SCE Quality Maintenance Program
Comprehensive Manufactured Home Program (CMHP)
Data Evaluability Assessment Report

Prepared for

Southern California Edison

Prepared by

ASW Engineering Management Consultants

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Executive Summary

Introduction

This is an Executive Summary of the Data analysis of the Southern California Edison (SCE) Comprehensive Manufactured Home Program (CMHP). The full report documents findings from an engineering analysis of the SCE's Comprehensive Manufactured Homes Program (CMHP). Operating data for existing HVAC package units (serving mobile homes, single-wide and double-wide family homes) was collected by the program implementer for a period of 9 months within Climate Zone 14 (CZ 14) for 548 project sites.

Specifically, the analysis addressed the following research questions:

1. What kind of [savings] analysis can we perform given the collected data?
2. What kind of conclusions can we draw from this information?
3. What kind of recommendations can we make?
4. Did we collect the right kind of data? Are there information and data gaps that we need to address?

Program Background

The CMHP is a direct install program intended to serve lower income customers who are not qualifying for low-income services. The target customers are mobile home owners and property owners/managers. The program covers both individual units and common areas. The majority of the energy savings for this program is coming from HVAC related activities.

The CMHP HVAC Quality Maintenance Program seeks to improve the efficiency of packaged and split system HVAC systems in manufactured and mobile homes as part of a more comprehensive direct install program. The QM measure consists of multiple treatments related to ductwork and HVAC unit tune-up. Air conditioning systems must be in working order to be eligible for the program; repair of non-functioning units is not covered in this program. Services are intended to improve the energy efficiency and performance of systems operating in "suboptimal" conditions.

Summary of Findings and Recommendations

The Work Paper savings for CZ14 applied to these mobile homes is 203 kWh/Ton/Yr. Using the calculation methodology outlined in the next section, the following results apply:

For the 548 mobile homes dataset provided to ASW, 298 (54%) passed the quality control criteria listed below.

Of the homes that passed the quality control criteria, the average savings were 71.9 kWh/Ton/Yr.

It is believed that improved training will lead to improved data collection, thus reducing the number of sites with excessive savings.

With improved quality control and training, the measurements key to the savings calculation provided here would improve.

There are a number of recommendations for program improvement outlined in the Conclusions section of this report, pertaining to the following areas:

- Program Delivery
- Data Collection
- Data Analysis and Quality Control

Data Collection Process

Data Collected During Test-In & Test-Out

From April to December 2012, test-in and test-out operating data was collected following the CMHP data collection protocols for 548 mobile homes. The data set encompasses homes in Climate Zone 14 in the following cities; San Bernardino, Apple Valley, Palm Springs, Hesperia, Perris, Murrieta, and Temecula.

For the purpose of recommending some of the data collection changes, the next three tables identify the type of data collected by the technicians during the performance of the system upgrades. It should be noted that the analysis is done from an energy savings perspective.

Table 1: Test-In and Test-Out Data Collection

		1 - Test-In	2 - Test-Out	
1	Program Name	Southern California Edison	Southern California Edison	
2	Sponsor	Southern California Edison	Southern California Edison	
3	Provider Account#			
4	Customer Name			
5	Site Address1			
6	Site Address2			
7	Site City	Apple Valley	Apple Valley	
8	Site State	CA	CA	
9	Site Zip	92307	92307	
10	Altitude	2900	2900	
11	Contractor Company	Synergy Companies	Synergy Companies	
12	Tech Id	T00104	T00104	
13	Tech Name	David Osborn	David Osborn	
14	Job Id	SC00232	SC00232	
15	Test Number	0	1	
16	Activity	Service: Test-In	Service: Test-Out	
17	Job Status	InProgress	InProgress	
18	QC Test Status	None	None	
19	Test Result	Pass	Fail	
20	Equipment Override Yes/No	No	No	
21	Unit#	461801	461801	
22	Condenser Manufacturer	York	York	
23	Condenser Model	h4db036s06a	h4db036s06a	
24	Condenser Serial#	WLLM027634	WLLM027634	
25	Evaporator Manufacturer	Not Specified	Not Specified	
26	Evaporator Model	AMVR3436	AMVR3436	
27	Evaporator Serial#	A0800006741	A0800006741	
28	Furnace Manufacturer			
29	Furnace Model			
30	Furnace Serial#			
31	System Type	ACSplit	ACSplit	
32	OU_Compressor Type	Reciprocating	Reciprocating	
33	HP_Compressor Type	Unknown	Unknown	
34	Multi Stage	No	No	
35	Electrical Single or Three Phase	SinglePhase	SinglePhase	
36	Airflow Method	VaneAnemometer	VaneAnemometer	
37	Airflow Operational Mode	CoolingWetCoil	CoolingWetCoil	

Table 2: Test-In and Test-Out Data Collection Cont'd

		1 - Test-In	2 - Test-Out	
38	Equipment SEER	10	10	
39	Total Capacity in Tons	3	3	
40	Fan Type	PSC	PSC	
41	Total cfm setting	1200	1200	
42	Refrigerant Type	R22	R22	
43	Metering Device	FixedOrifice	FixedOrifice	
44	Split System Line Set Length	15	15	
45	Spilt System Elevation Difference	3	3	
46	Test Type	InitialTest	SubsequentTest	
47	Test Date	2012-04-23	2012-04-23	
48	Test Time	11:42:00	15:05:00	
49	TOC Override Yes/No	No	No	
50	Condensing Air Entering Temperature	83.1	83.2	
51	Liquid Pressure/Discharge Pressure	219.9	236.5	
52	Suction Pressure	57.4	67.3	
53	Liquid Line Temprature	102.7	97.4	
54	Suction Line Temprature	73.3	50.4	
55	Return Air Dry Bulb	76.6	72.5	
56	Return Air Wet Bulb	61.5	62.9	
57	Supply Air Dry Bulb	49.1	47.6	
58	Supply Air Wet Bulb	45.5	45.1	
59	Outdoor L1 Volts	120.3	121.3	
60	Outdoor L1 Amps	12	13.4	
61	Outdoor L2 Volts	121.6	122.8	
62	Outdoor L2 Amps	12.1	13.3	
63	Outdorr L3 volts	0	0	
64	Outdoor L3 Amps	0	0	

Table 3: Test-In and Test-Out Data Collection Cont'd

65	Indoor L1 Volts	121.5	121.2	
66	Indoor L1 Amps	5.5	4.8	
67	Indoor L2 Volts	0	0	
68	Indoor L2 Amps	0	0	
69	Indoor L3 Volts	0	0	
70	Indoor L3 Amps	0	0	
71	Measure cfm	815	886	
72	Estimated Airflow	692.61	744.09	
73	Goal Airflow	1200	1200	
74	Measured cfm/ton	271.67	295.33	
75	Estimated cfm/ton	230.87	248.03	
76	Return Dimention	IWC	IWC	
77	Return Value	0	0	
78	Return Measurement Location			
79	Supply Dimention	IWC	IWC	
80	Supply Value	0	0	
81	Supply Measurement Location			
82	Supply Ductwork	0	0	
83	Supply Discharge	0	0	
84	Supply TESP	0	0	
85	Long Line Set Liquid Line Temperature at Metering Device	0	0	
86	Long Line Set Suction Line Temperature at Indoor coil	73.3	50.4	
87	CSR Validations Messages	CE010,LSP001,SC007,SH002,SH012	CE010,CR001,CR002	
88	TOC Validations Messages (TOC = Tech on Call)	CE010,LSP001,SC007,SH002,SH012	AF002,CE010,CR001,CR002	
89	Airside Capacity	32,520	40,141	
90	Compressor Capacity	27,636	33,712	
91	Goal Capacity	36,268	36,555	
92	Airside EER	9.3	10.7	
93	EER Normalized	0	10.6	
94	EER Improvement%	0%	14.48%	
95	Compressor EER	7.9	9	
96	Goal EER	9.4	9.4	
97	Normalized EER where EER improvement is Program Requ	0	10.6	
98	CTOA Actual	24.39	29.47	
99	CTOA Goal	22	22	
100	ET Actual	30.76	38.09	
101	ET Goal	39.01	39.38	
102	SH Actual	42.5	12.3	
103	SH Goal	9	11.3	
104	SC Actual	4.8	15.3	
105	SC Goal	12.6	12.5	
106	Enthalpy Actual	10.15	11.47	
107	Enthalpy Goal	7.69	7.71	
108	Temperature Split Actual	27.5	24.9	
109	Temperature Split Goal	22.36	17.97	
110	Approach Goal	9.44	9.46	
111	Approach Actual	19.6	14.2	
112	Approach used for System Charge	No	No	
113	Repairs Made	No Repairs Made(No Repairs Made		
114	TOC comment			

Calculation Methodology

One of the tasks sought to address whether there was sufficient data to estimate the potential energy savings between the test-in and test-out of each of the mobile homes. The answer is a qualified "Yes". It is possible to estimate the change in efficiency of the HVAC condensing using the reported data, but the estimates contain embedded assumption of 0.9 for the condensing unit power factor in lieu of direct field measurements. Although the condensing unit power factor is not likely to vary significantly from test-in to test-out, measuring this quantity directly will reduce the uncertainty in the condensing unit kW and efficiency measurements.

The data collected included Return and Supply Air Dry Bulb (DB) and Wet Bulb (WB). ASW used the Wet Bulb data to identify the return and supply enthalpies (h).

The equation used to calculate the total heat transfer across the evaporator air is as follows:

Measured CFM (test-in and test-out): ***CFM x 4.5 x Delta Enthalpy/12,000 BTU/Hr = Tons***

Table 4: Sample Calculation

	Return WB & h		*Supply WB & h*					
	WB	*h*	*WB*	*h*	*Delta h*	*CFM*	*Tons*	*Change*
Test-In	**65.4**	**30.31**	**52.4**	**21.67**	8.64	798	2.58	0.43
Test-Out	**64.4**	**29.56**	**49.4**	**19.97**	9.59	837	3.01	**16.5%**

FLH Estimate:

To estimate the full load hours per (FLH) year of the Air Conditioning Unit (ACU), The DEER mobile home prototype was used. The DEER prototype simulations provided an estimate of 883 cooling full-load hours based on nameplate HVAC unit cooling capacity in climate zone 14.

kW Estimate:

It should be noted that the collected data included test-in and test-out voltage and running amps of the unit, which allows us to calculate the kW of the HVAC unit at the Test-in and Test-out, based on an assumed power factor of 0.90

Equation: kW ***= Volts x amps x power factor*** – ASW used 0.9 PF.

Savings kWh/Yr:

Most of the mobile homes are located in Climate Zone (CZ) 14 – San Bernardino, Apple Valley, Palm Springs, Hesperia, Perris, Murrieta, and Temecula. In other words, most of the mobile homes have similar weather conditions. The tables below shows the calculated energy savings were performed.

Table 6: Sample kWh Savings

OSA = Outside ~ T = Tons ~ Calc = Calculated ~ AC = Air Conditioning ~ FLH = Full Load Hours ~ T-Hrs/Yr = Ton-Hours/Year

Table 5: Top Portion of the Savings Calculations

Calc Tons	Calc kW	kW /Ton	AC FLH	T-Hrs/Yr	Delta kW/Ton	Savgs kWh/Yr
2.93	2.62	0.89	883	2,649	0.08	221.36
3.62	2.93	0.81	883			
4.10	5.32	1.30	883	3,532	0.10	336.25
4.47	5.36	1.20	883			
1.98	2.01	1.01	883	2,649	0.03	77.01
2.04	2.01	0.98	883			
2.51	2.50	1.00	883	2,649	0.25	654.76
3.34	2.50	0.75	883			
3.30	4.76	1.44	883	3,091	0.21	647.93
3.71	4.58	1.23	883			
4.17	3.63	0.87	883	3,532	0.03	93.51
4.29	3.63	0.85	883			
4.04	3.13	0.77	883	3,091	**-0.11**	(337.67)
3.54	3.13	0.88	883			
4.84	3.56	0.74	883	3,532	0.02	57.84
5.25	3.78	0.72	883			
2.14	2.74	1.28	883	3,091	0.07	208.99
2.34	2.84	1.21	883			
2.93	3.35	1.14	883	3,091	**-0.01**	(22.51)
2.96	3.41	1.15	883			
3.41	3.84	1.12	883	3,532	0.02	57.35
3.44	3.81	1.11	883			
3.05	3.51	1.15	883	3,532	**-0.17**	(597.65)
2.72	3.59	1.32	883			
2.40	2.51	1.04	883	3,532	**0.32**	1,128.01
3.62	2.61	0.72	883			
2.28	2.01	0.88	883	2,208	0.19	413.95
2.89	2.01	0.69	883			
3.09	4.76	1.54	883	3,532	0.07	251.14
3.31	4.86	1.47	883			
3.05	2.43	0.80	883	3,091	0.02	50.23
3.19	2.49	0.78	883			
2.30	3.21	1.39	883	3,091	0.21	648.47
2.78	3.29	1.18	883			
5.89	4.13	0.70	883	3,532	**-0.44**	(1,550.83)
3.71	4.23	1.14	883			

Table 6: Bottom Portion of the Savings Calculations

Calc Tons	Calc kW	kW /Ton	AC FLH	T-Hrs/Yr	Delta kW/Ton	Savgs kWh/Yr
1.82	3.85	2.12	883	3,532	0.81	2,873
2.87	3.74	1.30	883			
2.51	3.96	1.58	883	3,532	1.22	4,311
2.87	3.78	0.36	883			
3.58	4.62	0.72	883	3,532	0.34	1,202
3.96	5.05	0.38	883			
1.07	4.03	3.77	883	3,091	0.45	1,382
1.25	4.17	3.33	883			
2.34	2.56	1.10	883	2,649	***-0.05***	(122)
2.28	2.61	1.14	883			
2.72	5.62	2.06	883	3,532	0.31	1,082
3.23	5.67	1.76	883			
2.68	4.70	1.75	883	3,532	0.34	1,210
3.33	4.69	1.41	883			
2.73	2.39	0.87	883	2,649	0.08	201
2.97	2.37	0.80	883			

Regardless of the savings results, positive or negative, they were included in the summary calculations. It should be noted that the preview tables were presented for the purpose of illustrating how the kWh was derived for each set of data. The savings were derived by using the calculated Delta kW/Tons (test-in minus test-out) and then, multiplying the Delta result by the calculated total ton-hours during the test-in.

The summary table below presents the results of the analysis and the projected kWh savings of all the Mobile Homes (MH).

Table 7: Projected kWh Savings for Mobile Homes

Threshold kWh/Ton/Yr	kWh Savings	EUL (Yrs)	kWh
500	132,440	5	662,200
Pass Threshold	**# of Mobile Homes**	**% of Mobile homes**	
298	548	54.30	
kWh/MB/Yr			
323.8			
Avg Rated Tons		**kWh/Ton/Yr**	
3.76		71.9	

Filter Criteria

The dataset was reviewed for reasonableness. There were three proposed filters on the kWh/ton savings estimate:

1. Remove negative savings,
2. Remove savings exceeding the absolute value of 2.5 times the Work Paper savings,
3. Remove data falling outside of a one-sigma average deviation.

With respect to removing negative savings, it was determined that there are scenarios where negative savings could result and therefore should not be excluded from the dataset. Of the 548 mobile homes in the dataset, 170 (31%) had negative savings. It was agreed that a threshold of +/- 500 kWh/Ton/Yr was a reasonable filter. This was used in the analysis.

It was also agreed that the one-sigma average deviation could be used as a filter; however, this proposed filter came very late in the analysis process. ASW was requested to proceed with the originally approved calculation methodology described above and the threshold filter of +/- 500 kWh/Ton/Yr.

Data quality control.

Quality control checks on field data reveal inconsistencies, suggesting issues with measurements:

- ~ 5% of records show an absolute humidity[1] increase from return to supply during cooling mode testing. These records were removed from the analysis
- ~ 27% of jobs show increase in return absolute humidity between test in and test out. Not a likely scenario unless a large release of moisture occurred in the space (e.g. cooking or showering) during the repair period. These records were removed from the analysis.
- Air flow measurements indicate a number of estimated values, where the recorded air flow is set to 400 cfm x tons. Database should indicate when estimated values are used. The range of the air flow data shows some very low (< 200 cfm/ton) values. About 18% of the test-in values are < 200 cfm/ton; 7 records are less than 100 cfm/ton. Jobs with test in or test out values < 200 cfm/ton were removed from the analysis.

Results

Once the calculation methodology was approved, the data was analyzed to determine what could be learned from this sample data set. In support of this report, the following files are embedded in the Appendix - QM/QI Work Paper, CMHP Training Document, Quality Maintenance Process, Field Data Collection Form and, ASW Analysis Spreadsheet including raw data set.

[1] Absolute humidity calculated from enthalpy and dry bulb temperature. Allowance made for normal measurement accuracy.

Analysis Response to Study Objectives

The following research questions are addressed below:

1. What kind of [savings] analysis can we can we perform given the collected data?
2. What kind of conclusions can we draw from this information?
3. What kind of recommendations can we make?
4. Did we collect the right kind of data? Is there information and data gap that we need to pursue?

What kind of [savings] analysis can we perform given the collected data?

223 of the 548 jobs in the dataset passed the QC criteria, representing 41% of the participant mobile homes.

The basic collected data included Return and Supply Air Dry Bulb (DB), Wet Bulb (WB) and associated measured CFM. ASW used the Wet Bulb data to identify the return and supply air enthalpies (h). Measurements of line voltage and current were used to estimate condensing unit kW, using an assumed power factor of 0.90. Average savings for jobs passing the QC criteria was 55.9 kWh/ton

What kind of conclusions can we draw from this information?

Based on the data collected, it is apparent that savings are delivered as a result of this program's interventions. However, the measured savings are less than the anticipated level of savings from the Work Paper. Given that only 41% of the jobs passed the data quality QC criteria, there were a number of areas where improvements could be made to the program delivery, data collection, and data analysis, that may lead to improved savings values.

What kind of recommendations can we make?

SCE should consider the following recommendations in order to improve program delivery:

1. Management should check the time it took the technicians to perform the HVAC improvements (Test-in & Test-out) before management accept the operating data and is inputted in the Project Database spreadsheet
2. Sanity checks should be incorporated into the program to ensure validity of data collected. The sample data set had some inconsistencies (e.g. absolute humidity variances) which should be flagged in the field.
3. The database/tool should identify when a field is estimated, and if not estimated when the data is unlikely. This recommendation should be incorporated particularly for airflow
4. There is ambiguity in what tool the technician should use in the field based on program materials. Further investigation should be performed to determine if technicians are given enough direction for tool selection.

5. On-site observations of technicians should be made to identify any other areas of improvement
6. The test-in/test-out field is confusing, the reliability of this data should be assessed
7. The unit must stabilize during test-in/test-out, whether or not this occurs should be investigated
8. Efficiency data obtained from in-situ tests should be normalized to standard (AHRI) conditions to facilitate valid test-in and test-out efficiency comparisons

To improve the data collection, SCE should consider the following:

1. Collect operating data (Test-in and Test-out) between 10 AM to 5 PM during the months of May through October in cities with extreme hot weather conditions to obtain better results
2. Observations of field technicians should be conducted to assess instrumentation accuracy and proper placement
3. Airflow measurements are a key component of the identification of faults and the savings claimed, they should be collected multiple times to ensure consistency
4. The instruments used for airflow measurements should be further examined for accuracy, alternatives such as TrueFlow plates should be considered
5. The location of airflow measurements needs to be more consistent and program guidance should be explored for improvements
6. Include in-situ true electric power readings
7. Include in-situ measurements of furnace or air handler fan power

Finally, to improve the data analysis, the following recommendations are made:

1. Airflow measurements should be converted to standard CFM
2. Identify the number of people living in each Mobile Home
3. If possible, identify the age of the HVAC equipment
4. Identify the ambient temperature away from the condensing unit
5. Identify when the AC is normally run – Example: when the outside air is 78°F. and above
6. Identify the months when they use the AC – Example: May through September
7. Identify the type of thermostat controlling the HVAC operation
8. Include the space temperature setting at the time of the data collection (Test-in & Test-out)
9. Add climate zones (CZ) to the spreadsheet for future analysis
10. Analyze the historic monthly electric consumption for a period of one year. This will help to firm up the established full load hours of operation of the air conditioning system of a given Mobil Home
11. Consider secondary data sources (e.g. modeling tools) for verifying full-load hours

Did Implementer collect the right kind of data? Is there information and data gap that we need to pursue?

The right kind of data was collected; however there is room for improvement in terms of accuracy. Based on the calculation methodology leveraged, the most critical data is the CFM and the power. The recommendations noted in the response to Question 3 should be implemented to improve these data points.

Discussion

It was stated that many of the EMHVAC quality control algorithms were not used for the CMHP datasets. These algorithms were not reviewed by ASW. The removal of the QC steps was reported to be a result of mobile homes being significantly different than single-family homes. As a result, some non-QC'd data, was provided in the supplied data set. As noted in the results section, further evaluation of these tools is necessary to ensure that quality data is collected, both for fault diagnosis and savings claims.

The CMHP Training Document and QM Process were provided for inclusion with this report. No further description of training performed, or how often it was offered was provided. Further investigation into the training and contractor implementation of training material would benefit the overall program.

In order to perform the data analysis, a number of key assumptions were made. The substantial assumptions in the calculation methodology approved by the team are:

- Full Load Hours used in the analysis (1498 FLH),
- Threshold levels set for reasonability (500 kWh/Ton/Yr)
- Negative savings are relevant to the data set and should be counted
- Measured CFM and Amp readings are reasonable.

Modifications to the program process which minimize the number of assumptions will be critical in minimizing future program scrutiny.

Additionally, it should be noted that as the program has continued to operate, more data has been collected which could be analyzed. With a defined, consistent calculation methodology, a greater sample size of data should lead to improved findings and recommendations.

Final Conclusions

The current program design and implementation does provide savings of 92.5 kWh/yr/ton. The savings identified through this effort does fall short of the savings estimated in the Work Paper. However, a number of recommendations have been made that should substantially improve the program results and bring the measured savings into closer alignment with the estimates. A number of these recommendations will require additional effort to identify, understand, and evaluate the benefits, so it is recommended that a second phase of this project be initiated to continue improving this program. This second phase should also incorporate the larger data set that is now available.

Appendix

Embedded Reference Files:

1. Applicable Work Paper.
2. CMHP Training Document.
3. Quality Maintenance (QM) Process.
4. Field Data Collection Form.
5. Savings Analysis Spreadsheet including raw data set.


CMHP Applicable WP.docx


CMHP Training Doc.pdf


QM Process.pdf


Field Data Collection Form.pdf


Savings Analysis Spreadsheet-Final_In