Energy Efficiency
Program Evaluation

Jackie Berger
February 11, 2021
Overview

1. Introduction
   - Usage Impacts
   - Projected Savings
   - Billing Analysis
   - Surveys
   - Observations & Inspections
   - Cost Effectiveness
   - Realization Rates

2. Evaluation
   - High Users
   - Major Measures
   - Quality Installations
   - Performance Measurement

3. Achieving High Savings
   - Health & Safety
   - Affordability
   - Water Cost
   - Maintenance Cost
   - Economic
   - Environmental

4. Non-Energy Impacts
5. Recommendations

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Applied Public Policy Research
Institute for Study and Evaluation

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Introduction
## Nonprofit Research Institute

- **Established in 2002**
- **Princeton, NJ**

## Mission

- Analyze data and information to assess and improve public programs

## Research Areas

- **Energy Efficiency & Renewables**
- **Energy Affordability**

## Clients

- Federal Government (DOE, HHS)
- State Governments
- Utility Companies
- Nonprofits
Why Energy Efficiency?
Energy Efficiency “The Invisible Fuel”

Cost - $/kWh

Source: ACEEE

We will revisit this number later in the presentation
Other Benefits

Home Comfort

- Drafts
- Humidity
- Cold/Hot Rooms
- Noise

Health & Safety

- Mold
- Air Quality
- Carbon Monoxide
- Asbestos
- Pests

Health & Safety

- Mold
- Air Quality
- Carbon Monoxide
- Asbestos
- Pests
Evaluation
Why Evaluate?

Measure Program Impacts
- Energy usage
- Energy bill affordability
- Economic impacts
- Environmental impacts
- Health, safety, and comfort
- Delivery to vulnerable households
- Cost benefit analysis

Assess Potential Improvements
- Goals
- Efficiency
- Effectiveness
- Equity
- Targeting
- Client satisfaction

Meet Regulatory Requirements
- State
- PUC
- Other

“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.”

— H. James Harrington
Evaluation Activities

Impact Evaluation Activities
- Program Data Analysis
- Usage Impact Analysis
- Payment Impact Analysis
- Economic Impact Analysis
- Environmental Impact Analysis
- Health & Safety Impact Analysis
- Participant Survey
- Cost-Benefit Analysis

Process Evaluation Activities
- How is the program designed?
  - Documentation review
  - Interviews with program design and management team
- How is the program implemented?
  - Interviews with program managers and implementers
  - On-site observation
  - Surveys with program participants
- Why is it working or not working?
  - Synthesis of all evaluation data
Energy Usage Impact Analysis
Usage Impacts

Research Questions

• Were expected energy savings results obtained?
• Are the treatments cost-effective?
• Should measure selection procedures be revised?
• Should installation procedures be reviewed?
• Should contractors be re-trained?

Approach

• Goal: Develop most accurate estimate of program savings
• Weigh costs and benefits of various approaches to measurement
• Consider possible causes of mis-measurement or bias

Options

1. Deemed Savings
3. Energy Usage Billing Analysis
## Analysis Approaches

<table>
<thead>
<tr>
<th>Approach</th>
<th>Cost</th>
<th>Accuracy</th>
<th>Attrition</th>
<th>Reasons for Excluding Jobs from Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deemed Savings</td>
<td>$</td>
<td></td>
<td>****</td>
<td>None</td>
</tr>
<tr>
<td>Engineering Estimate with Retrofit Data</td>
<td>$$</td>
<td>*</td>
<td>***</td>
<td>Retrofit Data Missing</td>
</tr>
<tr>
<td>Billing Analysis</td>
<td>$$$</td>
<td>***</td>
<td>**</td>
<td>Usage Data Missing or Inadequate</td>
</tr>
<tr>
<td>Metering</td>
<td>$$$$</td>
<td>****</td>
<td>*</td>
<td>Cost</td>
</tr>
</tbody>
</table>
## What Are You Measuring?

<table>
<thead>
<tr>
<th>Approach</th>
<th>Measures</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deemed Savings</strong></td>
<td>Expected usage change based on measures alone</td>
<td>• Assumptions</td>
</tr>
<tr>
<td><strong>Engineering Estimate</strong></td>
<td></td>
<td>• Installation quality</td>
</tr>
<tr>
<td><strong>Usage(_2) - Usage(_1)</strong></td>
<td>Actual change in usage</td>
<td>• Other usage changes</td>
</tr>
<tr>
<td><strong>Weather Norm Usage(_2) - Usage(_1)</strong></td>
<td>Change in usage if both periods had average weather</td>
<td>• Other factors</td>
</tr>
<tr>
<td><strong>Weather Norm Usage(_2) - Usage(_1) w/Comp. Group</strong></td>
<td>Other factors held constant (prices, economy, market information, etc.)</td>
<td>• Best estimate of program impact</td>
</tr>
</tbody>
</table>
Projections
Bad Forecast?
What are TRMs?

TRM
- Technical Reference Manuals
- Engineering Estimates
- Projections

Equations
- Calculate savings that result from measure installation
- Use of newly installed measure compare to a baseline

What is the Baseline?
- Existing equipment
- Current code requirements or standard equipment

- Existing equipment for remaining life in existing equipment
- Standard equipment for rest of the life of the new measure

Low-income households may continue to use equipment past the expected life
TRM Calculations

NJ 2018 TRM

• Lighting Savings (kWh/yr) = \frac{(Watts \times QTY)_{BL} - (Watts \times QTY)_{P}}{1,000} \times HRS \times (1 + HVAC_E)
• HVAC_E accounts for interaction, reduces gas heating saved, increases cooling saved

Mid Atlantic 2016 TRM

• HE Gas Boiler Savings (MMBTU/yr) = \frac{EFLH_{het} + Btuh \times AFU_{ee}}{AFU_{base}} \times \frac{1,000,000}{1,000,000}
• EFLH_{het} = equivalent full load heating hours
• AFUE = efficiency

MN 2019 TRM

• LF SH Savings (kWh/yr) = \frac{(GPM_{BASE} - GPM_{LOW}) \times (\frac{PH + SPD + SL}{SPH}) \times 365 \times \text{Density} \times C_p \times (T_{OUT} - T_{IN})}{ReEff \times 3,412}
• Gallons per Minute, People in Home, Showers per Day, Shower Length, Showers per Home, Shower Temperature, Groundwater Temperature, Recovery Efficiency (98%)
## TRM Advantages & Disadvantages

### Advantages (convenience)

- **Data Requirements**
  - No post usage data, weather data, or comparison group data

- **Lower Cost**
  - Less complicated data analysis

- **Timeliness**
  - No need to wait for post usage data

- **Planning & Reporting**

### Disadvantages (accuracy)

- **Measure Install Rates**
  - Power strip not installed

- **Measure Retention Rates**
  - Removed /broken LED

- **Pre-Treatment Usage/Existing Conditions**
  - Hours used for specific measure

- **Measure Effectiveness**
  - Quality (air sealing comprehensiveness)

- **Incorrect TRM Application**
  - Formula, Input values

- **Interactions**
  - Shell & heating system Lighting & heat gain/loss

- **New Measures**
  - Not included Or deemed savings

- **Variation in Savings**
  - Measured differences may relate to TRM
## How are TRMs Used?

### Regulatory Reporting

<table>
<thead>
<tr>
<th>Justify Program Investments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How are TRM values referred to?</td>
</tr>
<tr>
<td>Does the audience understand what they mean?</td>
</tr>
<tr>
<td>Is this measure an improvement over jobs completed or dollars invested?</td>
</tr>
<tr>
<td>Overemphasis on TRM as a measure of program accomplishments</td>
</tr>
</tbody>
</table>

### Non-Energy Impacts

<table>
<thead>
<tr>
<th>Economic, Environmental, and Other Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic: Energy savings translate into increased spending on goods with greater multiplier than energy</td>
</tr>
<tr>
<td>Environmental: Energy savings translate into reductions in greenhouse gas emissions</td>
</tr>
</tbody>
</table>

### Cost-Effectiveness Calculations

<table>
<thead>
<tr>
<th>Measure Selection, Program Implementation or Continuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key input for program and measure-level cost-effectiveness</td>
</tr>
</tbody>
</table>

### Program Comparisons

<table>
<thead>
<tr>
<th>Relative Investments and Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does variation in TRMs impact relative savings?</td>
</tr>
</tbody>
</table>

### Energy Efficiency Resource Standards (EERS)

<table>
<thead>
<tr>
<th>Performance Incentives &amp; Penalties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Require utilities to reduce energy consumption by a certain amount over a specified time period</td>
</tr>
</tbody>
</table>

### Decoupling

<table>
<thead>
<tr>
<th>Lost Revenue Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removes connection between utility revenue and sales volume</td>
</tr>
<tr>
<td>Sometimes can only recover revenue related to energy efficiency program savings</td>
</tr>
</tbody>
</table>

$.03 cost per kWh saved? Significantly higher?
# TRM Examples

## Example 1: Savings from One All Electric Program Based on Different State TRMs

<table>
<thead>
<tr>
<th>Measure</th>
<th>2011-2015 Jobs</th>
<th>Source</th>
<th>Mean TRM Savings (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation – Floor</td>
<td></td>
<td>CT (2016)</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IL (2016)</td>
<td>58</td>
</tr>
<tr>
<td>Room AC – Early Replacement</td>
<td></td>
<td>CT (2016)</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PA (2016)</td>
<td>39</td>
</tr>
<tr>
<td>Dehumidifier – Early Replacement</td>
<td></td>
<td>MN (2016)</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MA (2013-15)</td>
<td>329</td>
</tr>
</tbody>
</table>

## Example 2: MN Low-Income Utility Wx

**Basic TRM – no interactions, no pre-condition info**

<table>
<thead>
<tr>
<th>Utility</th>
<th>Delivery Agencies</th>
<th>Mean Cost</th>
<th>Mean TRM Savings (Therms)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WAP</td>
<td>$3,482</td>
<td>186</td>
<td>Consistent with WAP Billing analysis. No data to assess Non-WAP.</td>
</tr>
<tr>
<td>2</td>
<td>Non-WAP</td>
<td>$3,122</td>
<td>159</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>WAP</td>
<td>$3,354</td>
<td>318</td>
<td>Appears high</td>
</tr>
<tr>
<td>4</td>
<td>WAP</td>
<td>$6,689</td>
<td>546</td>
<td>Appears high. No info on usage. 21</td>
</tr>
</tbody>
</table>
Billing Analysis

Analysis Steps

1 Data Retrieval
2 Weather Normalization
3 Comparison Group Selection
4 Sub-Group Analysis

Challenges

Data Attrition
- Savings may not represent treated population

Sample Size
- If too few observations...
- Low precision for savings estimates
- Cannot perform sub-group analysis

Measure Savings
- Requires larger sample size,
- Variation in installed measures, and
- Significant installation of measures
## Billing Analysis

### Data Requirements

<table>
<thead>
<tr>
<th>Core Data Required</th>
<th>Supplemental Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy billing data</strong></td>
<td><strong>Energy efficiency measures</strong></td>
</tr>
<tr>
<td>• Read date</td>
<td><strong>Measure-specific impacts</strong></td>
</tr>
<tr>
<td>• Real / estimated</td>
<td></td>
</tr>
<tr>
<td>• Usage</td>
<td></td>
</tr>
<tr>
<td>• Units</td>
<td></td>
</tr>
<tr>
<td><strong>Service delivery date</strong></td>
<td><strong>Service delivery providers</strong></td>
</tr>
<tr>
<td>Divides period into pre- and post-treatment</td>
<td><strong>Provider-specific impacts</strong></td>
</tr>
<tr>
<td><strong>Weather data</strong></td>
<td><strong>Housing unit characteristics</strong></td>
</tr>
<tr>
<td>• Local weather station</td>
<td><strong>Relation between housing / household characteristics</strong></td>
</tr>
<tr>
<td>• Daily temp</td>
<td></td>
</tr>
<tr>
<td>• One year pre- and post-treatment</td>
<td></td>
</tr>
<tr>
<td>• Longer normalization period</td>
<td></td>
</tr>
</tbody>
</table>
Weather Normalize

**Household Level**

- PRISM
- Regression analysis for each household
- Weather-normalized pre-usage, post-usage, and change estimated for each household

**Fixed Effects Regression**

- Usage analyzed for all households within one model
- Average energy savings estimated for all homes

**Advantages**

- Remove outliers
- Detailed attrition analysis
- Analysis of usage & savings
  - High & Low Savers
  - Pre-Treatment Usage
  - Contractor
  - Measures
  - Household characteristics
  - Home characteristics

- Uses all data / all homes
- Does not require full year pre/post
- Direct estimate of impact
- Controls for exogenous factors
Weather Normalization

Household Level Analysis

Regression Analysis on Each Individual Home

\[ F_i = \alpha + \beta H_i(\tau) + \epsilon_i \]

- \( F_i \) = average daily usage, time interval \( i \)
- \( H_i(\tau) \) = heating degree days to reference temp \( \tau \) in interval \( i \)
- \( \epsilon_i \) = random error term

Normalized Annual Usage = 365\( \alpha \) + \( \beta H_o(\tau) \)

- \( H_o(\tau) \) = long term mean heating degree days

Pooled Analysis

\[ F_{it} = \alpha_i + \beta_1 H_{it} + \beta_2 POST_t + \beta_3 POST_t H_{it} + \epsilon_{it} \]

- \( F_{it} \) = average daily usage during the pre- and post-treatment periods
- \( H_{it} \) = average daily base 60 HDDs
- \( POST_t \) = a dummy variable that is 0 in pre-period and 1 in post-period
- \( \epsilon_{it} \) = estimation error term

- **PRE USAGE**
  - \( \alpha_i \) = average daily baseload usage in pre-treatment period
  - \( \beta_1 \) = average daily usage per HDD in the pre-treatment period

- **POST USAGE**
  - \( \alpha_i + \beta_2 \) = average daily baseload usage in post-treatment period
  - \( \beta_1 + \beta_3 \) = average daily usage per HDD in post-treatment period

- **SAVINGS**
  - \( \beta_2 \) = average daily baseload savings
  - \( \beta_3 \) = heating usage savings per HDD

Use House-by-House Analysis When

- Sufficient usage data for significant % of treatment and comparison
- Data to assess factors related to savings

Use Pooled Analysis When

- Limited usage data availability
- Concern for attrition bias
- Supplemental data not available
Comparison Groups

**Purpose**

Control for Exogenous Factors

- Energy Prices
- Economic Conditions
- Pandemics

**Random Assignment**

“Gold Standard”

- Difficult to apply
- Challenge to find participants
- Programs not willing to withhold treatment
- Serve those most in need

**Quasi-Experimental**

Best Alternative

- Later Program Participants
- Low-Income Non-Participants
- Matched Sample
## Quasi-Experimental Later Participant Comparison

### Difference-in-Difference Analysis

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Change</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment Group</strong></td>
<td>Year Before Services</td>
<td>Year After Services</td>
<td>Before - After</td>
<td>Program Impact + Other Factors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Comparison Group</strong></td>
<td>2 Years Before</td>
<td>1 Year Before</td>
<td>2 Years Before – 1 Year Before</td>
<td>Other Factors</td>
</tr>
<tr>
<td><strong>Treatment - Comparison</strong></td>
<td></td>
<td></td>
<td></td>
<td>Program Impact</td>
</tr>
</tbody>
</table>

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Quasi-Experimental Design

12 Months Pre-Wx Usage Weather Normalize

Wx

12 Months Post-Wx Usage Weather Normalize

A

B

Gross Energy Savings

13-24 Month Pre-Wx Usage Weather Normalize

1-12 Month Pre-Wx Usage Weather Normalize

Comp. Group Wx

C

D

Comparison Group Savings

Net Savings

Gross Energy Savings

Comparison Group Savings

A-B

C-D
Billing Analysis Subgroups

Research Questions
- Why are savings higher or lower than expected?
- Which measures are providing savings?
- Which contractors are most effective?
- How does savings relate to pre-treatment usage?
- Are certain types of homes providing higher savings?

Key Factors
- Measures Installed
- Measure Cost
- Pre-Treatment Usage
- Contractor
- Home Type

Major Measures
- Electric
  - Air Sealing
  - Insulation
  - Duct Sealing
  - Heating System Replacement
  - Air Conditioning Replacement
  - Refrigerator Replacement

- Natural Gas
  - Air Sealing
  - Insulation
  - Attic
  - Floor
  - Wall
  - Sidewall
  - Duct Sealing
  - Heating System Replacement
Rebate Impact
Gas Savings by Efficiency

New Jersey Natural Gas SAVEGREEN 2013 participants.
Measure Impacts

• Run regression to determine measure specific impacts

Usage change = α + γ^1* measure^1 + γ^2* measure^2 + γ^3* measure^3 + μ
Measure Impacts
Low-Income EE Program

New Jersey Comfort Partners 2010-2011 participants.
### Measure-Level Impacts

#### 2016 PGW Low-Income Usage Reduction Program

<table>
<thead>
<tr>
<th>Measure</th>
<th>Obs.</th>
<th>Savings (ccf/yr)</th>
<th>Projected Savings (ccf/yr)</th>
<th>Realization Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Insulation</td>
<td>364</td>
<td>87±33</td>
<td>133</td>
<td>65%</td>
</tr>
<tr>
<td>Heating System Replacement</td>
<td>523</td>
<td>284±25</td>
<td>409</td>
<td>69%</td>
</tr>
<tr>
<td>Air Sealing w/ Blower Door</td>
<td>718</td>
<td>40±24</td>
<td>112</td>
<td>36%</td>
</tr>
<tr>
<td>Air Sealing w/o Blower Door</td>
<td>482</td>
<td>24±26</td>
<td>76</td>
<td>32%</td>
</tr>
<tr>
<td>Programmable Thermostat</td>
<td>1,391</td>
<td>37±18</td>
<td>64</td>
<td>57%</td>
</tr>
<tr>
<td>Water Heater Replacement</td>
<td>60</td>
<td>71±66</td>
<td>38</td>
<td>184%</td>
</tr>
</tbody>
</table>
# Cost Effectiveness

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Description</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine</td>
<td>Comparison of program benefits and program costs</td>
<td>Costs to include</td>
</tr>
<tr>
<td>whether</td>
<td>Use of discount rate to determine total benefits over lifetime of the measures</td>
<td>Program costs</td>
</tr>
<tr>
<td>program is</td>
<td></td>
<td>Participant costs</td>
</tr>
<tr>
<td>cost-effective</td>
<td></td>
<td>Ratepayer costs</td>
</tr>
<tr>
<td>Determine</td>
<td></td>
<td>Benefits to include</td>
</tr>
<tr>
<td>whether</td>
<td></td>
<td>Utility avoided supply costs</td>
</tr>
<tr>
<td>specific</td>
<td></td>
<td>Participant savings</td>
</tr>
<tr>
<td>measures are</td>
<td></td>
<td>Non-energy benefits</td>
</tr>
<tr>
<td>cost-effective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cost Effectiveness

- Determine whether program is cost-effective
- Determine whether specific measures are cost-effective

Description

- Comparison of program benefits and program costs
- Use of discount rate to determine total benefits over lifetime of the measures

Options

- Costs to include
  - Program costs
  - Participant costs
  - Ratepayer costs
- Benefits to include
  - Utility avoided supply costs
  - Participant savings
  - Non-energy benefits
# Cost Effectiveness

## 2016 Low-Income Usage Reduction Program Evaluation

<table>
<thead>
<tr>
<th>#</th>
<th>Mean Savings</th>
<th>Mean Total Cost</th>
<th>Cost Per Unit Saved</th>
<th>Measure Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Electric Baseload</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric (kWh)</td>
<td>4,198</td>
<td>887</td>
<td>$444</td>
<td>$0.50</td>
</tr>
<tr>
<td><strong>Electric Heat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric (kWh)</td>
<td>162</td>
<td>1,129</td>
<td>$1,969</td>
<td>$1.74</td>
</tr>
<tr>
<td><strong>Gas Heat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric (kWh)</td>
<td>841</td>
<td>550</td>
<td>$203</td>
<td>$0.37</td>
</tr>
<tr>
<td>Gas (ccf)</td>
<td>854</td>
<td>89</td>
<td>$1,936</td>
<td>$21.76</td>
</tr>
</tbody>
</table>
Realization Rates

**Purpose**

How do estimated savings compare to projections?

- Are certain measures underperforming?
- How should the Technical Reference Manual (TRM) be adjusted?

**Computation**

Program Level or Customer Level

- Average Customer Realization = \( \text{Mean} \left\{ \frac{\text{Usage Impact Savings}}{\text{Projected Savings}} \right\} \)

- Average Program Realization = \( \frac{\text{Sum of Usage Impact Savings}}{\text{Sum of Projected Savings}} \)

**Adjustment**

Parameters to Improve Realization Rates

<table>
<thead>
<tr>
<th>Pre-Treatment Energy Usage</th>
<th>Use of Measures</th>
<th>Measure Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Rates</td>
<td>Installation Quality</td>
<td></td>
</tr>
</tbody>
</table>
Res High-Efficiency Furnace Replacement

TRM % Saved

- Furnace: 17%
- Boiler: 16%

Billing Analysis % Saved

- Furnace: 13%
- Boiler: 17%

Realization Rate

- Furnace: 48%
- Boiler: 62%
Res High-Efficiency Furnace Replacement

Pre-Treatment Usage

- Furnace: TRM 1,376, Billing 862
- Boiler: TRM 2,153, Billing 1,186
Res High-Efficiency Furnace Replacement

**TRM updated based on first evaluation findings**

![Realization Rate Graph](image)

- **Furnace**: 112%
- **Boiler**: 92%
Participant Surveys
Participant Surveys

Can provide insights into...

• Motivation to participate
• Barriers to participation
• Changes in energy usage behavior
• Impacts on home comfort
• Impacts on health
• Program satisfaction
Participant Surveys

Methodology

Select Survey Sample
- Understand who is represented – the sample frame
- Stratify to ensure sub-groups are represented

Send Advance Letters
- Explain purpose of survey
- Provide call-in option
- Incentive with letter increases response rates

Conduct Telephone Interviews
- Calls made day, evening, and weekends
- Leave message
- 12-call minimum
- 3-week survey period

Results & Reporting
- Weight for selection & response – to represent sample frame
- Report response rates
- Assess potential bias
Participant Surveys

2016 South Jersey Gas Home Performance Program Evaluation

Primary Installation Reason

- Old Equipment: 49%
- Reduce Energy Bills: 19%
- Converting to Natural Gas: 9%
- Financing: 6%
- Improve Energy Efficiency: 4%
- Upgrading Equipment: 4%
Participant Surveys

2016 South Jersey Gas
Home Performance Program Evaluation

Home Performance with Energy Star
Percent Satisfied

- Energy Finance Solutions: 81% Very Satisfied, 15% Somewhat Satisfied
- Energy Efficiency Improvements: 78% Very Satisfied, 20% Somewhat Satisfied
- Contractor: 75% Very Satisfied, 22% Somewhat Satisfied
- SJG HPwES Program: 88% Very Satisfied, 11% Somewhat Satisfied
On-Site Observations & Inspections
On-Site Observations and Inspections

**Description**
- Direct observation of service delivery
- Inspection of completed jobs

**Purpose**
- Implementation of program protocols
- Usability of program protocols
- Use of equipment
- Provider adaptability
- Comprehensiveness of service delivery
- Quality of work
- Client education
- Client interaction
On-Site Observations and Inspections

- Develop check lists and rating scales
- Train experts to implement consistently
- Quantify findings across all observations and inspections
- Enrich data with descriptive information
- Make recommendations based on prevalent issues
### National WAP Evaluation Check List Example

<table>
<thead>
<tr>
<th>Audit Air Leakage and Insulation Diagnostics</th>
<th>Applicable Observations</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured surfaces</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Inspected windows</td>
<td>100</td>
<td>96</td>
</tr>
<tr>
<td>Inspected all accessible attics</td>
<td>78</td>
<td>69</td>
</tr>
<tr>
<td>Measured insulation in all accessible attics</td>
<td>79</td>
<td>70</td>
</tr>
<tr>
<td>Created access to inaccessible attics</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>Measured insulation in exterior walls</td>
<td>95</td>
<td>47</td>
</tr>
<tr>
<td>Measured insulation in basement/crawlspace</td>
<td>74</td>
<td>55</td>
</tr>
<tr>
<td>Inspected for all typical bypasses</td>
<td>100</td>
<td>62</td>
</tr>
<tr>
<td>Visual inspection for air sealing opportunities</td>
<td>100</td>
<td>83</td>
</tr>
<tr>
<td>Used blower door while inspecting for leaks</td>
<td>96</td>
<td>64</td>
</tr>
</tbody>
</table>
# On-Site Observations and Inspections

## National WAP Evaluation Rating Example

### Quality of Attic Insulation

<table>
<thead>
<tr>
<th></th>
<th>Needs Improvement</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rating</td>
<td><strong>Total Points needed</strong></td>
<td><strong>Bold Points needed</strong></td>
</tr>
<tr>
<td>1</td>
<td>All air sealing work completed first</td>
<td>0-5</td>
</tr>
<tr>
<td>2</td>
<td>Exhaust fans vented to exterior as needed</td>
<td>6-7</td>
</tr>
<tr>
<td>3</td>
<td>Heat producing devices or systems protected from insulation contact</td>
<td>8-9</td>
</tr>
<tr>
<td>4</td>
<td>Attic checked for knob and tube wiring</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Workers wore respirators, safety glasses, gloves, and hard hats while insulating attic</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Insulation installed in sufficient quantity (bags per ft$^2$) to meet R-value requirement</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Proper insulation material chosen for attic conditions</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Open blow insulation is level and of consistent depth</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Attic ventilation maintained</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Confined areas blown to dense pack</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Proper containment used to protect client and belongings</td>
<td></td>
</tr>
</tbody>
</table>
On-Site Observations and Inspections

NJ Comfort Partners Inspection Example
Insulation Quality & Missed Opportunities

- Excellent: 12%
- Good: 24%
- Fair: 8%
- Poor: 4%
- Missed Opportunity: 52%

364 Measures Rated
Achieving High Savings
Achieving High Savings

**Policies**
- Target homes with highest potential
- Prioritize measures with greatest impact
- Furnish providers with right incentives

**Practices**
- Ensure staff have needed skills and tools
- Use best practices for measure selection
- Complete high-quality installation
- Identify problems, give feedback, resolve issues

**Target** high usage homes that need major measures

**Identify, prioritize, and install appropriate measures**

Ensure that weatherization staff do high quality work
Achieving High Savings

Target High Energy Users

Seven low-income gas efficiency program evaluations.

Seven low-income electric efficiency program evaluations.
Achieving High Savings

Target High Energy Users

South Jersey Gas
Home Performance with Energy Star

New Jersey Natural Gas
Home Performance with Energy Star
Achieving High Savings

Install Major Measures

- Identify and prioritize cost-effective measures with the greatest impact to achieve usage reduction goals

Major Measures Include:

- HVAC replacement
- Wall insulation
- Attic insulation
- Duct sealing
- Refrigerator replacement

Impacts of Installing Major Measures

Electric Heating Jobs

<table>
<thead>
<tr>
<th>Number of Measures Installed</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5%</td>
</tr>
<tr>
<td>2</td>
<td>9%</td>
</tr>
<tr>
<td>3</td>
<td>9.5%</td>
</tr>
<tr>
<td>4-5</td>
<td>14%</td>
</tr>
</tbody>
</table>

Amount of energy saved (kWh)
## GAS HEATING SAVINGS

<table>
<thead>
<tr>
<th>Number of Major Measures</th>
<th>Obs.</th>
<th>%</th>
<th>Net Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ccf</td>
</tr>
<tr>
<td>None</td>
<td>1,365</td>
<td>28%</td>
<td>11</td>
</tr>
<tr>
<td>1 Measure</td>
<td>1,066</td>
<td>22%</td>
<td>35**</td>
</tr>
<tr>
<td>2 Measures</td>
<td>1,284</td>
<td>27%</td>
<td>34**</td>
</tr>
<tr>
<td>3 Measures</td>
<td>792</td>
<td>16%</td>
<td>97**</td>
</tr>
<tr>
<td>4 Measures</td>
<td>260</td>
<td>5%</td>
<td>150**</td>
</tr>
<tr>
<td>5-6 Measures</td>
<td>57</td>
<td>1%</td>
<td>218**</td>
</tr>
</tbody>
</table>

**Statistically significant at 95% level.**
Ensure Quality Work

- On-site observation and inspections in addition to documentation of procedures, contractor training, and quality control can help increase the use of best practices.
Achieving High Savings

Ensure Quality Work

South Jersey Gas
Home Performance with Energy Star

Savings by Contractor

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Net Savings (ccf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>225</td>
</tr>
<tr>
<td>E</td>
<td>223</td>
</tr>
<tr>
<td>D</td>
<td>221</td>
</tr>
<tr>
<td>B</td>
<td>204</td>
</tr>
<tr>
<td>Other</td>
<td>195</td>
</tr>
<tr>
<td>F</td>
<td>144</td>
</tr>
<tr>
<td>C</td>
<td>135</td>
</tr>
<tr>
<td>All</td>
<td>206</td>
</tr>
</tbody>
</table>
Achieving High Savings

Ensure Quality Work

South Jersey Gas
Home Performance with Energy Star

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Treatment Obs</th>
<th>Treatment Pre</th>
<th>Treatment Post</th>
<th>Savings ccf</th>
<th>Savings %</th>
<th>Matched Comparison Group Obs</th>
<th>Matched Comparison Pre</th>
<th>Matched Comparison Post</th>
<th>Savings ccf</th>
<th>Savings %</th>
<th>Net Savings ccf</th>
<th>Net Savings %</th>
<th>Average Project Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>281</td>
<td>890</td>
<td>678</td>
<td>211***</td>
<td>23.7%</td>
<td>281</td>
<td>883</td>
<td>897</td>
<td>-14**</td>
<td>-1.6%</td>
<td>225***</td>
<td>25.3%</td>
<td>$14,756</td>
</tr>
<tr>
<td>B</td>
<td>98</td>
<td>834</td>
<td>637</td>
<td>198***</td>
<td>23.7%</td>
<td>98</td>
<td>806</td>
<td>812</td>
<td>-6</td>
<td>-0.7%</td>
<td>204***</td>
<td>24.4%</td>
<td>$17,697</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>746</td>
<td>615</td>
<td>131***</td>
<td>17.6%</td>
<td>50</td>
<td>742</td>
<td>745</td>
<td>-3</td>
<td>-0.4%</td>
<td>135***</td>
<td>18.0%</td>
<td>$14,839</td>
</tr>
<tr>
<td>D</td>
<td>47</td>
<td>901</td>
<td>696</td>
<td>205***</td>
<td>22.7%</td>
<td>47</td>
<td>882</td>
<td>898</td>
<td>-16</td>
<td>-1.9%</td>
<td>221***</td>
<td>24.5%</td>
<td>$15,743</td>
</tr>
<tr>
<td>E</td>
<td>34</td>
<td>872</td>
<td>694</td>
<td>178***</td>
<td>20.4%</td>
<td>34</td>
<td>875</td>
<td>920</td>
<td>-45*</td>
<td>-5.1%</td>
<td>223***</td>
<td>25.5%</td>
<td>$15,698</td>
</tr>
<tr>
<td>F</td>
<td>20</td>
<td>871</td>
<td>732</td>
<td>139***</td>
<td>16.0%</td>
<td>20</td>
<td>864</td>
<td>869</td>
<td>-5</td>
<td>-0.5%</td>
<td>144***</td>
<td>16.5%</td>
<td>$17,190</td>
</tr>
<tr>
<td>Other Contractors</td>
<td>116</td>
<td>887</td>
<td>702</td>
<td>184***</td>
<td>20.8%</td>
<td>116</td>
<td>879</td>
<td>890</td>
<td>-11</td>
<td>-1.2%</td>
<td>195***</td>
<td>22.0%</td>
<td>$15,595</td>
</tr>
<tr>
<td>All</td>
<td>646</td>
<td>859</td>
<td>675</td>
<td>194***</td>
<td>22.3%</td>
<td>646</td>
<td>859</td>
<td>871</td>
<td>-13***</td>
<td>-1.5%</td>
<td>206***</td>
<td>23.8%</td>
<td>$15,556</td>
</tr>
</tbody>
</table>
Performance Measurement
Performance Measurement

**Assessment Example**
Analyze Program Statistics

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Follow-up 1</th>
<th>Follow-up 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Usage &gt; 1,200 ccf</td>
<td>25%</td>
<td>35%</td>
<td>40%</td>
</tr>
<tr>
<td>3 or 4 Major Measures</td>
<td>15%</td>
<td>25%</td>
<td>35%</td>
</tr>
<tr>
<td>Wall Insulation</td>
<td>10%</td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td>Attic Insulation</td>
<td>50%</td>
<td>55%</td>
<td>60%</td>
</tr>
<tr>
<td>Major Air Sealing</td>
<td>55%</td>
<td>55%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Provides critical information about potential savings before post usage data are available.
Achieving High Savings
Lessons Learned

It is challenging to meet savings expectations

Target high usage customers

Ensure major measures are installed where opportunities exist

Maximize use of proven home performance techniques

Conduct performance measurement
Non-Energy Impacts
Non-Energy Impacts

**Background**

- NEIs accrue to participants, utility ratepayers, and society
- May be included in cost-effectiveness test

<table>
<thead>
<tr>
<th>Benefit Example</th>
<th>Description</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Societal</strong></td>
<td>Reduced emissions positively impact the environment</td>
<td>Economic, Environmental, Health &amp; Safety</td>
</tr>
<tr>
<td><strong>Ratepayer</strong></td>
<td>Reduced usage improves affordability and may reduce collections costs</td>
<td>Affordability, Collections Costs, System Reliability</td>
</tr>
<tr>
<td><strong>Participant</strong></td>
<td>Air sealing increases comfort</td>
<td>Health &amp; Safety, Affordability, Indoor Air Quality, Noise, Water Usage, Maintenance</td>
</tr>
</tbody>
</table>

**Typical Approach to Estimation**

- Review Past Studies
- Select Benefits for Inclusion
- Take Average of Past Study Impacts

**Challenges in the Literature**

- Past Estimates: Out of date, Applicability
- Research Quality not Assessed: Approach, Sample Size, Statistical Significance
- Documentation Lacking: Methodology, Assumptions, Limitations
# Non-Energy Impacts

## Two NEI Estimates from the Same Survey

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Reduction Estimate</th>
<th>Per Job Monetization First Year Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate 1</td>
<td>Estimate 2</td>
</tr>
<tr>
<td>CO Poisoning</td>
<td>0%</td>
<td>No Report</td>
</tr>
<tr>
<td>Home Fires</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Cold-Related Illness/Death</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Heat-Related Illness/Death</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Asthma Emergency Dept. Visits</td>
<td>1%</td>
<td>12%</td>
</tr>
<tr>
<td>Sleep Problems/Work Productivity</td>
<td>1%</td>
<td>21%</td>
</tr>
<tr>
<td>Sleep Problems/Housework Productivity</td>
<td>1%</td>
<td>21%</td>
</tr>
<tr>
<td>Missed Days of Work</td>
<td>.49</td>
<td>.52</td>
</tr>
<tr>
<td>Short-Term Loans</td>
<td>2%</td>
<td>9%</td>
</tr>
<tr>
<td>Prescriptions Affordability</td>
<td>10%***</td>
<td>10%</td>
</tr>
<tr>
<td>Food Affordability</td>
<td>4%</td>
<td>16%</td>
</tr>
<tr>
<td>Food Assistance</td>
<td>3%</td>
<td>6%</td>
</tr>
<tr>
<td>Total Benefit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Non-Energy Impacts

### Why Did the Results Differ?

<table>
<thead>
<tr>
<th>Estimate 1</th>
<th>Estimate 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Longitudinal Framework</strong></td>
<td></td>
</tr>
<tr>
<td>Same Participants in Pre and Post Periods</td>
<td>Unmatched Samples</td>
</tr>
</tbody>
</table>

### Comparison

| Net Change = (Pre-Treatment–Post-Treatment) – (Pre-Comparison–Post-Comparison) | Gross Change = Pre-Treatment – Post-Treatment  
Additional Measure = Pre-Treatment – Pre-Comparison |
|---|---|

### Statistical Significance

<table>
<thead>
<tr>
<th>At Least 90 Percent Confidence Level</th>
<th>No Requirement</th>
</tr>
</thead>
</table>

### External Data

<table>
<thead>
<tr>
<th>Only Data from Referenced Survey</th>
<th>External Data Used when Survey Found Small NEI</th>
</tr>
</thead>
</table>
Non-Energy Impacts

Methodologies have been developed to measure NEIs

Current literature on NEIs has many challenges

Additional research is needed

Difficult to apply findings from previous studies

Factors specific to programs, jurisdictions, participants, and implementation can impact the NEIs

Additional challenges relate to valuing benefits relating to health, comfort, and safety

Recommendations

• Review referenced studies
• Understand methodologies & limitations
• Assess applicability to evaluated program
Recommendations
Recommendations

**Energy Efficiency**

- Treat high users
- Install major measures where cost-effective opportunities exist
- Provide training and quality control to ensure high quality work

**Evaluation**

- Estimate savings using billing data
- Weather normalize energy usage
- Use comparison group
- Re-assess frequently

**Study Review**

- Sample
- Attrition/Response Rate
- Methodology
- Separation between implementation, evaluation, and advocacy?
- Ask questions!