



**REHAU MONTANA ECOSMART HOUSE PROJECT
Bozeman, MT
RMEH 08 Test Report**

**Comparison of Heating Energy Usage of
Radiant vs. Forced Air Configurations**

F.



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Executive Summary

An experiment was carried out at the REHAU Montana Ecosmart House in Bozeman to compare the energy usage to heat the house with radiant floor versus forced air using boiler as heat source. Collected data showed that the radiant configuration used 12.4% less energy than the forced air system. To account for whether variations across test scenarios, energy usage was normalized by using the Heating Degree-Day concept.

Experiment Description

The purpose of this experiment was to compare energy usage to heat the house comfortably in radiant heating scenario versus forced air scenario using boiler as heat source. For that, two test scenarios were run: one in radiant floor configuration at 68°F thermostat setpoint, and the other in forced air configuration at 72°F thermostat setpoint. Each scenario was run steady state for a period of 3 days and energy consumption was measured via gas meter readings. See Appendix B. Experiment Notes for dates of the experiments. The boiler has 154 MBTU heating capacity using natural gas. A reset schedule was used to control the water supply temperature to the radiant loops with the aid of a mixing valve. For the forced air scenario, the water supply to the air coil of the air handling unit (AHU) was fed directly from the buffer tank, which had a temperature setpoint equivalent to the same reset schedule used before plus 10°F, with a 8°F dead band. Heating Degree Days (HDD) were calculated for each time period in order to normalize and compare energy usage under different weather conditions. More details about the different configurations can be found in Appendix D. Experiment Setup.

Results

Energy usage during the radiant floor scenario was 17.7 standard cubic feet (SCF) per HDD whereas for the forced air scenario, the energy usage was 20.2 SCF/HDD. That is 12.4% less energy used by the radiant configuration. Table 1 show an overview of the results.

Table 1. Gas consumption in SCF per HDD during each test scenario

Test Scenario	Avg. Outdoor Air (°F)	°F-HDD 3-day period	Room Setpoint (°F)	Average Zone Temp. (°F)	Net Gas Usage (SCF)	Gas per HDD (SCF/HDD)	Energy Use Difference (%)
Radiant	36.2	75	68	69.2	1327	17.7	- 12.4
Forced Air	37.6	72	72	70.5	1457	20.2	

Another interesting observation derived from this experiment was the fact that the average room temperature achieved by the radiant floor configuration was 1.2°F above the thermostat setpoint. On the other hand, the average room temperature achieved with the forced air configuration was 1.5°F below the setpoint. It appears that the radiant method is capable of maintaining the setpoint more successfully than the forced air one. This might be a consequence of the radiant floors taking advantage of the high thermal mass of the house. This, in addition to the warm floors increasing the effective temperature as perceived by the occupants almost virtually makes up for a 4°F difference in thermostat temperature. Figure 1 and Figure 2 illustrate this fact.

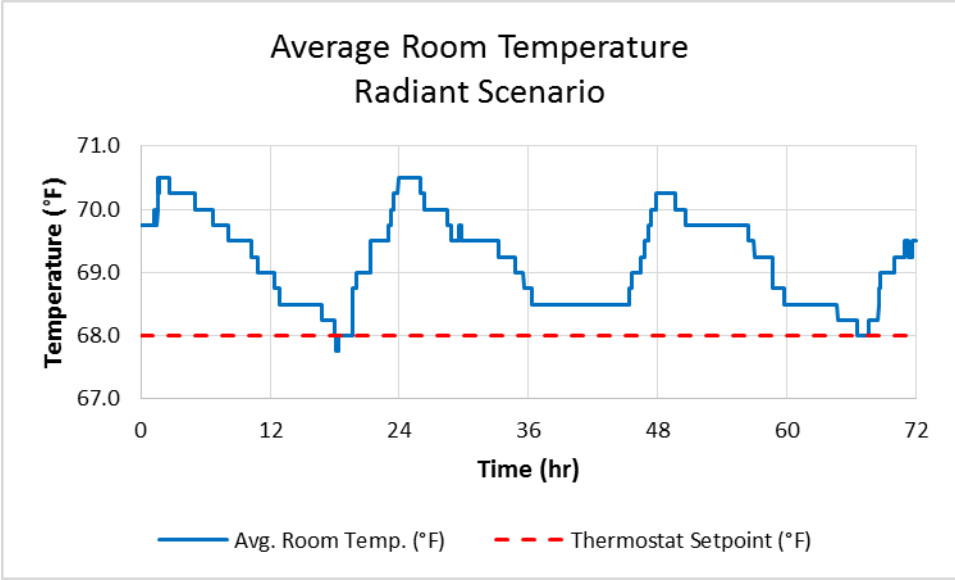


Figure 1. Average Temperature in the Main Zones of the House during the Radiant Test Scenario

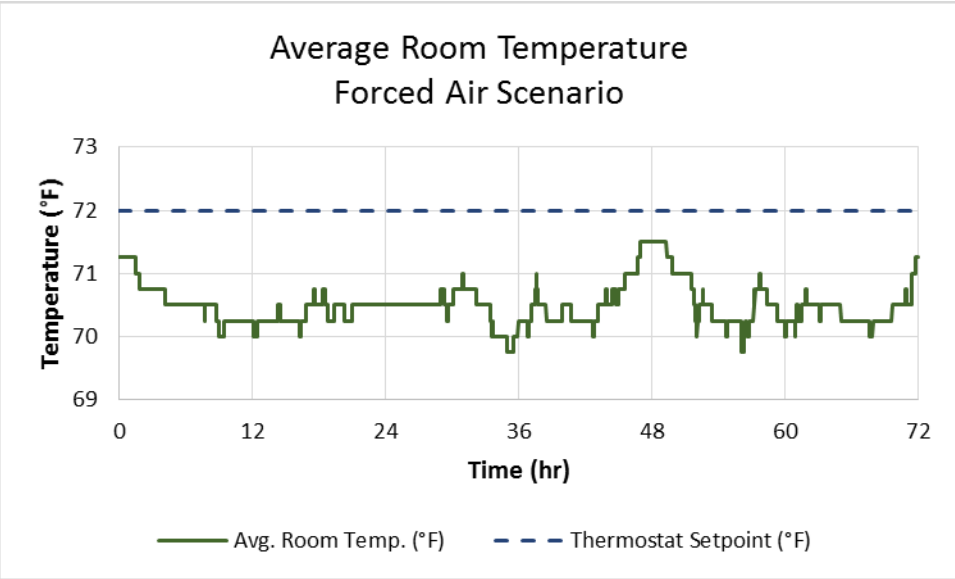


Figure 2. Average Temperature in the Main Zones of the House during the Forced Air Test Scenario

Calculations

***Original data sets will be provided upon request.

Heating Degree-Days

Heating Degree Days were calculated using the following equation [1]:

$$HDD = T_{base} - T_{ave}$$

Where

T_{base} = Selected base temperature, in this case 65°F

T_{ave} = Daily average temperature (°F), the arithmetic mean between the high and low temperature for a 24-hour period

HDD was computed daily and summed for each 3-day test period.

Sample Calculation

Table 2. Sample Calculation of HDD ($T_{base} = 65^\circ\text{F}$)

Date		RSC Outdoor Temperature (°F)	Observations
1/19/2015 14:13:00		40.55	This section is a sample of the outside air sensor values acquired by RSC
1/19/2015 14:13:30		40.44	
1/19/2015 14:14:00		40.48	
1/19/2015 14:14:30		40.64	
1/19/2015 14:15:00		40.47	
1/19/2015 14:15:30		40.60	
1/19/2015 14:16:00		40.52	
1/19/2015 14:16:30		40.47	
1/19/2015 14:17:00		40.49	
Day 1	T_{min}	21.70	Minimum Temperature Day 1
	T_{max}	45.41	Maximum Temperature Day 1
	HDD	31.44	HDD Day 1
Day 2	T_{min}	29.96	Minimum Temperature Day 2
	T_{max}	56.62	Maximum Temperature Day 2
	HDD	21.71	HDD Day 2
Day 3	T_{min}	29.99	Minimum Temperature Day 3
	T_{max}	55.37	Maximum Temperature Day 3
	HDD	22.32	HDD Day 3
3-Day Total HDD		75.47 (≈ 75)	Cumulative HDD Days 1-3

Appendix A. Test Schedule Sheet

System Performance
Data Collection

REHAU ECOSMART HOUSE
Bozeman, MT

lee2289

Test Number:	RMEH 08-001	
Description:	Compare energy usage to heat house comfortably in radiant heating scenario versus forced air scenario using boiler as heat source	
Objectives:	<ol style="list-style-type: none"> 1 Run house at 68F steady state with RFH 2 Run house at 72F steady state with forced air 3 Measure energy consumption for each scenario 4 5 	
Data Collection Parameters:	Description	Source
	1 OA Temp	RSC
	2 Zone Set Point Temp	RSC
	3 Zone Actual Temp	RSC
	4 Slab Sensor Temp	RSC
	5 Slab Set Point Temp	RSC
	6 HDD	MSU
	7 Boiler Gas Usage	MSU
	8 Buffer Tank Temp	RSC
	9 Boiler HWS Temp	RSC
	10 RFH HWS Temp	RSC
	11 RFH HWR Temp	RSC
	12	
	13	
	14	
	15	
	16	
	17	
	18	
Test Duration:	Length	3 day for each scenario
	Start Date	_____
	End Date	_____
Deliverables:	<ol style="list-style-type: none"> 1 Measure RFH energy usage 2 Measure forced air energy usage 3 4 5 	
Notes:		
MSU Notes:	test concurrently with RMEH-005 air stratification test	

Appendix B. Experiment Notes

Data for experiment RMEH 08 was collected during the following dates:

- Radiant Portion: 16-Jan-15 – 19-Jan-15
- Forced Air Portion: 02-Feb-15 – 05-Feb-15

Appendix C. Data Collection Parameters

REHAU Smart Controls (RSC), National Instruments (NI), Micro Control Systems (MCS) and eGauge data acquisition (DAQ) systems were used to collect data for this experiment. The most important data points collected were the following (the rest provided redundancy and/or additional information):

RSC Data Points

- Outdoor Air Temperature
- Zone Setpoint Temperature
- Zone Actual Temperature
- Slab Sensor Temperature
- Buffer Tank Temperature
- Boiler HWS Temperature
- RFH HWS Temperature
- RFH HWR Temperature

NI Data Points

- Boiler Gas Consumption

Appendix D. Experiment Setup

The REHAU Montana Ecosmart House has a hydronic radiant system based on 3/8" Crossed-linked Polyethylene (PEXa) pipe in different floor configurations (Figure 3). Water flow is controlled by valves with on/off actuators managed by the Rehau Smart Controls (RSC). Loops are centralized in a few panels and temperature is controlled is in a room by room basis (Figure 4).



Figure 3. Example of Radiant Floor Installation on Main Level

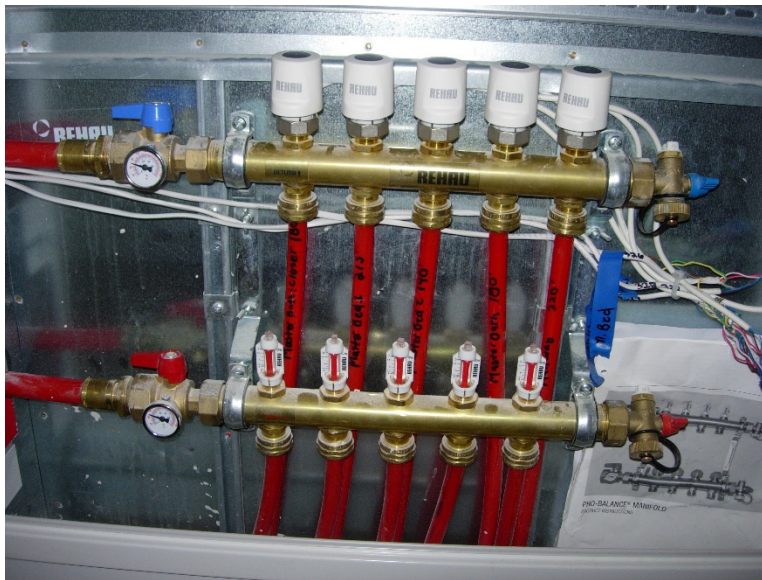


Figure 4. Radiant Floor Panel with Supply and Return Manifolds

The Ecosmart House has also a forced air system driven by a centralized Air Handling Unit (AHU) located in the mechanical room (Figure 5). Air is provided to four different zones in the house and controlled by individual dampers located at the head of each main branch of duct work. These dampers are controlled by the zone thermostats via RSC. Supply and return registers are located in different positions across the house (floor, wall or ceiling) (Figure 6).



Figure 5. Air Handling Unit with Forced Air and Integrated Geothermal Heat Pump



Figure 6. Floor Register and Return Grille

Appendix E. Additional Figures

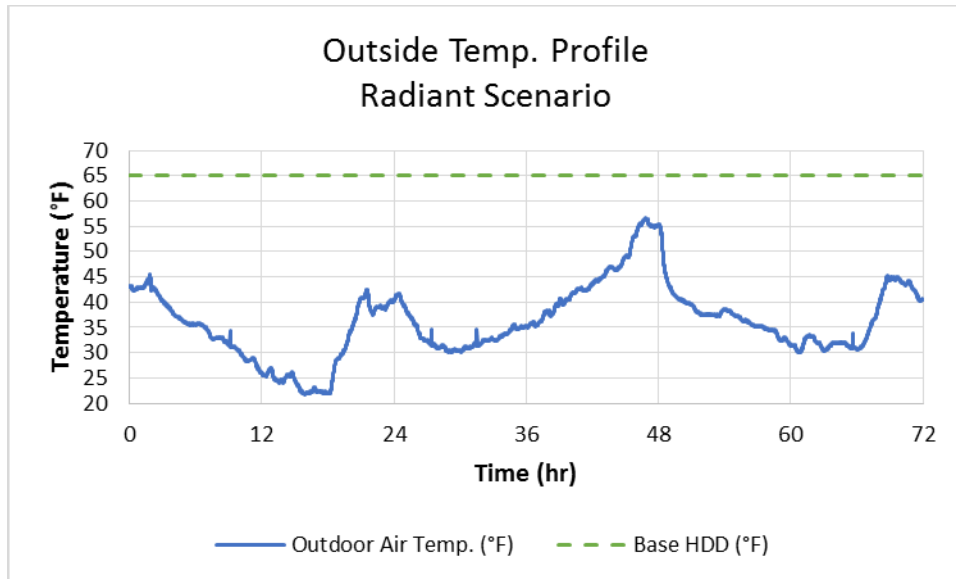


Figure 7. Outdoor Air Temperature Profile during the Radiant Test Scenario

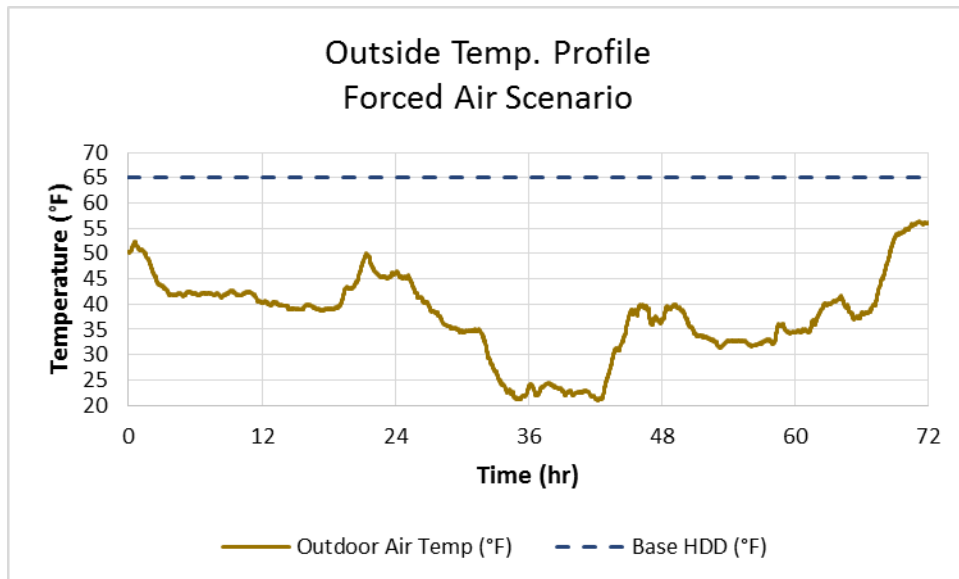


Figure 8. Outdoor Air Temperature Profile during the Forced Air Test Scenario

Appendix F. References

1. *2009 ASHRAE Handbook. Fundamentals.* (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2009), Chapter 14, p. 6-7.