

**Work Paper PGECOALL103  
Prescriptive Whole House Retrofit  
Revision # R1**

**Pacific Gas & Electric Company**  

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**Customer Energy Efficiency Department**

**Prescriptive Whole House  
Retrofit**

Measure Code WH\_\_

**Last revised 02/2010**

## At-a-Glance Summary

<b>Applicable Measure Codes:</b>	WH__ (tba)
<b>Measure Description:</b>	Prescriptive package of residential single-family detached home retrofit measures designed to improve the overall energy efficiency of the whole house.
<b>Energy Impact Common Units:</b>	kWh and therms per household
<b>Base Case Description:</b>	Source: PG&E Calculations for Existing California homes based on DEER <sup>1</sup> and RASS <sup>2</sup> data.
<b>Base Case Energy Consumption:</b>	Source: PG&E Calculations for base case rely on RASS annual energy use data for existing detached single family owner-occupied homes by climate zone. Range: 5,863 to 9,581 kWh/yr and 513 to 708 therms/yr per home. Population-weighted average of 7,647kWh/yr and 590 therms/yr per home.
<b>Measure Energy Consumption:</b>	Source: Based on EnergyPro model <sup>0</sup> of post-retrofit energy consumption and PG&E calculations. Range: 4,591 to 6,791 kWh/yr and 408 to 561 therms/yr per home. Population-weighted average of 5,558 kWh/yr and 465 therms/yr per home.
<b>Energy Savings (Base Case – Measure)</b>	Source: PG&E Calculations. Range of savings: 631 to 2,987 kWh/yr and 105-147 therms/year per retrofit. Population weighted average of 2,090 kWh/yr and 124 therms/yr per retrofit.
<b>Costs Common Units:</b>	kWh, Therms
<b>Base Case Equipment Cost (\$/unit):</b>	In the base case no action is taken, so the cost is zero.
<b>Measure Equipment Cost (\$/unit):</b>	Source: PG&E Calculations. The full measure cost averages \$4,500 per house retrofit and includes labor, overhead and profit.
<b>Measure Incremental Cost (\$/unit):</b>	Source: PG&E Calculations. Because the base case involves no action, the measure incremental cost is the full measure cost, including labor, overhead and profit, averaging \$4,500 per retrofit.
<b>Effective Useful Life (years):</b>	Source: DEER, <sup>4</sup> 18 years
<b>Program Type:</b>	Retrofit, Midstream/Downstream mass market residential program
<b>Net-to-Gross Ratios:</b>	Source: DEER, <sup>5</sup> 0.80
<b>Important Comments:</b>	

## At-A-Glance Measure List

Measure Code	DEER Impact ID	Measure Description	Building Type	Building Vintage	Climate Zone	Peak Electric Demand Reduction (kW / household)	Electric Savings (kWh / household)	Gas Savings (therms / household)	Base Case Cost (\$ / household)	Measure Cost <sup>1</sup> (\$ / household)	Measure Incremental Cost (\$ / household)	Effective Useful Life (years)
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	1	0	631	138	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	2	0	2,567	147	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	3	0	943	128	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	4	0	2,195	118	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	5	0	1,555	137	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	11	0	2,790	114	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	12	0	2,577	128	0	4,500	4,500	18

## At-A-Glance Measure List (continued)

<sup>1</sup> Includes equipment, labor, overhead and profit

Measure Code	DEER Impact ID	Measure Description	Building Type	Building Vintage	Climate Zone	Peak Electric Demand Reduction (kW / household)	Electric Savings (kWh / household)	Gas Savings (therms / household)	Base Case Cost (\$ / household)	Measure Cost2 (\$ / household)	Measure Incremental Cost (\$ / household)	Effective Useful Life (years)
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	13	0	2,987	105	0	4,500	4,500	18
		Prescriptive Whole House Retrofit	Residential Single Family Detached	1978	16	0	1,667	122	0	4,500	4,500	18

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<sup>2</sup> Includes equipment, labor, overhead and profit

# Work Paper Approvals

Redacted

Manager, Technical Product Support

Date

Redacted

Manager, Mass Market

Date

## Document Revision History

Revision #	Date	Description	Author (Company)
Revision 1	02/22/2010	PGECOALL103 R1 Whole House Energy Retrofits–Prescriptive Path.doc.	Scott Fable (Bevilacqua-Knight, Inc./CBPCA), Redacted (PG&E)

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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

### Catalog Description

The prescriptive whole house retrofit program (PWHRP) is a mid/downstream program that will address each detached single-family residential home as a whole system rather than separate components. It will optimize the building shell by following the energy efficiency loading order, starting with: air sealing, attic insulation, duct sealing, and hot water insulation. These measures will save on average more than 20% of total household energy consumption.

### Program Restrictions and Guidelines

**Terms and Conditions:** Applicant must be a current PG&E gas and/or electric residential customer. Not available for new construction. Work must be performed by a licensed contractor in accordance with applicable building codes.

**Market Applicability:** Applies to single-family residences within the PG&E service territory.

### Technical Description

A whole house retrofit typically consists of a set of residential energy retrofit measures ranging from a few efficiency measures completed in combination up to and beyond a full retrofit, which could include heating/cooling appliance upgrades, conversion of a significant part of the home’s lighting and possibly even photovoltaic (PV) panel installation.

In order to define an appropriate set of measures to include in a prescriptive whole house retrofit, contractor data reporting and personal conversations were used to identify those contractor improvements that are typically incorporated into moderate retrofit job scopes. Table 1 lists the improvements that define a Prescriptive Whole House Retrofit job scope, along with the approximate cost. In order to assess the depth of energy savings possible through a prescriptive whole house retrofit, the list of retrofit measures included in the prescriptive package was determined and the corresponding energy savings potential was estimated through modeling.

**Table 1: Description for a Prescriptive Whole House Energy Retrofit**

Whole House Retrofit Category	Typical Job Scope Elements
<b>Prescriptive Whole House Retrofit</b> (approx. \$3k – 6k) <sup>6</sup>	<ul style="list-style-type: none"> <li>• Upgrade attic insulation to R-38</li> <li>• Seal air infiltration gaps throughout home</li> <li>• Duct sealing</li> <li>• Insulate hot water heater and accessible piping from tank into house</li> <li>• Blower door and duct testing</li> </ul>

Note: Window replacements, pool and spa improvements, alternative heating/cooling systems, advanced water heating systems, improving duct insulation to R-6, tune/clean HVAC equipment, and plug loads are not listed here, although they are sometimes included in retrofits.

The improvement included in a Prescriptive Whole House Retrofit will be provided to the homeowner as a prescriptive package, with the improvement targets indicated in Table 2. Those homeowners that want to customize their retrofit package or add features will be referred to a home performance contractor that can provide a home assessment and recommend an appropriate customized scope of work.

**Table 2: Improvements for Prescriptive Whole House Retrofit Package**

Attribute	Target retrofit value
Attic Insulation	R-38, fiberglass
Infiltration	0.35 ACH <sub>n</sub>
Ducting	12% leakage (88% distribution efficiency), optional R-6 insulation where accessible
Hot water	R-6 insulation, tank and pipes (no replacement)

## 1.2 DEER Differences Analysis

The 2008 DEER data include demand, electric, and gas energy savings, equipment unit costs, equipment incremental costs, equipment lifetime, and net-to-gross values for many of the individual components of the prescriptive whole house package, but do not include a specific whole house package. DEER data are used as noted whenever they are applicable, and where necessary data from other sources are used as noted.

## 1.3 Codes & Standards Requirements Analysis

**Title 20:** This measure does not fall under Title 20 of the California Energy Regulations.

**Title 24:** Title 24 of the California Energy Regulations covers new construction and major retrofit. This program is not considered a major retrofit.

**Federal Standards:** Because it is a retrofit, this measure does not fall under Federal DOE or EPA Energy Regulations.

## 1.4 EM&V, Market Potential, and Other Studies

Existing regulatory approved values (DEER)<sup>1</sup> were used to determine the estimated useful life and net to gross value from installation of attic insulation, duct sealing, and hot water insulation. There were few studies available that reviewed the current status of retrofit work or the percentage of single family houses that have attic insulation, duct sealing, or hot water insulation. Nevertheless, major findings include:

- Nearly 28% of all dwellings in PG&E territory have no attic insulation<sup>7</sup>.

- Statewide, 46% of new homes built after 2001 have ceiling insulation values below R-19<sup>8</sup>.
- Ex-ante savings for installing R-30 or greater insulation into uninsulated or attics with existing insulation less than R-11 are on average 20% for cooling and 30% for heating<sup>9</sup>.
- Distribution losses in hot and cold water pipes represent approximately 16% of the annual electric Unit Energy Consumption (UEC) and 13% of the annual gas UEC. Pipe wrap decreases these losses by about 21%<sup>9</sup>.

**Delta Wattage Assumption ( $\Delta W$ ):** Zero delta wattage claimed under this work paper.

**Net-to-Gross (NTG) Assumption:** The net-to-gross for this measure falls in the category “New Measures or New Delivery Methods Where no Previous NTG results are Available in the 2008 DEER Update,” for which the NTG ratio is 0.80.<sup>5</sup>

**In-service factor/first year installation rate:** Because this is a service measure, the in-service factor is 1.0 (all relevant parts of the measure are completed at the time of installation).

**Hours of Operation:** Building envelope and pipe insulation measures are relevant at all times of day in a residential setting. Appropriate schedules for HVAC operation are included in the EnergyPro modeling software for residential service, and thus are reflected in the savings tables.

**Effective Useful Life:** 18 years<sup>4</sup>

### 1.5 Base Cases for Savings Estimates: Existing & Above Code

Contractor field data were used to develop a typical home configuration that could be used for simulation modeling of the Prescriptive Whole House Retrofit package. The result was used as the original or *base* condition of the home. To supplement the field data, the RASS database was used to determine average annual electricity (kWh) use, average annual gas (therms) use, and existing attic insulation levels for the average home in each of the Title 24 climate zones in PG&E territory. Table 3 lists the base condition assumptions for each of the Prescriptive Whole House Retrofit measures modeled in the EnergyPro residential energy use modeling software<sup>3</sup>. Energy efficiency improvements to the home were then entered into the model for each base condition house, and the interactive energy savings for the Prescriptive Whole House Retrofit package listed in Table 1 were predicted.

**Table 3: Base Conditions Assumptions for all models**

Attribute	Base case assumptions
Attic Insulation	RASS database average values, by CZ
Infiltration	0.75 ACH <sub>n</sub>
Ducting	40% leakage (60% distribution efficiency)
Hot water	40 gallon, EF 0.53; no insulation

Windows:	1/2" double glass, 1/4" air space, clear
furnace	78% AFUE, 100,000 Btu/hr
AC	SEER 8, 48000 Btu/hr

## 1.6 Base Cases & Measure Effective Useful Lives

The base case for the Prescriptive Whole House Retrofit assumes no action is taken. The Prescriptive Whole House Retrofit is considered a retrofit. Based on DEER 2008, effective useful lives of building envelope measures similar to those included in the Prescriptive Whole House Retrofit package are listed in Table 4.

**Table 4: DEER EUL for measures similar to prescriptive package**

Measure	DEER Impact ID	EUL
Duct sealing		18
Attic insulation		20

## 1.7 Net-to-Gross Ratios for Different Program Strategies

Table 5 below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

**Table 5: Net-to-Gross Ratios**

Program Approach	NTG
New Measures or New Delivery Methods Where no Previous NTG results are Available in the 2008 DEER Update <sup>5</sup>	0.80

## Section 2. Calculation Methods

### 2.1 Electric Energy Savings Estimation Methodologies

In order to estimate the interactive effects of installing the Prescriptive Whole House Retrofit measures simultaneously, all measures were simulated in the EnergyPro energy modeling system. Because DEER is missing an air sealing measure and because it would be inconsistent to model the interactive effect of only some of the Prescriptive Whole House Retrofit measures and use DEER values for the others, the Energy Pro results were used to determine the effectiveness of a Prescriptive Whole House Retrofit as a single package.

Based on results from the EnergyPro energy modeling system, it is estimated that a Prescriptive Whole House Retrofit will, on average, save 23% of a detached single family owner-occupied home's energy use per year. Using the average pre-retrofit energy use data from the RASS

database, the average post-retrofit energy savings is shown in Table 6 for the California climate zones in PG&E territory. Note that actual savings could fall outside of this range because it is an average over a large number of homes and there is variability between homes and retrofit packages selected.

In order to determine the Prescriptive Whole House Retrofit energy savings, the EnergyPro model was used to determine the climate-zone-specific energy savings rate for electricity and natural gas. These results were applied to the RASS average energy consumption results by climate zone. These results for the Prescriptive Whole House Retrofit package are shown in Table 6 below. Note that the electricity fraction of the energy saved is small compared with the total electricity used in the household. This is because a large fraction of the electricity consumption for a household is from appliances and electronics that constitute the baseload.

**Table 6: EnergyPro-modeled Annual Electricity Energy Savings for Average Detached Single-Family Homes by Climate Zone**

Climate Zone in PG&E Territory	Average annual kWh used	Electricity savings, kWh
CZ 1	7,376	631
CZ 2	7,224	2,567
CZ 3	5,863	943
CZ 4	7,485	2,195
CZ 5	7,205	1,555
CZ 11	9,581	2,790
CZ 12	8,602	2,577
CZ 13	9,292	2,987
CZ 16	6,258	1,667

*Source: 2003 California Energy Commission KEMA RASS survey: data for single-family owner-occupied homes in California.<sup>2</sup> (pre-retrofit energy use); EnergyPro residential energy modeling software (energy savings possible from retrofit)*

Milder climate zones use much less air conditioning, with some homes containing no air conditioning at all. For example, for climate zone 1, the cooling need was negligible, and electricity savings were limited to reductions in heater fan operation. All energy savings estimates follow the formula:

$$\text{Energy Savings [kWh/Unit]} = (\text{Base kWh/yr})/\text{unit} - (\text{Post-retrofit kWh/yr})/\text{unit}$$

## 2.2. Demand Reduction Estimation Methodologies

There is no anticipated demand reduction associated with this measure.

### 2.3. Gas Energy Savings Estimation Methodologies

The energy savings calculation methodology described in Section 2.1 applies to both electricity and gas energy savings. Using the RASS annual energy consumption data and EnergyPro post-retrofit energy consumption estimates, the annual gas savings were determined using the formula:

$$\text{Energy Savings [therms/unit]} = \text{Annual Base Gas Usage} - \text{Annual Energy Efficient Gas Usage}$$

The gas energy savings are listed in Table 7.

**Table 7: EnergyPro-modeled Annual Gas Energy Savings for Average Single-Family Detached Homes by Climate Zone**

Location	Average annual therms used	Natural gas savings, therms
CZ 1	670	138
CZ 2	708	147
CZ 3	608	128
CZ 4	573	118
CZ 5	599	137
CZ 11	533	114
CZ 12	606	128
CZ 13	513	105
CZ 14	623	129
CZ 16	557	122

*Source: 2003 California Energy Commission KEMA RASS survey: data for single-family owner-occupied homes in California.<sup>2</sup> (pre-retrofit energy use); EnergyPro residential energy modeling software (energy savings possible from retrofit)*

## Section 3. Load Shapes

Load Shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year. Thus, the net benefits calculation for a measure requires both the total annual energy savings (kWh) of the measure and the distribution of that savings over the year. The distribution of savings over the year is represented by the measure's load shape.

The measure's load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year. A Time-of-Use (TOU) load shape indicates what fraction occurs within five or six broad time-of-use periods, typically defined by a specific utility rate tariff. Formally, a load shape is a set of fractions summing to unity, one fraction for each hour or for each TOU period. Multiplying the measure load shape with the hourly avoided cost stream determines the average avoided cost per kWh for use in the life cycle cost analysis that determines a measure's Total Resource Cost (TRC) benefit.

### **3.1 Base Case Load Shapes**

The base case load shape would be expected to follow a typical residential HVAC end use load shape.

### **3.2 Measure Load Shapes**

For purposes of the net benefits estimates in the E3 calculator, what is required is the load shape that ideally represents the *difference* between the base equipment and the installed energy efficiency measure. This *difference* load profile is what is called the Measure Load Shape and would be the preferred load shape for use in the net benefits calculations.

The measure load shape for this measure is determined by the E3 calculator based on the applicable residential market sector and the HVAC end-use.

## **Section 4. Base Case & Measure Costs**

### **4.1 Base Case(s) Costs**

In the base case, no action is taken and therefore the cost is zero.

### **4.2 Measure Costs**

As shown in Table 1, the expected cost of the Prescriptive Whole House Retrofit ranges between \$3,000 and \$6,000, depending upon the level of effort and material needed to accomplish the targets listed in Table 2. An average value that may be used is \$4,500, including both materials and labor.

### **4.3 Incremental & Full Measure Costs**

Because the base case cost is zero, the incremental and full measure costs are the same: between \$3,000 and \$6,000, with an average of \$4,500.

## **References**

<sup>1</sup> California Public Utilities Commission, Database for Energy Efficient Resources (DEER) 2008 v2.05, Miser tool output, downloaded from [www.deeresources.com](http://www.deeresources.com).

<sup>2</sup> 2003 KEMA RASS survey: data for single-family owner-occupied homes in California. [[energy.ca.gov/appliances/rass](http://energy.ca.gov/appliances/rass)]

<sup>3</sup> EnergyPro (v. 5) developed by Energysoft [ [www.energysoft.com](http://www.energysoft.com) ]

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<sup>4</sup> California Public Utilities Commission, Database for Energy Efficient Resources (DEER) 2008 v2.05, spreadsheet “EUL\_Summary\_10-1-08.xls,” downloaded from [ [www.deeresources.com](http://www.deeresources.com) ], February 19, 2010.

<sup>5</sup> California Public Utilities Commission, Database for Energy Efficient Resources (DEER) 2008 v2.05, spreadsheet “Updated DEER NTG Values for 2006-07 final 2008-10-10.xls,” worksheet “All NTGR values-Final 100908,” downloaded from [ [www.deeresources.com](http://www.deeresources.com) ]February 19, 2010.

<sup>6</sup> Source for retrofit cost: California Building Performance Contractors Association, conversation with contractors regarding retrofit costs (February 17, 2010: CBPCA Home Performance Contractor (VENDOR A) estimated that the work scope defined as a Prescriptive Whole House Retrofit in Table 1 above would cost between \$3,000 and 6,000).

<sup>7</sup> California Residential Appliance Saturation Survey, Volume 2, June 2004.

<sup>8</sup> Itron. 2004. Residential New Construction Baseline Study of Building Characteristics Homes Built After 2001 Codes. Pg 3-20. [[http://calmac.org/publications/RNC\\_2003\\_Final\\_Report1.pdf](http://calmac.org/publications/RNC_2003_Final_Report1.pdf)]

<sup>9</sup> Robert Mowris & Associates. 2008. Evaluation, Measurement, and Verification Report for the Moderate Income Comprehensive Attic Insulation Program #1082-04. p 10-12. [[http://calmac.org/publications/BO\\_MICAP\\_1082\\_04\\_EMV\\_FINAL\\_Report\\_BOE000101.pdf](http://calmac.org/publications/BO_MICAP_1082_04_EMV_FINAL_Report_BOE000101.pdf)]

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