CALIFORNIA
TECHNICAL FORUM

Subcommittee Tracking Sheet: Residential HVAC Quality Installation Data Sources

Meeting #1: April 29th, 2015

I. Agenda Items for Discussion/Materials

a) Review subcommittee summary and objectives
b) Identify potential data sources for each workpaper performance parameter and discuss the merits and limitations of each source

ID	Ranking	Performance Parameter Description	WP (base case)	WP (Measure Case)	WO32 Non-Participant	WO32 Participant	Remarks
1	High Impact	Flow Performance (kW/cfm)	0.000510 kW/cfm	0.000383 kW/cfm (approx. 25% reduction)	0.000569 kW/cfm	0.000486 kW/cfm (Approx. 15% reduction)	**WP Assumptions** KW/cfm - Design full load power of the supply fan per unit of supply air flow rate. Note that in the DEER SFM prototype this parameter is defaulted to 0.000365 kW/cfm [1][2][3]. **WO32** Evaluation when possible measured fan power in cooling and either heating or fan-only modes. This difference may be partially due to the fact that QI participants also installed high efficiency units with more efficient fans. This aspect, however, was not studied as the focus was on the QI aspects not the unit efficiency and fan motor efficiency. Additional information on static pressure, fan settings, and design airflow were not part of the analysis, but collected and documented in WO32 - Appendix C.
2	High Impact	Duct Leakage	(24%) 0.0804	(12%) 0.0402	16.6%	11.5%	**WP Assumptions** **Duct Leakage (Duct Air Loss Ratio)** Fraction of the supply air that is lost from the ductwork, thereby reducing the design supply air at the zones.

							DEER Assumption [4] Baseline: 24% Leakage Measure: 12% Leakage Supply air leakage estimated as follow: (% leakage/2) x 0.75 - single-story house (% leakage/2) x 0.67 - two-story house **[9][10]** Data source can be used to inform base case and/or measure case parameter **WO32** According to evaluation, almost half of the participant tested systems had leakage meeting program requirements of 15% or less. Note that 2008 Title 24 required duct leakage less than 15% (of nominal system airflow) if a major component of the HVAC system (air handler, outdoor condensing unit, cooling or heating coil, or furnace heat exchanger) is replaced or installed. The evaluation also measured the leakage outside the conditioned space (LTO) relative to nominal unit airflow. Per evaluation, duct leakage to outside for recent residential installations are 7.42% and 10.73% for participants and non-participants respectively. Note that total duct leakage is the sum of leakage into conditioned spaces and leakage to outside of conditioned spaces.
3	High Impact	System Sizing (Cooling capacity, Btu/h)	Oversized by 20%	Defaulted per Prototype (0% Oversized)	13%	10%	**WP Assumptions** See supporting documentation further in the report [5] **[8]** Data source can be used to inform base case and/or measure case parameter **WO32** Data collected onsite informed the development of an ACCA Manual J-based system-sizing model for all participants and non-participants. The primary analysis compared the calculated size to the installed tonnage to determine the amount of over or under-sizing The QI programs require the use of both Manual J [*] and Manual S [**] for equipment sizing. The evaluation used program approved Manual J software in the analysis. Impact evaluation finding suggests oversized and undersized units in both the participant and nonparticipant samples. Both groups tended to have oversized units with a small difference in mean sizing ratio, but non-participants had a wide distribution with more cases of significant oversizing. Further, evaluation suggests that approximately 82% of evaluated participant

							systems were sized within 0.5-ton of design cooling capacity. [*]*ACCA Manual J is a standard for producing air conditioning and heating load calculations for single family homes, small multi-unit residential structures, condominiums, town houses, and manufactured homes.* [**]*ACCA Manual S provides sizing requirements for cooling and heating equipment, allowing the selection of equipment based on sensible and latent loads and ensuring the selected equipment will be properly matched to the local climate.*
4	High Impact	Airflow Capacity	350 cfm/ton	395 cfm/ton	299.7 cfm/ton	337.5 cfm/ton	**WP Assumptions** Referenced study suggests that design flow capacity (cfm) in Measure Case may be lower than the "standard" 400 cfm/ton (e.g., in the order of 340 cfm/ton in new California homes) assumed in the analysis of the measure. [3] [**9**][**10**] Data source can be used to inform base case and/or measure case parameter **WO32** Evaluation used nominal cooling tons established by AHRI ratings for each unit. The collected data showed that the averages were closer to 300 cfm/ton for non-participants and 338 cfm/ton for participants. These values are within the 300–350 cfm/ton range for Title 24 compliance. The 10% difference between participant and non-participant airflow was similar to workpaper assumptions.
5	Medium Impact	Equipment Efficiency	SEER 14 (Revised per 2015 Code Updtate)	SEER 15 thru SEER 21 (Revised per DEER2015 Update)			**WP Assumptions** Since the delivery mechanism on measure is Replace on Burnout (ROB), equipment efficiency (including base case efficiency) compares between the Code Case (e.g., SEER 14) and Measure Case **Updated Residential HVAC Measures** - SEER ratings and tiers on equipment efficiency in 2015 version of the workpaper, including both Air Conditioners and Heat Pumps, will be consistent with that documented in 2015 DEER updates, which includes additional tier levels and size ranges as required by the code update.

References:

[1] CPUC's MASControl software application created to generate DEER prototypical buildings (including latest building vintages (e.g., 2013) with current code updates) and to overview pre-developed DEER measures. The software application allows the use of existing prototypes to addressed non-DEER measures – www.deeresources.com.

[2] DEER SFM prototype with 1975 building vintage and California climate zone 6 (e.g., CZ06).

[3] Hidden Power Drains: Residential Heating and Cooling Fan Power Demand - John Proctor, Proctor Engineering Group, Ltd., Danny Parker, Florida Solar Energy Center. http://aceee.org/files/proceedings/2000/data/papers/SS00_Panel1_Paper19.pdf

[4] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc.

[5] Energy Center of Wisconsin | ECW Report Number 241-1 | Central Air Conditioning in Wisconsin | A compilation of recent field research. http://ecw.org/sites/default/files/241-1_0.pdf

[6] ASHRAE Handbook – Fundamentals | Energy Estimating and Modeling Methods.

[7] Homes by Building, Vintage, and Utility Climate Zone, Source: RASS, KEMA Estimates 2002-2007

[8] Peak Demand and Energy Savings from Properly Sized and Matched Air Conditioners, Robert Mowris and Ean Jones, Verified, Inc. http://aceee.org/files/proceedings/2008/data/papers/1_692.pdf

[9] Laboratory Measurements and Diagnostics of Residential HVAC Installation and Maintenance Faults, Robert Mowris, Ean Jones, and Robert Eshom, Robert Mowris & Associates, Inc. http://aceee.org/files/proceedings/2014/data/papers/1-195.pdf

[10] NIST Technical Note 1848 - Sensitivity Analysis of Installation Faults on Heat Pump Performance, Piotr A. Domanski, Hugh I. Henderson http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf

Other Data Sources

1. HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report - CPUC, ED - Prepared by DNV GL http://www.energydataweb.com/cpuc/search.aspx?did=1225
2. ACCA - Residential Load Calculation (Manual J)
3. ACCA - Residential Equipment Selection (Manual S)
4. ANSI/ASHRAE/IES Standard 90.1-2013 - Energy Standard for Buildings Except Low-Rise Residential Buildings
5. 2013 RESIDENTIAL COMPLIANCE MANUAL FOR THE 2013 BUILDING ENERGY EFFICIENCY STANDARDS, Title 24, Part http://www.energy.ca.gov/title24/2013standards/residential_manual.html%5d

II. Meeting Attendees

Jenny Roecks – Cal TF staff

Srinivas Katipamula – TF Member
David Pruitt – TF Member
Steven Long – TF Member
Christopher Rogers – TF Member
John Proctor – TF Member

Andres Fergadiotti, SCE
Scott Higa, SCE
John Neal, Association for Energy Affordability
Chris Ganimian, Energy Analysis Technologies
Buck Taylor, Roltay Inc. Energy Services
Mark Modera
Pete Ford, SDG&E
Justin Kjeldsen, PG&E
Chan Paek, SCG
Bashar Raad, SCG,
Joseph Pan, SCG

III. Key Issues Discussed

i. Seeking recommendations on whether better data is available to inform workpaper performance parameters than what is currently used in the Res QI workpaper.

ii. Duct Leakage

- The DOE2 calculations do not model energy savings correctly for this measure, so it doesn't matter how good your data inputs are.
    - The modeling tool will need to be evaluated through subcommittee at another point in time (second phase of workpaper revisions), but the current subcommittee scope is focused on data sources for updating 2015 RQI Workpaper
    - There are limitations to DOE2 and EnergyPlus for modeling duct leakage that will be potentially evaluated at a later time (e.g., phase 2)
    - DOE2 does not properly model vapor compression with implications when modeling different refrigerant technologies (e.g., R-22, R-410A, R-407C, etc.)
    - EnergyPlus also may not provide reliable results
- DEER (current WP source)

    - The DEER model assumes that some supply leakage goes to the attic space and some goes to the living space with different adjustments depending on stories.
    - DEER doesn't account for return air leakage, which is significant.
    - Mark Modera: based on historic flow measurements, observed approximately the same leakage on supply and return.
- Work Order 32 not considered better information than current workpaper assumptions
    - Results for the non-participant group are not representative of the actual market
        - Only permitted projects were selected for the non-participant group, and in normal industry practice likely only 10% of projects are permitted. Permits lead to a higher likelihood of duct testing and a 100% permitted control group is not representative of the actual market.
    - The methodology is unsuitable to provide reliable data
        - The evaluation of duct leakage for participants and non-participants is not apples to apples.
        - Manual J provides a procedure to engineer a system to meet peak load conditions and not to formally predict specific loads.
        - The WO32 methods did not determine duct leakage before and after QI projects for participants, therefore the actual effects of the program are unknown.
- Other options: Mowris, NIST studies
    - Laboratory Measurements and Diagnostics of Residential HVAC Installation and Maintenance Faults, Robert Mowris, Ean Jones, and Robert Eshom, Robert Mowris & Associates, Inc. http://aceee.org/files/proceedings/2014/data/papers/1-195.pdf
    - NIST Technical Note 1848 - Sensitivity Analysis of Installation Faults on Heat Pump Performance, Piotr A. Domanski, Hugh I. Henderson http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf

ACT: Subcommittee members to review Mowris and NIST studies to make final recommendation on duct leakage data source in next meeting

- Program data from Aeroseal, Energy Upgrade CA, other source data (Scott Higa to investigate)

- Mark Modera: older data from Aeroseal is not the same quality level as that gathered through a formal research effort, but would give you a lower limit on leakage
- Scott Higa may be able to get other program data, would need to address customer confidentiality.

ACT: Scott Higa to determine if program data can be obtained to inform duct leakage assumptions.

iii. System Sizing (Cooling Capacity, Btu/h)

- Chris Ganimian – There is substantial anecdotal evidence that contractors replace like-for-like equipment.
- Energy Center of Wisconsin – (current WP source, assumed 20% system oversizing)
- WO32
  - The methodology is unsuitable to provide reliable data
    - It is nearly impossible to exactly match a load with currently available equipment technologies. Furthermore, Work Order 32 (WO32) study did not properly address this issue; first, WO32 did not perform the Manual S procedure on the control group – they used the sensible heat ratio (SHR) value of the load to determine size based on AHRI rating capacity as an absolute value compared to load and they did not replicate this method for the test group (QIV projects) to compare the results of the contractors Manual S procedure to the load SHR. Manual S requires determining the system capacity at design load, not AHRI rating. [1]
    - WO32 did not properly address the Manual S procedure to differentiate the process of Manual S equipment selection from the non-participant control group. Furthermore, there is no data to show what was installed at either groups respective project prior to change-outs, so we don't know the real effects of Manual S in this situation – in other words, did any down-sizing actually occur in either group.[1]
  - A better answer could be obtained using the data from the study
- Other data sources – average size of units sold, upstream program data normalized per building population per Utility territory (e.g., RASS)

[1] Comments excerpted from Buck Taylor's write-up posted to the Cal TF subcommittee website, http://www.caltf.org/tf-subcommittees/; these comments reflect discussion during the subcommittee call.

    - Look at design capacity and compare to nominal tonnage, then figure out what the QI baseline is. This can be normalized on a square footage basis.
- **<u>Group recommendation: use existing data from upstream program and available sales data to refine workpaper system sizing estimates.</u>**

  ACT: Andres Fergadiotti to obtain upstream program data and sales data to refine system size estimates.

iv. Airflow Capacity (CFM/ton)

- Proctor study (used in WP)
    - Design flow capacity (cfm) in Measure Case may be lower than the "standard" 400 cfm/ton (e.g., in the order of 340 cfm/ton in new California homes) assumed in the analysis of the measure.
- Want contractors to do engineering correctly
- Trade-off between static pressure and airflow
- Picking a high-SEER product may mean selecting an evaporator coil with high static loses – and the real in-field performance may be several SEER values lower than its factory name-plate rating would otherwise suggest.
- WO32
    - Results for the non-participant group are not representative of the actual market
        - WO32 did not provide pre- and post- air flow measurements, so we don't know what the difference due to QI really is.
- Proctor and Mowris studies

  ACT: Andres Fergadiotti to identify relevant Proctor and Mowris studies for information on airflow capacity to be reviewed by group

- Other data sources
    - Program QI participant data
    - NCI (National Comfort Institute) pilot program with test in and test out QI data
    - 2013 Title-24 airflow capacity (cfm/ton) limits

ACT: Scott Higa and Andres Fergadiotti to obtain QI program data on airflow capacity and NCI program data to support workpaper assumptions

v. Flow Performance (kW/CFM)

- DEER (used by WP)
  - Similar results for non-participants as WO32
- WO 32
  - WO32 acknowledges that study does not represent the baseline across the population, but represents a comparison of control vs participant groups
- Data from the QI program

  ACT: Scott Higa and Andres Fergadiotti to obtain QI program data on flow performance to support workpaper assumptions

vi. Other Comments

- Bashar: the measures interact with one another and should be sequenced
- Include program implementation requirements related to proper system design/engineering, measure sequencing
- Consider a systems approach instead of individual measures

IV. Action Items

1. ACT: Subcommittee members to review all additional data sources prior to next meeting.
2. ACT: Subcommittee members to review Mowris and NIST studies to make final recommendation on duct leakage data source in next meeting
3. ACT: Scott Higa to determine if program data can be obtained to inform duct leakage assumptions.
4. ACT: Andres Fergadiotti to obtain upstream program data and sales data and normalized the same based on building population (e.g., RASS) to refine system size estimates.
5. ACT: Andres Fergadiotti to identify relevant Proctor and Mowris studies for information on airflow capacity (cfm/ton) to be reviewed by group. Additionally, evaluate airflow capacity limits prescribe in T24.
6. ACT: Scott Higa and Andres Fergadiotti to obtain QI program data on airflow capacity (cfm/ton) and NCI program data to support workpaper assumptions
7. ACT: Scott Higa and Andres Fergadiotti to obtain QI program data on flow performance (kW/ton) to support workpaper assumptions