California Residential Retrofits

# TEN IMPORTANT LESSONS LEARNED

by **MARK BERMAN and VICKI MONGAN**

When Dale Stocking and his wife decided to undertake an energy efficiency retrofit of their 1939 Tudor-style home in Stockton, California, they knew they were at the forefront of a movement that could go a long way toward reducing the nation's energy consumption and lower its greenhouse gas emissions. A retired dentist and member of the city's Climate Action Plan Advisory Committee, Stocking understood the effect home retrofits could have on greenhouse gas reduction, and he also knew that he and his wife were among a select few homeowners who understood the connection.

## TAPPING the POTENTIAL

One reason so few homeowners share the Stockings' understanding is that incentive-driven energy efficiency retrofit programs are relatively new to the market. Consumers typically know very little about the installed products and measures, and little research had been done on how to market and run a residential retrofit program until DOE's Better Buildings Neighborhood Program (BBNP) was funded under the American Recovery and Reinvestment Act of 2009. (For more on the BBNP, see "Better Buildings Neighborhood Program," *HE* Sept/Oct '13, p. 14.)

Though awareness of the idea is low among homeowners, climatologists and energy-demand experts know that the more than 90 million single-family homes in America offer remarkable potential for reducing the country's energy use. In California alone, 55% of homes were built before energy efficiency measures were incorporated into building standards. Finding ways to generate interest and provide incentives strong enough to inspire homeowners who lack the Stockings' understanding are critical to realizing this latent potential.

Author Mark Berman is president at Davis Energy Group, a California consulting firm that specializes in energy efficiency. Davis Energy Group has been working on raising awareness of energy efficiency among homeowners for many years. Though the group has developed several innovative products and provided engineering expertise to utilities, government agencies, developers, and others, the firm's principals are aware that lack of consumer understanding of the benefits of energy efficiency creates a limited market.

## RESEARCH SPURS EVOLUTION

The other major stumbling block is financing. That became especially clear in 2010, when Davis Energy Group conducted two BBNP pilot projects in Los Angeles County and Sonoma County neighborhoods. Because many energy efficiency measures come with high price tags (such as replacing leaky ducts), few homeowners could afford the investment, especially in a down economy when home equity loans were seldom available to provide funding. Research done by Davis Energy Group and others has produced some valuable insights:

- Retrofit programs must include attractive financing options to increase affordability.

Efficiency upgrades on the Stockings' 1939 home reduced electricity use by approximately 17% and gas consumption by 14%. The Stockings also report that they appreciate the less-tangible benefits of increased comfort and quiet.

- The geographic area covered by a program must be broad enough to reach a volume of homeowners with the wherewithal—time, money, and interest—to undertake retrofits.
- Working with a large number of contractors makes administration difficult and creates confusion for busy homeowners tasked with choosing the best contractor to perform the work.
- Projects must be large enough and packages must be standardized to create the economies of scale needed to reduce equipment and material costs.

The California Energy Commission (CEC) supported this research by funding a pilot Large-Scale Residential Retrofit Program (LSRP) in the Stockton area. Davis Energy Group conducted the program, called the Energy Challenge, through a Public Interest Energy Research (PIER) grant. And DOE's Building America Program (BAP) has enabled Davis Energy Group to do additional research in this area as the leader of one of ten national BAP teams and the only California-based team. The LSRP had two goals. They were determining the most effective ways to motivate large numbers of homeowners to complete energy efficiency upgrades; and increasing the number of retrofits completed by lowering costs through economies of scale in marketing, procurement, and installation.

The program began with a 1,000-home neighborhood and was quickly expanded, first to all of Stockton and then to the entire San Joaquin County. Unlike the earlier pilots, the LSRP enabled Davis Energy Group to identify a single, well-qualified contractor— Green Home Solutions by Grupe (GHS). GHS had a solid reputation in the community and a professional sales force capable of carrying out the program. The company proved to be competent and enthusiastic, even offering to provide significant match funding before being named as a partner in the LSRP contract.

In 2012, two parallel paths converged. Through his work on Stockton's Climate Action Plan Advisory Committee, Dale Stocking heard about the LSRP and knew the program would need early adopters to lead by example. He also knew if he expected others to retrofit their homes, he must do the same, so he was among the first to sign up for a GHS retrofit. He also agreed to allow Davis Energy Group to use his home as a test case.

## DESIGNING INDIVIDUAL RETROFITS

Each LSRP project begins with a detailed home assessment that includes air leakage testing with a blower door, combustion safety testing, and a thermographic scan and takes several hours to complete. Homeowners see the results, along with recommended retrofit measures, approximate cost, and potential energy savings associated with each measure, in order of priority. The Stockings' two-story home proved to be a prime LSRP candidate. It had undergone some remodeling since it was built in 1939, but no energy efficiency upgrades. There were measures that would reduce both gas and electricity consumption, so the Stockings had to decide where to invest the project budget they had set.

"This was a very collaborative process," says Stocking. "We discussed the list of recommended measures and costs with Davis Energy Group and decided which ones made the most sense for the money we could spend."

Davis Energy Group and GHS discovered that the ability to choose from a menu of suggested measures is an important program feature. It allows homeowners with varying budgets to assess measure benefits and costs to make informed decisions. Decisions need to be made so measures are installed in the proper order, however. For example, if the energy assessment determines that the HVAC system should be upgraded, it is important to air seal and install insulation before sizing and installing a new HVAC system. Done the other way around, the HVAC system will cost more than necessary and won't run efficiently.

The Stockings decided to go with a deep retrofit that included more-costly upgrades, including replacing more than 30 metal frame, single-pane windows with vinyl frame, dual-pane windows. The Stockings also chose to replace their gas storage water heater with a condensing tankless water heater and to upgrade their 45-year-old HVAC with a two-speed 95% AFUE furnace and a 16 SEER/12 EER air conditioner, which necessitated asbestos removal. While the Stockings agreed to added insulation in the attic and under the raised floors, they chose not to add insulation to the lath-and-plaster exterior walls for cost and cosmetic reasons.

The Stockings' deep retrofit went well beyond the standard Energy Challenge package, but it allowed them to make changes that provided significant energy savings, while replacing aging equipment, reducing maintenance, increasing the home's quiet and comfort, and eliminating asbestos.

"We were able to take advantage of the CHF Residential Energy Retrofit Program that offered financing at just over 3% for 15 years on energy efficiency upgrades," says Stocking.

Table 1. Stockton House Installed Measures

| Measure | Original Building | Retrofit Measure | Installed Costs |
|---|---|---|---|
| **Thermal Envelope**<br>**Attic**<br>**Raised floor insulation**<br>**Glazing** | Vented, R-11<br>None<br>Metal/single pane U=1.28<br>SHGC=0.80 | Vented, R-49<br>R-19<br>Vinyl/Dual Pane U=0.30<br>SHGC=0.30 | $16,243 |
| **Asbestos Removal** | Ductwork | Removed | $2,014 |
| **Infiltration** | 5,850 $CFM_{50}$ | 2,500 $CFM_{50}$ | $1,754 |
| **HVAC System**<br>**Heating**<br>**A/C** | (45 yr old)<br>Natural-gas furnace AFUE=64%<br>8 SEER/7.7 EER<br>4.0 ton | Natural-gas 2-speed furnace<br>AFUE=95%<br>16 SEER/12 EER<br>4.0 ton installed | $ 8,192 |
| **Ductwork Insulation**<br>**Duct Leakage** | Crawl space R-2.1<br>Attic R-2.1<br>36% $CFM_{25}$ | Crawl space R-8<br>Attic R-8<br>12% $SFM_{25}$ | $ 4,238 |
| **Fresh-Air Ventilation** | Existing bath fan | Additional bath fan | $ 852 |
| **Water Heating** | 13-yr-old gas storage (0.62 EF) | Condensing tankless (0.96 EF) | $ 4,357 |
| **Lighting** | 100% CFL | 100% CFL | $ 350 |
| **Total** | | | $38,000 |
| **Available Incentives** | | | ($ 4,000) |
| **Net Cost** | | | $34,000 |

"We had known that replacing the furnace in a home built in 1939 would require asbestos removal, so this allowed us to finance that cost, as well."

The Stockings' deep retrofit allowed them to take advantage of low-interest funding available from the state at the time to make needed changes to their home (see Table 1 for a list of retrofit measures and costs).

## DEEP-RETROFIT PROS AND CONS

The Stocking home represents a high-end retrofit that falls outside most homeowner budgets, but it allowed the Stockings to gain benefits beyond energy savings. "Changing the 30-some windows gave us a cosmetic change with good aesthetics. And our home is quieter and much more comfortable than it was," says Stocking. "We didn't test the difference beforehand, but I believe the improved air conditioner and ductwork reduced the upstairs temperatures by about 10°F in the summer."

Winter also revealed some appreciated improvements. "We used to feel cold air seeping in when we sat on the couch in the den," Stocking adds, "and we could see condensation on the windows. The moisture caused the steel sashes to rust, so we had to repaint them every couple of years. We don't have any of those issues with the dual-pane vinyl windows."

The Stockings' deep retrofit went well beyond the standard Energy Challenge package, but it allowed them to make changes that provided significant energy savings, while replacing aging equipment, reducing maintenance, increasing the home's quiet and comfort, and eliminating asbestos.

There was one thing Stocking would have done differently. The original recommendations called for a 95% AFUE furnace, but Davis Energy Group suggested a two-stage furnace for greater efficiency. "Looking back, I would have chosen a less sophisticated furnace, which was a little like getting a Maserati to drive to the grocery store," says Stocking, quickly adding, "but that's Monday morning quarterbacking. We're delighted with the results."

Author Mark Berman agrees with Stocking. "I installed a two-stage furnace in my own house for the reasons we recommended it to Dale. This is what sometimes happens with new technology. While we still think the technology is great for areas that experience cold winters, it's more than we need for our temperate California climate, so we no longer recommend them."

Other than the furnace misstep, the Stockings' retrofit was a picture-perfect case study of success. To replicate that success in future programs, it's wise to break out the contributing factors:

- Dale Stocking was a highly educated consumer who had a thorough grasp of upgrade benefits.
- The Stockings were ideologically inspired, but they were also motivated by the desire to replace their old HVAC, water heater, and windows.
- Low-cost financing enabled the Stockings to make all the needed changes at once.
- Other benefits realized—greater comfort, less noise, improved aesthetics, faster hot-water delivery, better air quality—may have helped motivate the Stockings and could inspire other homeowners to retrofit their homes.
- Working with a single, highly capable contractor simplified the process for Davis Energy Group and the Stockings.
- Dale Stocking collected the utility bill data Davis Energy Group needed to measure results.

## INSIGHTS

At this writing, the Energy Challenge has produced over 200 residential retrofits. While that number represents a significant improvement over earlier programs, equally important are the insights gained from the Stockings and other homeowners. Each lesson learned helps to fine-tune future programs so that home retrofits will one day become commonplace.

### LESSON 1: Marketing Must Sell Sizzle and Steak

While the Stocking home offers good information about the retrofit process, Dale Stocking is an uncommonly savvy, environmentally conscious consumer with a solid grasp of the benefits energy efficiency retrofits offer. For the general population, lack of knowledge about energy efficiency upgrades presents a significant obstacle. To create desire, energy efficiency programs and retrofit contractors must give consumers a clear picture of what efficiency upgrades are and the benefits they offer. Overcoming this challenge will require a large and well-coordinated marketing campaign that could include television ads and other advertising and marketing initiatives that are beyond the budgets of local programs.

Understanding what truly motivates homeowners to sign up for a high-cost retrofit is also critical to marketing the programs effectively. Consumers don't buy granite countertops, swimming pools, luxury cars, or high-fashion clothing because those purchases will eventually pay for themselves. In fact, most expensive purchases are completely impractical. So while government agencies fund energy upgrade programs to reduce power demand and greenhouse gas emissions, it's unlikely that consumers perform upgrades for those reasons. Most upgrade program marketing materials tout saving energy and lowering utility bills as the primary incentives to sign up for retrofits, yet most upgrades cost thousands of dollars and take years to achieve payback. Performing additional market research to understand homeowner motivation could provide better consumer insight and increase response rates.

**Table 2. Sample of 10 Homes With Adequate Pre– and Post–Upgrade Data Installed Measures**

| Reference Household # | Attic Insulation | Building Leakage | HVAC Duct Leakage | HVAC Duct Insulation (R-Value) | Windows (U-Factor/ SHGC) | Domestic Hot Water Heater* | Wall Insulation | HVAC Upgrades or Changes | Total Cost† |
|---|---|---|---|---|---|---|---|---|---|
| 4 Upgrade | ✓ R-38 | | | | | | | | $535 |
| 10 Upgrade | ✓ R-38 | ✓ 6.7 SLA | ✓ 9% | ✓ 6 | | ✓ GF, 50-gal, 0.62 EF | | | $9,785 |
| 11 Upgrade | ✓ R-38 | ✓ 5.9 SLA | ✓ 9% | ✓ 6 | | ✓ GF, 50-gal, 0.62 EF | | | $10,150 |
| 14 Upgrade | ✓ R-38 | ✓ 4.4 SLA | ✓ 13% | | ✓ 0.3/0.3 | ✓ GF, 50-gal, 0.62 EF | | | $15,875 |
| 15 Upgrade | ✓ R-38 | | ✓ 6% | ✓ 6 | ✓ 0.3/0.3 | ✓ GF, 50-gal, 0.62 EF | | | $17,227 |
| 16 Upgrade | ✓ R-38 | | ✓ 12% | | ✓ 0.3/0.3 | ✓ GF, 50-gal, 0.62 EF | | ✓ AFUE 80%, SEER 13/ EER 12 | $21,275 |
| 17 Upgrade | ✓ R-38 | | ✓ 12% | | | ✓ GF, 50-gal, 0.62 EF | ✓ R-13 Wall | | $11,270 |
| 18 Upgrade | ✓ R-38 | ✓ 4.0 SLA | ✓ 6% | ✓ 6 | ✓ 0.3/0.3 | ✓ GF, 50-gal, 0.62 EF | | ✓ AFUE 80%, SEER 13/ EER 12 | $29,035 |
| 37 Upgrade | ✓ R-38 | | ✓ 3% | ✓ 6 | | | ✓ R-13 Wall | ✓ AFUE 80%, SEER 13/ EER 12 | $14,750 |
| 44 Upgrade | ✓ R-38 | | ✓ 6% | | | ✓ GF, 50-gal, 0.9 EF | | ✓ AFUE 95%, SEER 16/ EER 14 | $27,730 |

* Gas-fired, 50-gal, energy factor tank-type water heater. The minimum federal standard is 0.62 EF.
† Total contract amount

**Table 3. Sample of 10 Homes Pre– and Post–Upgrade Energy Use**

| | Annual Electricity Usage Normalized to TMY3 [kWh] | | | Annual Natural Gas Usage Normalized to TMY3 [kWh] | | |
|---|---|---|---|---|---|---|
| Reference Household # | Pre | Post | Savings | Pre | Post | Savings |
| 4 | 5,562 | 4,998 | 10.1% | 860 | 803 | 6.5% |
| 10 | 11,218 | 4,420 | 60.6% | 601 | 557 | 7.3% |
| 11 | 11,452 | 10,943 | 4.4% | 311 | 302 | 3% |
| 14 | 8,361 | 7,258 | 13.2% | 721 | 553 | 23.4% |
| 15 | 16,361 | 15,562 | 4.9% | 563 | 550 | 2.4% |
| 16 | 8,625 | 7,072 | 18% | 449 | 352 | 21.8% |
| 17 | 8,964 | 9,842 | -9.8% | 767 | 571 | 25.5% |
| 18 | 6,433 | 6,499 | -1% | 274 | 312 | -14.1% |
| 37 | 4, 924 | 3, 894 | 20.9% | 145 | 288 | -99. 3% |
| 44 | 13,992 | 12,503 | 10.6% | 506 | 349 | 30.9% |
| **Average** | **9,589** | **8,299** | **13.5%** | **520** | **464** | **10.8%** |

### LESSON 2: Extensive Home Assessments May Not Be Needed

One project discovery was that homes of similar style tend to benefit from similar energy efficiency measures. Each Energy Challenge project began with a home assessment that took several hours, but similarities in climate and construction brought many projects to the same basic package. The similarities of recommendations call into question the need for the complex, time-consuming assessments. It also speaks to the newness of

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home retrofits—most homes are missing the basics, which are

- air sealing;
- duct sealing;
- attic insulation;
- storage water heater insulation jacket;
- HVAC tune-up with a refrigerant charge check;
- condenser cleaning; and
- energy-efficient light bulbs (such as LEDs).

The total cost for the base package listed above is approximately $7,300 less $2,750 in incentives (amounts may vary), making the installed cost about $4,550. Variations at the deeper level depended largely on the age of the home and equipment—for example, the age of the windows, water heater, or HVAC. Because the program allowed customers a menu of recommended measures, actual upgrades varied considerably, resulting in a wide range of gas and electricity savings. Following a four-to-five-hour assessment that included a blower door test, combustion testing, and thermographic scan, homeowners received a list of suggested upgrades with costs and projected energy savings for each measure. This menu-driven system allowed homeowners to design upgrade packages that matched their needs and budgets. Of course, actual energy savings are quite variable, depending upon occupant behavior patterns before and after the upgrade.

See Table 2 for a sample of ten homes with actual and post-upgrade energy use data.

Results indicate that tightening the thermal envelope alone produced the greatest reductions in gas and electricity use. Homes 18 and 37 increased their gas consumption when new HVACs were installed, which may be attributed to take-back—that is, homeowners who avoided running old air conditioners or furnaces because of the cost, noise, or inadequate performance may have increased their use after new systems were installed. See Table 3 for the ten sample homes' before and after energy use.

### LESSON 3: Simple Solutions Yield Greatest Results, But …

Another important discovery was that tightening the envelope without making any changes to HVAC systems produced significant energy savings. In the Stocking home, estimates show that the base package generated 9% site energy savings over prior utility bills, with the deep-retrofit measures gaining an additional 19% in site energy savings. However, the Stockings also solved the problems presented by asbestos, aging equipment, and high-maintenance windows, while increasing comfort and resale value. So while simpler, lower-cost measures such as sealing leaks and adding insulation provide cost-effective benefits, the benefits realized from deeper retrofits may provide important incentives that spur homeowners to action. More study on different packages could shed additional light on homeowner motivation.

### LESSON 4: The Take-Back Question Requires Further Study

Upgrading HVAC systems does not necessarily lower energy consumption and might even increase it. Efficient HVAC systems can create take-back, when occupants nullify the energy benefits of a new system by using it more or differently than they did an old system that didn't function well or was expensive to operate. In addition, occupants may have compensated for the old gas furnace by using electric-resistance space heating. When the new furnace eliminates the need for space heating, electricity use will drop and gas consumption will rise.

More study is needed to understand the causes and effects of take-back, including looking at how occupants are using electricity for space heating and how they are programming or setting thermostats before and after the retrofits. Other research questions might include analyzing before and after air quality and occupants' perceptions of comfort.

### LESSON 5: Financing Matters

As discussed earlier, the high cost of retrofit measures puts them out of the reach of many homeowners. Lost-cost financing helps them bridge the gap, as in the case of the Stockings. According to Dale Stocking, the low-cost financing available under the CHF Residential Energy Retrofit Program made the deep retrofit possible. Going forward, it seems clear that filling the financing need is critical to the success of any retrofit program.

### LESSON 6: Phased Approaches Should Be Expanded

Current programs encourage homeowners to sign up once for an upgrade. While they can select from a menu of choices, they cannot easily choose to do some now and others later under the same program. Given the high cost of upgrade measures, an approach likely to yield better results would be to allow homeowners to lay out road maps of upgrades that they can complete over time.

### LESSON 7: Data Gaps Exist That Need to Be Closed

Measuring energy savings after retrofits provides critical data for future work, quality control, and consumer satisfaction. And when it comes to data quality, postretrofit utility bills provide the only true measure of upgrade success. However, obtaining utility data proved challenging, even when homeowners gave utility companies permission to release the information. Because energy use can reveal personal information and habits, utility companies have very real concerns about sharing customer billing information. In addition, utility billing systems were not set up to share data with outside parties in ways that allow legitimate analysis while protecting personal information. In California, solving this challenge will likely require the California Public Utility Commission to get involved, so that investor-owned utilities can allocate sufficient ratepayer resources to accomplish this task.

Dale Stocking put together and maintained a spreadsheet to provide Davis Energy Group with information gathered from his utility bills. (See Figures 1 and 2 for the Stockings' postretrofit utility data.) Such commitment cannot be expected from average consumers, so a system that routinely pulls data directly from the utility company is needed to assess upgrade effectiveness.

**Electricity Comparison (Utility Bills)**

Figure 1. The Stockings' electricity use before and after retrofit.

**Natural Gas Comparison (Utility Bills)**

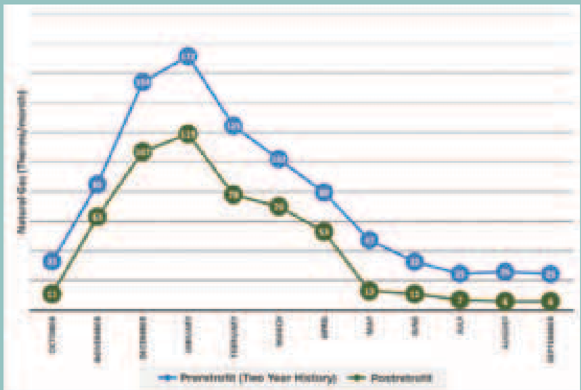

Figure 2. The Stockings' natural gas use before and after retrofit.

### LESSON 8: Program Operations Need to Be Streamlined

All residential retrofit programs should operate on the same project management and record-keeping platform, rather than requiring each program to develop its own. While Davis Energy Group was able to put together a system for energy assessments and upgrades, the homegrown model was expensive and proved laborious to contractors and others that had to upload information into the system. Limited time and resources prevented Davis Energy Group from creating a simplified system that incorporated postupgrade results.

### LESSON 9: Sales Professionals Increase Results

The Stockton project and one in Palmdale were much more successful than earlier BBNP projects where the contractors did not all employ professional sales staff. A well-trained professional sales team working one-on-one with each homeowner makes a big difference when consumers know very little about retrofits.

### LESSON 10: Economies of Scale Must Be Achieved

Cost is undoubtedly the greatest impediment to program uptake, which makes cost reduction imperative. Creating economies of scale in purchasing materials and equipment is the most obvious way to lower costs. But reaching a large enough scale is difficult when programs are new, upgrade packages are not standardized, or the programs cover too small a geographic area. Standardizing upgrade measures according to house style and a few other parameters is one way to increase volume. Negotiating volume pricing with manufacturers is another. Employing these approaches would help achieve the economies of scale needed to make upgrade costs attractive.

## CONCLUSION

The potential for reducing energy consumption and greenhouse gas emissions through retrofitting existing housing stock offers ample incentive to continue researching and refining efficiency upgrade programs. The work performed to date offers considerable insight into residential retrofits—what works, what doesn't, what can be adjusted to improve performance, what areas require further research, and what people want. It will take more work and continued funding to create a broad and successful residential energy efficiency retrofit program, but those investments will provide ample returns in the form of increased comfort, health, greenhouse gas reductions, and reduced energy demand for decades to come.

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For more information about Davis Energy Group, go to www.davisenergy.com.

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