DMQC review of the IOU 2010-2012 Prescriptive Whole House Retrofit Program energy savings estimates work papers, revised submission
6 June 2010

The following review comments are based on a technical review of the simulation model input files plus detailed spreadsheet calculations provided by each of the IOU's in response to Energy Division's request for input and other files pertaining to work papers for the Prescriptive Whole House Retrofit Program (PWHRP), dated April 30, 2010.

FINDINGS
The technical review confirmed that the work papers remain primarily based on detailed hourly simulation modeling using eQUEST v3.63b (SCE/SCG) and EnergyPro v5.0.20 (PG&E/SDGE), with SCE/SCG supplementing their eQUEST simulations with calculations for DHW pipe loss savings using the 3E Plus v4.0 pipe insulation calculator from the North American Insulation Manufacturers Association.

A principal purpose of the PWHRP work papers is to substantiate the PWHRP Program's ability to achieve the program goals of providing a statewide average reduction of approximately 20% of total residential energy use in the participating residences. In summary, the work papers estimated that the PWHRP Program will achieve whole premise savings presented in Table 1 below.

Table 1: Projected PWHRP Savings and Population Coverage

IOU	Savings per Residence	Vintages	% of Population
PG&E	9%	Oldest 3	99%
SDGE	9%	Oldest 3	96%
SCE/SCG	13%-17%	Oldest 2	85%

These estimates are based on a procedure where separate vintages of homes were simulated for separate climate zones such that the results by climate zone can be weight average based on the number of homes by vintage. For all work papers, only the oldest two or three DEER vintages (pre-1978, 1978-1992, 1993-2001) were used. The resulting coverage of the population ranged from 85% to 99% as indicated in Table 1 above. The targeted level of coverage was ~85%, hence each work paper achieved the targeted level of coverage.

PG&E and SDG&E analysis
A review of the files submitted in support of the PWHRP work papers found that the PG&E and SDG&E analysis procedures closely followed the procedures and recommendations from the previous PWHRP technical work paper review (19Mar10) in most respects, e.g., base case assumptions, calibration with RASS UEC's, analyzing measures interactively and reporting measures separately. Consequently, the resulting estimates of savings aligned well with the reviewer's DEER-based estimates for the same package of measures. Among the few issues identified in the PG&E and SDG&E analysis was the level of benefit attributed to the infiltration measure, i.e., a 30% reduction in

infiltration appears to have been assumed which significantly exceeds the 10% to 15% level reported in the literature and assumed as an available credit in the Title 24 Residential ACM. It was also noted that the PG&E and SDG&E analysis did not include an estimate for peak demand impacts. If PG&E and SDG&E elect to revise their PWHRP work papers, a revision to the credit claimed for infiltration should be included. If they chose to also include demand impacts in any revision, they should use the DEER methodology outlined on page 4 below. If they also chose to modify their base case assumptions, as was discussed on earlier PWHRP conference calls, specific test-in or qualifying procedures must be included in a re-submitted work paper. See the section below regarding base case assumptions for guidance.

<u>SCE and SCG analysis</u>
The SCE/SCG analysis departed from the procedures specified in the previous technical review, primarily in significantly altering key DEER base case assumptions, e.g., large reduction in attic insulation levels, in wall exterior insulation levels, lowered furnace AFUE, and reduced DW heater efficiency, without including commensurate test-in or qualifying procedures in the work paper that could cause the program to successfully target homes with these reduced efficiency features. The SCE/SCG analysis also assumes a 30% reduction in infiltration (see comment on this point in the PG&E-SDG&E section above). See the section below regarding base case assumptions for guidance. Consequently, the SCE/SCG estimates of savings do not align well with the reviewer's DEER-based estimates and will need to be re-run and re-submitted using the following guidelines.

COMMENTS AND RECOMMENDATIONS
The following comments and recommendations are offered to assist the IOUs with any further revisions to their PWHRP work papers.

BASE CASE ASSUMPTIONS
DEER baseline assumptions for all single family residence characteristics should be considered as the default base case. Consistent with this, the RASS UEC's adopted by DEER should be used as the target UEC for all model runs that employ the DEER baseline assumptions. Any runs that adopt departures from the DEER baseline assumptions for single family residence characteristics will fall into either of two cases:

1a) If departures from the DEER base case are argued to be reflective of the population, i.e., implies that the DEER characteristics are considered to be incorrect for a vintage's population of residences (e.g., attic insulation effective R-value too high to reflect typical houses for a specific DEER vintage), then substantiating documentation should be provided. The default simulation procedure would be to initially (temporarily) adopt the DEER baseline characteristics in the simulation models (e.g., DEER attic insulation values) and demonstrate that the simulation models are able to reproduce the DEER/RASS annual heating and cooling UEC's (for the DEER/RASS heating and cooling UEC's, see Appendix A1 in *2008 DEER Update - Summary of Measure Energy Analysis Revisions*, December 2008).

Demonstrating percentages of heating and cooling is not sufficient. The calibration should be based on the kWh and therms per year found in Appendix A1 of the above cited reference.

1b) Once the preliminary calibration in step 1a is completed, then the proposed departures from the DEER baseline assumptions should be adopted into the simulation model and a revised calibration should be completed wherein the revised model is 'rebalanced' to match the DEER/RASS annual heating and cooling UEC's, e.g., if attic insulation is reduced, then other changes must be made to the model such as thermostat set points to reduce the runtime on the HVAC equipment and realign the model with the DEER/RASS annual heating and cooling UEC's.

2a) If the proposed departures from the DEER baseline assumptions are NOT argued to be reflective of the population but rather are considered as characteristic of a specially targeted demographic, e.g., houses with no attic insulation, it is necessary to temporarily adopt DEER baseline assumptions and demonstrate that the simulation models are able to reproduce the DEER/RASS annual heating and cooling UEC's published in the 2008 DEER update (as described in 1a above).

2b) After calibrating the models as described in 2a above, the model baseline values may be revised to match the targeted demographic and run without further calibration. Since this case is argued to represent a special vintage demographic, specific test-in or qualifying procedures must be included in the work paper.

BASE CASE ATTIC AND WALL EFFECTIVE R-VALUES

One of the technical issues raised in earlier PWHRP conference calls was the degradation of effective R-value for attic and wall insulation to reflect poor quality installation of insulation, especially batt insulation. Details of a technical review of insulation degradation due to poor quality installation are provided in Appendix A.

In summary, sufficient technical basis has been identified to permit the DEER base case values for attic and wall insulation to be degraded if the IOUs identify field evidence of insulation installation problems. Generally, the allowed degradation follows RESNET national HERS standards which are generally consistent with 2008 Title 24 Residential ACM procedures and laboratory tests performed at ORNL.

It was also found that the DEER base case assumptions did not assume framing factors consistent with recent ORNL work. Accordingly, the degradation factors shown in Table 2 on the following page are approved for use in the PWHRP analysis. Owing to the limited available time, the requirement for model 'rebalancing' described in 1b above is waived for the next round of PWHRP work papers submission for these revisions to attic and exterior wall insulation effective R-value only. Other departures form the DEER base case assumptions are subject to the requirements of 1b described above.

Table 2: Wall and Ceiling Effective R-value Degradation Factors for use with the 2010 PWHRP Work Papers[1]

	Batt Insulation Installation Quality		
	Grade I (0% gap)[2]	Grade II (2% gap)[2]	Grade III (5% gap)[2]
Wall or Ceiling Construction	% Degradation[3]	% Degradation	% Degradation
2x4, 16" o.c. R-11 Wall	12%	2.4%	8.8%
2x6, 16" o.c. R-19 Wall	14%	4.8%	14.2%
2x6, 16" o.c. R-19 Ceiling	n/a[3]	9.5%	20.8%

[1] Degradation factors reported here include the combined effect of air gaps due to poor quality insulation installation (applicable to quality Grades II and III only) and the effect of increased framing factor (i.e., 'Whole Wall' framing factors) not included in DEER 2008 wall R-values. See Appendix A for details.

[2] These insulation installation quality grades and their implied air gaps are from the RESNET 2006 national HERS standards. The three-tier BPI quality rating ('Good', 'Fair', 'Poor') criteria are sufficiently similar to the RESNET/HERS criteria to be used to translate into the RESNET Grade I, II, & III tier levels for the purpose of the PWHRP work papers.

[3] The degradation factors for installation quality Grade I (minimal air gaps) include only the effect due to increased framing factor not included in DEER 2008 and therefore do not apply to the ceiling insulation case.

ESTIMATING PEAK DEMAND IMPACTS

DEER analysis procedures include a specific method to calculate peak demands. For each climate zone, the hottest three week days from the long term average CZ weather files are identified (see Table 3 below).

Table 3: Peak Demand Periods used for DEER 2008

Cimate Zone	Start Date of 3-day Period month	Day	Weekday	Peak Demand Period	Peak T (F°)	Avereage T (F°)	12p - 6p T (F°)
CZ01	Sep	30	Mon	2p - 5p	80	58	65
CZ02	Jul	22	Mon	2p - 5p	99	78	93
CZ03	Jul	17	Wed	2p - 5p	89	65	79
CZ04	Jul	17	Wed	2p - 5p	97	71	87
CZ05	Sep	3	Tue	2p - 5p	93	68	80
CZ06	Jul	9	Tue	2p - 5p	85	69	77
CZ07	Sep	9	Mon	2p - 5p	92	70	78
CZ08	Sep	23	Mon	2p - 5p	98	78	89
CZ09	Aug	6	Tue	2p - 5p	101	78	92
CZ10	Jul	8	Mon	2p - 5p	104	83	99
CZ11	Jul	31	Wed	2p - 5p	104	81	98
CZ12	Aug	5	Mon	2p - 5p	103	81	100
CZ13	Aug	14	Wed	2p - 5p	106	87	102
CZ14	Jul	9	Tue	2p - 5p	106	90	103
CZ15	Jul	30	Tue	2p - 5p	114	96	108
CZ16	Aug	6	Tue	2p - 5p	96	73	89

For the weekdays identified above, hourly results for the 2:00pm to 5:00pm time period on the three consecutive peak days should be averaged to provide the DEER peak demand estimate. The difference between the DEER peak demand estimates for base case runs and energy efficiency measure EEM runs are used to determine the peak demand savings for each EEM package.

INFILTATION

Although the ASHRAE Enhanced single zone infiltration model has been found to provide superior results for infiltration modeling, since it has not yet been adopted into DEER it will not be adopted as the basis of comparison for infiltration modeling for the PWHRP work papers. Rather, the DEER base case assumption will be retained, i.e., 0.35 ACH for the baseline with no wind or stack effect adjustments. This 0.35 ACH average level of infiltration is also broadly consistent with the predicted results of the ASHRAE Basic infiltration model which is the infiltration model specified in the 2008 Title 24 Residential ACM and hence, the infiltration algorithm used in the residential model in EnergyPro. It is anticipated that the ASHRAE Enhanced single zone infiltration model will be incorporated into DEER at a future date.

The two principal data sources for infiltration SLA (specific leakage area) values are California (LBL and CEC) and US DOE (especially through the Building America program). These are in reasonable agreement regarding the average maximum value of SLA for older homes (~4.9 to 5.1 for oldest vintages) as well as the benefit associated with typical infiltration measures (e.g., house wrap for new construction and sealing directed by blower door for existing homes) allowing 11% to 13% reduction in infiltration (i.e., SLA). This level of improvement due to infiltration measures is consistent with the ACM's prescriptive credit of 0.50 SLA (out of 4.3) for house wrap. Consequently, the average expected benefit due to blower door directed reduction in infiltration will not exceed 15%.

CONCLUSIONS

This most recent round of PWHRP work paper submissions has made it clear that the prescriptive package of measures as currently defined in the PWHRP Program Implementation Plans will fall well short of the targeted 20% savings level. Identifying additional measures suitable for inclusion in a revised and expanded prescriptive package of measures may be desirable and should be considered.

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APPENDIX A
Accounting for Insulation Installation Quality Effects on the Effective R-value of Wall and Ceiling Insulation in the PWHRP Work Papers

One of the technical issues raised in the Prescriptive Whole House Retrofit Project (PWHRP) conference calls has been the degradation of effective R-value for attic and wall insulation resulting from poor quality installation of insulation, especially batt insulation. Significant degradation in insulation R-values due to poor installation quality have been included in previous PWHRP work paper submissions. The follow summarizes findings of a detailed technical review of the issue.

First, the significantly degraded R-values for both roofs and walls that were assumed in some previous PWHRP work paper submissions are supported by a fact sheet published by the Building Performance Institute (BPI). See the attached "BPI EffectiveRValuesForBattInsulation-YellowSheet.pdf". This BPI fact sheet refers to three grades of insulation installation quality: 'Good', 'Fair', and 'Poor' and indicates large levels of degradation associated with the lesser two quality categories, i.e., 'Fair' earns a ~30% reduction in effective R-value while 'Poor' earns a ~70% reduction in effective R-value.

As the basis for these large levels of effective R-value degradation, BPI cites experimental (laboratory) tests compiled by UMASS Amherst for ASHRAE in 1993 (errantly cited as 1996 in the BPI fact sheet, see the attached "ASHARE Attic Insulation Degradation.pdf" ~4MB). This ASHRAE reference includes hot box measurements for two categories of residential ceiling construction: manufactured homes and site built homes. The ceiling test sections for site built homes all assumed 2x6 joists, 16 in o.c. with foil-faced nominal 6 in fiberglass batt insulation. Several of these cases were tested with and without various levels of air gaps intentionally placed between the edge of the fiberglass batts and the vertical surface of the 2x6 ceiling joists.

These test cases reported large effective R-value degradation consistent with BPI's fact sheet. Unfortunately, all of the ceiling construction sections tested for site built homes included a thermally significant construction detail that makes them not representative of typical California attic/ceiling construction techniques and greatly contributes to the large degradation in effective R-value found in the laboratory tests.

The critical construction detail prevents the ceiling drywall from being directly fastened to the bottom of the 2x6 joists. Rather, all of the tested ceiling constructions for site built homes in the ASHRAE reference attached nominal 1 inch wood furring strips directly to the bottom of the ceiling joists (running transverse to the ceiling joists) to which the sheet rock was then fastened. This creates a ¾ inch air gap below the batt, i.e., the foil face of the batt formed the upper boundary of this ¾ inch air gap. When additional air gaps were introduced in some of the test cases along the vertical sides of the batts (between the side of the batt and the vertical face of the joists), an air channel was created that completely surrounded the batt (i.e., no surface of the batt was in contact with a joist or sheet rock surface) which greatly promotes convective air flow around the batt.

This ceiling construction detail is not in widespread use in California homes. Almost all ceiling constructions attach the ceiling sheetrock directly to the ceiling joist (or the lower chord of the roof truss) in a manner that would maintain a large portion of the batt in direct contact with the sheet rock, thus significantly limiting the opportunity for free convection. Accordingly, this analysis concludes that the hot box measurements of heat transmission rates included in ASHRAE publication cited by BPI are not representative of California housing. Further, while the same ASHRAE reference included numerous wall sections among the tested cases, none of the wall cases included air gaps, thus the same source provides no assistance in estimating degradation due to air gaps in walls.

Through further review, a second source of experimental (laboratory) data was identified that includes air pockets in 2x6 wall construction cases intended to represent typical poor batt insulation installation practice. An important purpose of this work was to estimate the impact of typical air gaps in batt insulated walls on wall effective R-value. The work was performed by ORNL (Oak Ridge National Laboratory) and published in the 1998 ASHRAE Envelope VII Conference. For a summary of the findings, see "EDU Thermal Shorts.pdf" (0.3MB) attached. For a more complete description, see "Whole Wall Thermal Perf calculator.pdf" attached (1.2MB). Unfortunately, this work is limited to wall constructions and includes no ceiling constructions.

The following cases of air pockets in batt wall insulation were included in the testing: 1) air pockets created by not cutting and fitting batts around electrical wiring in walls; 2) 'rounded shoulders' (batts pushed into a wall cavity from one side where friction against the surfaces of the studs prevents the leading surface of the batt from fully seating in the cavity); 3) air pockets created by 'rounded shoulders' plus paper facers stapled to the inside 3-1/2 inch face of the studs rather than to the 1-1/2 inch stud faces; and 4) voids at the top or bottom of the cavity due to cutting the batt short prior to installation.

This work found the degradation in effective R-value due to these examples of poor batt installation varied from 5% (rounded shoulders only) to 14% (rounded shoulders, cavity voids and paper facer stapled to side of studs).

This ORNL work acknowledges that the measurements were performed without any induced air pressure difference across the wall sections as would be the case in situ. While air leakage through the construction sections may contribute to performance degradation caused by air gaps, these ORNL findings are consistent with the levels of degradation employed by RESNET in the current notational HERS standards to account for three quality grades of batt insulation installation (see pgs 3-22 & 2-23 in "RESNET National HERS Stds.pdf" attached, 1.0MB). These same quality grades have also been adopted in the 2005 EPACT/IRS tax credit procedures for residential energy performance. Harley provides a summary of this work in "Insulation Quality Inspection Harley ASHRAE 2007.pdf" attached (0.3MB).

Similar to the BPI fact sheet, the RESNET national HERS standards also provide for three quality tiers or grades for insulation: Grade I, II, and III, where Grade I assumes high quality installation. Degradation of effective R-value for the lower two grades assumes 2% overall gaps for Grade II (similar criteria to BPI's "Fair" category which allows 2.5% overall gaps) and 5% overall gaps for Grade III (similar criteria to BPI's "Poor" category which allows 5% overall gaps). Following a parallel path calculation procedure (see example calculation in the Harley paper), the Table A1 below reports the degradation in effective R-value for three common constructions.

Table A1: Degradation in Effective R-value due to Poor Quality Installation of Batt Insulation

		Batt Insulation Installation Quality	
		Grade II (2% gap)[1]	Grade III (5% gap)[1]
Wall or Ceiling Construction	Framing Factor[2]	% Degradation	% Degradation
2x4, 16" o.c. R-11 Wall	25%	2.4%	8.8%
2x6, 16" o.c. R-19 Wall	25%	4.8%	14.2%
2x6, 16" o.c. R-19 Ceiling	10%	9.5%	20.8%

[1] These insulation installation quality grades and their implied air gaps are from the RESNET 2006 national HERS standards

[2] These framing factors are from the 2008 Title 24 Residential ACM. The wall framing factors are consistent with the ORNL Whole Wall R-value work.

The level of degradation for walls shown in the table above are consistent with the test cases from the ORNL work (5% to 14% degradation) and with the 2008 California Title 24 Residential ACM Manual distinction between 'standard' and 'improved' quality insulation installation, i.e., 13% degradation for standard versus improved quality wall insulation and 8% to 21% degradation for ceiling insulation (see Residential ACM, Table R3-4 and Table 3-21).

An additional significant finding from the ORNL work is the importance of accounting carefully for the actual amount of structure (studs) contained within typical walls, i.e., the framing factor. The ORNL paper distinguishes 'clear wall' (walls that assume a framing factor assuming no windows, doors, corners or any intersecting interior walls) from 'whole wall' (walls that assume a framing factor based on more typical amounts of structure). The average difference between Grade II or Grade III clear wall and whole wall effective R-value is approximately 12% (i.e., 'whole wall' effective R-values are ~12% less than 'clear wall' effective R-values). DEER wall R-values generally employed wall framing factors more consistent with clear wall rather than whole wall assumptions. Note that the distinction between 'clear wall' and 'whole wall' does not apply to ceilings.

Accordingly, for the purpose of the PWHRP work papers, the CA IOUs are approved to use the following wall and ceiling insulation de-rating factors to reflect the impact of insulation installation quality AND to adjust for whole wall framing factors not included in DEER 2008. These are summarized in Table A2 below. Note that Table A2 differs from Table A1 above in that Table A1 reflects only the effect of air gaps (i.e., installation quality) while Table A2 includes the effect of air gaps PLUS the additional effect due to increased framing factors for walls not included in the 2008 DEER effective R-value base case assumptions.

Furthermore, the RESNET/HERS three-tier level quality grading system also includes cases where the thickness of insulation is sub-par due to poor installation quality. This latter category of insulation quality primarily affects loose fill insulation applications, whereas air gaps due to poor installation and compression of the insulation materials primarily applies to batt installations. Since the RESNET/HERS degradation levels for Grade II and Grade III are similar for both cases, i.e., for air gaps in batt installations and lower than specified levels of insulation for loose fill installation (see the Harley paper), it is not necessary to separately track homes with loose fill versus batt attic insulation. The three tier quality grading and degradation factors in Tables 1 and 2 can be used to cover both cases.

If the IOUs opt to use the effective R-value degradation procedure described herein, they will have to estimate the fraction of homes at each of the three insulation quality grades within each residential vintage. For the purpose of the PWHRP work papers, the criteria for the BPI three-tier quality rating are sufficiently similar to the RESNET/HERS criteria to be used to estimate the RESNET tier levels. A single base case run per model vintage may still be used by weight averaging the degradation for each of the three quality grades for wall and ceiling. It is recommended that the IOUs be conservative when estimating the split between quality grades as the insulation work contracted under this PWHRP program will certainly experience its own quality challenges which will tend to lower program accomplishments.

Table A2: Wall and Ceiling Effective R-value Degradation Factors for use with the 2010 PWHRP Work Papers[1]

	Batt Insulation Installation Quality		
	Grade I (0% gap)[2]	Grade II (2% gap)[2]	Grade III (5% gap)[2]
Wall or Ceiling Construction	% Degradation[3]	% Degradation	% Degradation
2x4, 16" o.c. R-11 Wall	12%	14%	19.6%
2x6, 16" o.c. R-19 Wall	14%	17.8%	26%
2x6, 16" o.c. R-19 Ceiling	n/a[3]	9.5%	20.8%

[1] Degradation factors reported here include the combined effect of air gaps due to poor quality insulation installation (applicable to quality Grades II and III only) AND the effect of increased framing factor (i.e., 'Whole Wall' framing factors) not included in DEER 2008 wall R-values.

[2] These insulation installation quality grades are from the RESNET 2006 national HERS standards. The three-tier BPI quality rating ('Good', 'Fair', 'Poor') criteria are similar enough to the RESNET/HERS criteria to be used to translate into the RESNET Grade I, II, & III tier levels for the purpose of the PWHRP work papers.

[3] The degradation factors for installation quality Grade I (minimal air gaps or insulation loss) include only the effect due to increased framing factor not included in DEER 2008. Note that the distinction between 'clear wall' and 'whole wall' framing actors does not apply to ceilings.