R91: Review of Impact Evaluation Best Practices

Natalie Bodington, Scott Reeves, Eric Rambo

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Motivation

- Research Question:
  - How do different calculation methodologies lead to different savings estimates?
    - R16 impact evaluation vs. Connecticut Program Savings Document (PSD)

- R16 provides a helpful case study
  - Multimethod evaluation approach
  - Evaluator-calculated (*ex post*) savings diverged from savings calculated using alternate methodologies in the PSD (*ex ante*)
  - We explore possible sources of divergence (reflected in realization rates)

Report Organization

- *Introduction*
  - *Key Impact Metrics*
- *Section 1: Best Practices in Impact Evaluation*
  - *Literature Review*
  - *Methodology Overviews and Application Guidance*
  - *Oil and Propane Evaluation*
- **Section 2: R16 Case Study—Comparison of Evaluation Approaches**
  - **Overview of R16 evaluation and PSD methodologies**
  - **How were they different?**
  - **Recommendations and Conclusions**
- *References*

R16 Evaluation

- Reviewed latest impact evaluation for Connecticut HES/HES-IE (R16)
- Multimethod approach
  - Whole-house savings
  - Measure-level savings
- Compared evaluated measure savings to claimed savings
  - Derived from PSD
- Savings diverge substantially across measures

Category	Measure	Realization Rate	
		HES	HES-IE
HVAC	Duct Sealing	42%	16%
Shell	Air Sealing	91%	61%
Shell	Attic Insulation	76%	129%
Shell	Wall Insulation	50%	32%

Distribution of Gas Savings

- R16 HES/HES-IE evaluated savings
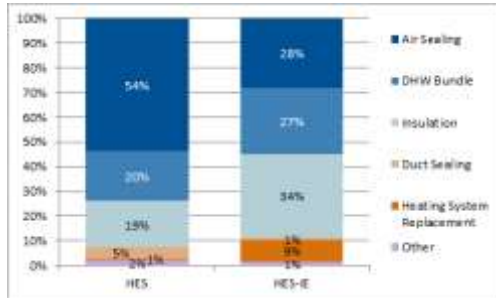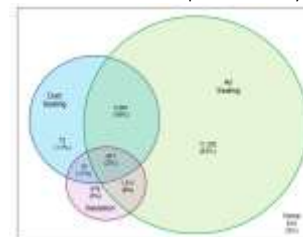
Approaches and Results

- Methodologies:
  - Billing analysis reflects actual conditions, behaviors, interactions
  - Calibrated simulations provide more accurate estimates of schedules, interactions
  - Algorithms more easily adaptable to participant inputs
- R16
  - **Simulation:** calibrated; inputs from program year tracking data; differentiated multifamily, heating types, Hartford/Bridgeport
  - **Billing analysis:** fixed-effects regression, measure- indicator variable
- PSD
  - **Simulation:** inputs from developer experience (2008); models themselves not available for review
  - **Algorithms:** adapted from REM/*Rate*, based on $\Delta\left(\frac{1}{R}\right)$, HVAC efficiency, and HDD

Methodologies in R16 Evaluation

Category	Measure	HES Evaluation Method	HES-IE Evaluation Method	PSD Method
HVAC	Duct Sealing	Enhanced Simulation	Enhanced Simulation	Simple Simulation
Shell	Air Sealing	Billing Analysis	Billing Analysis	Simple Simulation
Shell	Attic Insulation	Enhanced Simulation	Enhanced Simulation	Engineering Algorithm
Shell	Wall Insulation	Enhanced Simulation	Billing Analysis	Engineering Algorithm

General Realization Rate Drivers

- **Measure Interactivity:** Multiple measures installed concurrently reduces marginal benefit.
  - Inherent to HES/HES-IE program design. For example, 24% of 2014 participants received more than one measure (see diagram, from R151).
  - **Areas for Consideration:** Whole-house savings estimates where multiple measures are implemented may be adjusted down to account for interactivity.

- **HVAC System Efficiency:** PSD assumptions around HVAC system efficiency (75%) are estimates.
  - **Areas for Consideration:** Additional sources should be provided to corroborate this value, e.g.:
    - Market assessment
    - On-site data collection
    - Track HVAC efficiency and incorporate into PSD savings algorithms

Source: Connecticut HES Air Sealing, Duct Sealing, and Insulation Practices Report (R151) Study, pg. 2

Air Sealing

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
Envelope	Air Sealing	Billing Analysis	Billing Analysis	Simple Simulation
		91%	61%	

Five sources of differences identified:

(1) Actual participant characteristics vs. assumptions
(2) Installation quality and measure persistence
(3) Behavioral and education changes
(4) Interactivity
(5) Specificity of weather data

** Impact rankings indicate the expected improvement in accuracy, and are not directly related to changes in savings**

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Air Sealing

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
Envelope	Air Sealing	Billing Analysis	Billing Analysis	Simple Simulation
		91%	61%	

1) Actual Participant Characteristics vs. Assumptions:

- Billing analysis accounts for the actual home and equipment characteristics of participants
- Uncalibrated PSD models rely on broader assumptions

For Consideration: Calibrate PSD models to billing data and ensure assumptions are updated regularly.

Change in PSD Estimates: *Unknown, High Impact*

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Air Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
Envelope	Air Sealing	Billing Analysis	Billing Analysis	Simple Simulation
		91%	61%	

2) Installation Quality and Measure Persistence:

- Billing analysis captures reductions reflecting actual measure application
- Simulation model assumes installation is "as prescribed" (ideal)
- Billing analysis is more accurate
  - R151 found the quality of installation was considered sufficient, and unlikely to lead to significant persistence problems.
  - Inconsistent treatment of conditioned basements during testing may inflate air sealing reductions, reduction realization rates.

For Consideration: Ensure that leakage reductions are properly measured on site. Refer to the R151 study for more detail.

Change in PSD Estimates: *Decrease, Moderate Impact*

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Air Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
Envelope	Air Sealing	Billing Analysis	Billing Analysis	Simple Simulation
		91%	61%	

3) Behavioral and Education Changes:

- R16 billing analysis captures changes in participant education and usage (e.g., "take back," spillover)
- PSD simulation does not
- These factors all affect consumption so billing analysis better captures real savings

For Consideration: Additional research needed

Change in PSD Estimates: *Unknown, Low/Moderate Impact*

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Air Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
Envelope	Air Sealing	Billing Analysis	Billing Analysis	Simple Simulation
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4) Interactivity: See General Realization Rate Drivers section

Change in PSD Estimates: *Decrease, Low Impact*

5) Specificity of Weather Data:
- R16 study used data from each home's nearest weather station
- PSD models used statewide Connecticut profiles
- Closer alignment with participant characteristics is better

Areas for Consideration: Provide savings for Bridgeport and Hartford.

Change in PSD Estimates: *Decrease, Low Impact*

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Attic Insulation and Wall Insulation

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
Envelope	Attic Insulation	Enhanced Simulation	Enhanced Simulation	Engineering Algorithms
		76%	129%	
Envelope	Wall Insulation	Enhanced Simulation	Billing Analysis	Engineering Algorithms
		50%	32%	

Four sources of differences identified:*
(1)   HVAC system efficiency
(2)   Differentiating building types
(3)   Specificity of weather data
(4)   Heating degree-day adjustment factor

* For wall insulation HES-IE billing analysis, see Air Sealing section
- *R151 study found insulation projects were typically good/fair quality*
- *Use of fiberglass batt insulation may have reduced persistence, lowering ex post estimates.*

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Attic Insulation and Wall Insulation
(cont'd)

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		50%	32%	

1) HVAC System Efficiency: See General Realization Rate Drivers section

Change in PSD Estimates: *Unknown, Moderate/High Impact*

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Attic Insulation and Wall Insulation
(cont'd)

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Envelope	Attic Insulation	Enhanced Simulation	Enhanced Simulation	Engineering Algorithms
		76%	129%	
Envelope	Wall Insulation	Enhanced Simulation	Billing Analysis	Engineering Algorithms
		50%	32%	

2) Specificity of Weather Data
- R16 simulations use two representative weather stations (Hartford, Bridgeport)
- PSD uses single statewide average
- Using multiple weather stations improves accuracy

Areas for Consideration: Provide savings for Bridgeport and   Hartford.

Change in PSD Estimates: *Decrease, Low Impact*

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Attic Insulation and Wall Insulation
(cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
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		50%	32%	

3) Differentiating Building Types
- R16 simulations differentiate savings for HES and HES-IE, single family and multifamily
- PSD presents one set of savings
- Offering savings specific to customer type, home type improves accuracy

Areas for Consideration: Differentiate savings for single family and multifamily.*

Change in PSD Estimates: *Decrease, Low Impact*

* Distinguishing between HES and HES-IE would also improve accuracy of savings

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Attic Insulation and Wall Insulation
(cont'd)

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4) Heating Degree-Day Adjustment Factor:
- PSD: 64% adjustment applied to HDD base 65°F from 1989 ASHRAE Handbook, but is not referenced in newer versions
- Benchmarking against other TRMs (Ohio, Pennsylvania, Mid-Atlantic) could not corroborate this value (adjust cooling only; Mid-Atlantic uses HDD base 60°F)
- Calibrated simulation models match set points and schedules to participant billing data

Areas for Consideration: PSD should add additional detail about this adjustment factor, and validate using a more recent source or billing analysis.

Change in PSD Estimates: *Unknown, Low Impact*

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Duct Sealing

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
HVAC	Duct Sealing	Enhanced Simulation	Enhanced Simulation	Simple Simulation
		42%	16%	

Five sources of differences identified:

(1)   Billing data calibration

(2)   Assumptions and inputs

(3)   Types of modeling software

(4)   Differentiating building types

(5)   Multiple model locations

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Duct Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
HVAC	Duct Sealing	Enhanced Simulation	Enhanced Simulation	Simple Simulation
		42%	16%	

1) Billing Data Calibration
- R16 calibrated models (by building type and program participation) to weather-normalized participant billing data
- Calibration is better because it ensures outputs align with program populations

For Consideration: Calibrate PSD models against recent participant billing data.

Change in PSD Estimates: *Unknown, High Impact*

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Duct Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
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		42%	16%	

2) Inputs and Assumptions

- R16 used input assumptions based on actual 2011 participants, adjusted through the calibration process.
  - E.g., square footage, glazing, equipment efficiencies
- PSD simulation model inputs are based on modeler experience with 2008 Connecticut building stock.
- Periodic updates will improve accuracy of simulation model results

For Consideration: Draw from participant data, evaluation activities, white papers, industry standards, and other resources to update PSD models.

Change in PSD Estimates: *Unknown, High Impact*

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Duct Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
HVAC	Duct Sealing	Enhanced Simulation	Enhanced Simulation	Simple Simulation
		42%	16%	

3) Type of Modeling Software Used

- R16 used eQuest, an hourly iterative software
- PSD uses REM/*Rate*, a degree-day-based modeling software
- Hourly iterative software is typically more accurate.

For Consideration: The PSD should use an hourly iterative software for best practices

Change in PSD Estimates: *Unknown, Moderate Impact*

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Duct Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
HVAC	Duct Sealing	Enhanced Simulation	Enhanced Simulation	Simple Simulation
		42%	16%	

4) Differentiating Building Types

- R16 used separate calibrated models for single-family and multifamily homes, and for HES and HES-IE participants
- PSD uses a single set of models for a typical single-family home
- Multiple models is more accurate, especially multifamily vs. single family
  - R16 showed gas savings for multifamily homes higher than for single-family homes that receive duct sealing or attic insulation, and lower for wall insulation.

For Consideration: The PSD should differentiate savings for single family and multifamily homes.*

Change in PSD Estimates: *Increase, Low/Moderate Impact*

* Distinguishing between HES and HES-IE would also improve accuracy of savings estimates.

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Duct Sealing (cont'd)

Category	Measure	HES Evaluation	HES-IE Evaluation	PSD
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5) Multiple Model Locations

- R16 simulations use two representative weather stations (Hartford, Bridgeport)
- PSD uses single model location
- Using multiple weather stations improves accuracy

For Consideration: The PSD models should differentiate between savings for Bridgeport and Hartford homes.

Change in PSD Estimates: *Decrease, Low Impact*

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Recommendations

- ***Update PSD simulation models*** – software, calibration, data sources, multifamily
- ***Account for measure interactivity*** (i.e., HVAC and envelope)
- ***HVAC assumptions*** – review heating efficiencies and determine robust source for estimate
- ***Weather/Location Assumptions***
- ***HDD adjustment factor*** (for insulation measures)

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Natalie Bodington
Senior Analyst, Energy Sector
Office: (303) 389-2511

Eric Rambo, Ph.D.
Principal, Energy Sector
Office: (503) 575-4570

Scott Reeves
Senior Associate, Energy Sector
Office: (503) 467-7123

Lisa Wilson-Wright
Director, NMR Group, Inc.
Office: (617) 284-6230 ext. 15

Facebook.com/CadmusGroup

@CadmusGroup

linkedin.com/company/the-cadmus-group