Moving from Energy Efficiency to Carbon Footprint

KATHY GREELY

Tom Boothby of Performance Systems Development holds the IR camera during a Pennsylvania Home Energy mentoring session.

by Greg Thomas

I have been in the energy efficiency and renewable energy business for almost 30 years, and I am seeing more rapid change now in this industry than ever before. More and more people understand that energy prices are being, and will be, affected by global climate change, and by the long-term availability of fossil fuels, and they are responding by buying more energy-efficient homes, cars, and appliances. And another growing group of people—although they are not necessarily motivated by rising energy prices or by the hope of saving money—want to reduce their environmental impact and are looking to efficiency to do this. Since energy efficiency has evolved over that same 30 years, we now have a product to offer—home performance—that lets people be more comfortable, live in healthier, more durable homes, and help save the planet. Now if we could just install it on the roof where people could see it, like photovoltaic (PV) cells, or make it look trendy and special, like the Prius!

A New Type of Customer

More and more people are looking for information on doing well by the planet, and there are more and more organizations looking to tell them what to do. Just sign up at the Live Earth Web site and you can get all sorts of tips on saving the planet. Measure your carbon footprint and see how the total carbon dioxide (CO_2) produced by your consumption of resources compares to that of other people. Simplicity is the key word at most of these sites. It seems that it is more important to get people to do one thing—change a lightbulb, ride a bike to work one day—than it is to produce significant and lasting change. One site even says that one of the most important things we can do to save the planet is to stop taking receipts at ATMs. The typical approach used to make these actions seem significant is to multiply them by hundreds of thousands of people taking that action. Are these sites creating the wrong impression by making combating climate change seem too cheap and easy? Maybe we should be thinking about the more significant CO_2-reducing actions—fixing houses, for example—and multiplying those actions by hundreds of thousands of people.

For those who are looking for more serious solutions, there is the ever-present drumbeat of media and public interest in renewable energy. Efficiency is getting some of the spillover interest, but the real action for now, with homeowners, investors, and the media, is in solar, and other sources of renewable energy. Homeowners looking for advice on reducing carbon emissions may hear the gospel phrase "efficiency before renewables" repeated by start-up energy consultants, but in practice, at the residential level, this might mean installing a few compact fluorescent lightbulbs (CFLs) before the solar panels go up.

It might seem obvious that the best way to reduce the production of CO_2 that results from using electricity is to install sources of renewable energy, such as solar and wind energy systems. But is this really the most cost-effective way to reduce CO_2 production—not just from the use of electricity, but from the use of all fuels in a home? How do we motivate a customer to consider energy efficiency upgrades—upgrades that will make his or her house more comfortable—before spending $10,000, or $20,000, or more on a PV system? And how do we know how much efficiency a given customer should implement before he or she invests in solar energy?

My company is in the business of creating profits by reducing the consumption of resources. Knowing

National Carbon per kWh Intensity

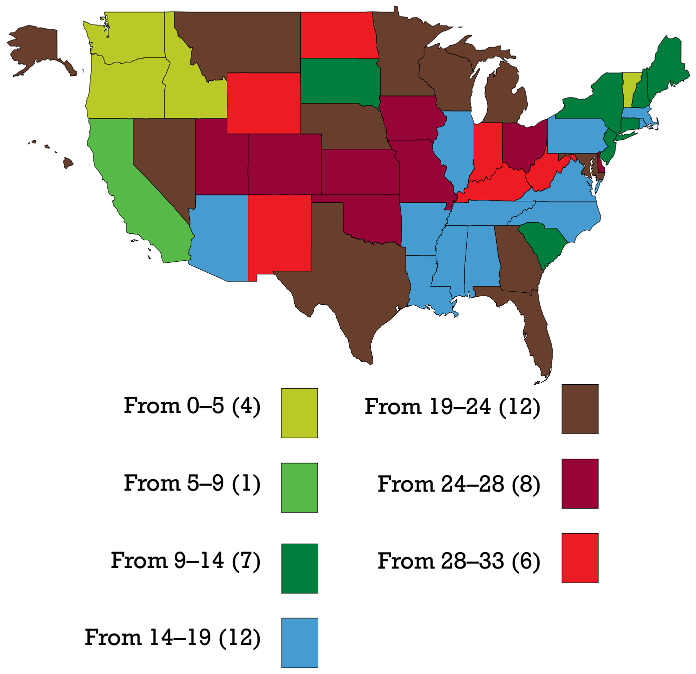


Figure 1. States that use electricity generated from hydropower or nuclear energy have a low CO_2 production per kilowatt-hour and are pictured above in green, while states that use electricity generated from burning coal have a higher CO_2 production—the red states.

how to answer the question, How much efficiency is best? is critical to earning the trust and respect of our customers. Sometimes we lose customers when we tell them things they don't like to hear, such as "You shouldn't put in a solar system because your house is really leaky and you should fix that first." To provide our customers with the best advice on ways to save energy and reduce their building's environmental impact, I researched how best to measure the carbon impact of the actions that we recommend. Here's how we make those calculations, and how other home performance companies can do the same.

Counting Carbon

To make these comparisons, we need clear and persuasive standards of measurement. Just how much carbon will it save to put the lid on the pot of heating water, or to refuse an ATM receipt? How do we get people to spend their precious time and money on the changes that will have the greatest carbon reduction impact for their investment? How do we calculate the carbon impact of installing an efficiency improvement, for example? And how does calculating carbon impacts change the decision-making process, especially with regard to home improvements? The best way to answer these questions is to calculate and compare the carbon impacts of conserving fuel, making home performance improvements, and installing PV panels.

Electricity and Carbon

To calculate the impact on carbon emissions of reducing the use of electricity in a given house, you need to know what type of fuel is used to produce electricity in that area. Different types of fuel produce different levels of CO_2. States that use electricity generated from hydropower or nuclear energy have a low CO_2 production per kilowatt-hour, while states that use electricity generated from burning coal have a higher CO_2 production. The state with the highest rate of CO_2 production, North Dakota, produces 74 times as much CO_2 per kilowatt-hour as the states with the lowest rates, Idaho and Vermont.

You can look at CO_2 production nationally, by region, by state, or by utility. I have chosen to look at average production by state, since policy that drives the development of new power plants is set at the state level. This information can be displayed geographically, with the green states being the ones with lower CO_2 production and the red states the ones with higher CO_2 production (see Figure 1).

Coal is an inexpensive, high-carbon source of energy for electricity. So it isn't surprising that, with a few exceptions, there is a strong correlation between the carbon impact of a state's fuel mix and the cost of energy there. A carbon tax will increase the cost of electricity the most in the high-carbon states—those that are shown in red in Figure 1.

Carbon Impacts of Heating Choices

To calculate the carbon impact of reducing the energy needed to heat a given house, you need once again to know what type of fuel is used to produce the heat. Different fossil fuels produce different amounts of CO_2 when burned (see Figure 2). The carbon impact is expressed in tons per 100 million British thermal units of energy load or delivered heat energy. The relative cost of the fuels per 100 million British thermal units of useful energy. Is also shown in Figure 2.

You can use Figure 2 to compare the carbon impact, and the effect on a homeowner's energy costs, of choosing different combinations of heating fuel and heating equipment. However, the case becomes complicated when it comes to using electricity for heating, since different fuels are used to generate electricity, and each of these fuels produces a different level of CO_2. Also, heat pump technologies can be used to enhance the heating output from electricity. The three columns in light blue represent the national average for CO_2 production per kilowatt-hour across the three types of electric heating system: electric-resistance or strip electricity, air source heat pumps, and ground source heat pumps.

In states with high CO_2 production per kilowatt-hour, strip heating produces roughly 5 times as much CO_2 per 100 million British thermal units of useful energy as a condensing gas furnace. But a ground source system in a state with low CO_2 production per kilowatt-hour produces half as much CO_2 as the condensing gas furnace. Move the ground source system into a high-CO_2 state and the ground source system produces 50% more CO_2 per 100 million British thermal units than the condensing gas furnace. The cost to the user of the energy produced by the ground source system is assumed to be the same across the three levels of CO_2 per kilowatt-hour, or roughly 60% of the cost of producing the same amount of energy with a condensing gas furnace, using the assumed cost per unit.

Ground source systems fare well in this analysis and will do even better if the electricity generation mix moves toward fuel sources that produce less CO_2, such as renewable energy and nuclear energy. But these systems cost more to install, and the cost per unit of energy will vary from state to state. When comparing these costs for a specific locale, the cost per 100 million British thermal units of useful energy should be adjusted for local energy costs.

Cost and Carbon Content of Heating Choices

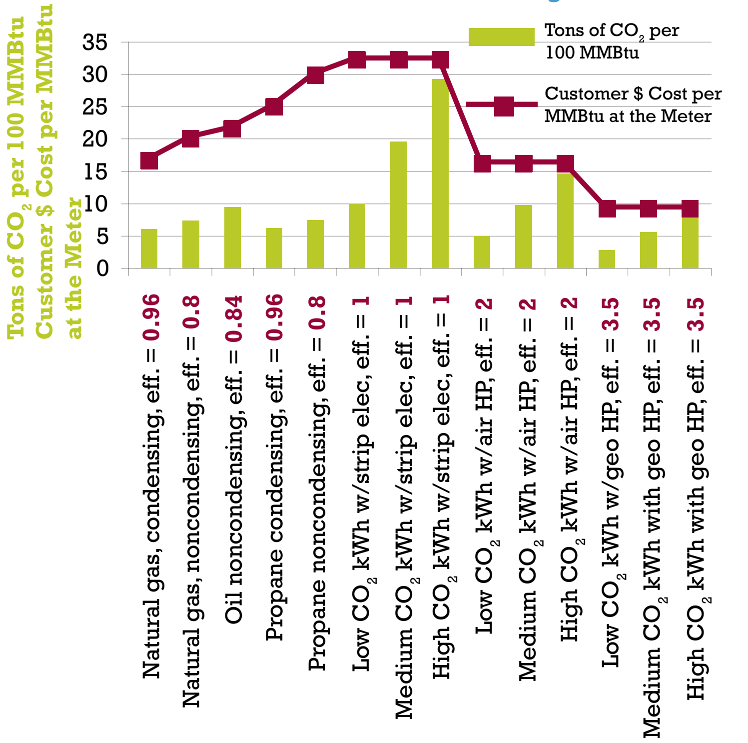


Figure 2. I compared the carbon impact, and the effect on a homeowner's energy costs, of choosing different combinations of heating fuel and heating equipment.

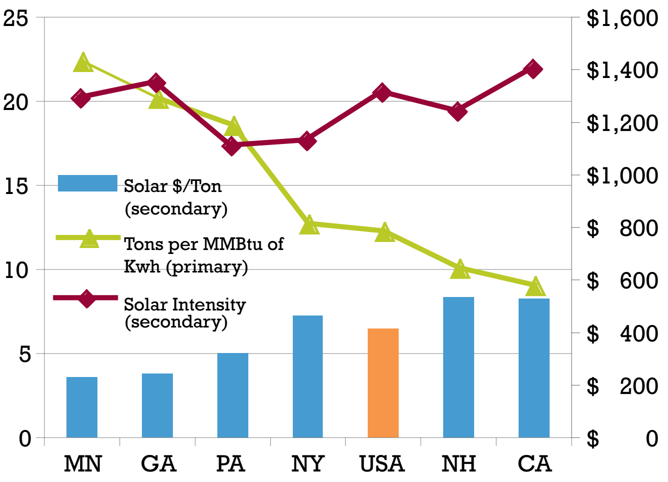


Figure 3. Solar intensity varies by state, which affects the cost-effectiveness of PV in avoiding carbon emissions.

Renewables

Cost-effectiveness and carbon-effectiveness work differently for energy efficiency than they do for solar energy. Saving energy starts out easy and cheap and gets more difficult and more expensive as you reduce the amount of energy being used. In other words, it's a case of diminishing returns. Solar energy works differently. Generating the first 10% is not any easier and cheaper than generating the next 10%. All you need to do is add more solar panels, and you will generate more energy, for roughly the same cost per panel added, until you run out of real estate to place panels. Solar energy scales up, and energy efficiency does not.

So how much does it cost to save a ton of carbon using PV panels, in different states? A couple of factors

KATHY GREELY

Jason Amory of Performance Systems Development ....
Pennsylvania Home Energy mentoring session.

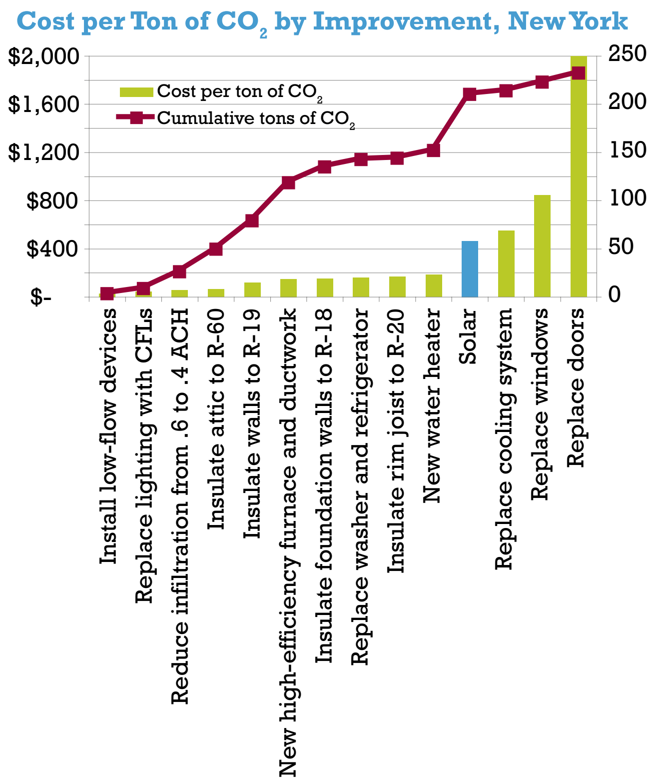


Figure 4. Here is the cost per ton of CO_2 savings produced by a range of improvements done to a typical poorly performing house in New York State.

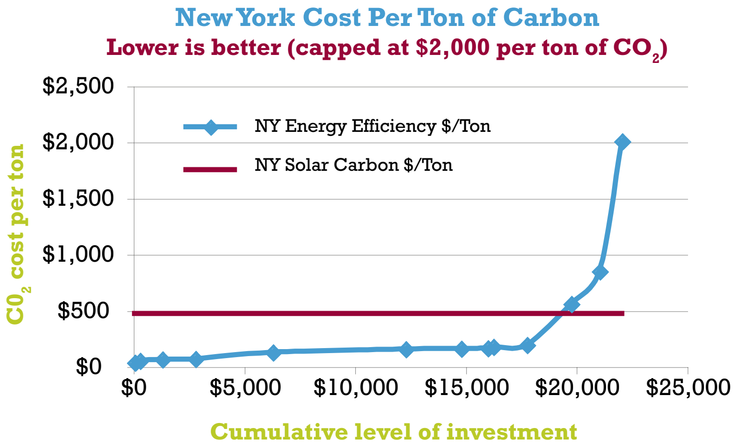
affect the cost-effectiveness of PV in avoiding carbon emissions. The first is solar intensity (see the red line ine Figure 3). Some areas get more sun over a year and therefore produce more solar-generated electricity from the same square footage of PV panel than places with less sun. A second factor is the fact that using PV reduces the use of utility-generated energy. This means that CO_2 emissions are likewise reduced, but they are reduced by different amounts in different states. These two regional factors combine with the cost of a typical solar installation (before incentives) to produce an average cost of saving 1 ton of carbon. If it costs $9,000 to install 1 kilowatt of solar panels, how much will it cost to save 1 ton of carbon by doing so, assuming a 40-year panel life?

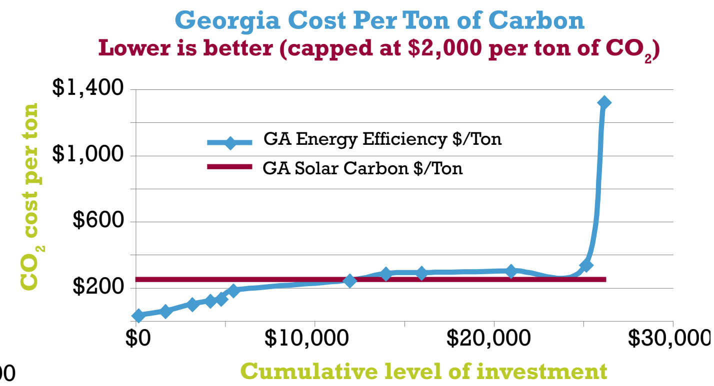
I calculated the answer to that question for six representative states, and I also calculated the national average (see Figure 3). PV output was calculated using the National Renewable Energy Laboratory's PVWATTS online calculator. Interestingly, the most expensive of the six states is California. California has so much nuclear- and hydro-produced electricity that it saves less carbon per solar kilowatt-hour than other states. The cost of saving a ton of carbon using solar energy in California is $527. In Minnesota, which uses a higher percentage of coal to produce its electricity, the cost is only $230 per ton. The national average cost, based on a midrange solar output from Nebraska and the national electricity generation mix, is $414 per ton. This calculation looks only at the societal cost—that is, this calculation does not include installation cost savings to the customer attributable to solar incentives.

Efficiency Improvements

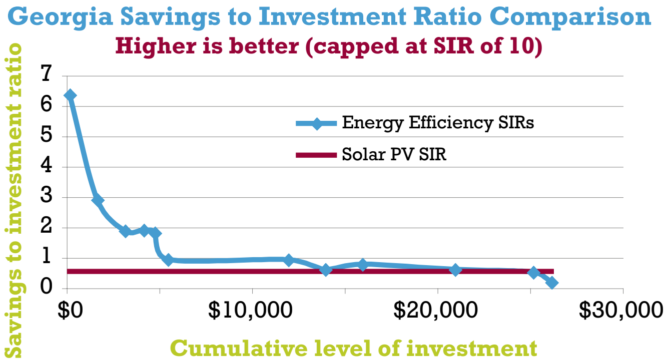
So what does efficiency cost per ton of carbon saved? Like the answers to most building science questions, the answer to this one is, It depends. It depends on the cost of the efficiency improvement and on the amount of avoided CO_2 emissions that results from the efficiency installation. And it depends on the climate and on the CO_2 production of the local electricity's fuel mix.

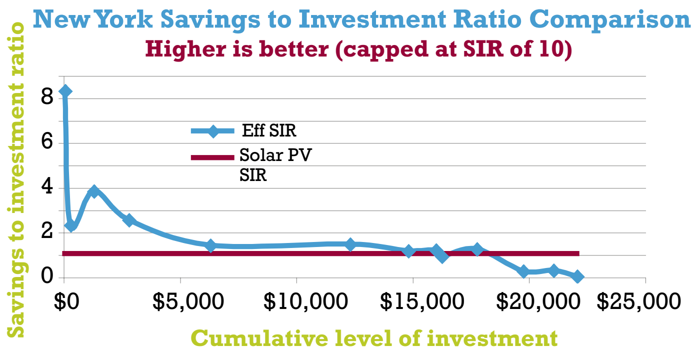
For example, let's look at the cost per ton of CO_2 savings produced by a range of improvements done to a typical poorly performing house in New York State (see Figure 4). The climate is that of upstate New York, and the impact of electricity improvements is based on





Figures 5 and 6. The crossover points for the poorly performing houses that I chose to model show how much could be invested in energy efficiency before saving carbon would be more cost-effective using PV.





Figures 8 and 9.

New York State's CO_2 per kilowatt-hour value.

In upstate New York, the cooling system replacement has a higher cost per ton than the solar installation. However, the solar panel does not cool the house in the summertime. This cost comparison would be different in a state with a higher CO_2 impact per kilowatt-hour, or with more need for cooling throughout the year. Upstate New York does get hot and humid during the summer, but our summers don't last that long.

Clearly, there are a number of improvements that will reduce CO_2 much more cost-effectively than installing PV. And, surprisingly to me, there are some efficiency improvements that will reduce CO_2 emissions less cost-effectively than PV, most notably window and door improvements.

Now let's compare the cost of saving carbon using a range of energy efficiency improvements for a relatively poorly performing home in New York (with ducts in the basement) with a similar home in Georgia (with ducts in the attic). See Figures 5 and 6. These curves were calculated using the TREAT software to calculate savings from a comprehensive set of efficiency improvements and a spreadsheet that converted energy savings by fuel type into reduced CO_2 emissions and calculated the carbon impact of installing PV panels.

Figures 5 and 6 show that for these poorly performing homes, the crossover points at which PV becomes more cost-effective varies from state to state. The crossover points for the poorly performing houses that I chose to model seem to range from $10,000 to $20,000—and that's how much could be invested in energy efficiency before saving carbon would be more cost-effective using PV. In general, in mild climates there is less carbon to be saved, and solar energy looks better faster, especially in states with a high CO_2 impact per kilowatt-hour. In cold states, more heating fuel is burned and therefore more CO_2 is produced that can be cost-effectively saved through efficiency improvements before solar becomes more cost-effective. The next most significant variable is the CO_2 impact of kilowatt-hour production. This raises and lowers the dollar per ton rate of solar energy more than the variation in solar availability does. A lower CO_2 impact per ton means a higher cost per ton for saving CO_2 with solar energy—and a more expensive crossover point at which PV becomes a better investment than efficiency.

Societal costs are not the only consideration. The incremental cost- effectiveness (as a ratio of the net present value of savings to the cost of the investment, or SIR) of improvements compared to the end user's cost of a solar installation, including current federal and local incentives, is an important factor in any homeowner's decision about making improvements. From this perspective, the economic crossover point where solar is a more cost-effective investment than efficiency is roughly $20,000 for Georgia and $17,000 for New York (see Figures 7 and 8). The variation in solar economics for the customer depends heavily on the subsidy available.

Knowledgeable Advice

We need to provide consumers with more information on sound ways to spend their money, not just on economic cost-effectiveness, but on the environmental impact of any efficiency improvements we might recommend. It is not enough simply to say, "Efficiency before solar"; we need to be able to say how much efficiency before solar. And we need to be able to provide homeowners with this information at the time when they are considering their investments. Our energy auditors should be able to perform solar assessments to determine the cost-effectiveness of PV. That does not necessarily mean installing PV panels, but it does mean being able to calculate the cost per ton of carbon saved by installing them. A customer should not be forced to call a different consultant just to calculate the impact of, and savings to be realized from, installing PV panels.

Of course, every customer needs to be reminded that home performance improvements do more than just save CO_2 emissions and dollars. They improve health, safety, and comfort; they even increase the life of the building. But being able to show just how big an impact home performance improvements have on the environment is extremely important. I hope that this article has provided you with guidance on making these calculations.

Greg Thomas is president/CEO of Performance Systems Development and Performance Systems Contracting. He lives in Ithaca, New York, and can be reached at gthomas@psdconsulting.com.