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| WHOLE BUILDING  High performance crawlspace  SWWB006-03 |

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Measure Name

High Performance Crawlspace

Statewide Measure ID

SWWB006-03

Technology Summary

A crawl space is a vacant area found under some homes, between the ground and the floor of the home. They can be categorized as conditioned or unconditioned, and vented or unvented. An unconditioned crawl space has no air transfer between the HVAC system and living spaces, and usually have vents leading to the outside that are meant to allow for passive ventilation. An unconditioned crawl space might have insulation under living space floors, between the crawl space, and living spaces. In some homes, the unconditioned crawl space may have vapor barriers installed on the earthen floors to reduce thermal transfer to the soil, moisture transfer from the soil, and radon gas influx.

Homes with vented crawl spaces tend to have the highest leakage rates, especially if ductwork is located in the crawl spaces. Research by Lawrence Berkeley National Laboratory (LBNL) reported approximately 14.6[[1]](#footnote-1) and 5.5[[2]](#footnote-2) air changes per hour at 50 Pascals (ACH50) for existing and new construction residences (after 2000), respectively.

**Unconditioned, Vented Crawl Space**



A sealed, conditioned crawl space has vapor barriers on their earthen floors, insulation on the crawl space walls, and pathways enabling conditioned air to circulate.

This measure improves building envelope air tightness, reduces duct leakage loads, reduces humidity levels, and improves overall air quality.



**Vapor Barrier and Insulation after Measure Installation**

Energy savings from this measure result from:

1. Reduction in HVAC system cooling load, due to circulating cool air from crawlspace,
2. Reduction in building infiltration and containment of duct leakage inside conditioned space,
3. Increased R-value between stem wall,
4. Reduction in sensible heat load, and
5. Reduction in latent heat load due to reduced humidity transfer from crawlspace to conditioned space from vapor barrier.

The Southern California Edison (SCE) Emerging Products (EP) group conducted a field study to evaluate and compare the energy savings and demand reduction potential of a vented, unconditioned crawlspace (base case) compared to an unvented, conditioned crawlspace (measure case). This study demonstrated energy savings for this measure, but its sample size was not large enough to provide usable cost or energy savings values. For this measure, those values are obtained through recognized cost estimating data and energy simulation modeling.

Measure Case Description

The measure case is defined as the addition of all the following to the crawlspace of an existing single-family or mobile home – double-wide residential dwelling:

1. A vapor barrier that covers the entire crawl space ground and wall area,
2. Rigid spray foam sealing and insulation applied on the crawl space interior walls, over the vapor barrier,
3. For any external crawl space entries, an insulated cover with a tight-fitting gasket, to complete sealing integrity while still allowing exterior access,
4. An airflow path through the conditioned crawlspace using transfer registers, ductwork, and/or fans.

Base Case Description

The base case is defined as the vented, unconditioned crawlspace under an existing single-family residence with no vapor barrier or airflow path for the heating and air conditioning (HVAC) system.

Code Requirements

This measure is governed by the California Building Energy Efficiency Standards (Title 24). Part 2.5, Section R408 stipulates that crawl spaces can be vented or unvented. If a crawl space is unvented, exposed earthen floors must have a continuous vapor barrier and must be either mechanically ventilated or have a supply of conditioned air with a return to the living area at a rate of 1 cfm/50 ft2 of floor area.

Applicable State and Federal Codes and Standards

|  |  |  |
| --- | --- | --- |
| **Code** | **Applicable Code Reference** | **Effective Date** |
| CA Appliance Efficiency Regulations – Title 20 | None. | n/a |
| CA Building Energy Efficiency Standards – Title 24 (2019) | Part 2.5, Section R408 | January 1, 2020 |
| Federal Standards | None. | n/a |

Normalizing Unit

Square foot of living space area

Program Requirements

Measure Implementation Eligibility

All measure application type, delivery type, and sector combinations established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements.  Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Implementation Eligibility

|  |  |  |
| --- | --- | --- |
| **Measure Application Type** | **Delivery Type** | **Sector** |
| Add-on Equipment | DnDeemed | Res |
| Add-on Equipment | DnDeemDI | Res |

Eligible Products

All four components detailed in the Measure Case Description must be installed by a qualified contractor.

Eligible Building Types and Vintages

This measure is applicable for Single-Family and Mobile Home – Double-Wide Residential building types of before 1978.

Eligible Climate Zones

This measure is applicable in California climate zone 15.

Program Exclusions

Used or rebuilt equipment is not eligible.

The residence must be equipped with a central HVAC system with distribution ducting located in the crawlspace.

Data Collection Requirements

The Program Administrator (PA) is encouraged to collect additional information from deemed measure sites, including total floor area, floor area over the crawlspace, material and labor costs, and HVAC system type.

Use Category

Building Envelope (BldgEnv)

Electric Savings (kWh)

The unit energy savings (UES) of this measure were calculated as the difference between whole building energy use simulations of baseline and measure scenarios using California Building Energy Code Compliance – Residential (CBECC-Res) 2019 program. A single-family residence was modeled using the Database of Energy Efficient Resources (DEER) 2005 residential prototype characteristics for single family residences equipped with crawl spaces in climate zone 15. The building type with vintage pre-1978 is the only prototype for the building type that includes a crawlspace area and was thus used for modeling purposes. The baseline and measure case scenarios were modeled with the characteristics outlined in the table below.

Overview of Base Case and Measure Case Model Characteristics

|  | **Base Case** | **Measure Case** | **Source for Alteration for  Measure Case Model** |
| --- | --- | --- | --- |
| Total Floor Area (ft2) | 1,555 |  |  |
| Number of Stories | 1 |  |  |
| Occupants | 3 |  |  |
| Roof Type | Roofing, shingle |  |  |
| Floor Type | Over Crawl Space |  |  |
| Ceiling Overall R-Value | 6.89 |  |  |
| Wall Overall R-Value | 6.68 |  |  |
| Floor Overall R-Value | 5.51 | 19.0 | California Energy Commission (CEC). 2019. *Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* 150.0. July 2019. |
| Glass Area (% floor) | 17.2 |  |  |
| Vertical Fenestration U-Factor | 1.23 |  |  |
| Vertical Fenestration SHGC | 0.87 |  |  |
| Cooling SEER | 8.5 |  |  |
| Heating AFUE | 0.70 |  |  |
| Total Duct Leakage (%) | 15 |  |  |
| Building Leakage (ACH50) | 14.6 | 3.0 | International Code Council (ICC). *2017. 2018 International Residential Code.* R402.4. August 31. |
| Effective Supply Duct R-Value | 2.8 |  |  |
| Ducting Location | Crawlspace | Conditioned |  |
| Vintage | Before 1978 |  |  |

The hourly output from the simulation was generated for both case scenarios for each orientation (North, East, South, and West). An average of these values was taken due to the small variance observed. Energy savings from this measure stems from 1) reduction in HVAC system cooling load, due to circulating cool air from crawlspace, 2) reduction in building infiltration and containment of duct leakage inside conditioned space, 3) increased R-value of the stem wall, 4) reduction in sensible heat load, and 5) reduction in latent heat load due to reduced humidity transfer from crawlspace to conditioned space from vapor barrier.

The average UES (and peak demand reduction) were calculated as the difference between the baseline and measure case whole-building electric usage (and peak demand).

The electric savings for the double-wide mobile home were calculated by applying a scaler to the single-family home savings. DEER2020 prototypes of single-family and mobile homes were used to derive the cooling capacities based on the eligible vintage type and climate zone. The capacities of both building types were normalized by square footage and the percentage difference was calculated. This difference in normalized capacities was used to reduce the savings of the mobile home building type.

|  |  |  |
| --- | --- | --- |
| **Building Type** | **SFm** | **Dmo** |
| **Vintage** | 1975 | MH72 |
| **Climate Zone** | CZ15 | CZ15 |
| **Floor Area** | 1555 | 1196 |
| **Cooling Cap (tons)** | 6.4 | 3.5 |
| **Normalized Cooling Cap (ton/sf)** | 0.00412 | 0.00293 |
| **Cooling Scaling Factor (percent difference)** | 29% | |
| **Heating Cap (kBtu)** | 89.7 | 55 |
| **Normalized Heating Cap (kBtu/sf)** | 0.05768 | 0.04599 |
| **Heating Scaling Factor (percent difference)** | 20% | |

Peak Electric Demand Reduction (kW)

The peak demand reduction was derived from the hourly CBECC-Res 2019 simulation output. See Energy Savings for an explanation of the baseline and measure case simulation models. The peak demand values represent the demand reduction during the peak period of 4 p.m. to 9 p.m. weekdays,[[3]](#footnote-4) thus a coincident demand factor (CDF) was not applied.

Gas Savings (Therms)

The approach to calculate the gas unit energy savings (UES) follows the approach to estimate electric UES values (see Electric Savings). The average gas savings were calculated as the difference between the baseline and measure case whole-building gas usage for the single-family home while savings for the double-wide mobile home was reduced by a scaler based on the normalized heating capacity percentage difference.

Life Cycle

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The EUL of this measure was calculated as one-third of the EUL of the host equipment, identified as the existing floor insulation. The EUL for residential floor insulation documented in the literature is 25 years;[[4]](#footnote-5) however, the value adopted for this measure was stipulated by the Energy Efficiency Policy Manual as the maximum allowable EUL.

There is no RUL associated with this add on equipment measure.

Effective Useful Life and Remaining Useful Life

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| EUL – host (yrs)  EUL ID – BS-FlrIns | 20.00 | California Public Utilities Commission (CPUC), Energy Division.  2003. Energy Efficiency Policy Manual v 2.0. |
| EUL – measure (yrs)  EUL ID – BS-FlrIns | 6.67 |  |
| RUL (yrs) | n/a | n/a |

Base Case Material Cost ($/unit)

The base case material cost for add on equipment measure is equal to $0, as the alternative would be to maintain the in-situ conditions at the residence.

Measure Case Material Cost ($/unit)

The measure case material cost was derived from equipment prices provided by the vendor for the *Residential Crawl Space Conditioning and Sealing Retrofits* field study.[[5]](#footnote-6) The material cost was determined to fall within the average range based on online resources of similar projects completed across the nation. One online resource[[6]](#footnote-7) determined the average cost to be between $5,000 and $7,000, while a second resource[[7]](#footnote-8) found an average of $5,500. Material cost of $5,500 was therefore used for the measure, or $3.54 per square foot.

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Measure Case Material Cost Inputs [[8]](#footnote-9)

|  |  |
| --- | --- |
| **Cost Input** | **Value** |
| Application of 2” of closed cell spray foam insulation on the foundation and crawlspace side-wall and rim joist area, and installation of the vapor barrier | $5.05/ft2, ≤ 900 ft2 |
| $4.25/ft2 > 900 ft2 |
| HVAC Redistribution | $500 per site (minimum) |

Base Case Labor Cost ($/unit)

There is no associated base case labor cost for add on equipment measures, as the alternative would be to maintain the in-situ conditions at the residence.

Measure Case Labor Cost ($/unit)

The measure case labor cost was estimated using from RSMeans 2019 Mechanical Costs data as the cost provided by the vendor was inclusive of labor. An estimate of two insulation laborers, for a two-day period was estimated as $2,736, or $1.76 per square foot.

Measure Case Labor Cost Inputs

|  |  |  |
| --- | --- | --- |
| **Cost Input** | **Value** | **Source** |
| Labor rate ($/hr) | $85.50 | Gordian. *Mechanical Costs with RSMeans Data. 2019.* |
| Labor hours (hrs) | 32 |  |

Net-to-Gross (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The NTG adopted for this measure is for emerging technologies, which is appropriate for this measure, given that the implementation of the measure is new for crawl space. This measure has not been offered in the marketplace to date. CPUC staff interprets this rule to say: if an emerging technology measure has been offered in any program for more than two years – then the higher emerging technology NTG value cannot be used. The important principle is that if the product is in the marketplace as an offered measure for more than two years, then it is no longer an emerging technology measure.[[9]](#footnote-10)

Net to Gross Ratios

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| NTG | 0.85 | California Public Utilities Commission (CPUC), Energy Division. 2013. Energy Efficiency Policy Manual Version 5. Page 21.  California Public Utilities Commission (CPUC). 2012. Decision 12-05-015 in the Order Instituting Rulemaking to Examine the Commission's Post-2008 Energy Efficiency Policies, Programs, Evaluation, Measurement, and Verification, and Related Issues (R.09-11-014). Issued May 18, 2012.  OP 14. |

Gross Savings Installation Adjustment (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. The GSIA value adopted for this measure was derived as the gross-savings weighted value from the statewide evaluation of residential retrofit measures published in 2010.

Gross Savings Installation Adjustment Rate

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| GSIA | 0.865 | The Cadmus Group, Inc. 2010. Residential Retrofit High Impact Measure Evaluation Report. Prepared for the California Public Utilities Commission. |

Non-Energy Impacts

Non-energy impacts for this measure have not been quantified.

DEER Differences Analysis

The table below summarizes the inputs and methods that are and are not based upon the Database for Energy Efficient Resources (DEER).

DEER Difference Summary

| **DEER Item** | **Comment / Used for Workpaper** |
| --- | --- |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | Yes |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | Yes |
| DEER Version | n/a |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| DEER Measure IDs Used | n/a |
| NTG | Source: Value of 0.85 is associated with NTG ID: ET-Default |
| GSIA | Source: DEER 2011. Value of 0.865 is associated with GSIA ID: Res-Ins-All |
| EUL/RUL | Source: DEER The value of 20.0 years is associated with EUL ID: BS-FlrIns |

Revision History

Measure Characterization Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision Number** | **Revision Complete Date** | **Primary Author, Title, Organization** | **Revision Summary and Rationale for Revision** |
| 01 | 7/17/2019 | Fernando Miramontes, AESC | New Measure |
| 02 | 12/17/2019 | Fernando Miramontes, AESC | Added Double-Wide Mobile Home |
| 05/05/2020 | Jesse Manao  SCE | Created separate EAD Table to the package with the following fixes:  - Changed MeasureID and EnergyImpactID to SWBE006A  - Added RUL ID  - ApplyIE = False; IE Table Name=None  - Changed Bldg HVAC Type to rWtd.  - Changed Version to ExAnte2020 |
| 03 | 11/02/2020 | Annie Hur, TRC | -Updated savings to based on scaling factor for the DMo building type.  -Updated electric load shape from “DEER:HVAC\_Split-Package\_AC” to “DEER:HVAC\_Eff\_AC”. Previous load shape applied to the commercial sector instead of residential. |

1. Sherman, M. H., & Dickerhoff, D. J. (1998). “Airtightness of US dwellings/Discussion”. ASHRAE Transactions, 104, 1359. [↑](#footnote-ref-1)
2. Chan, W. and Sherman, M. Ph.D. (2013). “Building Envelope and Duct Airtightness of New US Dwellings”. Proceedings of the Thermal Performance of the Exterior Envelopes of Whole Buildings XII International Conference. December. [↑](#footnote-ref-2)
3. California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. OP 1. [↑](#footnote-ref-4)
4. GDS Associates, Inc. 2007. *Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for the New England State Program Working Group (SPWG).*  [↑](#footnote-ref-5)
5. Southern California Edison (SCE), Engineering Services/Emerging Products. 2018. *Residential Crawl Space Conditioning and Sealing Retrofits.* ET14SCE1100 & DR14.07.00. January. [↑](#footnote-ref-6)
6. <https://home.costhelper.com/crawl-space-sealing.html> [↑](#footnote-ref-7)
7. <https://www.homeadvisor.com/cost/foundations/install-crawl-space-encapsulation/#encapsulation> [↑](#footnote-ref-8)
8. [↑](#footnote-ref-9)
9. California Public Utilities Commission (CPUC). 2020. Memorandum: CPUC Guidance on the Applicability of Emerging Technology (ET) Net-to-Gross (NTG) Values. November 10, 2020 [↑](#footnote-ref-10)