



SERVICE

DUCT OPTIMIZATION, DMO

SWSV013-01

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STATEWIDE MEASURE ID

SWSV013-01

MEASURE VERSION

Version 01

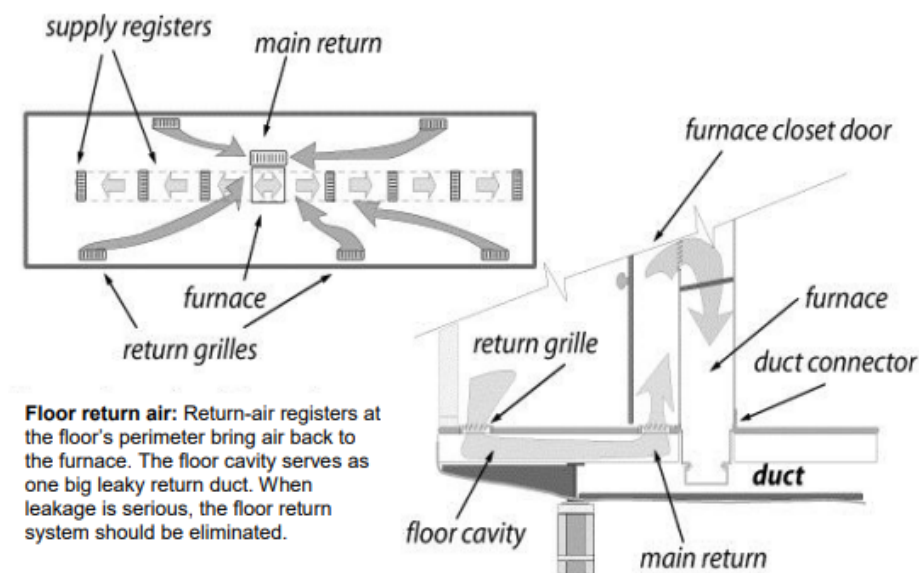
TECHNOLOGY SUMMARY

This workpaper includes two new duct optimization measures for mobile homes (aka, manufactured homes): 1) Return Duct Retrofit (Statewide Measure Offering ID: SWSV013A) and 2) Crossover Duct Replacement (SWSV013B).

Return Duct Retrofit

Consider the scenario where there is an existing open belly return with a supply system in the ceiling. The open belly return is a non-ducted return air system with high leakage. Return grilles in the floor allow a pathway for air to be drawn down into the space between the subfloor and the belly/road barrier, and from there on into the return side of the air handler/furnace. This measure requires the installation of a hard metal duct return, directly at the return air plenum and ducted to the main body of the living space. If a hard metal direct duct return is not able to be installed due to constraints at the residence, then a new insulated ducted return is installed in the crawlspace of the mobile home.

Figure 1



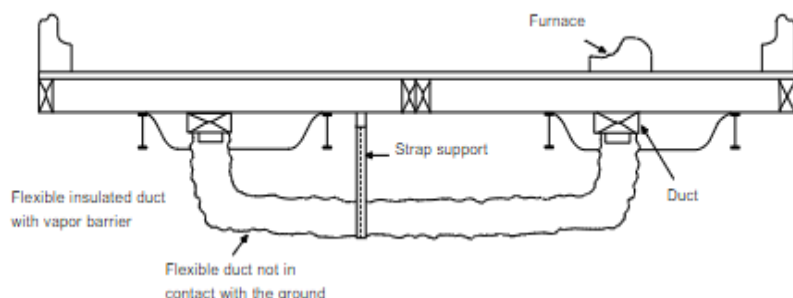
Source: <http://homeenergyplus.wi.gov/docview.asp?docid=27556&locid=25> (site accessed on 11/13/20)

Crossover Duct Replacement

The crossover duct is a common feature in double-wide mobile homes to connect the two halves (Figure 2). If a crossover duct is installed poorly or not connected properly it can fall off the duct system and become irreparably damaged. Often the crossover duct is made of flexible ductwork with a fragile inner liner that is impossible to repair and is easily damaged by vermin. This measure replaces a whole section

of the damaged or missing crossover duct. This measure is separate from statewide duct seal measures because it requires replacement of actual ducting and not just sealing of leaks.

Figure 2



Source: <https://www.law.cornell.edu/cfr/text/24/3285.606> (site accessed on 11/13/20)

MEASURE CASE DESCRIPTION

The measures in this workpaper are defined as duct optimization to reduce total leakage from a high as-found leakage rate to a low as-left leakage rate, as specified by residence type (double-wide mobile home - DMo) and measure description. The energy and demand impacts of these measures also vary by climate zone.

Measure Case Specification

Statewide Measure Offering ID	Measure Description	Residence Type	Measure Case Leakage Rate
SWSV013A	Return Duct Retrofit	DMo	15%
SWSV013B	Crossover Duct Replacement	DMo	15%
SWSV013C	Return Duct Retrofit for rNCGF System Only	DMo	15%
SWSV013D	Crossover Duct Replacement for rNCGF System Only	DMo	15%

rNCGF = DEER building type for furnace system with no cooling

BASE CASE DESCRIPTION

The base case is also specified by residence type (DMo) and measure description.

Base Case Specification

Statewide Measure Offering ID	Measure Description	Residence Type	Base Case Leakage Rate
SWSV013A	Return Duct Retrofit	DMo	50%
SWSV013B	Crossover Duct Replacement	DMo	35%
SWSV013C	Return Duct Retrofit for rNCGF System Only	DMo	50%
SWSV013D	Crossover Duct Replacement for rNCGF System Only	DMo	35%

CODE REQUIREMENTS

Applicable State and Federal Codes and Standards

Mobile homes are governed by Title 25 requirements. Although duct leakage for replaced ductwork is not dictated by Title 25, the materials and installation of ducting do have codes that apply. When installing these measures, technicians will abide by all applicable codes listed below.

Code	Applicable Code Reference	Effective Date
CA Housing and Community Development– Title 25	§ 4070- 280.715	5/15/2020
Federal Code Regulation	§ 3280.715	1979

NORMALIZING UNIT

Tons of cooling capacity (Cap-Tons) for SWSV013A and SWSV013B; kBtu/h of heating capacity (Cap-kBTUh) for SWSV013C & SWSV013D. It should be noted that the initial revision of this workpaper used Cap-Tons as the normalizing unit for all system options, which did not make sense for a furnace-only system that has no cooling capacity (where BldgHVAC = “rNCGF”). This has been updated so that the rNCGF system now has its own Statewide Measure Offering IDs where the normalizing units have been converted from Cap-Tons to Cap-kBTUh by applying a conversion factor per recommendation from CPUC staff¹. This conversion factor is shown in the following table.

Building Type	Ratio of Res Heat/Cool Cap, kBtu/h/ton
DMo	15.71

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for these measures 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.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

¹ R Murray (personal communication, November 19, 2020)

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
BW	DnDeemDI	Residential (DMo)

Eligible Products

The Return Duct Retrofit measure shall be installed by a residential HVAC contractor in a mobile home where there is an existing open belly return with a supply system in the ceiling. The open belly return is a non-ducted return air system with high leakage. Mobile homes with a ducted return are not eligible for this measure. Installed return ducts shall be made from either galvanized steel, tinplated steel, or aluminum, or shall be listed as Class 0 or Class 1 air ducts under Underwriters' Laboratories, Inc. Standard for Air Ducts, UL181-1972. This measure requires a hard metal ducted return installed directly at the return air plenum. Return ducts in unconditioned spaces shall be insulated with material having an effective thermal resistance (R) of not less than 4.0.

Testing: Belly return systems shall be verified by a pre and post total leakage duct test at 25 pascals on the return side of the duct system only. This shall be achieved by separating the supply from return side of the duct system by sealing at the air handler/furnace, typically at the filter slot to eliminate supply side leakage from the test.

The Crossover Duct Replacement measure shall be installed by a residential HVAC contractor in an extended mobile home where two or more sections of the home has been joined. The crossover duct connects the supply ducting of two or more sections. The ducting must be deteriorated, damaged, or not installed correctly to be eligible for this measure. Crossover ducts shall be made from galvanized steel, tinplated steel, or aluminum. The crossover duct shall be supported and or prevented from ground contact. If located in interior areas, not exposed to outdoor air, crossover ducts shall be insulated with material having an effective thermal resistance (R) of not less than 4.0. If the crossover duct is installed in an area that is exposed to outdoor air, such as outside the building's envelope, the ducts shall be insulated with material having effective thermal resistance (R) of not less than 8.0.

Testing: Crossover duct replacement leakage reduction will be verified by a total leakage test pre and post replacement in accordance with current RESNET standards by a qualified technician. Crossover replacement is done in conjunction with duct sealing measure SWSV001; refer to this measure's testing requirements for mobile homes.

Eligible Building Types and Vintages

This measure is applicable for any existing mobile home that uses air-cooled, direct expansion (DX) cooling and gas heating, gas heating with no cooling, or heat pump.

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

None

DATA COLLECTION REQUIREMENTS

Pre and post leakage rates will be recorded for both return duct retrofits and crossover replacements.

USE CATEGORY

Service

ELECTRIC SAVINGS (kWh)

SWSV013A & SWSV013C – Return Duct Retrofit

Energy savings and demand reduction for the Return Duct Retrofit measure were estimated using eQUEST 3.65-v7175 energy modeling software with the DEER2020 double-wide mobile home (DMo) prototype extracted from MASControl3 using Measure ID “RB-HV-DuctSeal-35pct-15pct”. The simulation approach for this measure was discussed with CPUC representation (DNV GL), and the following table summarizes the eQUEST keyword changes made for the Return Duct Retrofit measure.

SWSV013A & SWSV013C Modeling Parameters

Measure Description	Global Parameters			Keywords		
	DuctAirLoss	DuctInAttic1	SupplyAirLossFrac	DUCT-AIR-LOSS	DUCT-AIR-LOSS-OA	MIN-OUTSIDE-AIR
Return Duct Retrofit – Baseline Case	0.50	0.75	0.3	0.1125	1	0.5
Return Duct Retrofit – Measure Case	0.15	0.75	1.0	0.1125	1	Default

For the Return Duct Retrofit measure, the SupplyAirLossFraction global parameter specifies the percentage of total leakage, which is 15%/50%, or 30%. The DUCT-AIR-LOSS keyword does not change across cases for this measure since it refers only to supply duct loss, and this retrofit does not change the supply. The return leakage is then modeled using the MIN-OUTSIDE-AIR keyword, which is set to 50% for the baseline case indicating that 50% of the return air comes from the outside instead of from the conditioned space; CPUC stated that the crawlspace is most likely connected equally to the living space and to the outside. In the measure case with the retrofit in place, none of the return air comes from the outside so the MIN-OUTSIDE-AIR keyword can be modeled at the prototype default value.

Savings values were reported by building type (mobile home) and climate zone. For this measure, the “existing (weighted DEER vintages)” building vintage was specified. Savings derivation is detailed in the provided attachment (“DMo post-processing.xlsb”).

SWSV013B & SWSV013D – Crossover Duct Replacement

For the Crossover Duct Replacement measure the assumed total leakage reduction aligns with the DEER Res-DuctSeal-HighToLow-wtd measure, and as such energy savings and demand reduction come directly from that DEER measure.

Savings values were reported by building type (mobile home), climate zone, and HVAC system type, with the “existing (weighted DEER vintages)” building vintage was specified.

PEAK ELECTRIC DEMAND REDUCTION (kW)

SWSV013A & SWSV013C – Return Duct Retrofit

Peak demand reduction for this measure were estimated using eQUEST 3.65-v7175 energy modeling software as described above in the Electric Savings (kWh) section. Peak demand reduction was reported by building type (mobile home) and climate zone, with the “existing (weighted DEER vintages)” building vintage specified.

SWSV013B & SWSV013D – Crossover Duct Replacement

Peak demand reduction for this measure was drawn directly from the DEER Res-DuctSeal-HighToLow-wtd measure, per the rationale provided above in the Electric Savings (kWh) section.

Peak demand reduction was reported by building type (mobile home), climate zone, and HVAC system type, with the “existing (weighted DEER vintages)” building vintage was specified.

GAS SAVINGS (therms)

SWSV013A & SWSV013C – Return Duct Retrofit

Gas energy savings for this measure were estimated using eQUEST 3.65-v7175 energy modeling software as described above in the Electric Savings (kWh) section. Gas energy savings were reported by building type (mobile home) and climate zone, with the “existing (weighted DEER vintages)” building vintage specified.

SWSV013B & SWSV013D – Crossover Duct Replacement

Gas energy savings for this measure were drawn directly from the DEER Res-DuctSeal-HighToLow-wtd measure, per the rationale provided above in the Electric Savings (kWh) section.

Gas energy savings were reported by building type (mobile home), climate zone, and HVAC system type, with the “existing (weighted DEER vintages)” building vintage was specified.

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. The DEER EUL ID of HV-DuctOpt-BW is applicable and is used for these measures.

Effective Useful Life and Remaining Useful Life

Statewide Measure Offering ID	Measure Description	EUL ID	EUL Value (yrs)	RUL	Source
SWSV013A	Return Duct Retrofit	HV-DuctOpt-BW	18	0	DEER
SWSV013B	Crossover Replacement	HV-DuctOpt-BW	18	0	DEER
SWSV013C	Return Duct Retrofit for rNCGF System Only	HV-DuctOpt-BW	18	0	DEER
SWSV013D	Crossover Replacement for rNCGF System Only	HV-DuctOpt-BW	18	0	DEER

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. RUL is set to zero as these measures replace or modify ducts that are damaged or inadequate, therefore having no remaining useful life.

Additional EUL References:

- Pacific Gas & Electric Company. 2006. Retention Study of Pacific Gas & Electric Company's 1996 and 1997 Residential New Construction Energy Efficiency Programs. PG&E Study ID number: 386R2 CALMAC Study ID number: PGE0247.01.
- Itron, Inc. 2004. 1994 Residential New Construction Ninth-Year Retention Evaluation (Energy Advantage Home Program) Study Number 716A. Prepared for Southern California Gas Company
- Form 4099.F, Fannie Mae, August 2019

This property condition assessment form provides estimated useful life tables in Appendix F listing an EUL of 30 years for ductwork ("Combustion Air, Duct with fixed louvers", p.5), with no source or basis for estimate.

- Florida Housing Finance Corporation Capital Needs Assessment Guide, Florida Housing Finance Corporation, December 2018

This capital needs assessment guide provides estimated useful life tables in Appendix F listing an EUL of 35 years for metal ductwork ("Duct, rigid sheet metal, insulated if not in conditioned space", p.10) and 20 years for flexible ductwork ("Duct, flexible, insulated", p.10), with no source or basis for estimate.

- Energy Audits and Improvements for Commercial Buildings, Ian M. Shapiro, John Wiley & Sons, 2016

This book provides estimated useful life tables in Appendix Q listing an EUL of 30 years for ductwork (p.353), with the source for this estimate listed as follows: “Data obtained from a survey of the United States by ASHRAE Technical Committee TC 1.8 (Akalin, 1978). Some updates in 1986.”

- Comprehensive Hard-to-Reach Mobile Home Energy Savings Program Evaluation, Measurement and Verification Report, AESC (under CPUC Contract #1275-1276), March 2007

This report provides a 20-year EUL for duct test and seal (p.3-6, Table 3.1) with no source or basis for estimate.

- Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

This report provides a 20-year EUL for duct sealing (p.1-3, Table 1). The report states that the EULs listed within are based on “critical review of all state program administrator-specific values, values from other sources compiled in the course of this study, and discussion with the SPWG,” which is the New England State Program Working Group (p.1-2).

- STANDARD PROTOCOL FOR ESTIMATING ENERGY SAVINGS OF MANUFACTURED HOME DUCT SEALING RETROFIT PROGRAMS, Regional Technical Forum, December 2016

This protocol document lists an 18-year EUL for duct sealing (p.6). The analysis approach identifies this estimate is based on “PG&E/SCE workpapers and residential evaluations”, and from “DEER Team discussion on EUL decision making process”. (p.6).

Also note that each of the measures proposed in this workpaper does not have its EUL tied to the HVAC system. That is, when the HVAC system is replaced the duct improvements made by these measures will remain in place.

MATERIAL & LABOR COST (\$/UNIT)

Material and labor costs for these measures were obtained from program data but were based on material costs including flexible ductwork (\$570 for the Return Duct Retrofit and \$420 for the Crossover Replacement). Program costs included testing ducts for leakage. These costs were adjusted to meet the measure requirements of only using metal ductwork; using data from RSMeans it is assumed that the metal ductwork materials would add \$81 to the Return Duct Retrofit cost and \$242 to the Crossover Replacement cost. The resultant costs were then normalized by the DEER prototype system capacity (3.5 tons or 55 kBtu/h as appropriate) to arrive at per-ton measure costs.

Duct Optimization Cost

Statewide Measure Offering ID	Measure Description	Material Cost	Labor Cost	Total Cost
SWSV013A	Return Duct Retrofit	\$186.00/ton	\$108.57/ton	\$294.57/ton
SWSV013B	Crossover Replacement	\$189.14/ton	\$80.00/ton	\$269.14/ton
SWSV013C	Return Duct Retrofit for rNCGF System Only	\$11.84/kBtu/h	\$6.91/kBtu/h	\$18.75/kBtu/h
SWSV013D	Crossover Replacement for rNCGF System Only	\$12.04/kBtu/h	\$5.09/kBtu/h	\$17.13/kBtu/h

NET-TO-GROSS

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 value for this measure, documented in the DEER Database 2011 Update study conducted by Itron, Inc., can be traced to the 2008 version of DEER. Itron released an evaluation of the 2006 – 2008 California programs estimated NTG for residential duct sealing that varied across the investor-owned utility programs from 0.54 to 0.96.

Net-to-Gross Ratios

NTG ID	Value	Source
NTG	0.7	DEER2019 - ex ante database tables: NTG2020 - All-Default<=2yrs

GROSS SAVINGS INSTALLATION ADJUSTMENT

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. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

This default GSIA is supported by the HVAC sector impact evaluation for program year 2018² which showed a gross realization rate (GRR) of 98% for electric kWh and 130% for natural gas therms, and has been directed for use by the CPUC.³

Gross Savings Installation Rate Adjustments

GSIA ID	Value	Source
Def-GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

² DNV GL. 2020. *Impact Evaluation Report, HVAC Sector – Program Year 2018, EMV&V Group A. CALMAC Study ID: CPUC0209.01*. Prepared for the California Public Utilities Commission. April 20.

³ California Public Utilities Commission. 2021. *CPUC Comments on SWSV001-02 Duct Seal, Residential*. Comments dated 02/04/2021.

NON-ENERGY IMPACTS

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

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	SWSV013A	SWSV013B	SWSV013C	SWSV013D
Modified DEER methodology	No	No	No	No
Scaled DEER measure	No	No	No	No
DEER Base Case	n/a	n/a	n/a	n/a
DEER Measure Case	No	n/a	No	n/a
DEER Building Types	Yes (DMo)	Yes (DMo)	Yes (DMo)	Yes (DMo)
DEER Operating Hours	n/a	n/a	n/a	n/a
DEER eQUEST Prototypes	DEER2020, pulled from MASControl3	n/a	DEER2020, pulled from MASControl3	n/a
DEER Version	n/a	DEER2020 READi v.2.5.1	n/a	DEER2020 READi v.2.5.1
Reason for Deviation from DEER	Measure does not exist in DEER	n/a	Measure does not exist in DEER	n/a
DEER Measure IDs Used	n/a	Res-DuctSeal-HighToLow-wtd	n/a	Res-DuctSeal-HighToLow-wtd

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	06/30/2020	Tai Voong, PG&E Phil Jordan, CLEAResult	New workpaper for DMO duct optimization when repair is not possible.
	11/10/2020	Tai Voong, PG&E Phil Jordan, CLEAResult	Update per CPUC's comments. (MAT=BW, EUL=18 years, & EUL ID=HV-DuctOpt-BW) Update energy impact for Res-DuctSeal-HighToLow-wtd by DEER dated September 2020 Add normalizing unit statement for rNCGF
	12/23/2020	Tai Voong, PG&E Phil Jordan, CLEAResult	Updated the normalizing unit for rNCGF from Cap-Tons to Cap-kBTU/h Updated the savings for rNCGF using new normalizing unit, Cap-kBTU/h with a conversion factor of 15.71 kBTU/h/ton Updated the costs for rNCGF using new normalizing unit, Cap-kBTU/h with a conversion factor of 15.71 kBTU/h/ton Added Statewide Measure Offering IDs SWSV013C and SWSV013D for rNCGF System Only
	3/26/2021	Lake Casco, PE, TRC Tai Voong, PG&E	Update per CPUC Comments on 2/4/2021 Added eligibility requirements for duct insulation requirement per CFR § 3280.715 Adopted Def-GSIA value based on PY2018 EM&V report