# Deep Energy Retrofits - Reducing Costs and Increasing Cost-Effectiveness

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This document begins by providing suggestions for controlling deep retrofit costs and increasing cost-effectiveness, including both Do's and Don'ts. This is followed by a brief discussion of the larger context for thinking about the economic value of deep energy retrofits. Finally, estimates are provided (based on actual U.S. projects) of average DER project costs, energy cost savings and cost-effectiveness.

## Guidance for reducing costs and increasing cost-effectiveness

DERs will be most cost-effective for developers or home owners when the costs are financed, and the monthly utility bill savings can be used to offset monthly loan increases. Ideally, the improvements are aligned with existing equipment replacement, maintenance and remodeling activities. This means that deep retrofit measures are incrementally added to other remodeling activities that were already planned to occur. When properly balanced, the annual energy cost savings can equal or exceed the annual loan costs—these are referred to as having neutral net-monthly costs. A number of studies have used building energy simulations to generate optimal cost-neutral DER packages, which can be useful for reference (Fairey & Parker, 2012; Polly et al., 2011), but their results are highly dependent on assumptions for the pre-retrofit home, interest rates, loan terms, discount rates, etc. Building energy professionals can use BEopt (free energy simulation software developed by Building America program) to generate a cost-optimized retrofit solution based on a specific project, if desired.

As a rough guide, DER designers can use the table below to estimate how much annual utility bill savings are required to have neutral net-monthly costs, when the project is financed for a 30-year term at various interest rates and loan amounts. This approach does not tell project teams what specific upgrades to do, but rather provides a very basic financial structure for project planning. For example, if you are targeting a $1,100 annual cost reduction, and you are targeting net-neutral monthly costs, then your target energy upgrade costs should not be more than ~$20,000, depending on available interest rates. This is not intended to be a precise guide for project cost planning, but rather to provide a gut-check for the overall feasibility of a cost-effective DER in any given scenario.

| Interest Rate | Energy Upgrade Costs ($) | | | | | |
|---|---|---|---|---|---|---|
| | $5,000 | $10,000 | $15,000 | $20,000 | $50,000 | $100,000 |
| | Required Annual Savings for Neutral Net-Costs | | | | | |
| **3.0%** | $204 | $408 | $612 | $817 | $2,041 | $4,083 |
| **3.5%** | $221 | $442 | $663 | $884 | $2,211 | $4,421 |
| **4.0%** | $239 | $477 | $716 | $954 | $2,386 | $4,771 |
| **4.5%** | $257 | $513 | $770 | $1,026 | $2,566 | $5,132 |
| **5.0%** | $275 | $550 | $826 | $1,101 | $2,752 | $5,503 |

**Table 1 Quick guide to determining the necessary energy cost savings for a cost-neutral retrofit, for a variety of project costs and interest rates. This table assumes a 30-year loan term, no down payment and a 25% mortgage interest deduction.**

The following guidance is based upon the most and least cost-effective projects in a review of U.S. DERs (Less & Walker, 2014).

- **The most cost-effective projects were** generally in poor condition with little or no insulation and had low-efficiency equipment throughout. They also generally had higher than average utility bill savings, and in one case, heating energy made up a large majority (~75%) of annual energy costs. These homes had lots of potential, high utility bills, and generally did not pursue extremely expensive retrofits.
- **The least cost-effective projects were** generally very-aggressive, super-insulation retrofits, but they also had lower pre-retrofit energy bills, and in some cases pre-retrofit conditions were better than average (i.e., considered insulated but not to DER levels, had double pane windows, with modern HVAC equipment, etc.). In combination, these factors led to low overall cost-effectiveness. It should be noted that these projects are not be seen as "failures", because cost-effectiveness may not have been a project goal.

## What works well for cost-effective DERs?

- Begin by **comprehensively addressing low- and no-cost efficiency solutions**, such as behavior, controls, window operation, lighting, hot water fixture upgrades, etc.
- **Select simple, off-the-shelf, high-efficiency systems**. In addition to lower up-front costs, this also makes it much easier to find capable suppliers, installers and service providers.
- When facing decisions among equivalent strategies/products, **select the lower-cost options** (e.g., blown cellulose versus spray polyurethane foam, air-source mini-split heat pump versus ground-source heat pump). The perceived benefits of the higher-costs alternatives rarely lead to substantially better energy performance.
- **Target homes with high pre-retrofit energy use and costs**.
- **Target homes that lack intermediary efficiency measures** (e.g., single-pane window homes versus existing double-pane windows, uninsulated walls versus those you think are "poorly" insulated, existing SEER 8 A/C versus existing SEER 13).

- **Target existing remodeling projects and equipment replacement** for incremental DER measures. These projects will typically already be engaging design and construction professionals, as well as code officials, and the added DER energy upgrade measures are reduced in cost. For example, if replacing a furnace or air conditioner, use the highest efficiency model, as the additional cost of a high efficiency unit are typically justified relative to a code-minimum unit. Or when re-siding a home, install insulation in the wall cavity and consider exterior continuous insulation, as the cost of the re-siding is already being spent.
- **Address all building systems and end-uses** without an obsessive focus on any one use (e.g., space heating). For example, during an aggressive envelope upgrade, very low-cost improvements, such as upgraded lighting, appliances, low-flow hot water fixtures, or plug-controls can often be overlooked.
- **Engage the home occupants** (if willing and available) early and often in the planning process. How the home is used and what owners expect will provide strong insight into where investments are appropriate and what outcomes are desirable and reasonable. This engagement also provides opportunities to better match outcomes to owner expectations.
- **Be sure to assess the impacts of DER measures on energy costs**, rather than relying solely on site energy reductions. Some improvements (e.g., heat pumps) can increase the use of more costly energy sources, while appearing to provide site energy reductions.
- Where applicable, **aggressively target peak load reductions**, so as to avoid increased electricity rates at those times. This includes passive measures, such as solar shading and selective glazing applications for different faces of the home, or HVAC controls that pre-cool a home prior to the peak period.
- If a cost-effective retrofit is desired, it is useful to **have estimates of pre-retrofit energy costs**, so as to provide some sense of what possible gains can be provided by the efficiency measures. Pre-retrofit billing data from the home is best, but other estimates could be from regional averages, simulations, or the occupants' current usage (if in another property), adjusted for home size if applicable. For example, if the current usage (or estimated pre-usage) is $1,100 per year, then a retrofit >$15,000 is not likely to be cost-effective, based on cash-flow alone (see table above).

## What are the problems to look out for in cost-effective DERs?

- **Avoid custom-engineered, complex systems**. Rarely do these perform as intended/expected/advertised, and commissioning, repairs and maintenance can become highly burdensome, as can simply identifying a contractor who is capable of working on the system.
- **Budget for unanticipated needs.** These emerge in all projects, and these contingencies need to be both accommodated and budgeted for. Identify potential contingencies and unknowns, and then attempt to develop plans for dealing with these. Or prioritize the various elements of a project early on, so that trade-offs can be made in an informed and careful manner.
- **Be flexible about performance targets.** Be wary of aggressive performance targets that mandate precise levels of performance, and which may lead a project down a high-cost path. It has been demonstrated that many paths to successful deep retrofits are available, and there is no one-size-fits-all approach that will guarantee either success or failure in every circumstance.
- **Beware the perceived performance benefit of higher cost systems and strategies.** For example, while spray foam (SPF) insulation is costly, it is often seen as the best way to establish an air barrier. Nevertheless, SPF provided no benefits in terms of airtightness relative to other air sealing strategies in a community of DERs in Massachusetts and Rhode Island.

- **Be aware that the addition of energy consuming features** is common in a DER project, and these have the potential to offset savings or even increase usage, most commonly of electricity.
- **Fuel switching** from gas to electricity may seem to provide great site energy savings, but energy costs may increase, because electricity is on average three to four times more expensive than natural gas per unit of delivered energy (and it also often has higher carbon emissions).
- **Homes with low pre-retrofit utility bills do not have as much potential for cost-effective savings**. There may be other reasons to deeply retrofit these properties, but strong cost-effectiveness should not be anticipated, unless project costs are kept on the lower end.

## The context for DER costs and cost-effectiveness

A number of DER research reports have reflected on the poor cost-effectiveness of DER homes (Boudreaux, Hendrick, Christian, & Jackson, 2012; Chandra et al., 2012), while others have aggressively targeted and achieved traditional cost-effectiveness (McIlvaine, Sutherland, Schleith, & Chandra, 2010). It is also clear that reasons other than utility bill savings motivate many DERs and home energy upgrades (Boudreaux et al., 2012; Fuller et al., 2010; Neuhauser, 2012). Furthermore, developer driven DERs (such as in low-income housing and redevelopment projects) may have very different goals and approaches to economic value. Either way, high project costs and questionable cost-effectiveness are often seen as some of the most important barriers to widespread DERs. Yet, reported project costs for U.S. DERs are similar in magnitude to those reported every year by tens of thousands of Americans for conventional home renovation activities (Less & Walker, 2014). Clearly, there is a subset of the U.S. population who have the financial resources to deeply retrofit their home.

There is a traditional view of cost-effectiveness that tabulates all project costs and balances them against only some of the project benefits. But the value of a DER greatly exceeds the traditional balance between design/construction costs and energy cost savings. DERs are financially and socially justified due to a combination of utility bill savings and non-energy benefits (NEBs) (e.g., increased home value, economic stimulation, and improved comfort, convenience, disaster resistance, IAQ and durability, as well as lower maintenance).

These additional benefits are real. Research by economists on standard renovations and other home efficiency upgrades (e.g., solar PV and efficiency certification) suggests that DER costs may be at least partially recouped by homeowners through increases in their property value (Dastrup, Zivin, Costa, & Kahn, 2012; Kok & Kahn, 2012). Similarly, assessments of the economic value of home energy upgrades have estimated that the value of non-energy benefits ranges from 50% to 300% of the utility bill savings (Amann, 2006; Imbierowicz & Skumatz, 2004; Knight, Lutzenhiser, & Lutzenhiser, 2006). When properly accounted for and marketed, these can all contribute significantly to the desirability of DERs and to the building owner's willingness to invest in the home.

## Actual project costs, savings and cost-effectiveness for U.S. DERs

While motivations and the need for cost-effectiveness (traditional or more nuanced, as discussed above) will vary by project and by developer type, it is a rare project where money is totally disregarded and where controlling costs is not seen as beneficial. Below we provide average estimates of DER project costs, average energy cost savings, and the cost-effectiveness of DERs based on 30-year financing. These should provide some context for those beginning on the DER path.

An LBNL review of U.S. DERs suggests that an average project will cost approximately $40,000 ($22 per $ft^2$) (Less & Walker, 2014). There was lots of variability in project costs, which was driven by mostly by project scope, performance targets and choices in materials and technologies. Total project costs were always greater than those costs associated with energy efficiency improvements, because DERs nearly all included other home upgrades, including new finishes, deferred maintenance, and overall repairs. Energy measure costs varied from 25% to 75% of the total costs in the few cases where this level of detail was provided (Gates & Neuhauser, 2014; Keesee, 2012; McIlvaine et al., 2010). Projects in cold climate regions were more expensive on average, because they often targeted extreme airtightness (<2 $ACH_{50}$) and super-insulated envelopes. Most projects in more mild climates had overall lower average costs, but very aggressive projects in these mild climates also had high costs. Costs were lowest in hot-humid projects, where performance targets were generally lowest.

Utility bill savings averaged $1,300 per year in U.S. DERs, with little variability with climate. Energy costs in pre-retrofit homes in the review were slightly above average for the U.S., and post-retrofit bills were approximately 30% below the U.S. average. Notably, some aggressive retrofits were documented in low-usage homes and energy cost savings were low. Presumably these projects were driven not by a desire for cost-effective improvement, but rather by the common desire, noted above, to update the home, increase comfort, durability, etc.

On average, the U.S. DERs were cash-flow neutral on a monthly basis. However, variability was large, with some projects substantially reducing net-monthly costs and others substantially increasing net-costs.

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