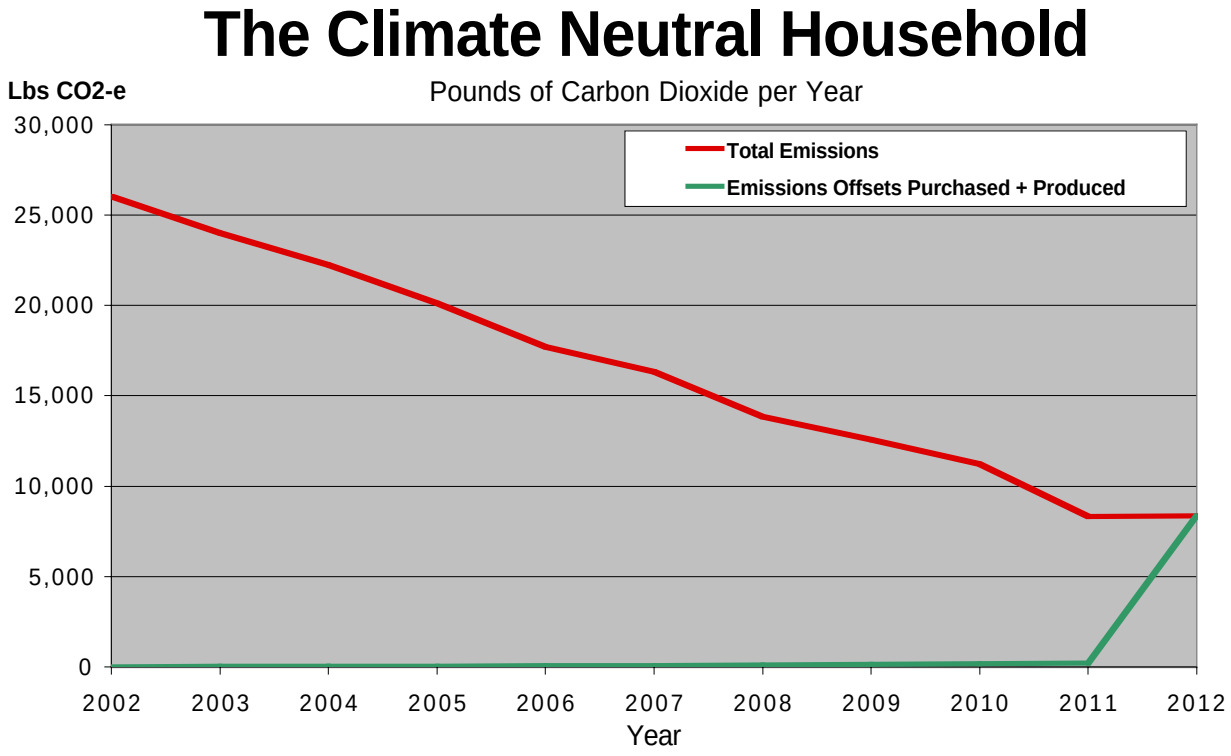
Individual homeowners can consider making a commitment to reduce greenhouse gas emissions over the next several years. Step one would be to estimate the emissions from their own household (our numbers should only be used as a guideline), and we have added a simple worksheet at the end of this brief to help homeowners do their own accounting. (Forthcoming *Cool Citizens* briefs will follow up with discussions of other emissions—transportation, waste to landfill, at work, travel and recreation, food choices, and so forth—and present solutions to reducing our overall emissions.)

Once your family's current level of household emissions has been calculated, then you can consider the variety of measures available to reduce emissions while you also discuss your family's emissions reduction options. For example, your family can use the no-cost measures and save an estimated 14 percent of emissions in our hypothetical household. This goal may be sufficient for some families, but others may wish to take advantage of far deeper savings by using our suggested measures as a guide. Another possible goal is to aim for reducing emissions by, say, three or four percent per year. Yet another objective is to exceed the U.S. "commitment" (that is, by more than a seven percent reduction). Or we can aim for something a bit more dramatic: a 50 percent reduction by 2012, using the measures discussed in this brief as an implementation guide. Some families may even choose to go for the whole enchilada: *climate neutrality* or *net zero emissions,* discussed below.

A household climate neutral plan

We can illustrate the steps you can take in your own home using an imaginary house in Roseville, an imaginary town in the middle of America. Let's begin by stating a greenhouse gas reduction goal for the Roseville household, and let's give ourselves ten years to accomplish it: achieve "climate neutrality," or net zero emissions, for our household emissions by 2012.[9] Hopeless? We don't think so. Here's how we can do it: starting with the no-cost measures, we'll save 3,605 lbs of CO_2 right off the bat, and we assume that we'll take two years to implement all of these measures. Then, each year starting in 2005, we'll implement three or four cost-effective measures that will cost us a little money each but have quick payback times. We'll use these savings to pay for additional and gradually more costly measures (such as insulating the woefully under-insulated walls or replacing the old refrigerator) in the middle of our ten-year time period. We can wait to implement the costliest measures nearer the 2012 "deadline," because we'll save money if we wait for the expensive retrofits later, when we can replace the old heating and cooling equipment with much smaller and far more efficient equipment.

Along the way—once we've cut our consumption of electricity through lighting, cooling, and appliance efficiency measures—we'll sign up for green power to *eliminate* carbon emissions from our use of electricity. See the chart below, where we've sketched just such a scenario for our Roseville home. The ten-year sum of our energy-efficiency retrofit costs plus total energy bills is significantly smaller *with* our climate neutral commitment than without it.[10] Folks who want the nitty-gritty details can see the extensive discussions of measures and costs on our website (where numerous tables are posted, with downloadable PDF files also available).



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We have assumed in our analysis that the home's heating and cooling system needs replacement (with much smaller and more efficient units) by 2011, after all of the energy-saving measures to the home's building exterior and internal loads have been implemented. By this method we will achieve total savings of 68 percent of our current emissions, or going from 26,028 lbs of CO_2 in 2002 to 8,355 lbs of CO_2 in 2011. What do we do with the remaining emissions? First, as we mentioned above, we sign up for the carbon-free renewable electricity—green power—with our utility, which reduces emissions from the remaining 6,715 lbs of CO_2 emissions from electricity consumption of 4,696 kWh (at 1.43 lbs CO_2/kWh) to zero.[11]

Now we have 1,640 lbs of CO_2 remaining from consumption of space and water heating fuels, and this we will "offset" by planting trees and buying a small portfolio of carbon sequestration measures on the emerging carbon credit market.[12] We have also estimated the result of planting two trees per year from 2002 through 2012, each of which "fix" 4 lbs of CO_2 in 2002, 8 lbs in 2003, 12 lbs in 2004, and so forth.[13] Since this household tree-planting program offsets an estimated 260 lbs of CO_2 by 2012, we now have 1,380 lbs of CO_2 emissions remaining in 2012. We can offset this remainder by purchasing that amount of carbon credit on the market (which we assume will be active and available to citizens well before 2012).[14] We have met our goal of net zero emissions while also meeting our guideline of maximizing emissions reduction before buying credits.

Voilà—climate neutrality by 2012!

Celebrate both your commitment and your progress by informing your neighbors, colleagues, and friends. Please let us know about your progress, too, by writing to us at heede@rmi.org.

Good luck in your climate stewardship adventures!

Rocky Mountain Institute, Snowmass, CO.

Estimate your own family's household emissions*

Step one: gather your energy bills for the past year, and sit down with a pencil, this form, a calculator, and a relaxing beverage. **

Step two: sum the electricity and fuel bills for the 12 months for which you have bills:

Electricity _____ kWh x 1.43 lbs per kWh consumed *** = _____ **lbs CO_2/yr**

Heating and other fuel *(if other than electricity)*

If fuel oil _____ gallons x 22.38 lbs CO_2 per gallon = _____ **lbs CO_2/yr**

If natural gas _____ therms x 11.71 lbs CO_2 per therm**** = _____ **lbs CO_2/yr**

If propane _____ gallons x 12.67 lbs CO_2 per gallon = _____ **lbs CO_2/yr**

If kerosene _____ kWh x 21.54 lbs CO_2 per gallon = _____ **lbs CO_2/yr**

If wood _____ cords x 3,050 lbs CO_2 per cord = _____ **lbs CO_2/yr**

Total energy-related household emissions from your home: = _____ lbs CO_2/yr.

If you do not save or pay your utility bills, the following simple approximation will give you an idea of your emissions: multiply the square footage of your home by 11.4 lbs CO_2 per square foot per year: _____ square feet x 11.4 lbs CO_2/sqft/yr = _____ lbs CO_2/yr.

This is the national average emissions per square foot per year, and you can compare your more detailed calculation to this result, if desired.

* This form is for carbon dioxide emissions resulting from energy used in the home (including emissions from fossil-fuel power plants). Future *Cool Citizens* briefs will discuss other household-related emissions, such as from personal vehicles, methane from household waste at the landfill, nitrous oxide from fertilizers applied to the nation's farms, and so on. Preliminary results show household emissions equal to 16 percent of total per household emissions (residential: 26,028 lbs CO_2 vs total U.S. emissions of 160,828 lbs CO_2-equivalent). This includes emissions that families and consumers have little control over, and our focus will remain on emissions we can effectively reduce with a variety of approaches, such as reducing organic waste to landfill, increased recycling of paper and aluminum, buying organic rather than industrial beef (or eating a vegetarian diet), using less fertilizer and water, ensuring the recovery of refrigerants from land-filled refrigerators, effective at-work emissions-reducing measures, etc.

** This method will be slightly inaccurate, for several reasons (energy consumption varies by yearly changes in temperatures and weather, you may be counting some gas purchased for last year), but such changes are relatively unimportant for these purposes. We also assume that the relaxing beverage will not compromise your accuracy with the calculator.

*** Carbon emissions vary greatly from utility to utility, and vary monthly or even hourly, depending on power purchased from other utilities and plants brought on-line. The factor used here (1.43 lbs CO_2 per kWh consumed) is the national average for 1999. If you want to get your state's average, see ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/e-supdoc.pdf for state emissions per kWh *generated*. To adjust to emissions per kWh *consumed*, which is the factor we're interested in, multiply the column titled "lbs/kWh" by 1.072 for your state to account for electricity lost in the transmission and distribution to your home from the power plant (again, a national average).

**** 1 therm = 100,000 Btu of gas. If your bills list consumption in units of cubic feet, multiply cubic feet by 0.1206 lbs CO_2 per cubic foot.

Household CO_2 Savings

All Measures Ranked by Cost of Saved Carbon

	Energy (10^6 Btu/yr)	CO_2 Saved (lbs/yr)	$ Saved ($/yr)	CSC life ($/ton CO_2)
Lower water heater temp to 120˚F	**1.67**	**214**	**$12.12**	**$0.00**
Increase AC thermostat by 3F˚	**2.45**	**339**	**$18.90**	**$0.00**
Lower thermostat in winter by 2F˚	**2.72**	**353**	**$19.04**	**$0.00**
Wash clothes in cold water	**2.56**	**327**	**$18.58**	**$0.00**
Air dry clothes during summer	**5.64**	**779**	**$43.60**	**$0.00**
Use energy-saving appliance features	**5.61**	**769**	**$43.04**	**$0.00**
Turn off unneeded lights	**2.72**	**376**	**$21.04**	**$0.00**
Dryer savings from new H-axis	**1.20**	**166**	**$9.29**	**$0.00**
Unplug extra fridge in garage	**3.24**	**448**	**$25.04**	**$0.00**
Programmable thermostat	**8.17**	**1,071**	**$58.10**	**$9.34**
Seal large air leaks	**11.36**	**1,489**	**$80.76**	**$10.07**
Insulate water heater	**2.06**	**263**	**$14.95**	**$12.66**
Add attic insulation	**16.34**	**2,142**	**$116.20**	**$15.56**
Seal and insulate ducts	**11.58**	**1,512**	**$81.90**	**$17.64**
Efficient showerheads	**2.89**	**370**	**$21.01**	**$18.02**
Weatherize windows, doors	**4.74**	**621**	**$33.70**	**$25.72**
Faucet aerators	**0.86**	**110**	**$6.22**	**$27.27**
Fix hot water leaks	**0.22**	**28**	**$1.62**	**$28.57**
Add basement insulation	**8.85**	**1,148**	**$61.88**	**$29.04**
Cooking savings	**1.30**	**165**	**$9.20**	**$30.30**
Replace 6 interior incandescents	**4.10**	**566**	**$31.68**	**$30.77**
New furnace (from 0.50 to 0.96 AFUE)	**32.69**	**4,238**	**$228.48**	**$34.08**
Home office equipment savings	**0.99**	**137**	**$7.68**	**$36.00**
Insulate hot & cold water pipes	**0.41**	**53**	**$3.01**	**$37.74**
New efficient refrigerator	**6.00**	**829**	**$46.40**	**$46.40**
Replace 1 exterior incandescent	**1.52**	**210**	**$11.76**	**$47.37**
Heating system modification	**4.09**	**530**	**$28.56**	**$50.25**
Occupancy sensor	**0.48**	**66**	**$3.68**	**$60.00**
New AC (from 9.0 to 12.0 SEER)	**3.40**	**471**	**$26.25**	**$65.36**
New H-axis clothes washer	**2.54**	**326**	**$18.48**	**$67.75**
Add air gap window films	**5.65**	**733**	**$39.51**	**$70.91**
Add an attic radiant barrier	**1.36**	**188**	**$10.50**	**$90.43**
Add wall insulation	**6.54**	**857**	**$46.48**	**$91.02**
Add solar water heating system	**11.67**	**1,494**	**$80.80**	**$117.14**
Cut phantom loads by half	**2.27**	**313**	**$17.52**	**$128.21**
Upgrade to high-performance windows	**7.29**	**971**	**$51.36**	**$133.88**
Heating system tune-up	**4.09**	**530**	**$28.56**	**$150.94**
Roof whitening	**3.40**	**471**	**$26.25**	**$229.30**
Add low-e window films	**2.72**	**377**	**$21.00**	**$241.38**

Note: The savings estimates listed above are based on the end use energy consumption of our typical single-family home in Roseville, somewhere USA. Your savings, costs, and priorities will no doubt differ from our estimates.

Organizations and Resources

American Council for an Energy Efficient Economy, Washington, DC, www.aceee.org
American Forests, Global ReLeaf Campaign, www.americanforests.org
Business Council for Sustainable Energy, Washington, DC, www.bcse.org
Business for Social Responsibility, Business and the Environment, San Francisco, CA, www.bsr.org
Center for Energy Efficiency & Renewable Technologies, Sacramento, CA, www.cleanpower.org
Center for a Sustainable Economy, Washington, DC, www.sustainableeconomy.org
Center for Clean Air Policy, Washington, DC, www.ccap.org
Center for Energy and Climate Solutions, Annandale, VA, www.cool-companies.org
Center for Neighborhood Technology, Chicago, IL, www.cnt.org and www.airhead.org
Cities for Climate Protection, International Council for Local Environmental Initiatives, www.iclei.org
Climate Action Network, Washington, DC, www.climatenetwork.org
Climate Institute, Washington, DC, www.climate.org
Climate Network Europe, Brussels, Belgium, www.climatenetwork.org
Climate Neutral Network, Underwood, WA, www.climateneutral.com
Climate Partners Network, Inc., Victoria, BC, www.climatepartners.com
Climate Solutions, Olympia, WA, www.climatesolutions.org
Conservation International, Washington, DC, www.conservation.org and www.safeclimate.net
David Suzuki Foundation, Climate Action Team, Vancouver, BC, www.davidsuzuki.org
Earth Island Institute, San Francisco, CA, www.earthisland.org
ECONET, Atmosphere and Climate Change, San Francisco, CA, www.igc.org
Environmental Defense, Partnership for Climate Action, New York, www.environmentaldefense.org
Friends of the Earth, Washington, DC, www.foe.org
Global Climate Coalition, Washington, DC, www.globalclimate.org & www.climatechangedebate.org
Global Environment & Technology Foundation, Annandale, VA, www.earthvision.net, www.getf.org
Greenpeace USA, Climate and Energy Campaign, Washington, DC, www.greenpeaceusa.org
Heartland Institute, Palatine, IL, www.heartland.org
Heat Is On, Brookline, MA, www.heatisonline.org
INFORM, Inc., NY, www.informinc.org
International Council for Local Environmental Initiatives, Toronto, www.iclei.org/
International Institute for Energy Conservation, Washington, DC, www.geei.org and www.iiec.org
International Institute for Sustainable Development, Winnipeg http://iisd.ca & www.iisd.ca/
International Project for Sustainable Energy Paths, El Cerrito, CA, www.ipsep.org
Land and Water Fund of the Rockies, Boulder, CO, www.lawfund.org and www.cogreenpower.org
Lawrence Berkeley National Laboratory, Center for Building Science, homeenergysaver.lbl.gov
National Center for Atmospheric Research, Boulder, CO, www.ncar.ucar.edu
Natural Resources Defense Council, San Francisco, CA, www.nrdc.org
Oregon Climate Trust, Portland, OR, www.climatetrust.org
Pacific Institute for Studies in Development, Environment, and Security, Oakland, www.pacinst.org
Pembina Institute for Appropriate Development, Drayton Valley, Alberta, www.piad.ab.ca
Pew Center on Global Climate Change, Arlington, VA, www.pewclimate.org
Redefining Progress, Oakland, CA, www.rprogress.org
Resources for the Future, Washington, DC, www.rff.org and www.weathervane.rff.org
Rocky Mountain Institute, Snowmass, CO, www.rmi.org
Sierra Club, Global Warming and Energy Program, Washington, DC, www.sierraclub.org
Sustainable Energy and Economy Network, Institute for Policy Studies, Washington, www.seen.org
Torrie Smith Associates, www.torriesmith.com
Trexler & Associates, Portland, OR, www.climateservices.com
Union of Concerned Scientists, Cambridge, MA, and Washington, DC, www.ucsusa.org
United States Climate Action Network, Washington, DC, www.climatenetwork.org
University of Wisconsin Center for Sustainability & the Global Environment, http://sage.aos.wisc.edu
World Resources Institute, Safe Climate, Sound Business, Washington, DC, www.wri.org
World Wide Fund for Nature, European Climate and Energy Policy Unit, www.wwfnet.org
World Wildlife Fund, Energy and Climate Change Program, www.wwfus/climate/climate.cfm,

End notes

[1] Foley's interview in *Audubon* magazine (March 2001) estimates annual emissions at 42,000 lbs CO_2. Based on the energy consumption data mentioned in the article, we have re-calculated the Foley's emissions at 46,323 lbs CO_2. Electricity: "550 kWh/month" = 6,600 kWh/year; at Wisconsin's average carbon intensity (1.792 lbs CO_2/kWh and 6.72 percent transmission and distribution losses [the U.S. average] = 1.921 lbs CO_2 per kWh consumed) = 12,679 lbs CO_2. Natural gas: "1,500 therms" (0.1 million Btu) of natural gas (corrected to 1,200 therms, personal communication, 26Mar02): 120 million Btu x 117.08 lbs CO_2 per million Btu) = 14,050 lbs CO_2. Gasoline: "35,000 miles per year, two cars each driven 30-mile commute per workday, 25 mpg city" (we assume 35 mpg combined, based on long commute), or 35,000 ÷ 35 mpg = 1,000 gallons x 19.594 lbs CO_2 per gallon = 19,594 lbs CO_2. Total = 46,323 lbs CO_2. Household only: electricity (12,679 lbs) + gas (14,050 lbs) = 26,729 lbs CO_2.

[2] Electricity: "295 kWh/month" = 3,540 kWh/yr x 1.921 lbs CO_2 = 6,800 lbs CO_2. Natural gas: "900 therms" = 90 million Btu x 117.08 lbs CO_2 per million Btu = 10,537 lbs CO_2. Gasoline: "10,000 miles in a Prius" at 48 combined mpg (www.toyota.com) = 208 gallons x 19.594 lbs CO_2 per gallon = 4,076 lbs CO_2. The Foley's have signed up for green power (primarily wind power, for 100 percent of their electricity consumption, personal communication, 26Mar02), hence we do not count electricity emissions. Sum of natural gas and gasoline = 14,613 lbs CO_2 per year, or 31.55 percent of their previous budget. Taking their household emissions only, the Foley's went from 26,729 (12,679 elec + 14,050 gas) lbs CO_2 to 10,537 lbs CO_2—or 39.42 percent of the previous emissions.

[3] Rocky Mountain Institute gratefully acknowledges financial support from Richard and Rhoda Goldman Fund for the research, writing, and publication of the series of *Cool Citizens* briefs.

[4] Household energy consumption varies greatly depending on house size, climate, solar heating, age, household income, number of occupants, equipment installed, and personal energy habits. Emissions of greenhouse gases vary even more due to the use of different heating fuels and the fossil-fuel intensity of the electricity supply. On a state level (individual utilities vary), carbon dioxide emissions per kWh (generation, not including T&D losses or generation by non-utility generators) range from 0.017 lbs in Vermont to 2.193 lbs in Wyoming. U.S. Department of Energy (2000), *Revised/Updated State-level Greenhouse Gas Emission Factors for Electricity*. www.eia.doe.gov and ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/e-supdoc.pdf

[5] Our analysis accounts for all fuels, including electricity consumption, for each end use. Some electricity is thus allocated to water and space heating, for example. We count electricity at the full energy value at the power plant to account for conversion losses.

[6] This information, including PDF files with extensive footnotes and calculations, and a very detailed spreadsheet of U.S. and per capita emissions of all greenhouse gases, will be posted to our site by 10 May 2002.

[7] Average fleet fuel economy has been in slow decline over the past several years, after gradual improvement due to cars that meet CAFE standards replacing older, less efficient cars. Now, however, the popularity of light trucks, minivans, and SUVs—which are classified as light trucks and thus have far lower fuel economy standards—have lowered composite personal fleet fuel economy to 19.62 miles per gallon. Calculations by RMI using DOT data.

[8] Solar applications, and, for that matter, energy-saving technologies, must pay the full cost of investment against conventional electricity and fossil fuels that are heavily subsidized and do not internalize the environmental and societal costs of their extraction, processing, transportation, use, and disposal. Tax incentives for renewable energy and energy efficiency were estimated to total $1.5 billion in FY1989 compared to supply incentives of $20 billion to $33 billion, of which $13 to $21 billion went to the fossil fuel industries (1989$; Koplow, Doug, (1993), *Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts,* Alliance to Save Energy, Washington, DC.

[9] Net zero emissions allows our Roseville household to emit some greenhouse gases (since we'll still use some fuel and electricity), while making a strong effort to minimizing the emissions before we take credit for carbon savings or offsets made elsewhere (e.g., planting trees in the community) and purchased to "offset" the remaining emissions. While credits can be purchased to cover the emissions of an inefficient household, and thus legitimately claim climate neutrality, our guideline is to reduce source emissions by *at least* 40 percent—to ensure "walking the talk"—before applying credits and offsets.

[10] Ten years of utility bills at each $1,441 = $14,410, which use as the baseline of costs (realistically, we'd probably add a few energy-using widgets over the years, and fuel and electricity prices are more likely to rise than to stay as low as they are now, but let's stick with this conservatism). For the 57 percent savings discussed above, we estimated costs of $5,006, with corresponding utility savings of $824 per year. *If* we assume implementation of all of these measures in 2002, then we'd spend $5,006 plus 10 yrs x ($1,441 – $824 =) $6,170 = $11,176. Of course, a more detailed financial analysis would model the implementation of the measures in a more realistic sequence (not all in one year), but we still expect net savings, especially if we finance the more costly measures with a low-cost home equity loan.

[11] Our analysis suggests that the typical homeowner can cut electricity consumption from 11,278 kWh to 4,696 kWh, saving 6,582 kWh, or 58 percent. The electric bill will then be $376 per year (saving $526/yr), but the green

power *margin* of 2.5 cents/kWh will cost $117.40 per year. Since this saves 9,412 lbs of CO_2 per year (6,582 kWh x 1.43 lbs CO_2/kWh), the Cost of Saved Carbon = $117.40 ÷ 4.71 tons CO_2/yr = $24.93 per ton of CO_2 saved. This passes our "buy" test.

[12] Sequestration refers to removing carbon dioxide from the atmosphere, typically by planting trees, sustainable forestry practices, or other biological carbon absorption or enhanced storage, but also including sequestering CO_2 in natural gas wells, "disposal" into the deep ocean, or other long-term carbon storage.

[13] Alternatively, we can count the carbon fixation of each tree for its lifetime—for which American Forests's *Global ReLeaf* program suggests a total of 670 lbs CO_2—but we think it's more accurate to count the rate of carbon fixation per year. The total amount of carbon sequestration per tree is the same over its lifetime, but we're only counting the actual amount of carbon offset each year. We estimate the carbon removal based on the planting of two native trees (to minimize disease and irrigation needs) each year from 2002 through 2012, or 20 trees total. Total carbon dioxide absorption per year increases from 4 lbs of CO_2 in 2002 and reaches 260 lbs of CO_2 in 2012. Since each tree, if well cared for, will live for decades past 2012, the amount of carbon fixation will continue to increase (to 76 lbs CO_2 in 2020 for the oldest tree, and 580 lbs CO_2 for all twenty trees in that year). These trees can be planted on each homeowners' property, or by participating in community tree-planting programs, or by donating to similar efforts. Clearly, by this accounting method, it's important to start early.

[14] Carbon dioxide market-clearing costs range from about $1 to $11 per ton of CO_2. (the price cited by Pew Center for Climate Change, Oregon Climate Trust, Environmental Financial Products, World Bank Prototype Carbon Fund, UK Carbon Trust., and other sources). This suggests that homeowners would be advised to achieve climate neutrality primarily by buying carbon credits rather than invest in higher-cost CO_2 reductions in the home, since the free measures (3,605 lbs) plus the measures that cost less than $11.00 per ton of CO_2 saved ("seal large air leaks" at 1,489 lbs) only add up to 5,094 lbs CO_2. There are two reasons why homeowners can dismiss, at this point, seeking climate neutrality by buying carbon offsets and foregoing home GHG savings: 1: credits are not yet available on the market, and 2: credits would have to be purchased every year, whereas our home emissions savings are far more durable. (Even at low prices, the emissions remaining after the no- and low-cost savings, 20,934 lbs, or 10.47 tons CO_2, would cost ~$58 per year at $5.50 per ton.) Besides, the bill-savings from our energy efficiency measures are substantial and cost-effective, whereas *not* implementing them commits us to perpetual high bills, let alone not walking the talk.

Household Climate Neutral Strategy:

Emissions Reduction Measures, 2002-2012