Estimating Residential Indirect HVAC Savings from CFL installations: Are building simulation results good enough?

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What we'll cover

- Why do residential lighting-HVAC interactive effects matter?

- What drives the large variation in interactive effects parameter values across 13 states' Technical Reference Manuals (TRMs)?
- How can coordinated research improve the accuracy of estimating this important parameter?

Changing to efficient lighting affects HVAC loads

Changing over to efficient lighting

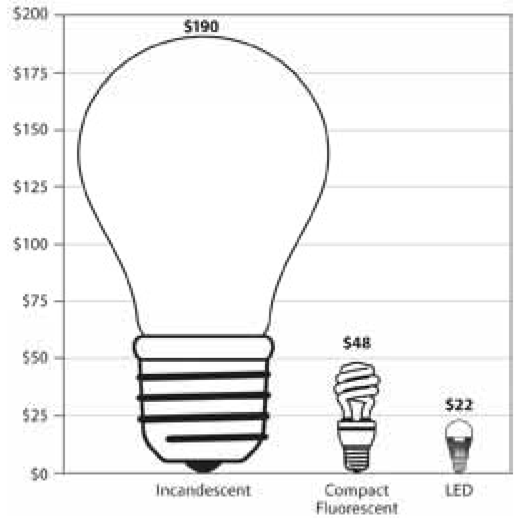
↓

Reduction in waste heat

↙ ↘

Cooling Benefit

Heating Penalty



Impact is expressed as a multiplicative factor in savings

Demand:

kW = Direct lighting demand savings x **WHFd**

Energy:

kWh = Direct lighting energy savings x **WHFe**

WHFd = Waste Heat Factor for peak demand savings

WHFe = Waste Heat Factor for energy savings

Impact is expressed as a multiplicative factor in savings

Demand:

kW = Direct lighting demand savings x **WHFd**

↓

Summer cooling benefit

Energy:

kWh = Direct lighting energy savings x **WHFe**

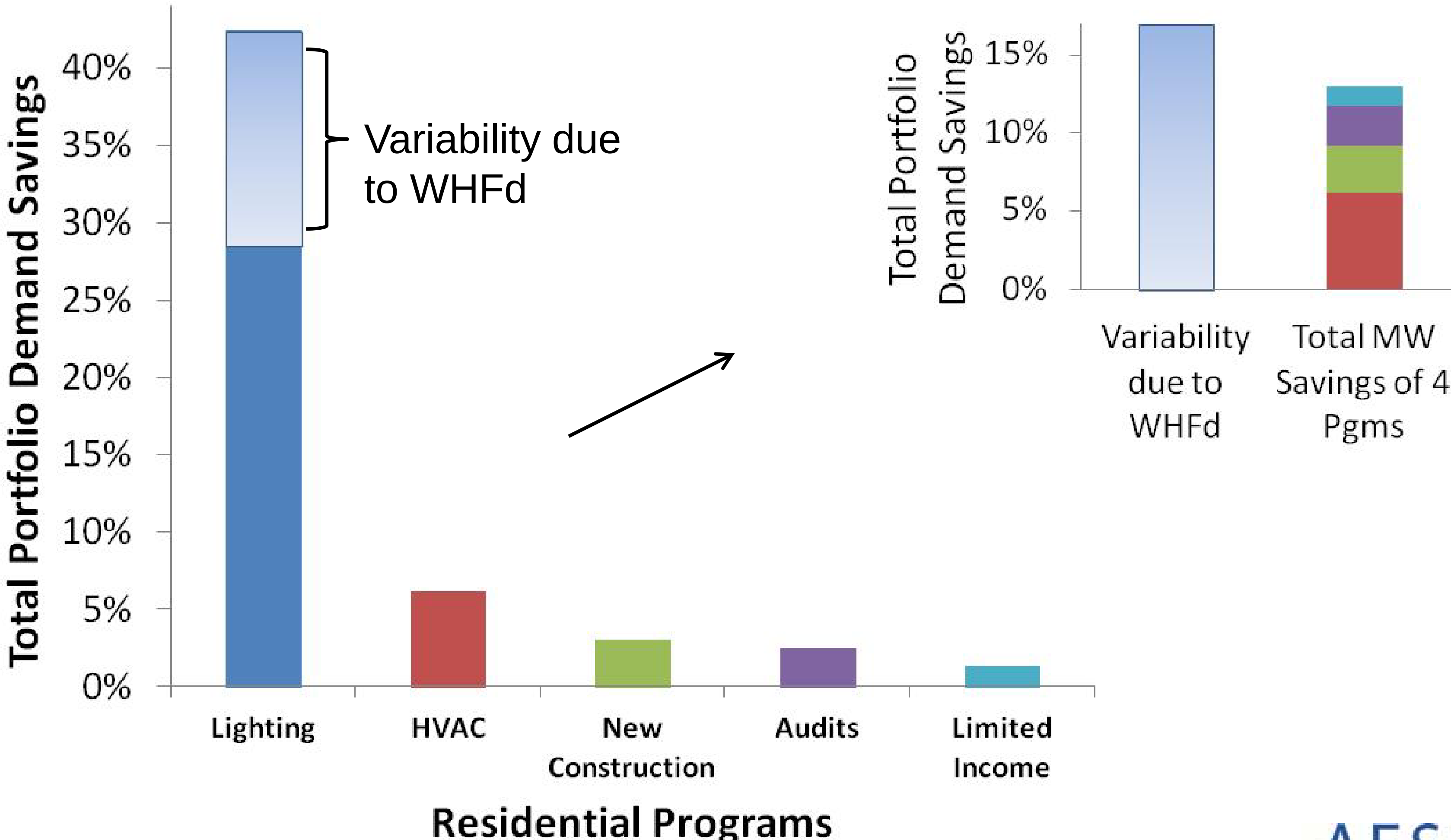
↙ Summer cooling benefit

↘ Winter heating penalty

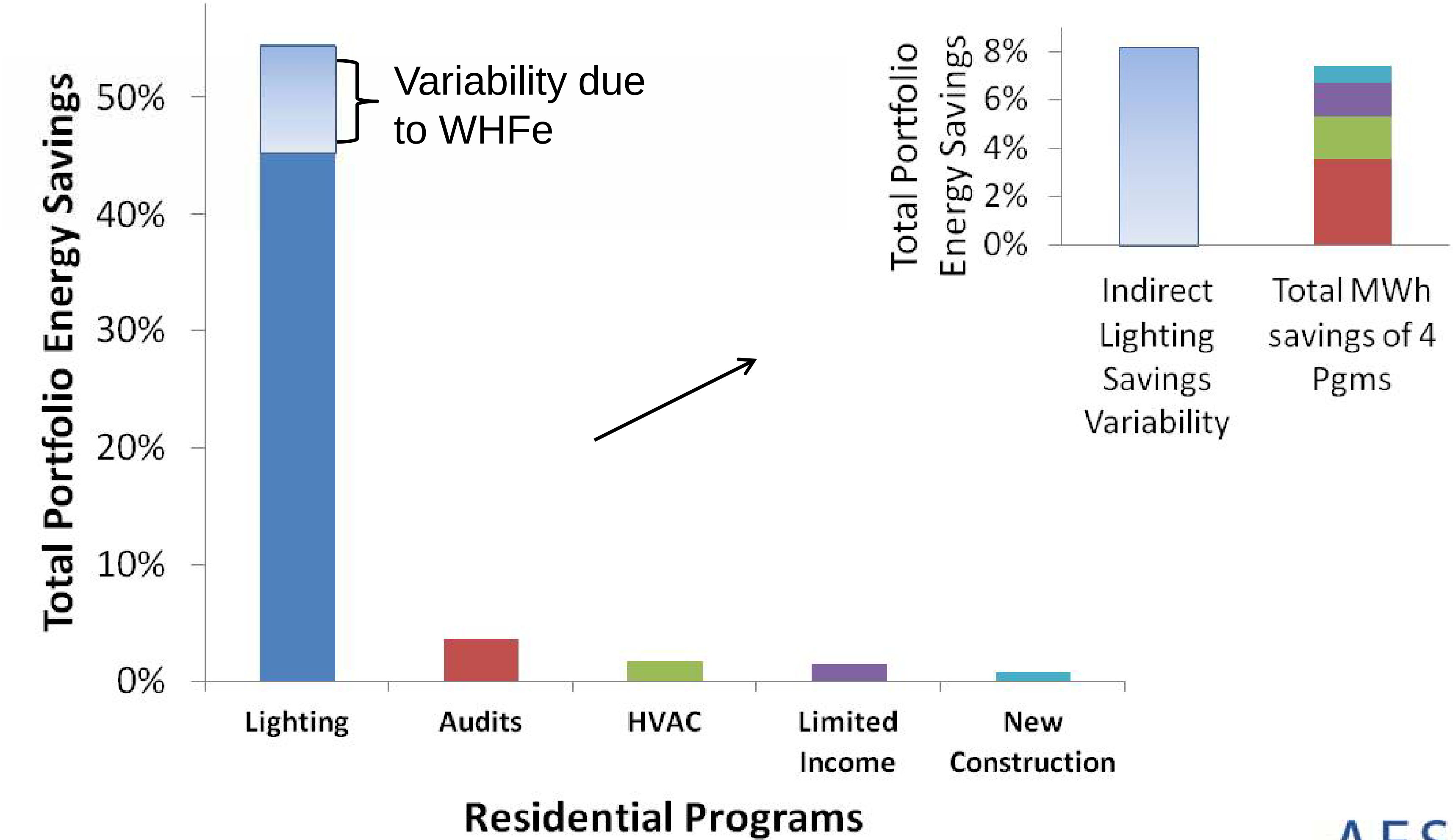
WHFd = Waste Heat Factor for peak demand savings

WHFe = Waste Heat Factor for energy savings

WHFd variability is > direct savings of 4 programs



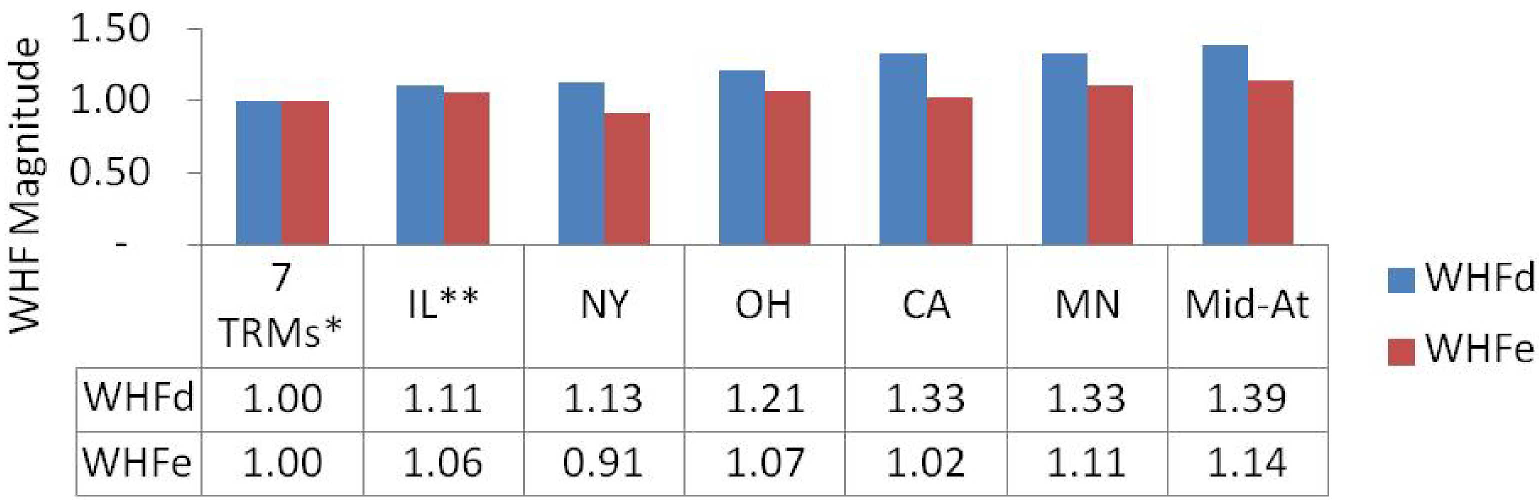
WHFe variability is also > direct savings of those 4 programs



What drives the variation observed across TRMs?

- Inclusion/exclusion of lighting-HVAC interactive effects in the savings algorithms altogether?
- Boundary definitions for the input variables?
- Differences in housing characteristics and climate?

Inclusion/exclusion of WHF is critical, 40% range for WHFd



	7 TRMs*	IL**	NY	OH	CA	MN	Mid-At
WHFd	1.00	1.11	1.13	1.21	1.33	1.33	1.39
WHFe	1.00	1.06	0.91	1.07	1.02	1.11	1.14

* 7 states with 1.00 for WHFd and WHFe: CT, HI, MA, ME, MO, PA, VT

** Cooling savings only. Algorithm is also provided in IL TRM to calculate electric heating penalty.

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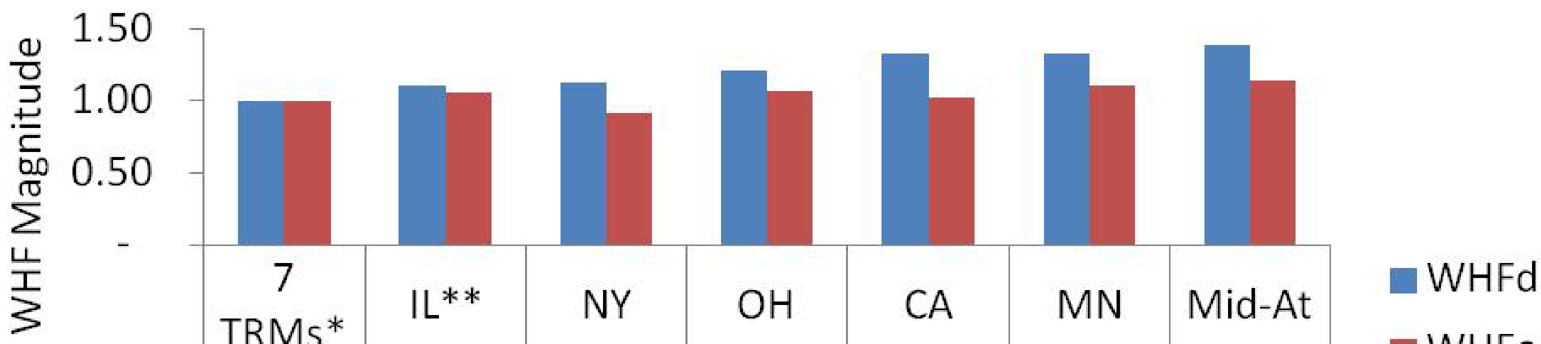

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How have WHFd and WHFe been estimated?

- Direct experimental measurement
  - Parekh et al. (2005) [Ottowa], PG&E (2009) [Indiana]
- Billing analysis
  - Brunner et al. (2009) [SDG&E]
- Simple spreadsheet
  - NEEP (2011)
- Building energy simulations (commercial)
  - Franconi and Rubinstein (1992), Rundquist et al (1993), Sezgen and Huang (1994), Sezgen and Koomey (1998)

Adapted from: Hirsch, James J. and Associates, 2012. Project Report: A Study of the Sensitivity of DEER HVAC Interactive Effects Factors to Modeling Parameters. Submitted to California Public Utilities Commission (CPUC) Energy Division. March 28, 2012.

Simplified models: Modeling input variability for 3 key inputs:

WHF = (1 + %INT*%HH/COP)

- **%INT** = Coincidence factor between lighting and space cooling or space heating equipment
- **%HH** = Proportion of households with space cooling/heating equipment affected by waste heat
- **COP** = Coefficient of Performance, efficiency of the space cooling and space heating equipment

WHFe: Input Variability, %INT

%INT:
Range: 0.27-0.45

Various sources:
-Output from RemRate?
-Cooling season length?
-Avg cooling load/max?

$$WHFe = (1 + \%INT * \%HH / COP)$$

%INT = Proportion of the year lighting interacts with the space cooling or space heating equipment

%HH = Proportion of households with space cooling/heating equipment affected by waste heat

COP = Coefficient of Performance, efficiency of the space cooling and space heating equipment

WHFe, Input Variability, %HH

%HH:
Range: 0.64-0.78

Various sources:
% homes with central AC?
% with CAC or 2+ room units?

$$WHFe = (1 + \%INT * \%HH / COP)$$

%INT = Proportion of the year lighting interacts with the space cooling or space heating equipment

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WHFe, Input Variability, COP

COP:
Range: 2.5-3.1

Various sources:
-Differentiated for energy and demand?
-Name plate or field ratings?

$$WHFe = (1 + \%INT * \%HH / COP)$$

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WHFd: Input Variability, %INT

%INT:
Range: 0.466-1.0

Various sources:
-Avg cooling load at peak?
-Assume complete overlap?

$$WHFd = (1 + \%INT * \%HH / COP)$$

%INT = Proportion of the year lighting interacts with the space cooling or space heating equipment

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Sensitivity Analysis, Key Inputs

	Demand		Energy	
	Low	High	Low	High
%HH	64%	78%	64%	78%
%INT	47%	100%	27%	45%
COP	2	3.1	2.5	3.1
WHF	1.10	1.39	1.06	1.14
% Diff	27%		8%	

%INT = Proportion of the year lighting interacts with the space cooling or space heating equipment

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Including winter electric heating penalty increases the range :

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Housing features and climate: DOE-2 Sensitivity Analysis

Parameter	Base Case	Alternates	Range		
			WHFd	WHFe	Gas Takeback
Cooling Setback	78°F day/ 76°F night	80°F day/ 76°F night 83°F day/ 76°F night 85°F day/ 76°F night	2.48	0.032	0.03
Load profile	One daytime occupant	0 or 3 daytime occupants	0.91	0.043	0.16
Cooling T-stat Setpoints	78°F day/ 76°F night	74°F day/ 74°F night 76°F day/ 76°F night 78°F day/ 78°F night 80°F day/ 80°F night	0.5	0.053	0.11
Glass type	Double pane, clear glass, low-e	Single pane clear to double clear low-e argon	0.42	0.062	0.38
Infiltration Rate	0.35 Air Cycles/Hour	0.14 to 1.06	0.36	0.064	0.62
Window/Floor Ratio	0.18	0.09 to 0.27	0.34	0.046	0.32

From Hirsch et al, 2012

Housing features and climate: DOE-2 Sensitivity Analysis

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The Need for Coordinated Research

- Current practice is to deem indirect savings in most states - leads to large difference in magnitude of indirect savings? (0 affect vs 40%)
- Some state TRMs acknowledge the need for primary research:
  - Missouri TRM: “WHFe…is assumed to be 1.0 due to the difficulty in identifying and quantifying interactive effects. Interactive effects most certainly exist, and future TRMs will incorporate a specific value to the extent it is identified and measured in a future potential study or future EMV report after more research is conducted."

Prioritizing Interactive Research

Coordinated research can inform inputs to building simulation models by finding population distributions of key inputs:

	Targeted Parameter		
Research Priority:	**COP**	**%HH**	**%INT**
Efficiency of HVAC equipment, including part-load and partial operation	●		
Building shell/construction type, window types & window/floor ratio	●		
Distributions of HVAC type and heating fuel		●	
Thermostat info: location and setback/operation			●
Demographic data linked to HVAC metering data:			●

Prioritizing Interactive Research

What types of evaluation approach or methods should be used to estimate interactive effects?

- Primary data collection on instrumented HVAC and lighting systems in residential dwellings
- Spot measurement of average HVAC COP by housing vintage?
- Building simulations to estimate overall heat loss coefficients for a sample of SF and MF buildings and thus probability that lighting loads need to be removed?
- Billing Analysis of homes with range of CFL saturations

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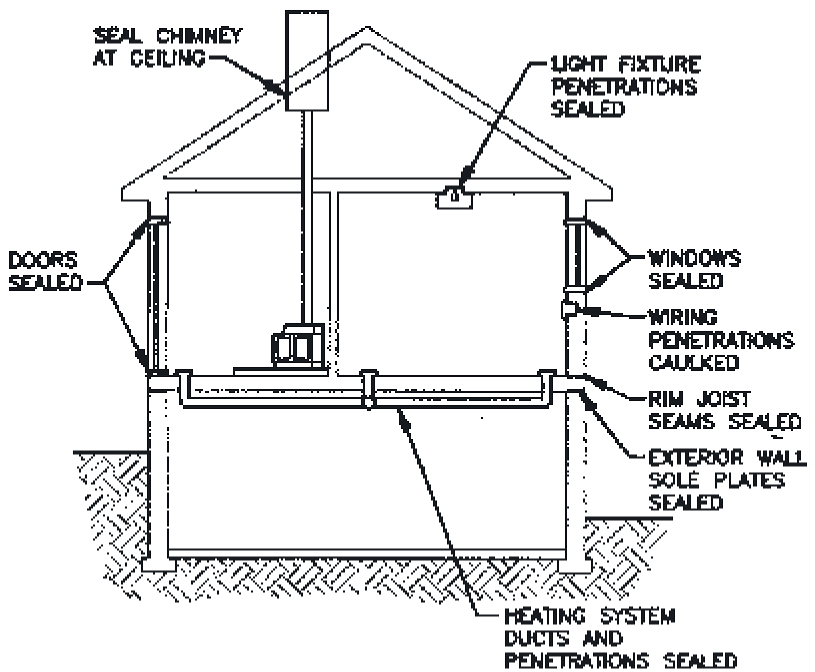
Additional Research Questions

What is the significance of…

- Location of lights relative to thermostat?
- Minimum threshold for lighting change to have a measurable effect on HVAC?
- Thermal lag of waste heat effects?
- Differentiating among housing stock (single family, multi-family…)?
- Excluding exterior bulbs?
- Adjusting for proportion of homes with with AC system not running?



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Policy Implications

- Is it best to just “deem” indirect savings factors at regional or national level, or use a building simulation approach at state or local level?
- What are the risks of using highly uncertain WHF’s?
  - Overpayment in ISO markets?
  - Skewed resource planning?
  - Lever for attainment of savings goals?
  - Credibility?

Funding possibilities

- Possible organizing bodies for a collaborative effort
  - NEEP?
  - National?
  - a single state?

Conclusions

- Differences in calculation inputs and approach are responsible for a large range in reported savings from residential lighting program: +/- 40%.
- The large variation in interactive effects parameter values across 13 states' Technical Reference Manuals (TRMs) is driven by:
  - Inclusion/exclusion of WHFe and WHFd parameter values altogether
  - Boundary definitions for key input variables and outputs considered (electricity, natural gas, others)
  - Differences in housing characteristics and climate

Conclusions, cont'd

- How can coordinated research improve the accuracy of estimating this important parameter?
  - A concerted data collection effort can refine the input assumptions in energy simulation models
    - Bound the impacts of climate, housing characteristics, and thermostat usage patterns on interactive effects
    - Confidence intervals around some of the key input values to building energy simulation tools would be a major contribution emerging from this effort
  - Next steps: Do scoping studies to test whether e.g. demographic data collected in one service territory can be applied to another

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Orlando, FL

Apr. 29-May 1, 2013 — AESP's Spring Conference
Dallas, TX

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