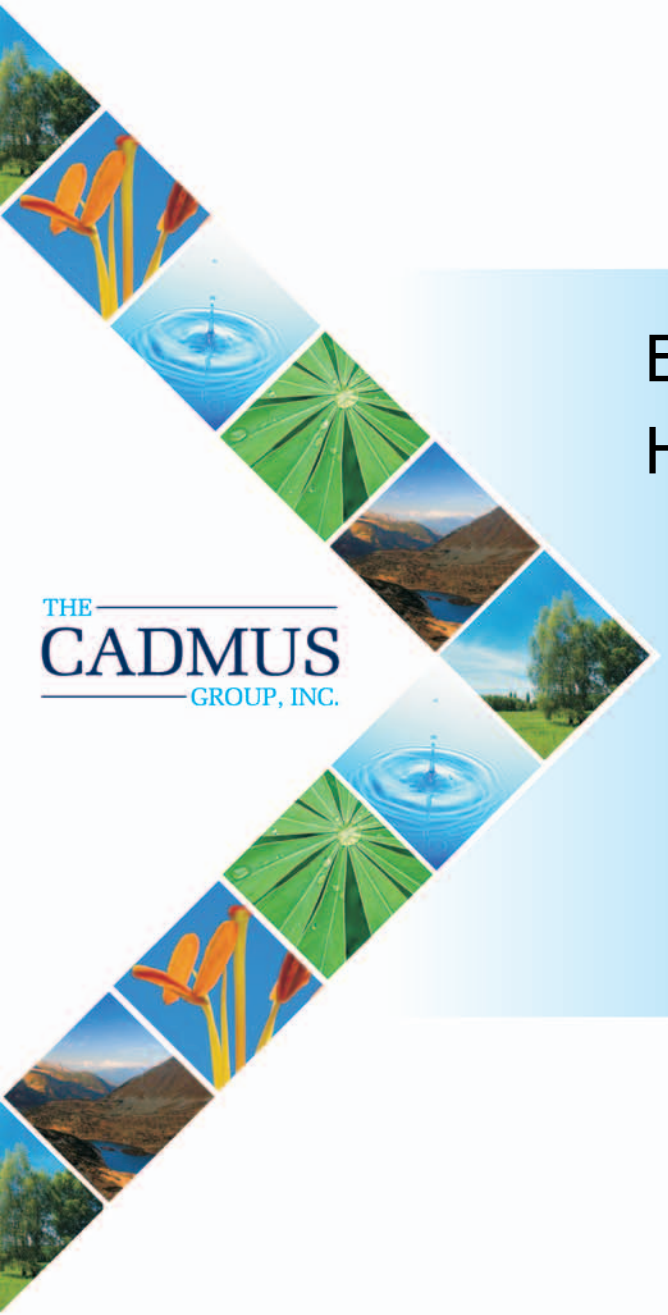

THE CADMUS GROUP, INC.

EM&V Uniform Methods Project (UMP)- HVAC (Gas Furnaces and Boilers)

David Jacobson
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Agenda

- Overview of Measure Covered
- Who Reviewed Protocol
- Who Wrote Protocols
- Overview of Protocol
- Major Points Requiring Reconciliation
- Key Assumptions
- Comparison to Industry Practices
- Questions/Comments

Measures Covered by Protocol

- Normal/Time of Replacement/New Construction Boilers and Furnaces in Residential, Multifamily and Small Commercial Applications
  - 60 kBtu/hr to 300 kBtu/hr
  - Single unit per billing meter
  - Baseline is standard practice or code compliant unit
  - Core component of most residential gas EE programs
- Typical delivery mechanism
  - Standard Rebate (majority)
  - Delivered by HVAC and Plumbing Contractors

Who Wrote Protocol??

- David Jacobson, Jacobson Energy Research
  - Former Manager of Evaluation for National Grid
  - Mechanical Engineer with 30 years experience in EE analysis and evaluation
  - Involved with EM&V of this measure for the past four years (gas evaluation is newer)
  - Key input from Matei Perussi and Arlis Reynolds (Cadmus), Ken Agnew and Jeremiah Robinson (KEMA), Pete Jacobs (Building Metrics and TAG member)

Who Reviewed Protocol??

- TAC Members:
  - Kevin Cooney and Elizabeth Davis -Navigant
  - Pete Jacobs - Building Metrics

- SC Members:
  - NREL – David Roberts

- Others from Cadmus and KEMA listed in previous slide

Background of Protocol

- Less work done on gas EE than electric
  - fewer past studies to rely on for methods
- Three TRM Equations in Use:

1) Savings = Capacity* EFLH * ($AFUE_e$ / $AFUE_b$ - 1)

2) Savings = Capacity* EFLH * (1/ $AFUE_b$ – 1/ $AFUE_e$)

3) Savings = Capacity* EFLH * (1– $AFUE_b$ / $AFUE_e$)

Where capacity = input or output capacity in Btu/hr; EFLH= Equivalent Full Load Hours; $AFUE_b$, $AFUE_e$ = Annual Fuel Utilization Efficiency base and efficient units

- Which equation is correct/best to use depends on assumptions about meaning of "capacity"(input or output Btu/hr) and specifics of derivation

Overview of Protocol

- 1st Task to sort out the differences in equations (lots of algebra)
- Input capacity data more readily available (imbedded in model number, ie York YP9C0**60**B12MP12C is 60,000 Btu/hr input capacity`)
- Approximation that Annual Fuel Utilization Efficiency(AFUE) = peak output capacity/peak input capacity values works for non-condensing units, but for condensing boilers this assumption not valid
  - Peak efficiency is lower than annual efficiency so AFUE does not equal peak output capacity/ peak input capacity
- Formula that is recommended(derivations included in protocol) is:

$$Savings = Capacity_{input\text{-}e} * EFLH_{e\text{-}installed} * (AFUE_e / AFUE_b - 1)$$

Overview of Protocol(con't)

- Noting that:
  - $Capacity_{input\text{-}e}$* $EFLH_{e\text{-}installed}$ = Normalized Annual Gas Usage for Heating = NAH_e

- Saving = NAH_e * ($AFUE_e$ / $AFUE_b$ - 1) where:
  - NAH_e is determined from **billing analysis** by separating out weather and non-weather sensitive gas usage
  - Savings determined from just AFUEs and Post installation billing data; $AFUE_e$ from tracking data and $AFUE_b$ from code or standard practice
  - EFLH = NAH_e / $Capacity_{input\text{-}e}$ with $Capacity_{input\text{-}e}$ from the tracking database

- Results can be used to produce average evaluated "deemed" savings in therms for a specific type and size range of units or can be used to produce inputs to TRM equations so savings calculations can be done on each unit rebated

Overview of Protocol(con't)

- Disadvantage of this approach is savings are not based on any measurement of CHANGE in consumption resulting from installation of a new furnace/boiler replacing unit at end useful life. But that change is not representative of savings from baseline to efficient model but from ***replaced*** unit which is not true base case

- Alternate/Enhanced approach developed using the CHANGE in consumption from REPLACED to energy efficient unit to the measured and scaling that change to the actual code

- Using an estimated of the replaced efficiency $AFUE_{replaced}$ and the delta in heating usage from the replaced unit and the efficient unit $\Delta NAH_{e\text{-}replaced}$ the resulting savings is:

$$Savings_{e-b} = \Delta NAH_{e\text{-}replaced} * (1/AFUE_b - 1/AFUE_e) / (1/AFUE_{replaced} - 1/AFUE_e)$$

- All billing analysis methodologies for this protocol reference the Residential Whole-House Retrofit protocol

Fundamental Assumptions/Points of Reconciliation-

- Measurement of unit level gas consumption is prohibitively expensive and since baseline units not readily available for direct measurements not a viable option
- AFUE is a good indicator of the relative efficiency though not necessarily a good measure of real world measured efficiency of a given unit
- Use of large scale billing analysis "grounds" the results in actual consumption; something that engineering analysis or even metering of furnace fan or hot water pump cannot do
- Methods should work with a format compatible with prevailing TRM equations listed above even though many agree the equations are simplification

How Protocol Compares to Existing Industry Practices

- Protocol is similar to most recent studies in approach:

NMR and Cadmus. October 2010. “High Efficiency Heating and Water Heating Equipment Process and Impact Evaluation.” Conducted for Gas Networks, a group of New England gas utilities offering energy-efficiency programs.

KEMA. November 2008. “Puget Sound Energy’s Residential Energy Efficient Furnace Program Impact Evaluation.”

- Protocol provides enhanced guidance and corrections regarding which of the common TRM equations to use and why

Questions/Comments?