Rethinking Design for Low-Load Homes

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Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Session Learning Objectives

- Identify three reason for re-evaluating HVAC design for low-load homes.
- List three differences between Manual J8 and PHPP HVAC sizing methods.
- Understand the concept of heat capacitance and how it affects heating system response time.
- List two methods for providing setback capability in low-load homes.

Overview

- Rationale for Research
- Differences between MJ8 & PH
- Modeling Results
- Research Methods
- Monitoring Results
- Recommendations & Design Considerations

What is a Low-Load Home?

- Super insulated?
- 2012 Code?
- 2009 Code?
- Load smaller than smallest equipment available?
- X Btuh/sq ft?

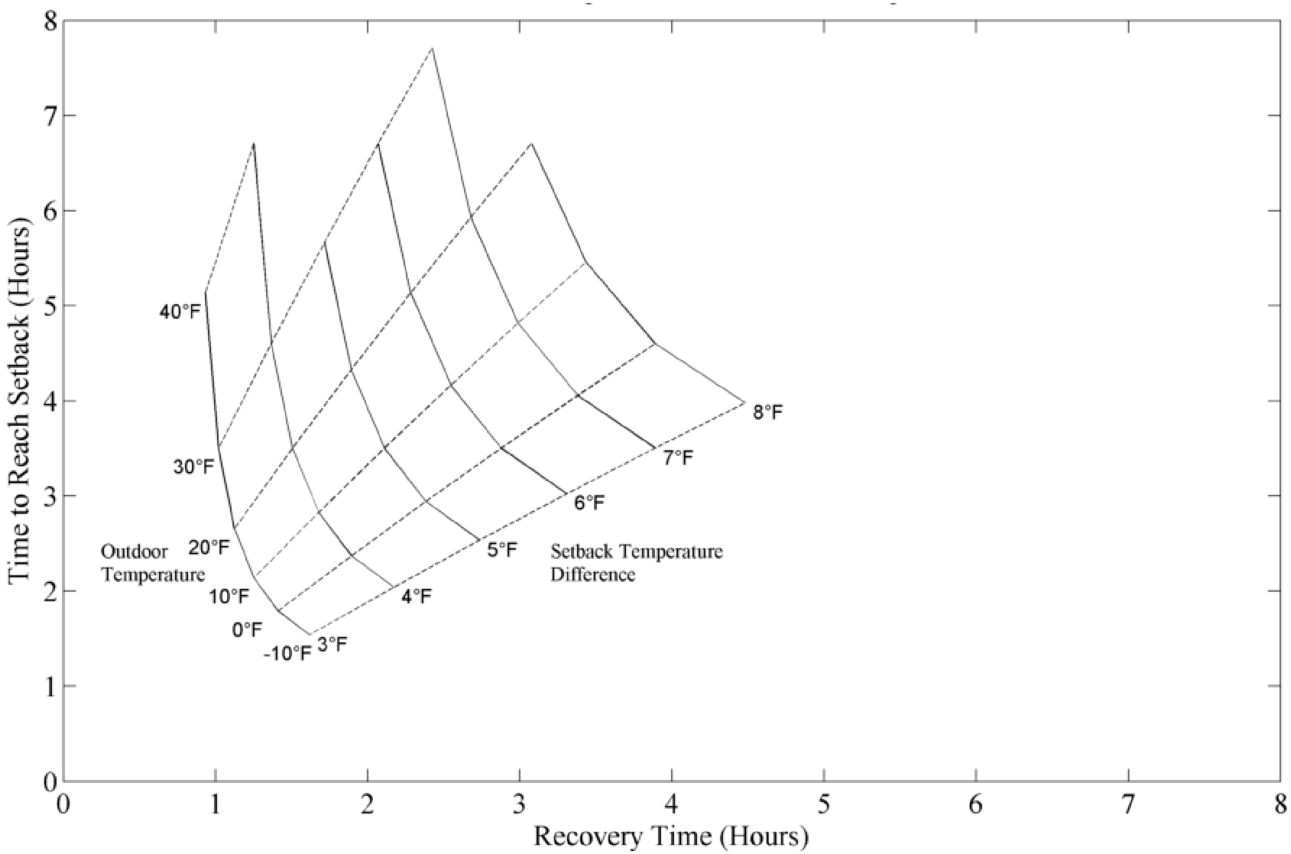
Why Look at This?

- MJ8 states not applicable for:
  - "solar homes that have passive features"
- What are passive features?
  - Homes built to the PH standard usually incorporate sun tempering
  - PHs aren't typically built with excessive mass in the form of concrete, the amount of insulation in the structure can lead to a mass affect
- So . . . Is MJ8 appropriate for super insulated buildings with sun tempering strategies?

Why Look at This?

- Previous studies on boilers indicate extremely slow recovery from setback
  - 2009 code levels
  - 2 ACH@50
  - 15,000 kBtuh design loads

Recovery from Setback



2009 Code Built Home, Ithaca, NY

Why Look at This?

- Experience w/ Passive House presents different sizing methods

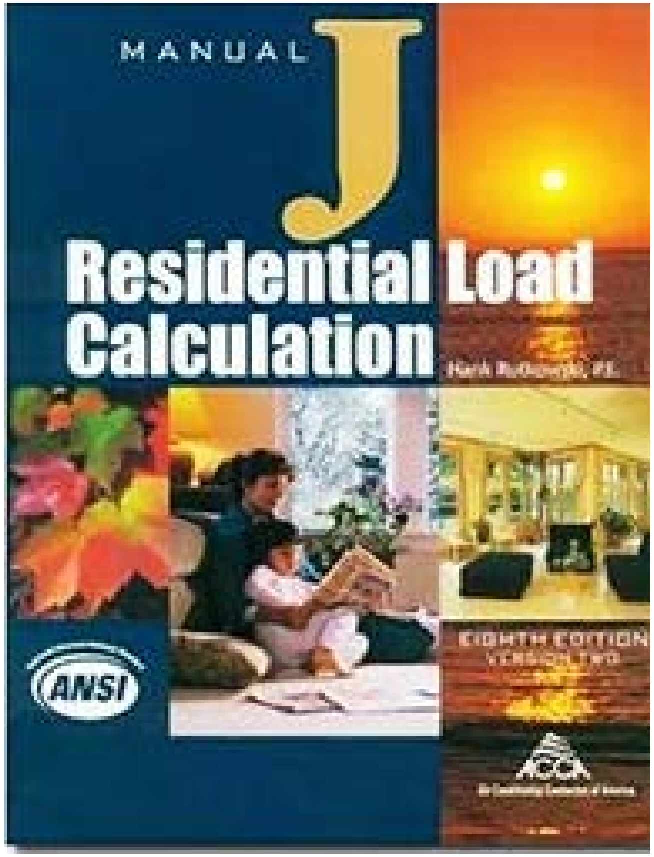
Research Questions

- How do the design loads calculated using MJ8 and PH methods compare to the measured peak building loads?
- If the modeled loads are significantly different from the actual loads, can the differences be explained?
- What recommendations can be made about heating equipment sizing for super insulated buildings?

SIZING FOR LOW LOAD HOMES
MJ8 VS PHPP

Manual J v.8

- Primary method used in the U.S. to calculate residential design heating and cooling loads
- The estimated heating load is calculated as an instantaneous load that is the sum of all building envelope and equipment loads.



Manual J v.8

- MJ8 envelope loads include foundation, walls, ceiling/roof, and fenestration heat loss.
- HVAC equipment loads include duct losses and ventilation loads.
- Recommended sizing protocols,
  - 1% winter design temperature (0 F in Ithaca, NY)
  - indoor temperature of 70 F.
  - WrightSoft® Version 12.0 was used to implement the MJ8 calculations.
  - Design loads were calculated for each room and the electric baseboards were sized accordingly

PHPP

- Includes:
  - thermal inertia
  - solar gains
  - internal gains from occupants and equipment

- 2 outdoor design temperatures: daily averages and represent the maximum heating load days
  - a cold but sunny winter day with a cloudless sky – 14.6 F
  - a moderate cold but overcast day with minimal solar radiation 15.2 F
- Interior design temperature is 68 F.
- Resulting temperature differences between the interior and exterior:
  - 53 F for PHPP load calculations
  - 70 F using MJ8.

MJ8 vs PHPP Inputs

Parameters	Manual J8	Passive House	
		Weather Condition 1	Weather Condition 2
Outside Design Temperature	0ºF	14.6°F	15.2°F
Indoor Design Temperature	70ºF	68°F	68°F
Interior Relative Humidity	40 %	55 %	55 %
Mean Earth Temperature	50°F	42°F	42°F
Conditioned Area [ft^2]	1,664	1,267	1,267
Conditioned Volume [ft^3]	13,312	10,389	10,389

MJ8 vs PHPP Inputs

- Exterior surface areas
  - For PH, the wall height is measured from the top of the roof insulation at the wall's edge to the bottom of the slab
- Conditioned volume
  - only the interior floor area is used in PHPP and any interior walls are eliminated.
- Internal and solar gains are deducted from the total design load in the PHPP.

Modeling Results

Building Heating Loads	Heating Load Values (Btuh)			
	Manual J8	Manual J8 w/ PH Parameters	Passive House	
			Weather Condition 1	Weather Condition 2
Walls	2,196	1,663	2,122	2,100
Glazing	2,750	2,082	2,139	2,117
Doors	412	312	299	296
Floors	1,259	953	723	723
Ceiling	641	485	474	469
Infiltration	1,641	991	977	976
Ventilation	188	188	183	181
Subtotal	**9,059**	**6,674**	**6,917**	**6,861**
Solar Heat Gain	0	0	-1,627	-867
Internal Gain	0	0	-643	-643
Total	**9,059**	**6,674**	**4,647**	**5,352**

Differences in Modeling Results

- Manual J
  - MJ8 multiplies a thermal resistance factor, F-value, by the perimeter of the slab
  - F-value for TREE was 0.155 Btu/ft· F·hr. Similar soil conductivities were used in both sizing calculations.
- PHPP
  - multiply overall heat transfer coefficient (U-value) through the body of the slab by the surface area
  - perimeter losses accounted for by calculating the thermal bridge (psi value) @ slab/wall intersection x the perimeter length of the slab edge.
  - this value is then added to the heat loss calculated through the floor of the slab

Oversized Baseboard

MONITORING SETUP

Measured Loads

- 3 Homes in Ithaca, NY: Climate Zone 6
  - Two of the three homes were occupied
  - Monitoring period was November 2013 to end of Feb 2014
- Current transformers (CTs) were installed on circuit breakers inside electrical panel, downloaded over internet
- One minute data was collected for the following:
  - Interior temperature [F]
  - Exterior temperature [F]
  - Total power at the main lines into the panel [W]
  - Electric resistance baseboard heaters [W]
  - Refrigerator [W]
  - DHW [W]
  - ERV [W]

Measured Loads

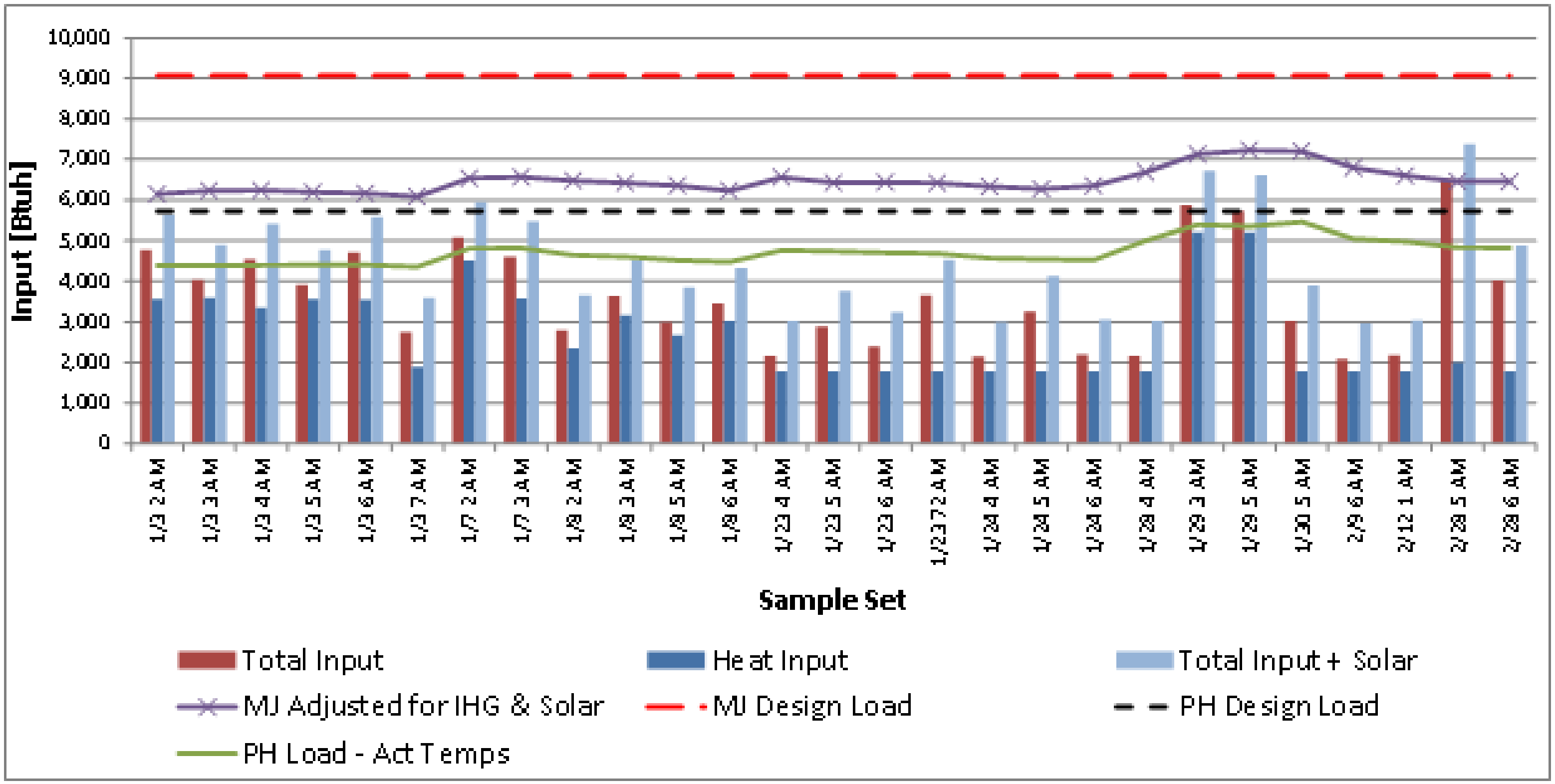
- Stove, dishwasher and washing machine not used during periods evaluated.
- Miscellaneous plug load energy use was calculated by subtracting the appliance and heating energy use from the total energy use at the mains.
- Actual peak heating loads were calculated using temperature data collected on site and the overall building UA's for each home.

Measured Loads

- Hourly blocks of data evaluated when:
  - Outdoor temperatures fell between -1 F and 1 F, (0 F was the outdoor design temperature used in MJ8), and
  - Hours fell between 12:00am and 6:00am to eliminate any effects of solar heat gains.
- For these blocks of data hourly values were calculated:
  - Total electricity use
  - Heating energy use
  - Appliance energy use
  - Miscellaneous plug loads

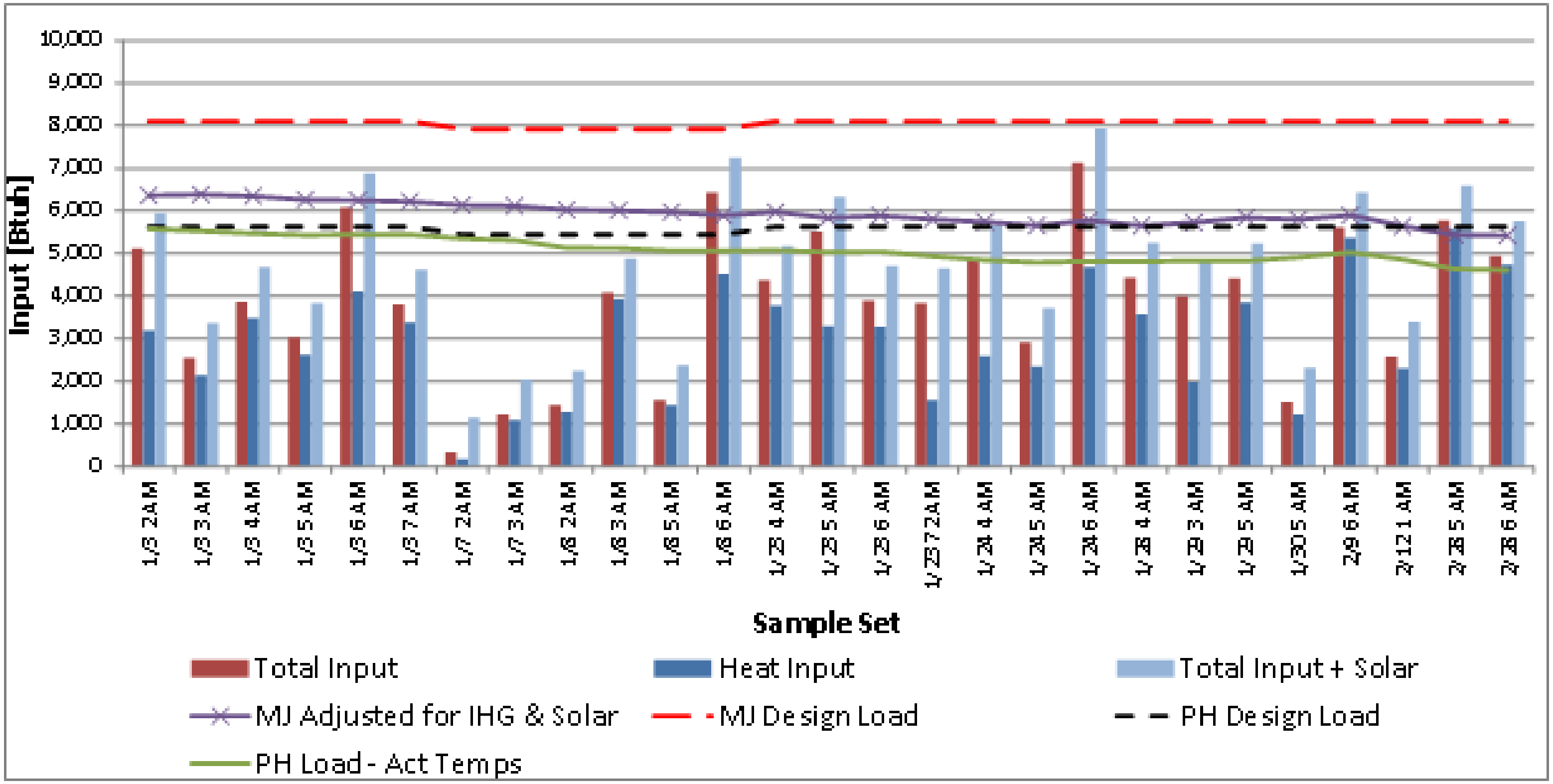
MONITORING RESULTS

House #1



10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Input [Btuh]
1/3 2 AM
1/3 3 AM
1/3 4 AM
1/3 5 AM
1/3 6 AM
1/3 7 AM
1/7 2 AM
1/7 3 AM
1/8 2 AM
1/8 3 AM
1/8 5 AM
1/8 6 AM
1/23 4 AM
1/23 5 AM
1/23 6 AM
1/23 7 2 AM
1/24 4 AM
1/24 5 AM
1/24 6 AM
1/28 4 AM
1/29 3 AM
1/29 5 AM
1/30 5 AM
2/9 6 AM
2/12 1 AM
2/28 5 AM
2/28 6 AM
Sample Set
Total Input
Heat Input
Total Input + Solar
MJ Adjusted for IHG & Solar
MJ Design Load
PH Design Load
PH Load - Act Temps

House #2



10,000
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Input [Btuh]
1/3 2 AM
1/3 3 AM
1/3 4 AM
1/3 5 AM
1/3 6 AM
1/3 7 AM
1/7 2 AM
1/7 3 AM
1/8 2 AM
1/8 3 AM
1/8 5 AM
1/8 6 AM
Sample Set
Total Input
Heat Input
Total Input + Solar
MJ Adjusted for IHG & Solar
MJ Design Load
PH Design Load
PH Load - Act Temps

Results Summary

	Measured Indoor T	Total Input	Heat Input	MJ Design Load	PH Design Load	MJ Load - Actual Temps	MJ Adjusted for IHG & Solar	PH Load - Actual Temps
	°F	Btuh	Btuh	Btuh	Btuh	Btuh	Btuh	Btuh
House #1	61	3,613	2,690	9,059	5,726	7,994	6,484	4,729
House #2	64	3,898	3,017	8,067	5,587	7,385	5,926	5,076
House #3	67	5,186	5,120	7,795	4,874	7,331	6,291	4,743

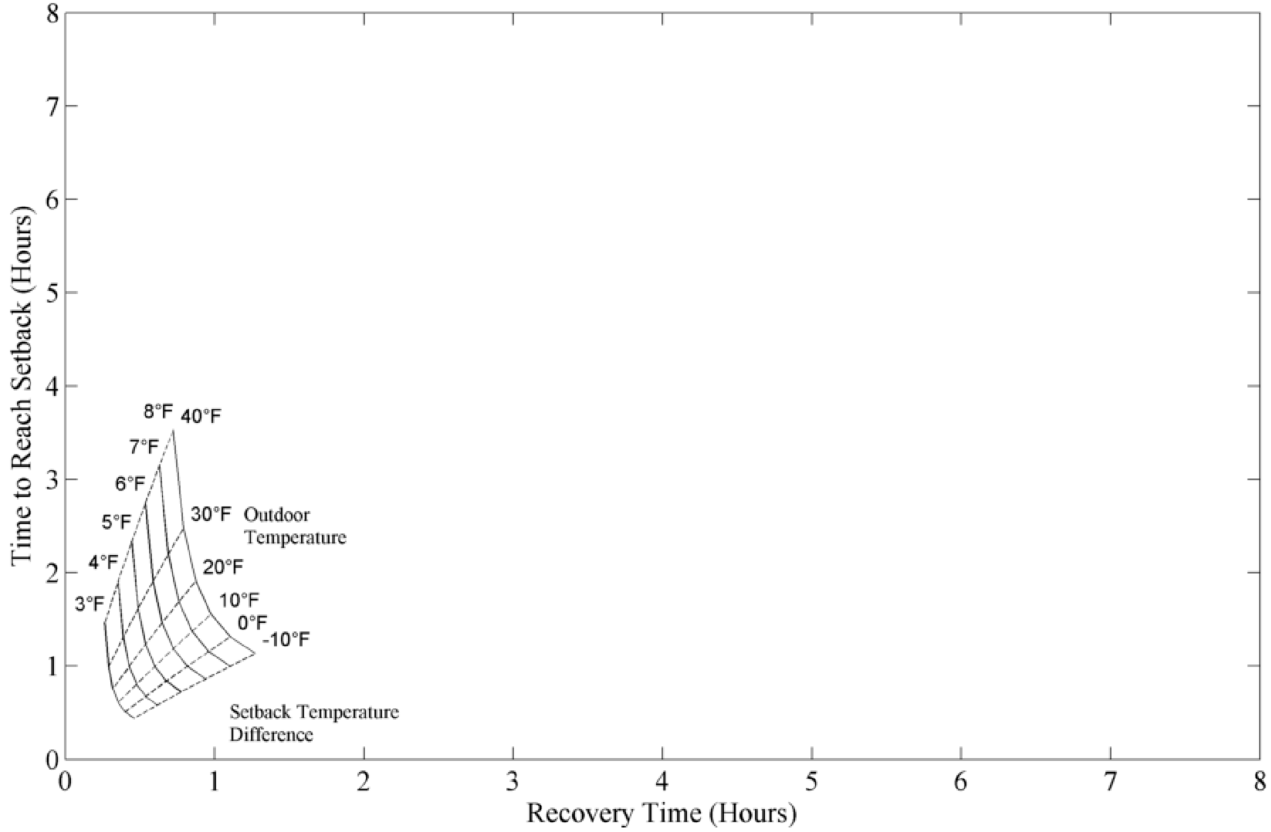
House #3: unoccupied, no appliances

Comparison to Total Input

	Total Input	Heat Input	MJ Design Load	PH Design Load	MJ Load - Actual Temps	MJ Adjusted for IHG & Solar	PH Load - Actual Temps
House #1	--	-34%	61%	37%	55%	44%	24%
House #2	--	-29%	52%	30%	47%	34%	23%
House #3	--	-1%	33%	-6%	29%	18%	-9%

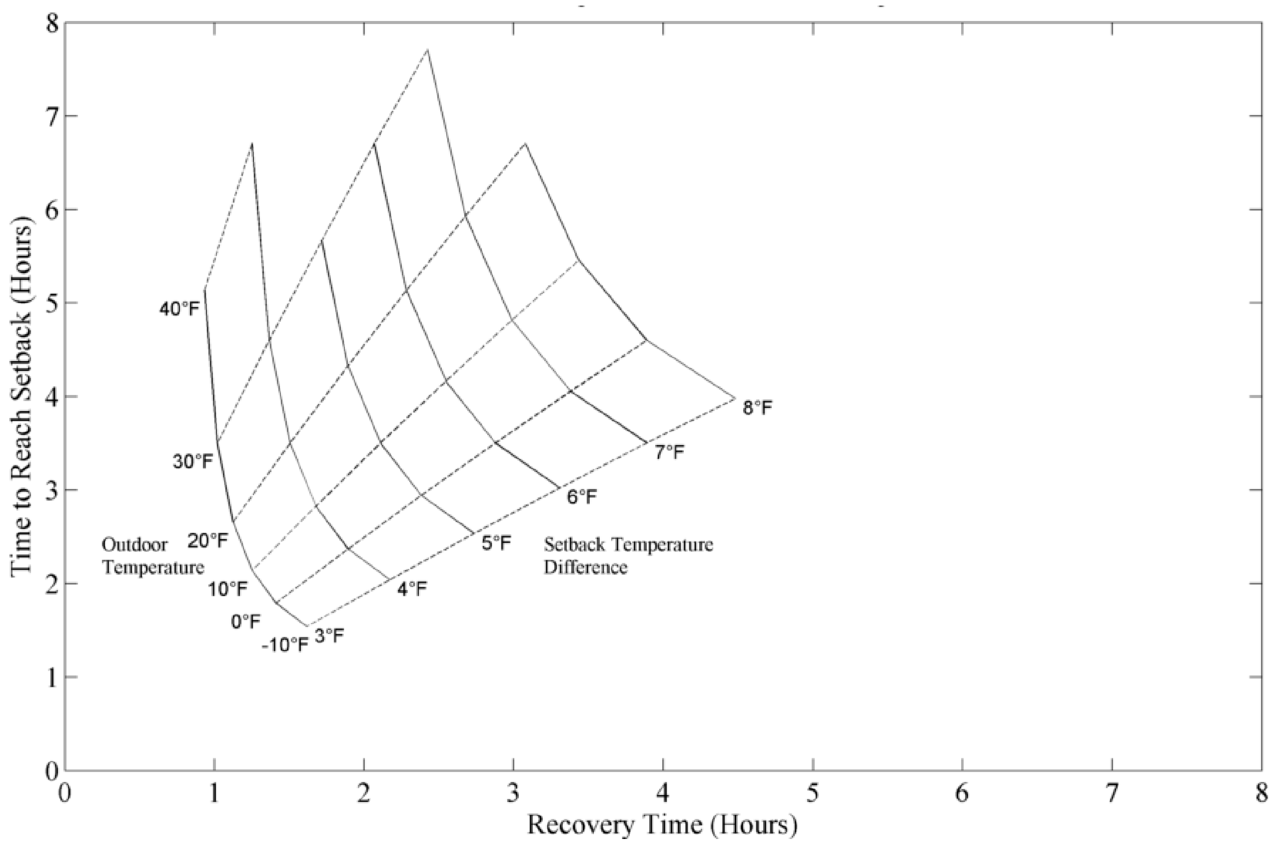
DO WE REALLY WANT TO SIZE TO THE LOAD?

Recovery Response



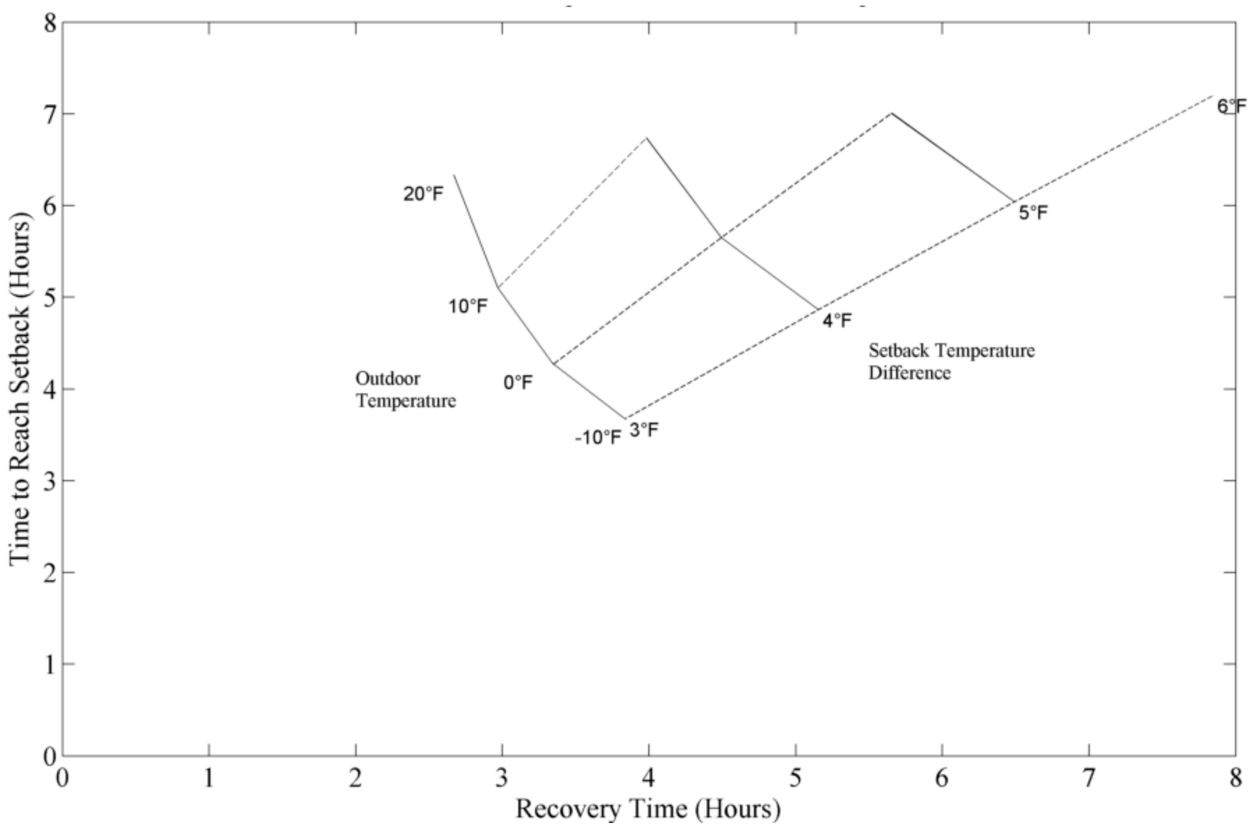
Uninsulated, old home , Ithaca, NY. HVAC oversized 100%

Recovery Response



2009 code home , Ithaca, NY. HVAC oversized 100%

Recovery Response



Super insulated home, Ithaca, NY. HVAC oversized 100%

Recovery Response

Efficiency Level	Heat Capacity	Design Load	Boiler Size	Recovery Time
	[Btu/°F]	[Btu/h]	[Btu/h]	[hours]
Super Insulated	10685	8,540	17,080	6.9
2009 IECC	8131	15,441	30,882	3.4
Old, uninsulated	6600	44,030	88,060	1.0

Analysis performed for Ithaca, NY, Climate Zone 6, 8 F setback, 1200 ft^2

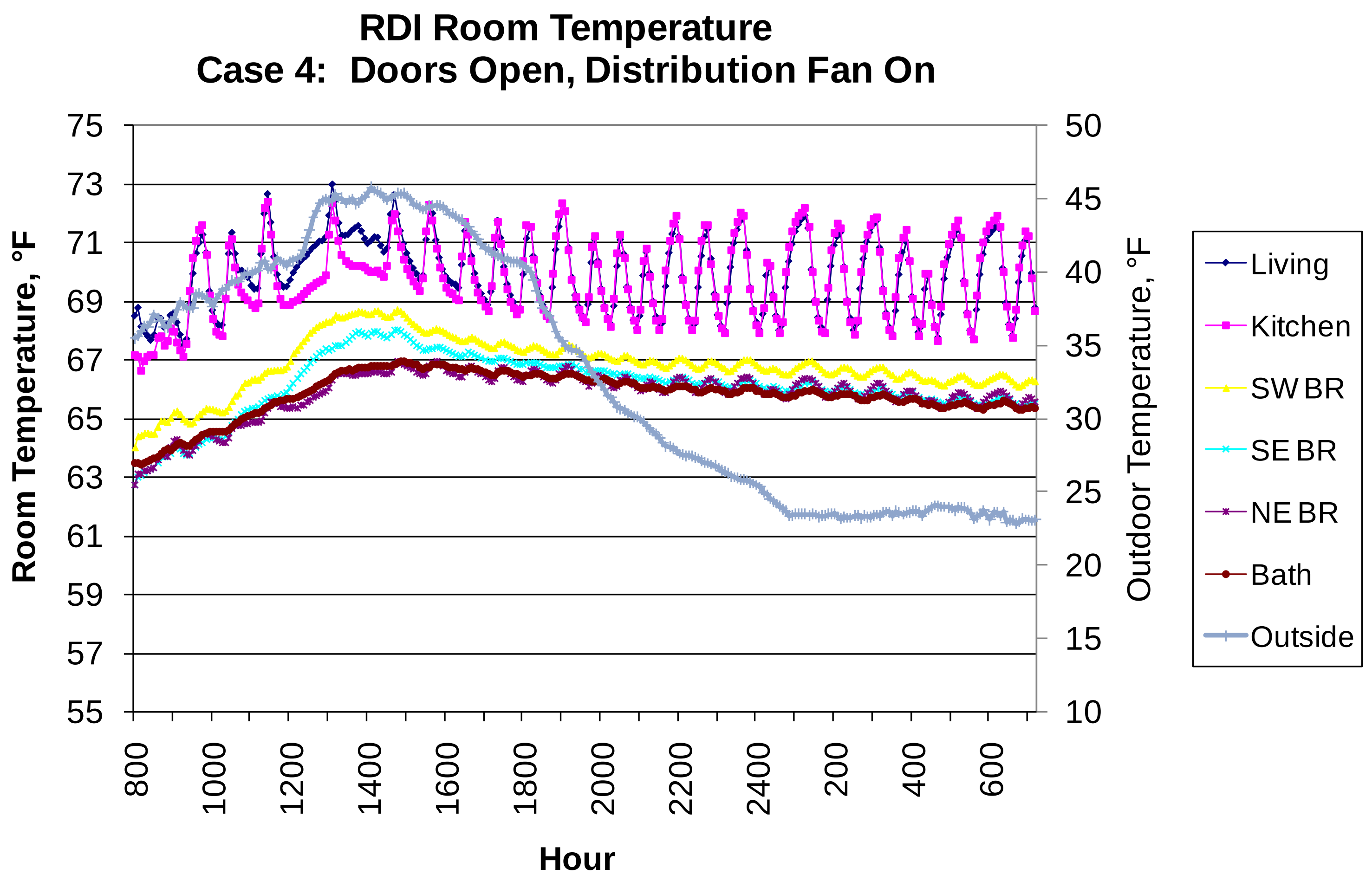
Design Considerations

- Is thermostat setback desired?
  - Is setback is appropriate for home?
  - Will it result in energy savings for the heating system being used?
  - What are the effects of cycling on equipment life and performance?
  - What are the additional equipment costs to provide this function?
  - Should not be used w/ high mass heating systems – radiant flooring, radiators, etc.

Possible Solutions

- Minimum temperature maintained by small, central, efficient system with point source heaters where desired
- Closing off sections of the home to allow some cooler and some warmer areas
- Install all the capacity on the lower level, and allow to "float" up – cooler beds, warmer living spaces
- Audience?

Point Source Solution



Questions?

Thank you.

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