**Subcommittee Summary:**

**Residential HVAC Quality Installation Data Sources**

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| **Subcommittee** | ***Subcommittee Name Here*** | |
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| **Subcommittee Members:**  Cal TF Members | Srinivas Katipamula  Tom Eckhart  David Pruitt  Steven Long  Andrew Brooks  Christopher Rogers  George Roemer  Sherry Hu  John Proctor | PNNL, [Srinivas.Katipamula@pnnl.gov](mailto:Srinivas.Katipamula@pnnl.gov)  UCONS, [tom@UCONS.com](mailto:tom@UCONS.com)  PL Energy, [david@pl-energy.com](mailto:david@pl-energy.com)  SCE, [steven.long@sce.com](mailto:steven.long@sce.com)  Association for Energy Affordability, [abrooks@aea.us.org](mailto:abrooks@aea.us.org)  PECI, [crogers@peci.org](mailto:crogers@peci.org)  Franklin Energy, [groemer@franklinenergy.com](mailto:groemer@franklinenergy.com)  PG&E, [S1HU@pge.com](mailto:S1HU@pge.com)  Proctor Engineering, [john@proctoreng.com](mailto:john@proctoreng.com) |
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| **Final Deliverable(s)** | Document detailing the recommendations and supporting reasoning resulting from subcommittee discussion and consensus | |
| **Commencement Date** | 4/29/15 | |
| **Conclusion Date** | 5/13/15 | |

1. **Subcommittee Objective**

The objective of the Residential HVAC Quality Installation subcommittee will be the following:

1. Identify applicable data sources, including but not limited to Work Order 32, to inform each of the Residential HVAC Quality Installation performance parameters listed in Section II. A non-inclusive list of data sources to consider is included in Section III.
2. Discuss the suitability of each data source for informing the performance parameters.
3. Select the most appropriate data source(s) for each performance parameter, with justification for each selection.

The final deliverable will be a document detailing the recommendations and supporting reasoning resulting from subcommittee discussion and consensus that will support parameter updates in the Residential Quality Installation workpaper. The document will include:

* A list of all data sources applicable to each performance parameters, with discussion of the merits and limitations of each source.
* Justification for the selection of the preferred data source for each performance parameters, with discussion of why other data sources were not selected.

1. **Description of Issues**

Data sources for the following Residential HVAC Quality Installation performance parameters will be identified. The subcommittee will recommend the most appropriate data source to inform these performance parameters for a workpaper revision.

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|  | **ID** | **Impact** | **Evaluated Parameter** | **General Parameters** | **Keyword** | **Current WP Source** | **Other Sources to Consider** |
|  | 1 | High Impact | **Flow Performance**  **kW/CFM** | Design full-load power of the supply fan per unit of supply airflow - Fan power; System airflow | SUPPLY-KW/FLOW | [DEER](http://www.deeresources.com) [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  [Proctor study](http://aceee.org/files/proceedings/2000/data/papers/SS00_Panel1_Paper19.pdf) [3] | [WO32](http://www.energydataweb.com/cpuc/search.aspx?did=1225) [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 | **Airflow capacity**  **CFM/Ton** | System airflow; system delivery capacity; system (ARI) rated capacity | - | [Proctor study](http://aceee.org/files/proceedings/2000/data/papers/SS00_Panel1_Paper19.pdf) [3]  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. | [WO32](http://www.energydataweb.com/cpuc/search.aspx?did=1225) [11]  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.  [Mowris et al, Lab Measurements of HVAC Install & Maintenance](http://aceee.org/files/proceedings/2014/data/papers/1-195.pdf) [9]  [NIST Sensitivity Analysis](http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf) [10] |
|  | 3 | High Impact | **Duct Leakage**  **Leakage (%)** | 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 | [DEER](http://www.deeresources.com) [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.  [DEER 2005 Report](http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf) [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 | [WO32](http://www.energydataweb.com/cpuc/search.aspx?did=1225) [11]  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.  [Mowris et al, Lab Measurements of HVAC Install & Maintenance](http://aceee.org/files/proceedings/2014/data/papers/1-195.pdf) [9]  [NIST Sensitivity Analysis](http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1848.pdf) [10] |
|  | 4 | High Impact | **Equipment Sizing**  **Manual J Manual S** | HVAC equipment capacity | COOLING-CAPACITY COOL-SH-CAP | [Energy Center of Wisconsin](http://ecw.org/sites/default/files/241-1_0.pdf) [5] | [WO32](http://www.energydataweb.com/cpuc/search.aspx?did=1225) [11]  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.*  [Mowris et al, Energy Savings from Properly Sized AC](http://aceee.org/files/proceedings/2008/data/papers/1_692.pdf) [8] |
|  | 5 |  | **HVAC System basecase HVAC Sub-systems basecase** | SEER; duct leakage; duct insulation; flow performance; etc. | - | [DEER](http://www.deeresources.com) [1] [2] | [WO32](http://www.energydataweb.com/cpuc/search.aspx?did=1225) [11] |
|  | 6 |  | **Delivery Mechanism** | ROB | - | Program Requirements |  |
|  | 7 | Medium Impact | **System Efficiency**  **EIR (at ARI rated conditions)** | 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  **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. |  |
|  | 8 |  | **Refrigerant Charge Adjustment (RCA)** | - | - | [DEER](http://www.deeresources.com) [1] [2] | [WO32](http://www.energydataweb.com/cpuc/search.aspx?did=1225) [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>

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

[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 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>

1. **Background information**

Southern California Edison (SCE) maintains a Residential HVAC Quality Installation workpaper for use by the statewide IOUs. SCE is planning to update this workpaper by the end of 2015 with the best available data to support key performance parameters in the energy simulation model for the Quality Installation suite of measures. SCE is seeking Cal TF subcommittee feedback on which of the many data sources available is most appropriate for use in the revised workpaper. Data sources for consideration include, but are not limited to:

1. HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report - CPUC, ED - Prepared by DNV GL
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
6. Data sources used on the development of the current version of the workpaper include but are not limited to:
   1. Hidden Power Drains: Residential Heating and Cooling Fan Power Demand - John Proctor, Proctor Engineering Group, Ltd., Danny Parker, Florida Solar Energy Center.
   2. Energy Center of Wisconsin | ECW Report Number 241-1 | Central Air Conditioning in Wisconsin | A compilation of recent field research
   3. Peak Demand and Energy Savings from Properly Sized and Matched Air Conditioners - Robert Mowris and Ean Jones, Verified, Inc.
   4. Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc.

SCE is seeking data source suggestions from the subcommittee beyond what is listed above. SCE may also be seeking feedback on the Residential Quality Installation modeling approach at a later point in time.

1. **Schedule**

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| **Date** | **Agenda** | **Next Steps** |
| 4/29/15 | * Review of subcommittee summary and objectives * Discussion of data sources for Res QI performance parameters * Identify merits and limitations of each | Subcommittee members to consider data sources discussed and determine best source for each performance parameter. |
| 5/13/15 | * Identify most suitable data source for each performance parameter, and justification. | Cal TF to memorialize subcommittee findings to be circulated via email and reviewed by the full TF through the Res QI workpaper abstract review at the 5/28 TF meeting. |

1. **Attachments/Links**

[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>

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

[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 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>