The Sun Devil in the Details: Lessons Learned from Residential HVAC Programs in the Desert Southwest

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ABSTRACT

Utilities in the desert southwest are interested in reducing system peak demand and overall energy use associated with residential air conditioning systems. To this end, many programs with similar design options have been implemented across the region. However, the results of these comparable programs have varied widely.

The southwest has a unique climate, characterized by low humidity and very high temperatures for a significant part of the year, which renders traditional methods of estimating energy use inadequate, because of the higher temperatures and lower humidity. This led the Measurement and Verification (M&V) team to attempt to track down some of the driving factors that influence the performance of residential HVAC efficiency programs in the desert southwest.

The authors conducted primary field data collection in Phoenix, AZ and Palm Desert, CA in the course of evaluating existing energy efficiency programs. These programs covered a range of measures, including:

- High efficiency new equipment
- Early retirement of air conditioning equipment
- Equipment sizing for new construction

The resulting studies show that residential HVAC energy efficiency programs need to be designed carefully in order to ensure maximum return on investment. In general, high efficiency equipment retrofits produced lower savings than expected, while early retirement and proper system sizing appear to offer significant benefits. The program design principles presented here can be applied directly to other residential programs in hot, dry climates and can be modified and applied to other regions with high cooling loads.

Introduction

The following paper presents the results of three residential HVAC research efforts undertaken during the summer of 2009. These studies included:

- Early retirement and high efficiency equipment retrofit in Palm Desert, CA
- High efficiency equipment retrofit in Phoenix, AZ
- New construction air conditioning sizing in Phoenix, AZ

While additional HVAC measures were evaluated in both areas, only the studies with broadly applicable results are presented here. Each study section includes a brief description of approach, results, and lessons learned. After each of the studies are described, program design implications for HVAC equipment programs are discussed more broadly, with potential solutions to the problems uncovered during the course of these studies.

Arizona Efficient Equipment Study

During the cooling season of 2009, 28 air conditioners at 23 homes in the Phoenix, AZ region were studied to determine the energy and peak demand savings of high-efficiency air conditioners. The overall analysis approach was to collect field data from a representative sample of high-efficiency AC units installed under the program and use this 2009 data to calibrate a model which will accurately predict energy consumption and peak demand for a typical year as a function of the unit's rated Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER).

Data loggers were used to monitor the air conditioners over the course of the summer of 2009, collecting current draw for the indoor and outdoor units and indoor temperature and humidity at 10 minute intervals. Spot measurements of voltage and power factor were used to convert logged current into power readings.

In order to arrive at the ultimate goal of producing energy and demand savings as a function of SEER and EER, the analysis was divided into three main components which comprised the overall residential HVAC model:

- *A Building Simulation Model (Runtime Model)*, built in eQuest, to determine system hourly run time, as well as indoor and outdoor temperatures, for a typical year in Phoenix.
- *Manufacturer HVAC Performance Maps (Performance Model),* which details power consumption as a function of outdoor dry bulb (ODB), evaporator entering dry bulb (EDB) and entering wet bulb (EWB) temperatures for a representative set of HVAC equipment.
- *Performance Adjustment Factors,* a set of equations (as a function of ODB) which adjust manufacturer predicted power draw to that observed in Phoenix.

To calculate annual energy and peak demand for a given unit, the hourly temperature conditions from the runtime model were first used to interpolate within the manufacturer's performance maps to determine a baseline power draw for each hour, which was then adjusted using the calculated adjustment factor. The resulting power was multiplied by the unit runtime to give total kWh consumption for each hour. Annual kWh was calculated as the sum of the 8760 hourly kWh, and peak kW was calculated as average kW consumption over the utility peak period. This was repeated for a representative set of 120 HVAC units, and overall functions for annual kWh and peak kW as a function of SEER and EER were derived through a regression analysis.

Arizona Equipment Study: Results

The results of this study confirmed earlier analysis that showed SEER to be a questionable predictor of performance in hot dry climates. In addition, the cooling runtime came in lower than expected, with a mean between 1050 and 1100 equivalent full load hours. Figure 1 shows the annual energy consumption of each of the simulated air conditioners. While there is definitely a trend towards lower consumption with higher SEER, there is about 10% performance variability within each SEER group.

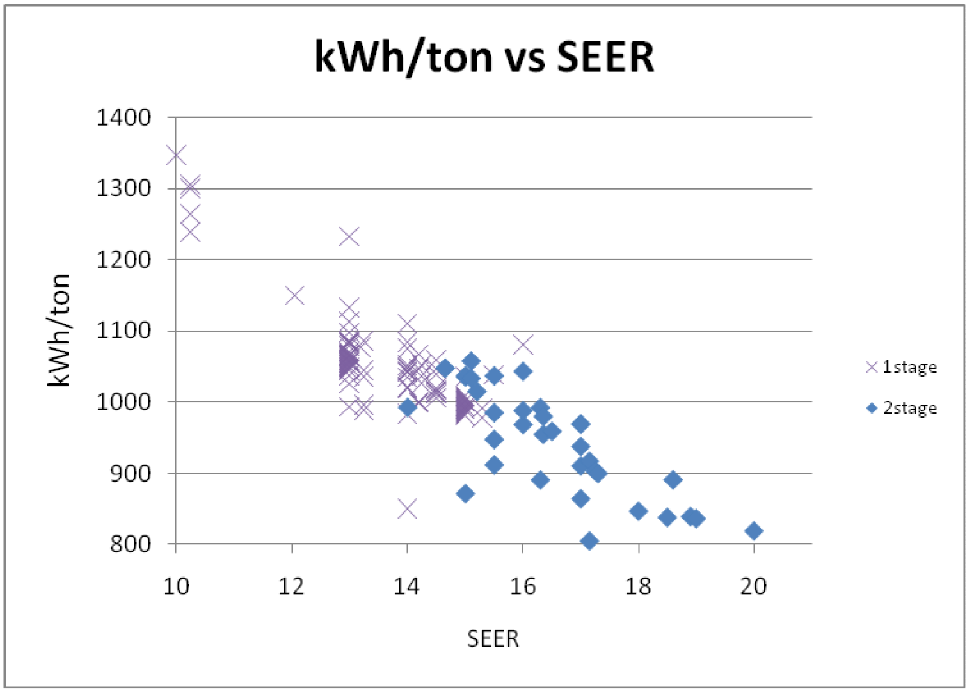

Figure 1. Phoenix Annual New Residential HVAC Cooling Consumption (All)

This variability may be larger than the potential savings of moving up one SEER. For example, if one examines the performance of SEER 13 to SEER 15 equipment, on average a SEER 14 or SEER 15 unit will perform better than a SEER 13 unit, but there are some SEER 13 equipment that perform better than the average SEER 14 or SEER 15 unit and some SEER 14 and SEER 15 equipment that perform worse than the average SEER 13 unit. The variability in predicted performance is caused by differences in the strategies employed by manufacturers to achieve higher SEER – some strategies result in better performance only at temperatures close to the SEER test, while others results in better performance at all temperatures. Additional variability in performance may be due to installation parameters, including sizing, airflow, and refrigerant charge. Figure 2 shows the average annual consumption at each SEER level for SEER 13 and higher equipment.

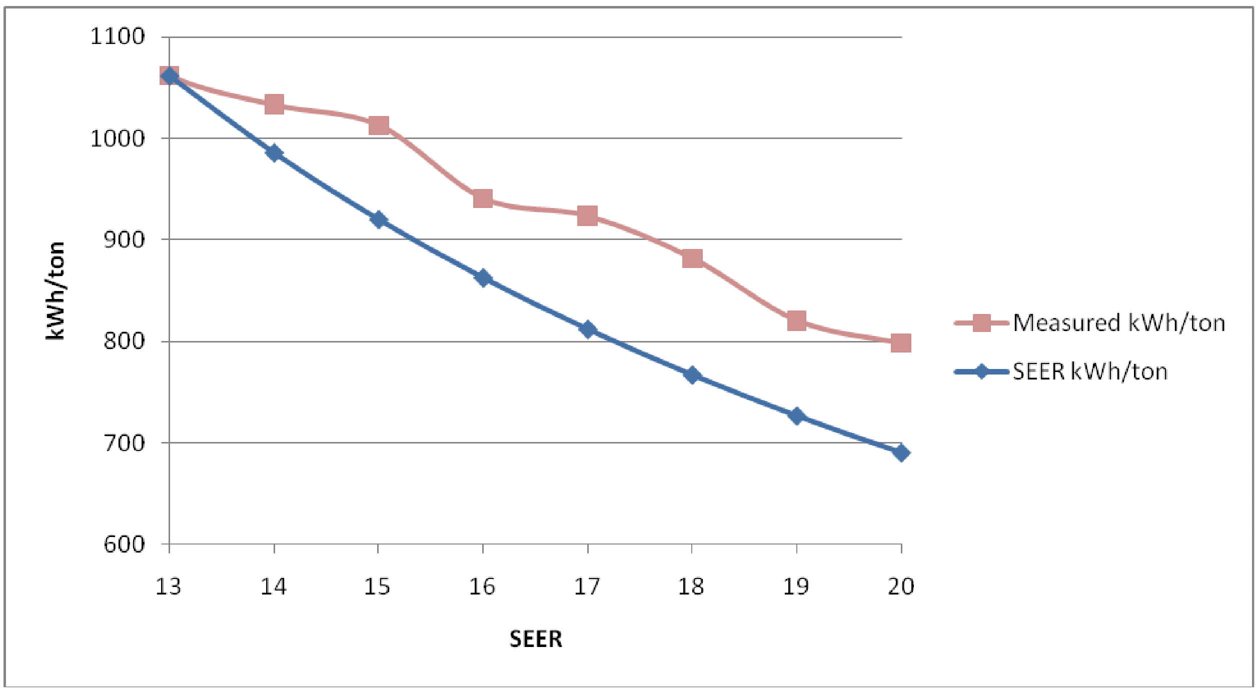

Figure 2. Phoenix Annual New HVAC Residential Cooling Consumption (Average)

The theoretical performance on the basis of SEER is shown for comparison, where consumption is assumed to be proportional to 1/SEER and the curve is normalized to SEER 13 performance. There is a large change in consumption from SEER 15 to SEER 16 equipment, which coincides with the shift from single stage equipment to two stage equipment.

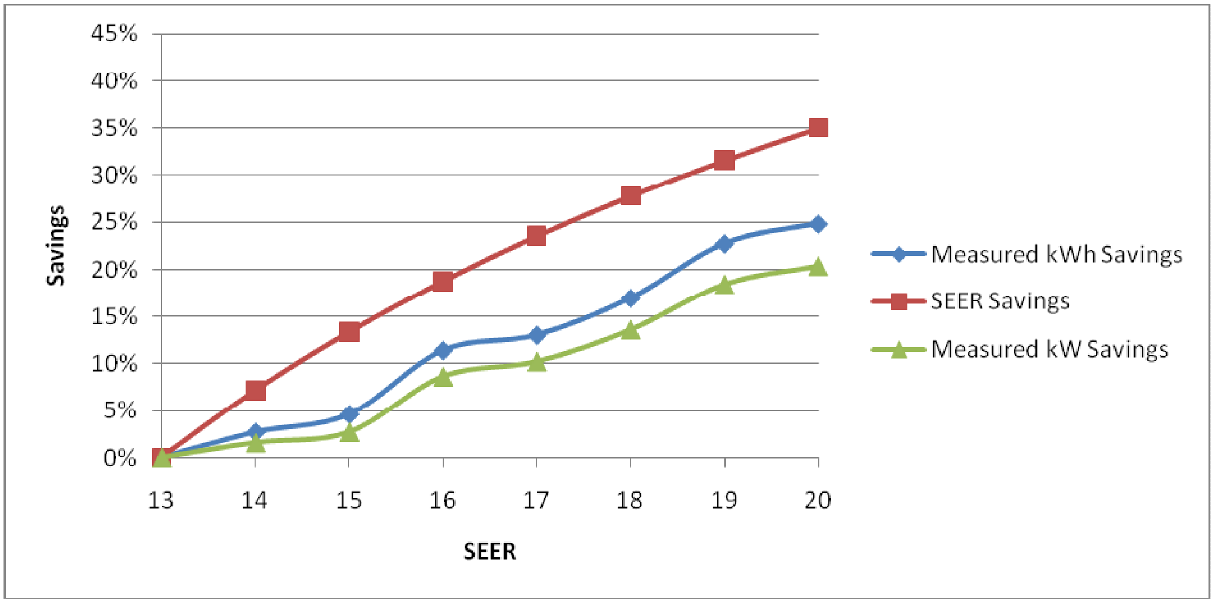

Figure 3. Measured Energy and Demand Savings Compared to 1/SEER Savings

The results in Figure 3 show that the *savings* for high efficiency residential HVAC equipment were not close to the theoretical SEER performance improvement, where energy consumption and peak demand are proportional to 1/SEER. If all performance was at the conditions defined by the SEER test (82 deg F outdoor drybulb, etc.), then the savings would follow the SEER savings line in Figure 3. Many have commented on the inadequacy of SEER as a measure of AC energy performance in hot dry climates. The results of this study explicitly show that SEER is a questionable predictor of the magnitude of energy savings associated with energy-efficient residential air conditioning equipment in hot climates. Peak demand savings are even further from the ideal SEER curve, which is not surprising, given that peak demand conditions in Phoenix occur at temperatures around 110 degrees F. The main reason for this poor performance is that SEER is performed at 82 degrees F outdoor temperature, whereas the bulk of residential cooling in Phoenix occurs at much hotter temperatures (94 deg F average). Figure 4 shows the distribution of air conditioning run time by outdoor temperature measured in Phoenix.

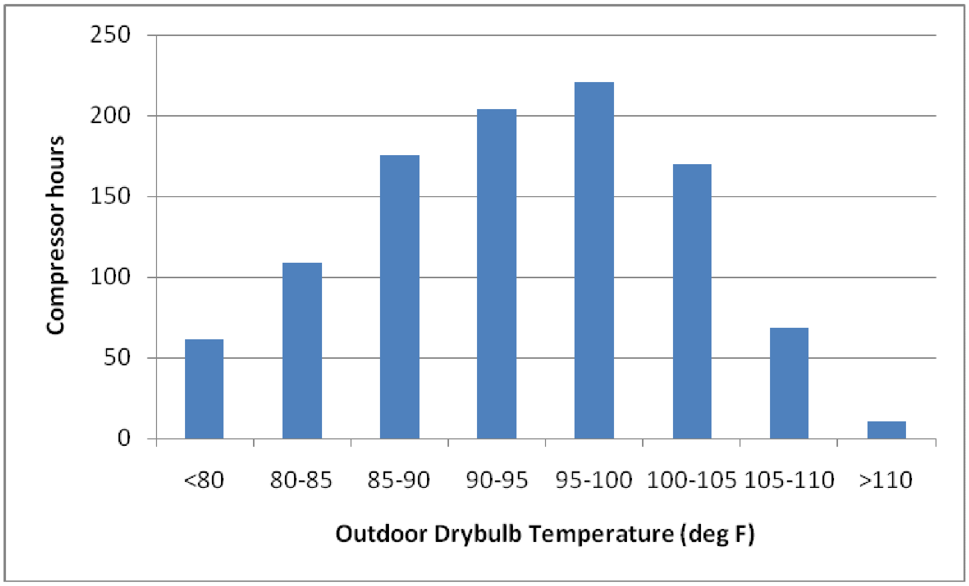

Figure 4. Runtime By Outdoor Drybulb

Because equipment is optimized and tested for performance at the low temperature SEER test conditions, higher SEER equipment may not perform much better at high temperatures than typical SEER 13 equipment.

Arizona Equipment Study: Lessons Learned

- The high SEER equipment currently on the market does not create energy or peak demand savings anywhere near what a 1/SEER consumption curve would indicate.
- The main cause of this is that bulk of operation in Phoenix occurs at higher temperatures than the SEER test
- It is clear that equipment that performs well under the SEER rating conditions does not necessarily perform well at high temperatures. Additional studies in other climates may confirm this result is broadly applicable.

Palm Desert AC Replacement Study

Also in the summer of 2009, the authors performed field monitoring of AC units in Palm Desert, CA to determine the energy and demand savings of high-efficiency units, early retirement of AC units, and refrigerant charge and airflow (RCA) tune-ups. The RCA results were highly program-specific, but the results of the efficient equipment and early retirement portions of the study provide some illuminating lessons. The Palm Desert program provided an additional benefit for high efficiency HVAC program participants who retired working air conditioners. All early retirements in the program were combined with a high efficiency air conditioner rebate.

The 34 AC units selected were monitored to collect energy consumption and temperature and humidity in both the supply and return plenums at 1 minute intervals. Logged data was broken into distinct run periods, and in-situ efficiency for each period was calculated using the change in enthalpy in the supply airstream and the logged energy consumption. Annual energy and demand savings were then determined using an eQuest/DOE 2.2 hourly building simulation model. First, an updated equipment efficiency curve was derived by taking a regression of in-situ efficiency versus outdoor temperature for all of the monitored units. This curve was entered into the eQuest model, built using observed site characteristics from the monitored sites. The model was then calibrated to the average logged energy consumption (per nominal ton capacity) of the monitored group.

Efficiency and age of the baseline units was determined from inspection reports, and a remaining useful life (RUL) curve was derived from appliance mortality curves fit to a Weibull distribution. The average nameplate SEER rating observed in the inspection was 9.74, and the average unit in the early retirement program was 18.7 years old. The estimated air conditioner RUL curve was applied to a sample of the units that were retired early, giving a mean RUL of 5.9 years. The units retired tended to be older than the expected useful life of the full population.

Base case models for both the high-efficiency (SEER 13 base) and early retirement (SEER 9.74 base) cases were developed using data from other contract groups, who measured a variety of equipment, including newer SEER 13 (new baseline efficiency) and older lower SEER equipment (early retirement baseline). The only portion of the model that was changed was the equipment efficiency curve; it was assumed that since the efficiency curve for the efficient case was derived independently of the model, the model calibration adjusted the thermal loads such that the model was an accurate representation of an average home in Palm Desert. Savings were derived by taking the difference in peak demand and annual energy consumption for high efficiency units, new code base units, and existing units.

Given the high likelihood of free ridership in AC replacement programs, a separate net-to-gross analysis was performed via telephone survey to quantify the savings attributable to the program.

Palm Desert AC Replacement Study: Results

Table 1 below shows gross unit savings from early AC replacement, broken into the portion of savings attributable to the early retirement as opposed to the efficient equipment:

Table 1:Palm Desert AC Replacement Unit Annual Energy and Demand Savings

Measure Category	Unit Energy Savings (kWh/ton)	Peak Demand Savings (kW/ton)
Early Retirement (Existing up to Code minimum)	326	0.21
High Efficiency Equipment(Code up to High Efficiency)	68	0.03
Total	394	0.24

These numbers show the surprising result that the early retirement portion of the Palm Desert program accounted for nearly all of the savings. This is because the high efficiency equipment performance was worse than expected. Also surprising was the low level of free ridership in the program, demonstrated by the net-to-gross ratio of 0.74.

Palm Desert AC Replacement Study: Lessons Learned

- Early retirement programs create much larger early year savings than high efficiency equipment upgrades in hot dry climates (83% of energy and 88% of peak demand savings in this program). Early retirement likely create large savings in other climates as well.
- The remaining useful life of older equipment is longer than one might expect – 6 years on average in this program, with an average age of replaced equipment of 19 years
- Savings per ton associated with early retirement in Palm Desert were 326 kWh and 0.21 kW.
- Freeridership was lower than expected, with a net-to-gross ratio of 0.74
- Cost-effectiveness was not examined as part of this study

Phoenix Air Conditioning Sizing Study

During the summer of 2009, the authors monitored thirteen new homes in the Phoenix metro area to determine whether or not air conditioners were being oversized. The thirteen homes were chosen to depict the homes in the new building stock that had the highest cooling loads relative to the size of their air conditioners. The sample of homes met the following criteria:

- Plans were selected that had the lowest predicted oversizing by the HVAC contractor's sizing calculations
- Homes with the worst case orientation for a given plan were monitored
- Homes with relatively low set points were monitored (78 deg F or lower)
- A mixture of single zone and multizone homes were monitored

All thirteen newly constructed homes had air conditioners that had been nominally sized using Manual J, with high efficiency envelopes. The sample included a mixture of occupied homes, model homes, and newly-constructed spec homes.

Arizona Sizing Study: Results

The detailed results of the study are presented in Table 2.

Table 2. Detailed Site Results.

Plan Number	SZ-1A	SZ-1B	SZ-2	SZ-3	SZ-4A	SZ-4B	SZ-5A	SZ-5B	MZ-1A	MZ-1B	MZ-2
Occupancy Status	spec	occ.	model	model	model	spec	spec	model	spec	spec	occ.
Characteristic Design Temp	115	126	113	118	112	117	135	118	147	122	118
Manual J Equip. Cap. (tons)	2.8	2.8	3.6	2.8	3.3	3.3	3.5	3.5	4.8	4.8	5.3
Actual Installed	3	3	4	3	3.5	3.5	3.5	3.5	5	5	5

Plan Number	SZ-1A	SZ-1B	SZ-2	SZ-3	SZ-4A	SZ-4B	SZ-5A	SZ-5B	MZ-1A	MZ-1B	MZ-2
Cap. (tons)											
Predicted Manual J Oversize Percentage	5.3%	5.3%	9.4%	6.9%	5.1%	5.1%	0.0%	0.0%	4.7%	4.7%	-6.8%
Measured Oversize Percentage	13.0%	26.0%	6.1%	15.3%	4.6%	16.3%	47.5%	14.0%	63.3%	22.7%	11.8%

In the table above:

- **Plan number** identifies a home that was monitored.
- **Occupancy status** identifies if a home is an unoccupied spec home, a home used as a model, or an occupied home.
- **Characteristic Design Temp** is the experimentally-determined outdoor temperature at which the A/C system just meets the load (i.e. holding temperature constant at the typical thermostat setpoint), while running 100% of the time.
- **Manual J Equip Cap** is the load predicted (in tons) by a Manual J calculation and equipment capacity adjustment performed by the HVAC contractor.
- **Actual installed cap** is the nominal size (in tons) of the equipment installed at the home.
- **Predicted Manual J Oversize Percentage** is the percentage by which the installed nominal capacity exceeds the contractor's predicted required capacity (Manual J Equip Cap).
- **Measured Oversize Percentage** is the percentage by which the installed nominal capacity exceeded the measured required capacity.

Two sites had failed data loggers and had to be thrown out. The operations were corrected for variations in occupancy and thermostat behavior. As shown in Figure 5, none of the air conditioners ran at 100% at the Phoenix design temperature of 108 degrees F. At 115 degrees F, three out of eleven units ran at 100% and at 120 degrees F, seven out of eleven units ran at 100%.

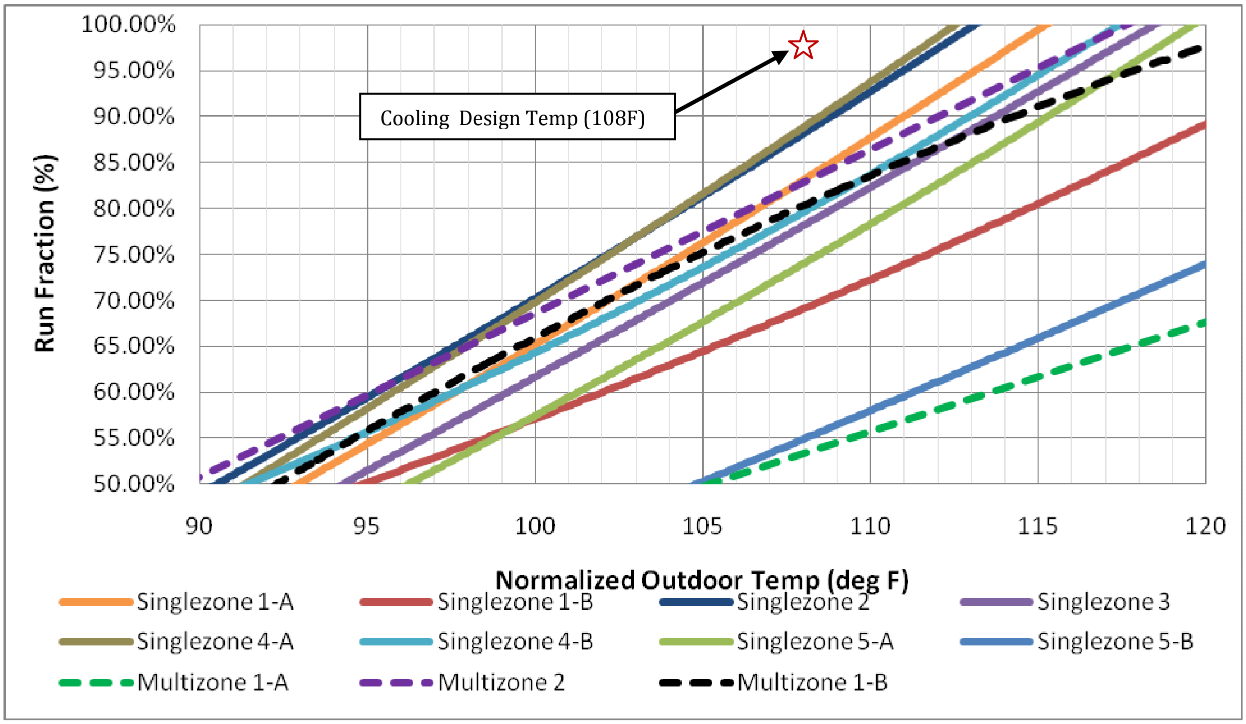

Figure 5. Run Fraction vs. Normalized Outdoor Temp

The field-measured results were combined with the Manual J predicted loads and equipment sizes to derive an estimate of actual system oversizing at each site, compared to the system oversizing predicted by the Manual J sizing and equipment selection. The results of this comparison are shown in Figure 6.

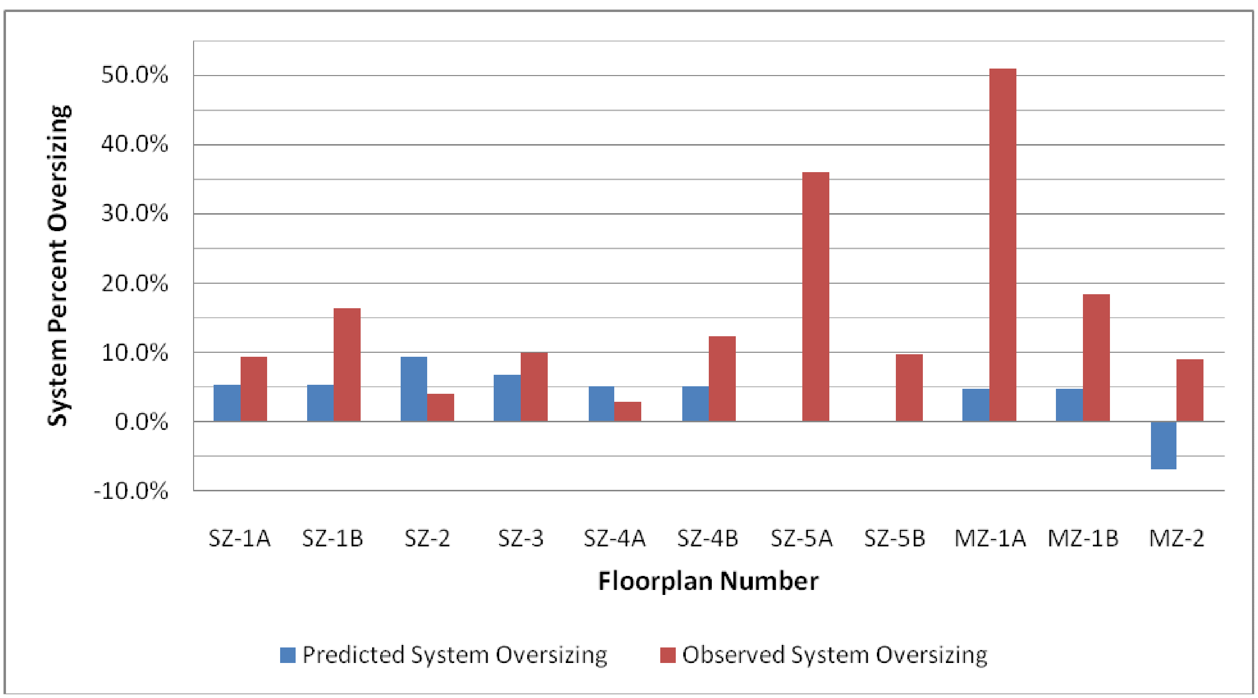

Figure 6. Predicted vs. Observed Oversizing

Nine out of eleven sites showed significantly more oversizing in the field than predicted by the comparing the HVAC contractor Manual J sizing requirement with the installed equipment size. The site with the least amount of oversizing (SZ-4A above) was given further investigation in the field, which revealed an unbalanced outdoor air ventilation system and a gaping hole in the supply plenum, likely caused after the system was installed. The oversizing of the equipment at that site would prevent the homeowner from ever knowing there was a problem. We suspect that SZ-2, the other site with lower field oversizing than predicted also had some sort of similar problem. If these two outliers are thrown out, the field work shows a median value of 14% *higher* oversizing than predicted by the HVAC contractor. When the Manual J/Manual S calculations are corrected to best practices, the field work shows a median value of 3.5% higher oversizing the Manual J/Manual S prediction. Best practice Manual J/Manual S results in sizing equipment 10-12% smaller than the Manual J method used by the contractor.

Arizona Sizing Study: Lessons Learned

As a result of this study, we conclude the following:

- The median system oversizing in this study was 15%. All systems that were likely installed correctly were oversized by at least 10%. This means that a significant number of systems could be downsized without impacting thermal comfort. Because the sampled homes were chosen to all have the least amount of oversizing possible, we expect that this study gives a conservative estimate of oversizing of air conditioners in new construction.
- The oversizing of current system installations is hiding problems with HVAC systems that are in need of repair. If these systems were not oversized as much, the systems with problems would be more likely to create comfort complaints and get repaired, increasing comfort and reducing energy consumption for homeowners.
- In Phoenix, best practice Manual J /Manual D sizing with a design temperature of 108 deg F, a sensible heat ratio of 0.8, and proper use of Manual S will provide a better estimate of the necessary equipment size, very close to optimally sized in new construction.

Discussion of Program Design Implications

Efficient Equipment

Utility programs are struggling with poor performance from high efficiency equipment in hot dry climates. Because the bulk of operation in this climate occurs at temperatures in the 90s and 100s, while the SEER test occurs at 82 deg F, air conditioners do not create savings according to the expected 1/SEER relationship. Homeowners, contractors, and program managers are being misled by the use of current SEER numbers for characterizing equipment performance. The savings are roughly 60% less than a 1/SEER assumption would indicate. The average energy and peak demand savings in Palm Desert were 68 kWh/ton and 0.03 kW/ton for upgrading from a SEER 13 unit to an average SEER 14.8 unit. The average energy and peak demand savings in Phoenix were 116 kWh/ton and 0.09 kW/ton for upgrading from a SEER 13 unit to an average SEER 15.4 unit. The higher savings and average SEER in Phoenix reflect the greater number of two-stage, high SEER equipment in Phoenix, which has much higher savings than the single stage equipment in this climate. Palm Desert also showed a higher incidence of seasonal residents participating in the program, resulting in lower average savings.

The low savings associated with high efficiency air conditioning equipment in hot dry climates is also a result of lower than expected runtime. While one might intuitively expect savings to be proportional to cooling degree day hours, this is really savings *per home*. When design conditions are taken into consideration, the savings *per ton* may not be much larger.

Unfortunately, the problem of high SEER performance is difficult to solve locally. EER minimums can help weed out some equipment with poor peak demand performance, but that does not fix the whole problem. A much better solution would be to require an alternative h-SEER and h-EER for use in hot selling equipment in hot climates. For the desert southwest, a more appropriate h-SEER would rely on part load performance at 95 deg F. An h-EER test of full load efficiency at 110 would be useful for peak demand estimates. While it is possible to calculate alternative h-SEER and h-EER values from extended performance ratings information from manufacturers, the process for agreeing on an alternative measure of AC efficiency is likely to be time-consuming. Federal law limits performance claims that can be made outside of SEER and EER. Some manufacturers producing equipment that performs better in hot climates may see a competitive advantage in being able to market their equipment on the basis of hot climate performance.

In the meantime, utilities could consider a branding program whereby a sticker could be added to equipment that meets a certain performance standard, as a way to make a statement about the performance of this equipment in a hot climate. This would require significant work on the part of the utility or their contractors to certify pieces of equipment, making it unlikely that a single utility would take this on unless they were very large. A coalition of utilities encompassing the hottest part of the United States would be able to effectively advocate for alternate HVAC performance criteria, drive the development of those criteria, and share information about weather-dependent energy efficiency measures work in their climate.

Given the high public awareness of high efficiency air conditioning equipment, utility program designers should consider bundling equipment with additional HVAC system measures, such as duct sealing and quality installation including proper sizing. There continues to be plenty of opportunity for sizing reductions, even in new construction with Manual J sizing runs nominally being performed. Reduction in size can help pay for higher efficiency equipment, improving the benefit-cost ratio of efficient equipment programs. In time, equipment can be redesigned to perform better in hot dry climates, but performance criteria that make this hot dry performance transparent to the public and industry will need to be developed in order for this equipment to meet its market potential.

Early Retirement

Early retirement of older air conditioning systems creates large near-term savings in both energy and peak demand, much larger annual savings than upgrading from a SEER 13 unit to a SEER 16 unit. While there is some evidence that a certain amount of early retirement of air conditioning systems goes on without utility involvement, utilities can influence people to replace their equipment before it breaks. Also, while the incremental cost appears to be quite high initially, because people are replacing working equipment instead of purchasing incrementally better equipment, the true cost to the consumer is equal to the financing cost of making the purchase now instead of 6 years from now. The true cost of the equipment early retirement is equal to the net present value of 6 years of uniform series payments for the base equipment cost.

Contrary to some beliefs, research on remaining useful life of air conditioning equipment shows that there is still significant remaining useful life (4 or more years) in equipment that is up to 25 years old, which is significantly beyond the median life. In short, equipment that has been running for 25 or 30 years is likely to keep running for at least a few more years. Tune-up program evaluation results showed equipment still running that was installed 35 years ago.

Potential problems with early retirements:

- *Freeridership.* Like high efficiency equipment upgrades, early retirements have the potential for high amounts of freeridership. Plenty of people retire their systems early, even without a utility program in place. However, our study of freeridership in Palm Desert revealed relatively low levels of freeridership, so it appears utility programs can be constructed with low freeridership.
- *Replacement of newer, higher efficiency equipment.* Our study of early retirements in Palm Desert showed an average retired equipment SEER value of 9.75 and an average age of 18.7 years. However, there was equipment as new as 6 years old, with efficiencies as high as SEER 12. Replacing a SEER 12 unit with a SEER 13 unit does not generate nearly as much savings as replacing a SEER 9 unit with a SEER 13 unit. As the air conditioning stock continues to turn over, the average efficiency of the replaced units will rise and SEER 13 equipment (with zero savings) will start to show up in the mix. Utility programs should place an upper SEER limit on the replaced equipment for participation in the early retirement program. A nameplate 10.5 SEER limit or documentation of operating efficiency less than 9 EER is suggested.
- *False claims of early retirement***.** It is necessary to put steps in place to prevent people from claiming a false early retirement. In the Palm Desert Partnership, the program required that a certified technician sign a statement that the unit was working or that it could be repaired for less than $500. These or similar requirements are necessary to keep people from claiming an extra large incentive when they purchase a new piece of equipment.

The change in federal minimum efficiency standards from SEER 10 to SEER 13 in 2006 forced the air conditioning industry to manufacture and install equipment with much higher efficiency. Before 2006, equipment with SEER 11 and higher had a very small share of the market equipment with SEER 13 and up had an even smaller share of the market. After 2006, nearly all equipment installed has been SEER 13 or better. This large market has driven the cost of SEER 13 air conditioning equipment down. This step change in the market presents a unique opportunity to replace old SEER 10 equipment with newer SEER 13 and higher equipment. At the same time, this change has made it much less cost-effective to install high efficiency equipment instead of standard equipment, because the new standard equipment is very efficient and the cost premiums for installing high efficiency equipment are large.

For the next 10-15 years, there will still be very large numbers of SEER 10 or worse air conditioners in operation without intervention. Utility programs are poised to cause that stock of air conditioners to turn over much faster, saving large amounts of energy and reducing peak demand in the near term. Savings in early years of programs are more cost effective, because their benefits are immediate and not discounted as much as savings in later years.

Opportunities for marketing early retirement programs to customers and contractors:

- Customers see large immediate savings from early retirements – a 30-40% reduction in summer electricity bills is possible in homes with high cooling loads. This gives participants immediate evidence to convince friends and neighbors to participate.
- Early retirements create a large amount of savings in a single transaction. This can keep overhead costs lower.
- Early retirements may be attractive to people who don't want to have their air conditioner fail when it is 110 degrees outside and then be forced to make an emergency purchase. Customers can shop for a new air conditioner at the best price instead of having to pay for an emergency installation.
- Early retirement programs can give HVAC contractors a new sales channel during the shoulder and offseason months, allowing them to increase sales during their slow times.

Conclusions

While traditional high efficiency air conditioning equipment retrofit programs are struggling with poor performance of high SEER equipment in hot dry climates, there continue to be large opportunities in residential HVAC system energy efficiency programs. Early retirements offer much larger savings and reasonably long remaining useful lives (6 yrs on average for equipment replaced at 18 yrs on average), and will offer large opportunities for savings over the next 10 to 15 years. Promotion of alternate performance criteria may drive a market transformation towards air conditioning equipment that is better suited for a hot dry climate. In the meantime, coupling high efficiency equipment with early retirements, quality installation including sizing, and duct sealing offers the best chance to drive large savings through public awareness of high efficiency air conditioning equipment.

References

Conant, A., J. Proctor, and L. Eberling. 2008. "Field Tests of Specially Selected Air Conditioners for Hot Dry Climates" In *Proceedings from the 2008 ACEEE Summer Study on Energy Efficiency in Buildings*. 1:49-62. Washington, D.C.: American Council for and Energy-Efficient Economy.

Downey, T. and J. Proctor. 2002. "What Can 13,000 Air Conditioners Tell Us?" In the *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings.* 1:53-67. Washington, D.C.: American Council for and Energy-Efficient Economy.

Masiello, J. A., M.P. Bouchelle, D. S. Parker, and J.R. Sherwin. 2004. "Measured Energy and Peak Demand Reduction from High Efficiency Air Conditioner Replacement" In *Proceedings from the 2004 ACEEE Summer Study on Energy Efficiency in Buildings*. 1:200-211. Washington, D.C.: American Council for and Energy-Efficient Economy.

Mowris, R. J., A. Blankenship, E. Jones. 2004. "Field Measurements of Air Conditioners with and without TXV's" In the *Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings.* 1:212-227. Washington, D.C.: American Council for and Energy-Efficient Economy.

Mowris, R. and E. Jones. 2008. "Peak Demand and Energy Savings from Properly Sized and Matched Air Conditioners" In the *Proceedings of the 2008 ACEEE Summer Study on Energy Efficiency in Buildings.* 1:196-208. Washington, D.C.: American Council for and Energy-Efficient Economy.

Proctor, J. and G. Cohn. 2006. "Two-Stage High Efficiency Air Conditioners: Laboratory Ratings vs. Residential Installation Performance" In the *Proceedings of the 2006 ACEEE Summer Study on Energy Efficiency in Buildings.* 1:223-234. Washington, D.C.: American Council for and Energy-Efficient Economy.

Sachs, H. M., H. Henderson, D. Shirey, III, S. Nadel, and D. W. Jaynes. 2006. "Can SEER be Saved?" In the *Proceedings of the 2006 ACEEE Summer Study on Energy Efficiency in Buildings.* 1:272-285. Washington, D.C.: American Council for and Energy-Efficient Economy.

Townsend, A. and K. Ueno. 2008. "Effects of Air Conditioner Sizing on Energy Consumption and Peak Demand in a Hot-Dry Climate" In the *Proceedings of the 2008 ACEEE Summer Study on Energy Efficiency in Buildings.* 1:291-305. Washington, D.C.: American Council for and Energy-Efficient Economy.