SCE DRET Findings
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DR14.07: Residential Crawl Space and Attic Conditioning and Sealing Retrofits

Evidence Shows Potential Benefits for Conditioning Residential Crawl Spaces and Attics

The field study data and analysis showed a variety of results. The highest savings were observed in the hottest climate zone and with ducting in the crawl space. Electrical energy savings of 19-28% was observed for the crawl space sealing while gas savings showed mixed results. Electrical energy went up with attic sealing but gas usage decreased by 45% at the site with ductwork in the attic. Total net savings after both measures were 0-32% of electrical usage and 26-39% of gas usage. However, the sites should be considered separately since each had different measure designs, equipment, ducting locations, and climate zones. Savings for each measure is highly dependent on duct leakage and locations.

Electrical savings were well-distributed over the daytime in the summer and demand response tests showed reductions similar to existing DR programs. Comparisons between the crawl space and attic phases suggested that the additional thermal inertia and conditioned air may reduce unwanted indoor air temperature increases during a demand response event. Although outdoor air conditions were not identical across the demand response testing, the indoor air temperature increases were roughly 30-50% of what was observed before attic sealing.

Indoor air quality and humidity levels were improved in all cases. High humidity levels in the crawl spaces and attics that can lead to mold and rot were virtually eliminated. Additionally, carbon monoxide and radon levels in the home were confirmed to be largely unaffected by the measures and in no case were increased to unsafe levels.

The average measure costs were $8.70 per square foot for crawl space sealing and $6.70 per square foot for attic sealing but could likely be reduced with standardization and increased market adoption. The existing vented crawl space market size is approximately 1,387,700 and 441,600 homes in California and SCE service territory, respectively. The existing vented attic market size is approximately 2,650,100 and 8,030,600 homes in SCE territory and California, respectively. Of these that have central air, the estimated potential savings is on the order of 400 and 1,100 GWh/year for SCE and California, respectively, if the Fullerton and Desert Hot Springs sites are considered typical.

INTRODUCTION

What Is This Technology?

CONDITIONED CRAWL SPACES/ATTICS

The measure under study is the sealing and conditioning of vented crawl spaces and attics in single-family residences. Sealed, conditioned crawl spaces and attics have vapor barriers, insulation on exterior walls, and a path for conditioned air to circulate. The measure can improve building envelope air tightness, reduce duct leakage loads, reduce humidity levels, and improve overall air quality. It also has potential to improve demand response effectiveness by increasing available cool air and thermal inertia.

In summary, the potential benefits of these measures include:
- Reduced envelope leakage, infiltration, and exfiltration.
- More thermal mass available to smooth out interior temperature response to outside temperatures and enhance demand response (DR) potential.
- Improved insulation over existing baseline conditions.
- Reduced risk of dry rot, wood deformation, pests such as termites, standing water, and mold within the vapor barrier.
- Reduced duct leakage with unconditioned air, depending on duct location.

What We Did?

3-YEAR STUDY AT 4 RESIDENTIAL SITES

A field assessment at four existing residential sites was conducted over three years to study the effects and implications of conditioned crawl space and attic retrofits. The findings can help determine which programs and stakeholders would need to be involved in future efforts, market transformation, or support roles. Energy usage, indoor air quality, market size, and market barriers were explored. The first year was for baseline monitoring while the second and third years were for measure monitoring (crawl space measure monitored during second year, and attic measure during third year).

This study had several objectives:
1. Measure energy usage and estimate savings of residential unvented, conditioned retrofit crawl spaces and attics.
2. Perform DR tests to establish whether crawl space measures improve residential HVAC DR effectiveness.
3. Explore residential building and compliance whole building modeling and investigate the compatibility of existing software with conditioned crawl spaces and attics.
4. Measure effects of crawl space and attic sealing measures on indoor air quality.
5. Provide findings and recommendations for ET, EE program, DR program, and code readiness purposes.
6. Provide data and analytical results in a field assessment report for public dissemination to increase understanding of the measures in a retrofit case.

HOST SITES OVERVIEW (GENERAL DETAILS)

Host Site	CA CZ	Year Built	Baseline Leakage (ACH50)[2]	Living Space Area (ft^2)	Baseline Energy Intensity (kWh/ft^2-yr)[3]	Baseline Energy Intensity (therm/ft^2-yr)[4]
Desert Hot Springs	15	1946	15.3	900	13.48	0.30
Fullerton	8	1957	13.2	1,220	5.07	0.22
Murrieta	10	1980	13.7	1,500 (1st floor) 940 (2nd floor)	4.33	n/a
Pomona	9	1920	37.6	1,160	7.36	n/a

FINDINGS

In all cases, comfort conditions improved in the living space. The inside air temperature and RH stayed closer to the typical comfort range over the observed range of outside air conditions. Additionally, radon and carbon monoxide levels were not adversely affected and stayed within safe bounds in both the baseline and post-measure cases. Humidity in the crawl space and attic improved in all cases and excessive levels that could lead to moisture problems were virtually eliminated. This can help reduce risk of structural degradation as long as proper ventilation of the roof deck is included in the installation.

Evidence suggests that the additional thermal inertia created by the sealing and insulating measures can help reduce the inside air temperature gains during DR set-point adjustments. However, the DR reduction was less after attic conditioning. The net results for both measures combined using the existing baseline (original homes) indicated an electricity savings range of 0-32% and a natural gas savings range of 26-39%.

Crawl Space Measure Results with Existing Baseline

HOST SITE	ENVELOPE LEAKAGE REDUCTION AT 50 PA (CFM)	AVG DEMAND RESPONSE REDUCTION (KW)	ELECTRICITY SAVINGS (KWH/YR)	NATURAL GAS SAVINGS (THERMS/YR)
Packaged AC with Gas Heat – Desert Hot Springs	280 (15%)	1.14 (60%)	2,132 (28%)	55 (59%)
Split System with Gas Heat – Fullerton	-605 (-28%)	0.95 (49%)	828 (26%)	-17 (-10%)
Supplemented Heat Pump – Murrieta	410 (8%)	n/a	0	n/a
Window Units - Pomona	73 (1%)	n/a	64 (19%)	n/a

Attic Measure Results with Crawl Space Phase as Baseline

HOST SITE	ENVELOPE LEAKAGE REDUCTION AT 50 PA (CFM)	AVG DEMAND RESPONSE REDUCTION (KW)	ELECTRICITY SAVINGS (KWH/YR)	NATURAL GAS SAVINGS (THERMS/YR)
Packaged AC with Gas Heat – Desert Hot Springs	265 (17%)	0.98 (40%)	-2,140 (-28%)	-31 (-81%)
Split System with Gas Heat – Fullerton	605 (22%)	0.50 (46%)	-337 (-15%)	88 (45%)
Window Units - Pomona	570 (10%)	n/a	49 (18%)	n/a

[1]Average DR reduction for California SFR programs is about 1.09 kW (Southern California Edison, 2009).

CONCLUSIONS

What We Concluded?

The field assessment of conditioned, sealed crawl spaces and attics under differing conditions produced a variety of results. Normalized energy savings were calculated for each site and extrapolated to the other participating climate zones for comparison. Indoor air quality was observed, and DR tests were performed during the measure period. The market size, potential savings, and barriers were studied. These measures are particularly useful for homes with ductwork in the sealed space, high envelope leakage, high duct leakage, excessive crawl space or attic venting, homes with little insulation and homes with high HVAC energy usage. Baseline conditions without vapor barriers already installed would see more savings, and those homes with ductwork in the crawl space or attic should be the primary target of outreach efforts due to the highest energy savings opportunity.

Successful DR simulations were conducted at two of the four sites. These tests were remote adjustments of the thermostat set-point by 1 degree per hour over three peak summer hours. The two sites showed average, baseline adjusted DR reductions of 0.5 and 1.14 kW (40-60%), similar to other residential DR testing in other studies (Southern California Edison, 2009).

These Findings are based on the report "Residential Crawl Space and Attic Conditioning and Sealing Retrofits" which is available from the ETCC program website, https://www.etcc-ca.com/reports.

Recommendations

Based on the promising nature of this measure and the variety of benefits, consideration for program support is recommended. Additional recommendations for further measure support include code enhancement studies, packaged residential rebates or incentives, best practice guidelines, and outreach and training for contractors to help foster market adoption and availability.

SUBSEQUENT STUDIES

Any subsequent studies should focus on controlling conditions as much as possible. For instance, any future study should install programmable thermostats with appropriate settings before the baseline. This will allow for baseline DR testing and help to avoid changes to occupant behavior due to improved set-point control.

Additionally, occupants should be screened for their HVAC use and set-point preferences prior to enrollment to avoid unusual cases such as the Murrieta and Pomona sites. Several planned side-by-side, unoccupied, controlled sites for this study had been planned but could not be included. This type of test site could help maintain control conditions.

PROGRAM SUPPORT

Potential program support includes code changes, new construction energy budgeting of conditioned crawl space savings, contractor outreach and training, and incentives for retrofits potentially packaged with other measures for improving overall cost-effectiveness.

ADDITIONAL RECOMMENDATIONS

- Gather construction and industry professionals for a workshop to identify opportunities for cost reduction and standardization.
- Perform a comprehensive building modeling study and a sensitivity analysis of building conditions, measure design, and climate zones to determine optimal building and sub-sector targets for existing or new construction programs.
- Study code change implications (crawl space measure only) since new building costs are lower and TDV savings would likely provide improved cost-benefit.
- The highest savings building type is older homes with ductwork in vented crawl spaces or attics, especially if the return and supply are co-located in the same space (attic or crawl space). The measure impacts are complicated when return and supply are located in both the attic and crawl space. Any targeted programs could focus on buildings with attic-only or crawl space-only ductwork first.
- Develop custom modeling of buildings with conditioned crawl spaces to inform changes to compliance and whole building software such as CBECC-Res.
- Leverage previous CASE work to model sealed, conditioned attics in existing homes.
- Explore options for optimizing crawl space airflow during heating and cooling seasons. Energy penalties may exist during heating season that could potentially be mitigated by control strategies.