# Deep Energy Retrofits - Design and Construction Process

*Brennan Less & Iain Walker, 2015*
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Deep retrofit projects (DERs) have different phases, and how each phase is managed can impact the success of a project. Phases include: pre-planning, planning, construction, test-out and post-occupancy. Detailed guidance is provided for each phase below. Notably, we do not cover all of the major variations in project phases or types. For example, major distinctions in opportunities and limitations may exist between projects in homes that are occupied during renovations versus those that are empty. Or between those that are homeowner driven versus developer driven. Or those that are comprehensive renovations versus focused home performance upgrades. Furthermore, for projects not using an all-at-once approach, guidance and suggestions for over-time/phased DERs can be found here. Process guidance and suggestions provided below should be applied flexibly to projects depending on their needs, scope and the experience of those involved. We recommend reviewing some of the useful planning documents provided by the Thousand Home Challenge.

## Pre-Planning Phase

The first step of a Deep Energy Retrofit is to **establish and clarify the project needs, opportunities, goals and objectives.** This will influence the overall scope of the project, as well as the strategies used throughout. Carefully assess the occupants' needs, desires and priorities (find a useful priorities planning tool here). Determine if the project will occur all-at-once or over-time, and decide if the home will be occupied during renovation activities. Also assess the existing performance of the home, and then tailor a retrofit plan based on these assessments. Find more on occupants and DERs here. This pre-planning phase may be best carried out by a home energy professional, with the experience necessary to inspect the home and help to develop performance baselines and overall project direction/strategy.

### Establish a performance baseline

**Perform home inspection and energy audit.** Assess existing condition of the home, including all major systems. Perform building diagnostic tests to quantify air leakage, duct leakage, ventilation airflows, and HVAC system performance, where appropriate. Create specific performance targets for each test that will be achieved during retrofit and can be used to verify contractor performance. Note, not all projects need to measure of all these systems. Prioritize those diagnostic tests needed to obtain information that will impact project decisions. For example, it is not strictly necessary to test duct leakage if the project plan is to eliminate forced air ducts (but such testing may be useful in energy modeling and establishing an energy baseline, if desired).

**Identify *Healthy Homes* health and safety issues** that can be solved during retrofit, such as gas or water leaks, radon intrusion, improperly vented heating appliances, moisture or pest damage, lead paint, asbestos, structural inadequacy, etc. Identify paths to solving any issues, which can include either fixing a faulty gas appliance exhaust duct or eliminating the appliance entirely. For a useful tool in planning how to address Healthy Homes issues click here. For more detailed guidance on addressing health and safety issues, refer to the U.S. EPAs Healthy Indoor Environment Protocols for Home Energy Upgrades.

**Establish energy baseline using utility bill analysis**, preferably with minimum 12-month duration. Depending on fuel type, estimate heating, hot water, cooling and other energy categories. If bills are unavailable, a consumption or performance target may be more appropriate (see Figure 2 below). Also consider performing an electricity audit for miscellaneous devices in the home (find a useful tool here). Use a plug-in electrical meter to estimate use of appliances, entertainment centers, computers/peripherals, etc.

## Develop project goals and performance metrics

**Establish an annual performance target or energy reduction goal.** Setting specific goals for a project unites the project team, and ensures that priorities are clear to all parties. Many DER research efforts and programs have begun to prefer specifying a post-retrofit target, rather than reductions. This is because pre-retrofit data is often unavailable, and the assessment of reductions is often confused by changes in floor area, occupancy, and building services. In these cases, *Consumption Targets* or *Performance Targets* are appropriate (see Figure 2 below for examples of these goal types). If pre-retrofit energy use is either known (from utility bills) or estimated by simulation, then *% Reduction* and *Absolute Reduction* targets can be used, potentially in-addition to consumption/performance targets.

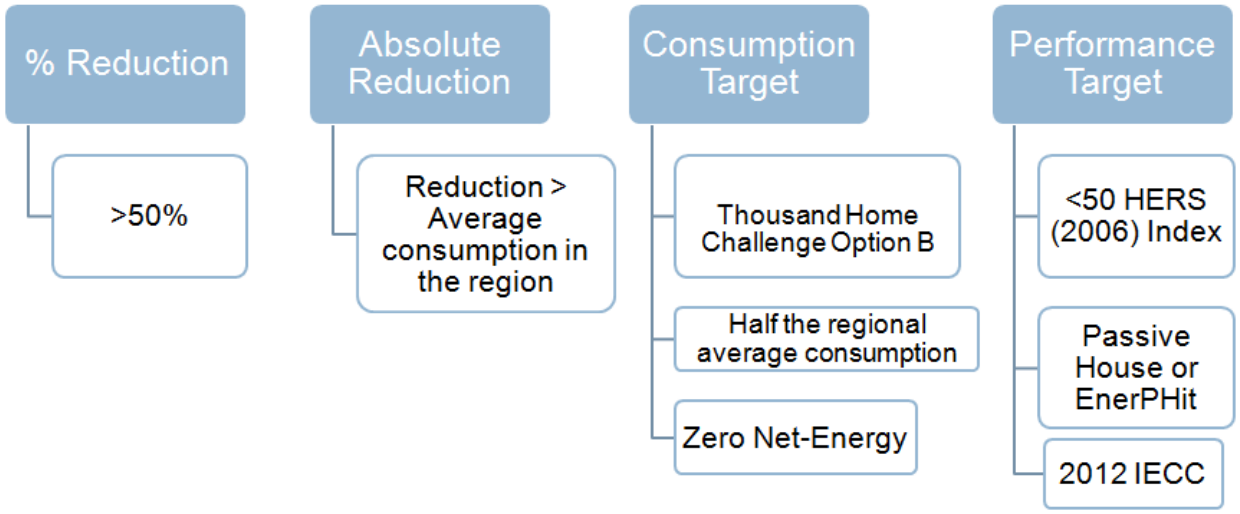


Figure 2 Example definitions of DERs that can be used in project planning and assessment.

**Establish metrics to be used in assessing progress towards project goals**. The metric used to assess performance will drive the results. In the case, of performance targets, fulfillment of some 3rd party standard is an appropriate metric. All metrics are useful in some way, but the appropriate metric to use in a given case depends on project priorities and who(m) is responsible for the retrofits (i.e., homeowner vs. utility). Nevertheless, for energy-based goals, we recommend:

- **Whole house assessment**, rather than floor area normalization.
- **Site energy**, if fuel sources are not changing for heating end-uses and if substantial additional energy using features are not added.

- **Source energy and/or carbon emissions**, if fuel sources are changing and/or end-uses are being added. See our Source Energy and Carbon guidance.
- Warning, the HERS rating methods will not adequately reflect whole house energy and environmental performance when the project includes occupant behavior modification, changes in floor area or fuel mix, or innovative strategies/technologies that cannot be modeled in HERS software.
    - In these cases, we recommend that alternative modeling and assessment methods be used in addition to HERS assessments.

**Establish non-energy goals of the project**, including improvements in aesthetics, comfort, disaster resistance, water efficiency, IAQ, health, durability, structural integrity, home resale value, accessibility, etc. It is also essential to determine if traditional cost-effectiveness is a project goal. Metrics are also important for assessing achievement of non-energy goals. These can be informally assessed by occupants/designers, or here are some specific examples:

- IAQ - ASHRAE Standard 62.2-2013 compliance
- Environmental Health – Use of the Healthy Indoor Environment Protocols for Home Energy Upgrades
- Comfort - ASHRAE Standard 55
- Accessibility - Use of Certified Aging-In-Place Specialist
- Cost-effectiveness - positive monthly cash-flow when energy upgrades are financed
- Structural integrity – compliance with current seismic guidance or local requirements
- Water efficiency – U.S. EPA WaterSense certification

## Project Planning Phase

### The design team

**Assemble qualified and trusted team.** A DER team will likely include an energy consultant/home performance professional, a contractor, engineers and a designer, though the composition of the project team can depend heavily on the project scope and goals. Project costs may be reduced by not hiring an extensive team. Some high performance homes contractors provide much of this varied expertise in-house, and our guidance is an attempt to convey some expert knowledge which is otherwise only available from consultants and other for-hire experts. Smaller teams may be ideal for projects that do not include major general remodeling, structural improvements and architectural design. Ideally, the chosen professionals will have knowledge and experience in energy efficient construction techniques and building science principles. Team members should read this guidance, so that they all have some basic background as to the goals and methods of DERs. Strategies:

- Hire the best professionals you can find locally.
- Avoid lowest-bidder mentality. Inexperienced construction professionals were repeatedly noted as limitations in DER projects.

### Planning approaches

**Plan all aspects of the project as if it were new construction**. Be as thorough as possible. Do not leave major decisions to the last minute, where cost, lead-times and convenience can result in bad decisions. But be aware that projects in existing homes always have surprises (e.g., hidden moisture damage, radon infiltration, structural problems), which requires flexibility and an openness to changes in the project and recalibration if necessary. Careful attention to detail by team members through all phases of design and construction is essential for successful implementation.

**Systems integrated approaches** allow for creative problem solving and synergistic measures. For example, existing duct work can often be extensively air sealed, or can be brought inside the building envelope, or could be eliminated entirely.
**Design to the energy reduction goal or target**. Be specific about the energy reductions that are targeted for each end use, account for everything that will get you to your target/goal.

**An integrated project delivery method** is advisable in a DER. Include the occupants, architect, engineers, contractor and subcontractors from the beginning in order to holistically address all aspects of the project.

**Use energy models** to test retrofit approaches but with caution. A thorough understanding of the limitations of these models is necessary, as is an experienced modeler. Many advanced system types cannot be modeled using commercial software (e.g., combisystems). Also, occupant behavior can be challenging or impossible to model.

## Construction Phase

**Plan product procurement for a DER as you would any remodel**, allowing lots of lead time and ensuring flexibility for change orders. Many DER project teams have complained about long lead times and retailers who were poorly equipped to answer questions and provide service on advanced equipment/materials. In particular, plan ahead for:

- Advanced windows, namely triple-pane, imported units
- Advanced HVAC, such as mini-split heat pumps, combisystems, etc.

**Be prepared for unexpected issues to arise**, such as hidden structural issues or pest/moisture damage. Expect that these unanticipated obstacles will have costs in terms of time, money and the scope of other improvements. Early in project development, the creation of contingency plans and priority lists will help in making decisions during these challenging periods.

**Provide quality assurance wherever possible.** Always have a trusted and knowledgeable representative overseeing the work of insulation, HVAC and other subcontractors. Due to reported problems with contractor quality in DERs, it is a best practice to have the work of any contractor verified by a third party inspector, such as HERS rater, energy auditor or other knowledgeable project team member. Where feasible, use diagnostic testing equipment, such as a blower door, to track progress and fulfillment of project goals during construction.

## Test Out

**Verify installation and performance of retrofit measures.** The same diagnostic tests that were performed prior to the retrofit should be performed post-retrofit, in order to evaluate whether the goals were achieved or not. Blower door tests should ideally be performed prior to finishes in order to allow for additional air sealing if needed.

**Commission all building systems.** This includes measurement of airflows for ventilation and forced air space conditioning systems (e.g., room-by-room measurements and total system flow), heat pump and air conditioner diagnostics (e.g., refrigerant charge, superheat, subcooling), and confirmation of correct operation of controls (e.g., thermostats, ventilation controllers, etc.).

## Post-Occupancy Evaluation

**Provide post-occupancy performance feedback to occupants.** A DER is not complete once the building is occupied, but in many ways is only beginning. The energy savings are the main focus of a DER, therefore, the energy use must be monitored and compared to the baseline in order to evaluate progress. More detailed levels of metering allow occupants and energy professionals to identify problems or anomalies linked to equipment or behavior. Monitoring can occur at three levels:

- *Minimum:* consumption through utility billing data should be used.
- *Better:* install whole house electricity meter and provide continuous feedback/access to occupant and potentially contractor.
- *Best:* install end-use metering, with a focus on biggest energy consumers.

**Encourage occupants to make acceptable behavioral adjustments** based on feedback from monitoring.

**An electricity audit of miscellaneous equipment** can be just as valuable after the retrofit is complete, as DERs often include new equipment, new home offices and a variety of miscellaneous energy draws.

**Guide occupants using short-term usage targets** that are easier to track and achieve. Have weekly or even monthly energy use targets, rather than an annual target. This allows for tracking of progress and earlier discovery of trends.

## References

Less, B. D., & Walker, I. S. (2015). *Deep Energy Retrofit Guidance for the Building America Solutions Center* (No. LBNL-184443). Berkeley, CA: Lawrence Berkeley National Laboratory. Retrieved from https://eetd.lbl.gov/sites/all/files/brennan_less_-_deep_energy_retrofit_guidance_for_the_building_america_solutions_center.pdf