



# **Subcommittee Tracking Sheet: Residential HVAC Quality Installation Data Sources**

Meeting #3: May 20<sup>th</sup>, 2015

## **I. Agenda Items for Discussion/Materials**

- a) Duct leakage: group to make final recommendations
  - i. Consideration of NW findings (report not currently available)
  - ii. Source for % of permitted vs unpermitted projects for baseline assumptions
- b) Identify potential data sources for additional workpaper performance parameter and discuss the merits and limitations of each source; make final recommendation on best data source for workpaper.

ID	Impact	Evaluated Parameter	General Parameters	Keyword	Current WP Source	Other Sources to Consider
1	High Impact	<b>Flow Performance</b>  <b>kW/CFM</b>	Design full-load power of the supply fan per unit of supply airflow - Fan power; System airflow	SUPPLY-KW/FLOW	<a href="#">DEER</a> [1] [2] 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  <a href="#">Proctor study</a> [3]	<a href="#">WO32</a> [11] 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	<b>Airflow capacity</b>	System airflow; system delivery capacity; system	-	<a href="#">Proctor study</a> [3] Referenced study suggests that	<a href="#">WO32</a> [11] Evaluation used nominal cooling tons established by

		<b>CFM/Ton</b>	(ARI) rated capacity		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.	<p>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.</p> <p><a href="#">Mowris et al, Lab Measurements of HVAC Install &amp; Maintenance</a> [9]</p> <p><a href="#">NIST Sensitivity Analysis</a> [10]</p>
3	High Impact	<b>Duct Leakage Leakage (%)</b>	Duct leakage - fraction of the supply air that is lost from the ductwork, thereby reducing the design supply air at the zones	DUCT-AIR-LOSS	<p><a href="#">DEER</a> [1] [2] 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.</p> <p><a href="#">DEER 2005 Report</a> [4] Baseline: 24% Leakage Measure: 12% Leakage</p> <p>Supply air leakage estimated as follow: (% leakage/2) x 0.75 - single-story house (% leakage/2) x 0.67 - two-story house</p>	<p><a href="#">WO32</a> [11] According to evaluation, almost half of the participant tested systems had leakage meeting program requirements of 15% or less.</p> <p>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.</p> <p>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.</p> <p><a href="#">Mowris et al, Lab Measurements of HVAC Install &amp; Maintenance</a> [9]</p> <p><a href="#">NIST Sensitivity Analysis</a> [10]</p>
4	High Impact	<b>Equipment Sizing</b>	HVAC equipment capacity	COOLING-CAPACITY COOL-SH-	<a href="#">Energy Center of Wisconsin</a> [5]	<p><a href="#">WO32</a> [11] Data collected onsite informed the development of an ACCA Manual J-based system-sizing model for</p>

		Manual J Manual S		CAP		<p>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</p> <p>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.</p> <p>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.</p> <p>[*]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.</p> <p>[**]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.</p> <p><a href="#">Mowris et al, Energy Savings from Properly Sized AC</a> [8]</p>
5		HVAC System basecase HVAC Sub-systems basecase	SEER; duct leakage; duct insulation; flow performance; etc.	-	<a href="#">DEER</a> [1] [2]	<a href="#">WO32</a> [11]
6		Delivery Mechanism	ROB	-	Program Requirements	

7	Medium Impact	<b>System Efficiency</b> <b>EIR (at ARI rated conditions)</b>	System Efficiency (SEER)	COOLING-EIR	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 <b>Updated Residential HVAC Measures</b> - 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.	
8		<b>Refrigerant Charge Adjustment (RCA)</b>	-	-	<a href="#">DEER</a> [1] [2]	<a href="#">WO32</a> [11]

[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](http://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](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. [http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport\\_ItronVersion.pdf](http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf)

[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](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](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 sources to consider

[11] 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>

[12] ACCA - Residential Load Calculation (Manual J)

[13] ACCA - Residential Equipment Selection (Manual S)

[14] ANSI/ASHRAE/IES Standard 90.1-2013 - Energy Standard for Buildings Except Low-Rise Residential Buildings

[15] 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](http://www.energy.ca.gov/title24/2013standards/residential_manual.html%5d)

## II. Meeting Attendees

Jenny Roecks, Cal TF staff

Andres Fergadiotti, SCE  
Chris Ganimian

## III. Key Issues Discussed

- From last time
  - Tom Eckhart brought up the impact evaluation that was done in the northwest that did not find a correlation between duct leakage reduction and energy savings. Tom feels that this should be investigated in CA. The impact evaluation does not appear to be publicly available so Tom's comments will be noted in the final write-up for the subcommittee.
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- **Duct Leakage**
  - Last time: recommendation to use program data for the baseline and measure case, but to weight the baseline by leakage represented by unpermitted projects (existing conditions) and permitted (T24 or 15%)
  - Source for permit compliance rate
    - DNV GL study commissioned by IOUs
      - Sample size 52, selected from residential sites through Work Order 54 and CLASS market assessment studies
      - Study found 38% compliance
    - Testimony to Little Hoover Commission
      - Indicates 10% compliance
      - Original source for 10% claim could not be located
    - SMUD impact evaluation
      - Only 4% of non-participants permitted
    - Anecdotal estimates of permit rates are in 5% - 10% range, so more thorough study should be done
    - Other options to evaluate permitting in long term:
      - Compare equipment sales data from manufacturers to permits issued, based on region
      - Manufacturers and distributors reluctant to provide serial numbers for tracking
      - Get data from HERS raters doing the compliance reporting: inspections done annually multiplied by AC saturation, compared with 15% replacement rate of homes with air conditioning

- DNV GL may not be best statistical study buy commissioned by utilities and seems to be best available
  - DNV GL is doing fully funded study on HVAC permitting that will come out towards the end of the year that will statistically significant (res or commercial scope TBD)
  - WO32 suggests for the IOUs to keep exploring to-code permitting.
- **Recommendation: Use DNV GL study of 38%, update when better data becomes available at the end of the year (or explore alternatives to getting better data if forthcoming DNV GL study is inadequate)**
- **Equipment Oversizing**
  - Last time: Andres presented upstream program data with capacities based on Manual J/S, compared with DEER prototype load calculations for SFM
  - New Res QI pilot program data available, analyzed by Buck Taylor
    - Pilot attempted to utilize in-field system measurement by participating contractors, was able to collect information about existing system measure performance prior to replacement through Res QI
    - Able to get the make/model number of pre-existing equipment
    - Have reasonably accurate building loads for building based on Manual J
    - Data analysis compares system capacity of previous system to newly replaced system
    - Because didn't have Manual S for the existing older equipment, Buck used software to create a Manual S equivalent and calculated the approximate capacity of the system.
    - To estimate total capacity required some assumptions about the equipment, and capacity was adjusted based on outdoor temperature, wet bulb temperature, and mass flow
    - Manual S selections for new equipment was based on a previous version of Manual S, and the new version of the manual has been updated. Older version of Manual S didn't delineate between variable, multi-speed requirements
    - OEMs only produce high-efficiency multi-stage equipment in 1-ton increments, so new system may appear to be oversized based on nominal tonnage; New Manual S allows for different % oversizing depending on type of equipment (15% single stage, 30% variable flow)

- As EE programs push SEER up, end up with variable stage/ multiple flow which complicates nominal tonnage, as well as run time, etc.
  - Numbers do not include fan heat – makes the system capacity go up because system is responding to load. If the fan is located after the cooling coil, the fan heat added to air stream after air is cooled, capacity effect.
  - None of existing systems were “burned out” due to “test-in” measurements
  - Sample size 32, no statistical analysis, and testing was done by better contractors who are more proactive about learning about system performance than other contractors; need to be skeptical of data
- WO32 compared total sensible heat ratio (SHR) load vs nominal capacity; need to use actual capacity
- Through the Energy Upgrade program, if significant improvements are made to the building shell, then swapping like-for-like equipment results in more complications in system performance
- Res QI pilot data is a good start for ball-parking energy savings
- **Recommendation: use this Res QI pilot data (13.9% oversizing) in the short term, gather more data for robust statistical analysis in the long term.**
- **Airflow (kW/CFM)**
  - Title 24 limit is 0.58 kW/CFM, and is consistent with WO32
  - Measure airflow value of 0.369 kW/CFM from program data is consistent with WO32, however the large program data source (over 2000 sample size) is better to use.
  - WO32 did not compare field values to what was reported by contractors during commissioning. The program reported values cannot be correlated to the field values.
  - **Recommendation: Use T24 0.58 kW/CFM for the baseline, use 0.369 kW/CFM for the measure case**
- **System efficiency**
  - Using metrics from DEER, applying within the model.
  - Discuss with Cal TF the use of T24 gas furnace efficiencies
  - **Recommendation: use DEER**
- **HVAC System Base Case, HVAC Sub-systems**

- When equipment dies, you would be purchasing something that meets T24 base case, based on those tiers, go to higher efficiencies.
- **Refrigerant Charge Adjustment**
  - Lots of problems with misidentification of sub-cooling. Number of customers not collecting charge
  - Contractors are necessarily identifying correct charge because they're not looking at lines and OEM requirements, and don't even know how much charge is in there to begin with
  - There is the potential for refrigerant charge savings based on same permit/unpermitted split. Of the contractors pulling permits, some will be properly charged. Others will not be.
  - **Recommendation: Consider addressing refrigerant charge in the long term due to on the ground issues faced by contractors**
- **Airflow Capacity (CFM/ton)**
  - WO32 non-participant is consistent with Proctor data that is referenced in the workpaper
  - Mowris low limit (base case) of 300 is adequate
  - Chris Ganimian has data for average CFM/ton (2400 jobs) that can be provided for this effort, based on measurements at the return grill.
  - The CFM value should be engineered and not nominal.
  - Based on T24, the tonnage is nominal.
  - Nominal metric is hard to achieve when pushing multi-stage equipment, therefore adjusted design capacity based on Manual S for this metric is appropriate
  - **Recommendation: use WO32 for baseline due to best available information, and use forthcoming program data for measure level CFM/ton value. May need better baseline data based on engineered values in long term if WO32 used nominal values.**

#### IV. Action Items