NATIONAL RENEWABLE ENERGY LABORATORY

Variability in Measured Space Temperatures in 60 Homes

David Roberts
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Technical Report
NREL/TP-5500-58059
March 2013

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Nomenclature

A/C	Air conditioning
ach50	Air changes per hour at 50 Pascals of pressure differential
AFUE	Annual fuel utilization efficiency
AHU	Air handling unit
CFM50	Cubic feet per minute at 50 Pascals of pressure differential
HERS	Home Energy Rating System
HEST	Home Energy Scoring Tool
HSP	House Simulation Protocols
HSPF	Heating season performance factor
HVAC	Heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
RESNET	Residential Energy Services Network
SEER	Seasonal energy efficiency ratio
SHGC	Solar heat gain coefficient

Executive Summary

This report discusses the measured variability in indoor space temperatures in a set of 60 homes located in Florida, New York, Oregon, and Washington. Temperature data were collected at 15-minute intervals for an entire year, including living room, master bedroom, and outdoor air temperature (Arena et al. 2010). The data were examined to establish the average living room temperatures for the heating and cooling seasons, the variability of living room temperatures depending on climate, and the variability of indoor space temperatures.

The accuracy of software-based energy analysis depends on the accuracy of input values. Thermostat set point is one of the most influential inputs for building energy simulation. Several industry standards recommend differing default thermostat settings for heating and cooling seasons. These standards were compared to the values calculated for this analysis (see Table ES-1 and Table ES-2). The data examined for this report show a definite difference between the climates and that the data do not agree well with any particular standard. Table ES-3 shows the average indoor temperature differences between the living room and master bedroom for these homes.

Table ES-1. Summary of Set Point Assumptions Specified in Standards

Standard	Cooling Set Point (°F)	Cooling Setup (°F) 8:00 a.m. – 5:00 p.m.	Standard	Heating Set Point (°F)	Heating Setback (°F) 8:00 a.m. – 5:00 p.m.
HSP[1]	76	–	**HSP**	71	–
IECC[2]	75	–	**IECC**	72	–
RESNET/HERS[3]	78	–	**RESNET/HERS**	68	–
HEST[4]	78	84	**HEST**	68	60

Table ES-2. Summary of Living Room Temperatures

Dataset	Cooling (°F)	Dataset	Heating (°F)
Florida	78.5	**New York**	65.0
New York	74.0	**Oregon/Washington**	63.9
Combined Florida and New York	76.8	**Combined New York and Oregon/Washington**	64.5

[1] Hendron and Engebrecht (2010)

[2] ICC (2009)

[3] RESNET (2006)

[4] Bourassa (2012), https://sites.google.com/a/lbl.gov/hes-public/home-energy-scoring-tool

Table ES-3. Summary of Indoor Temperature Differences (Living Room – Master Bedroom)

Cooling Season			Heating Season		
Dataset	**Mean Indoor ΔT (°F)**	**Standard Deviation (°F)**	**Dataset**	**Mean Indoor ΔT (°F)**	**Standard Deviation (°F)**
Florida	0.8	1.8	**New York**	–0.3	4.9
New York	–1.0	2.2	**Oregon/Washington**	0.8	3.9
Combined Florida and New York	0.1	2.2	**Combined New York and Oregon/Washington**	0.2	4.9

This dataset is not sufficient to provide a statistical validation for establishing standard set points, but it does contribute to the body of research characterizing set point values and provides valuable lessons that can be used for future experiments that support standards development.

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1 Introduction

The accuracy of whole-house building simulations often depends on the accuracy of the input values and how well they reflect "actual values." Whether an input is a defaulted value or measured, discrepancies between the actual value and input value can occur and propagate throughout the simulation, creating errors in the output (Polly et al. 2011). Among the most influential inputs for software-based energy analysis are the thermostat set points and associated indoor air temperatures that drive heat loss calculations. Standards such as the Building America House Simulation Protocols (HSP) (Hendron and Engebrecht 2010), International Energy Conservation Code (IECC) (ICC 2009), and Home Energy Rating System (HERS) Standards (RESNET 2006) require differing default thermostat settings. Similarly, the Home Energy Scoring Tool (HEST), an asset rating tool that assumes typical occupancy, uses default thermostat temperatures that the software user cannot change. Discrepancies can largely be attributed to inadequate data in this area. Table 1 lists the thermostat settings for each standard.

Table 1. Assumed Thermostat Set Points for Heating and Cooling Seasons

Standard	Cooling Set Point (°F)	Cooling Setup (°F) 8:00 a.m. – 5:00 p.m.	Heating Set Point (°F)	Heating Setback (°F) 8:00 a.m. – 5:00 p.m.
HSP	76	–	71	–
IECC	75	–	72	–
RESNET/HERS	78	–	68	–
HEST	78	84	68	60

This report examines temperature data that were collected for an entire year in a set of 60 homes in three climates. The analysis sought to determine the average living room temperatures for the heating and cooling seasons, whether the average values vary with climate, and the variability of indoor air temperatures throughout these homes. This dataset is not sufficient to provide statistical validation of a particular standard or default assumption, but it does contribute to the body of research characterizing home indoor air temperatures, and provides valuable information for developing future experiments that could help develop standards.

2 Background and Context

This section provides insight into the motivation and objectives for analyzing the dataset and some background on its origin.

2.1 Motivation

Differences in industry standards for heating and cooling season thermostat set point assumptions exist in part because of the lack of data and research, and the high variability in occupant behaviors and indoor temperatures. Collecting data and researching thermostat set points and indoor temperatures provide valuable information that leads to better standards and improved accuracy in software-based building energy simulations.

2.2 Objective

The initial vision of this research project was to analyze the building characteristics and temperature data gathered for this dataset and determine if there was a relationship between the overall building shell U-value and the temperature variations inside the homes. No clear relationship was found and the focus shifted toward answering the following research questions:

- What are the average "set point"[5] temperatures for heating and cooling seasons?
- Do average "set points" vary with climate?
- What is the variability of indoor air temperature within a home?

Recommendations for improving future data collection efforts were also sought to provide adequate data to support standards development and increase modeling accuracy.

2.3 Data Background

This dataset originates from a study that was conducted to assess the impacts of moisture on the thermal performance and durability of homes (Arena et al. 2010). Three U.S. regions were targeted for the study: hot, humid southeast (Florida), cold northeast (New York), and the marine Pacific Northwest (Oregon and Washington). Twenty homes in each climate were outfitted with five Onset HOBO U12 data loggers that recorded temperature and relative humidity at 15-minute intervals for an entire year during 2008 and 2009. The data loggers were installed at each house in the primary living space (living room), master bedroom, primary bathroom, attic, and basement or crawlspace, depending on the house construction and the outdoors. The HOBO U12 has a reported accuracy of ±0.63°F from 32° to 122°F.

Short-term testing and data collection were also performed to understand additional house characteristics. House data that were collected included year built; size; occupancy levels; enclosure construction; heating, ventilation, and air conditioning (HVAC) description; and enclosure and duct leakage. Table 2 shows the average building characteristics for each region, and Appendix A lists all the data that were collected for each house.

---

[5] Set point is in quotes here because the actual thermostat set points are unknown. For purposes of this analysis the living room temperature sensor is assumed to best represent the set point temperature.

Table 2. Average House Characteristics for Each Climate

Component	Florida	New York	Oregon/Washington
n	20	20	20
Year Built	1998	1966	1947
Size (ft^2)	1989	3118	2059
Air Leakage (ach50)	6.0	6.1	11.1
Dominant Heating Type	Air-source heat pump	Furnace	Furnace
Attic R-Value ($ft^2 \cdot °F \cdot h/Btu$)	22	36	24
Wall R-Value ($ft^2 \cdot °F \cdot h/Btu$)	12	12	7
Dominant Foundation Type	Slab	Partially finished basement	Basement/crawlspace

3 Cooling Season Living Room Temperature Analysis

This section discusses the cooling season living room temperature data analysis in detail. The living room temperature sensor is assumed to best represent the thermostat set point; however, actual set points and exact locations of the data loggers in the rooms are unknown. The 15-minute data were averaged to obtain hourly data. The cooling season analysis was performed for Florida and New York homes only, because most homes in the Oregon/Washington dataset do not have central cooling.

The cooling season is defined for purposes of this analysis as May–September for the Florida homes, and June–August for the New York homes.

3.1 Florida

This section describes the living room temperature distribution, hourly temperature profiles, and average temperatures for the Florida homes during the cooling season.

3.1.1 Living Room Temperature Distribution

Figure 1 shows the living room temperature distribution for all hours and all Florida homes during the cooling season. The average living room temperature is 78.5°F with a standard deviation of 3.2°F.

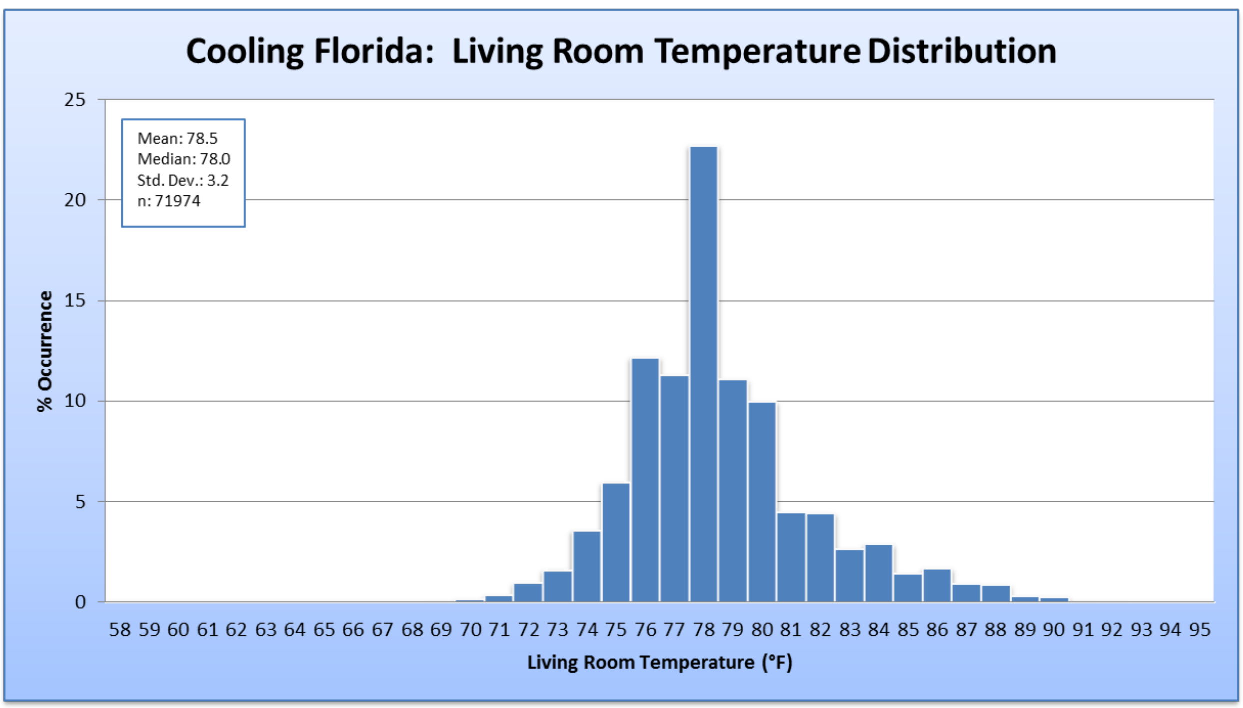


Figure 1. Florida living room temperature distribution

3.1.2 Average Hourly Living Room Temperature Profiles

Figure 2 shows the average hourly temperature profile for each Florida house during the cooling season. The value at each hour is the average of the four 15-minute logger readings following the top of the hour indicated. For example, the value at 7 might be the average of readings taken at 7:05, 7:20, 7:35, and 7:50. The 0 hour is midnight. Most Florida homes control the temperature to a fixed set point, except homes 1 and 18, which appear to have a setup in the morning, and homes 3, 7, 11, 13, and 20 which appear to rarely use their air conditioning (A/C). House 6 does not have central cooling, central ventilation, or room A/C units, but stays relatively cool compared to other Florida homes.

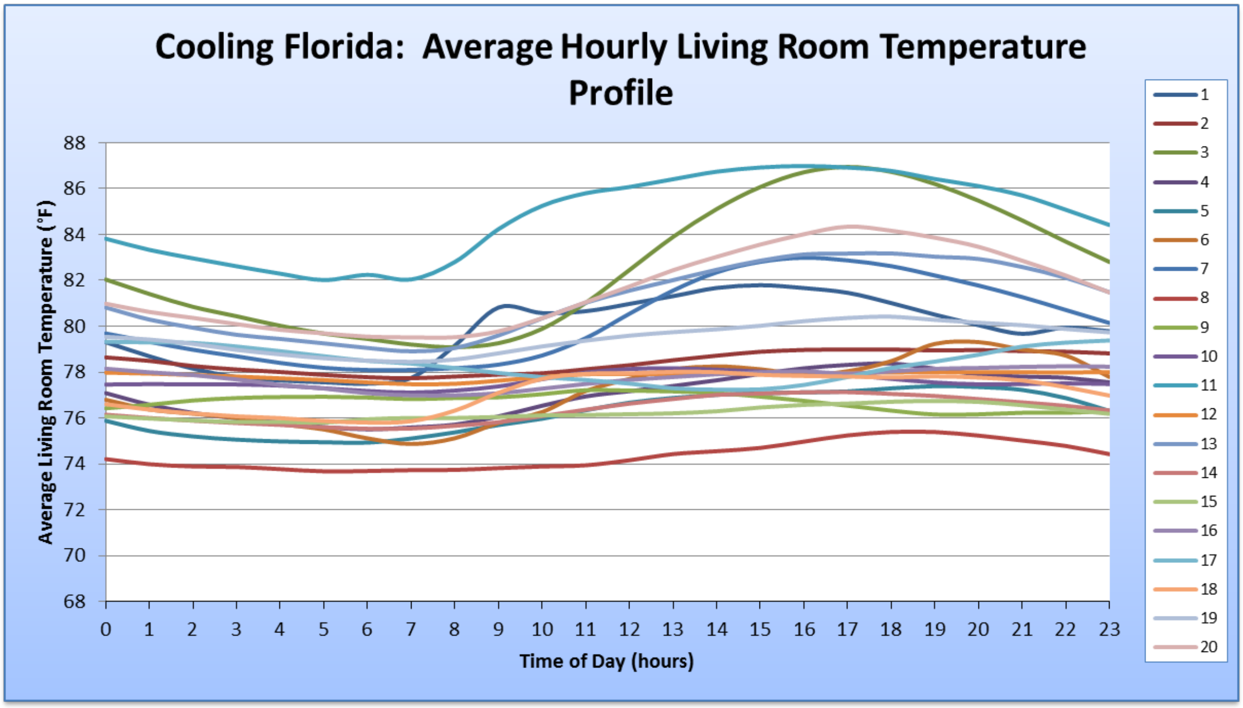


Figure 2. Florida hourly living room temperature profiles

Figure 3 shows a comparison of the average weekday and weekend hourly temperature profiles. The average hourly profiles are for all the Florida homes combined. There is only a slight difference between the weekday and weekend temperature profiles. There is about a 2.5°F difference between the daily minimum and maximum temperature in all three profiles. The shape of the temperature profiles suggests that the living room temperature is driven by the outdoor temperature and occupants using thermostat setups during the day when they might not be home.

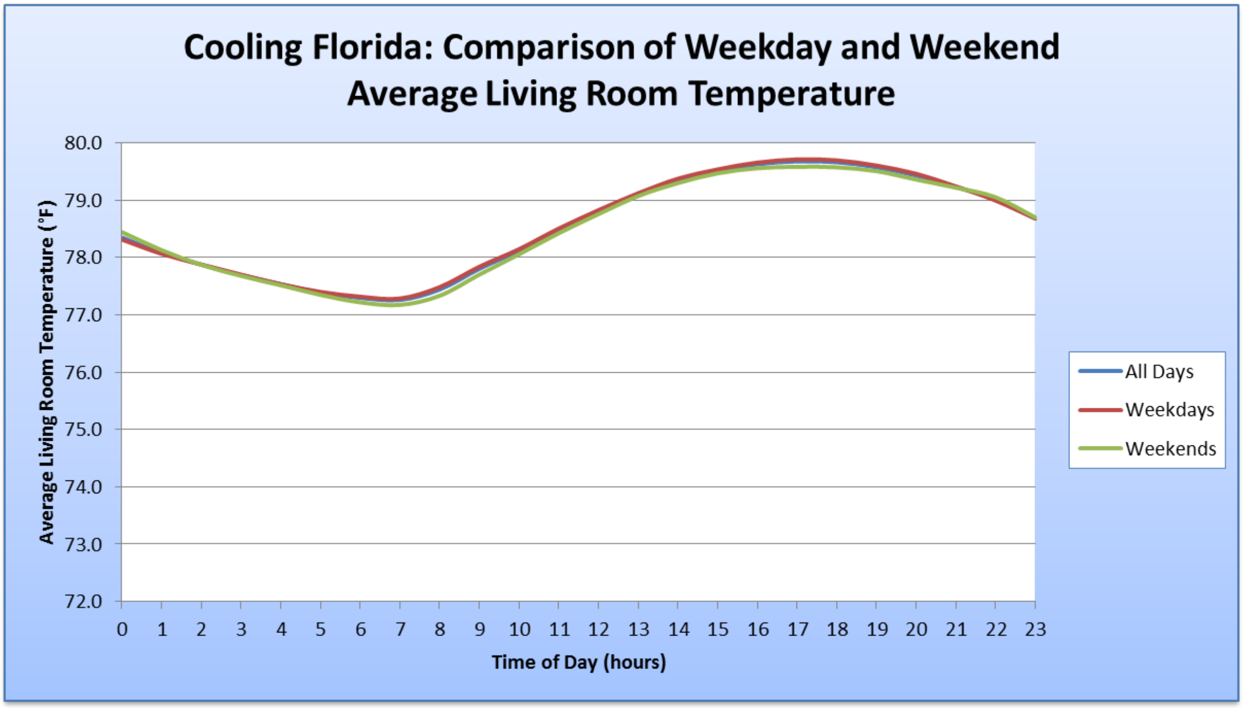
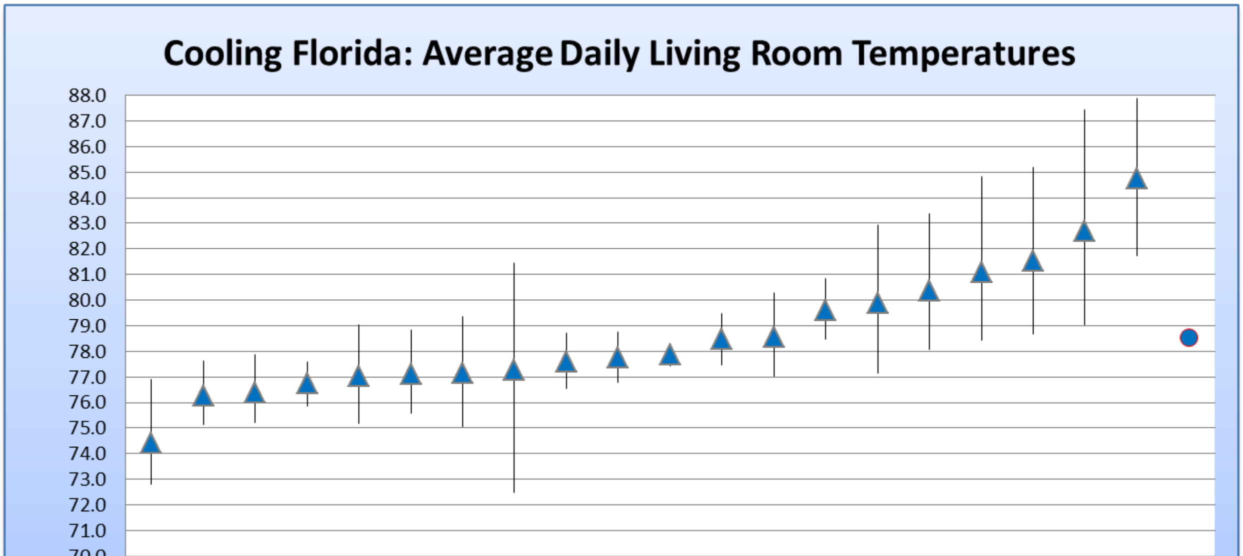


Figure 3. Florida weekend and weekday temperature profiles

3.1.3 Average Daily Temperatures

Figure 4 shows the daily average living room temperature for each Florida home in order of increasing mean temperature. The last point on the graph is the average for all the Florida homes combined. Homes 1, 3, 7, 11, 13, and 20 all have relatively high mean temperatures and large spreads between the daily average minimums and maximums, which signify that they most likely do not use their A/C systems or turn them off for longer durations. House 6 does not have cooling, so the larger spread in daily temperature is expected. Homes with a small spread in daily temperature might signify that the occupants leave the A/C systems running continuously without setup periods. Overall the Florida homes have a daily average of 78.5°F, and there is 10.3°F difference between the homes with the lowest and the highest daily means.



	8	15	14	9	4	5	18	6	10	16	12	2	17	19	1	7	13	20	3	11	All
Avg Max	76.9	77.6	77.9	77.6	79.0	78.9	79.4	81.4	78.7	78.7	78.2	79.5	80.3	80.8	82.9	83.4	84.8	85.2	87.4	87.9	
Avg Min	72.8	75.1	75.2	75.9	75.2	75.6	75.1	72.5	76.5	76.8	77.4	77.5	77.0	78.5	77.2	78.1	78.5	78.7	79.1	81.7	
Mean	74.4	76.3	76.4	76.7	77.0	77.1	77.1	77.3	77.6	77.7	77.9	78.5	78.6	79.6	79.9	80.4	81.1	81.5	82.7	84.7	78.5

Figure 4. Average living room temperatures for Florida homes during the cooling season

3.2 New York

This section describes the living room temperature distribution, hourly temperature profiles, and average daily temperatures for the New York homes.

3.2.1 Living Room Temperature Distribution

Figure 5 shows the living room temperature distribution for all hours and New York homes during the cooling season. The average living room temperature for the New York homes is 74.0°F with a standard deviation of 3.5°F.

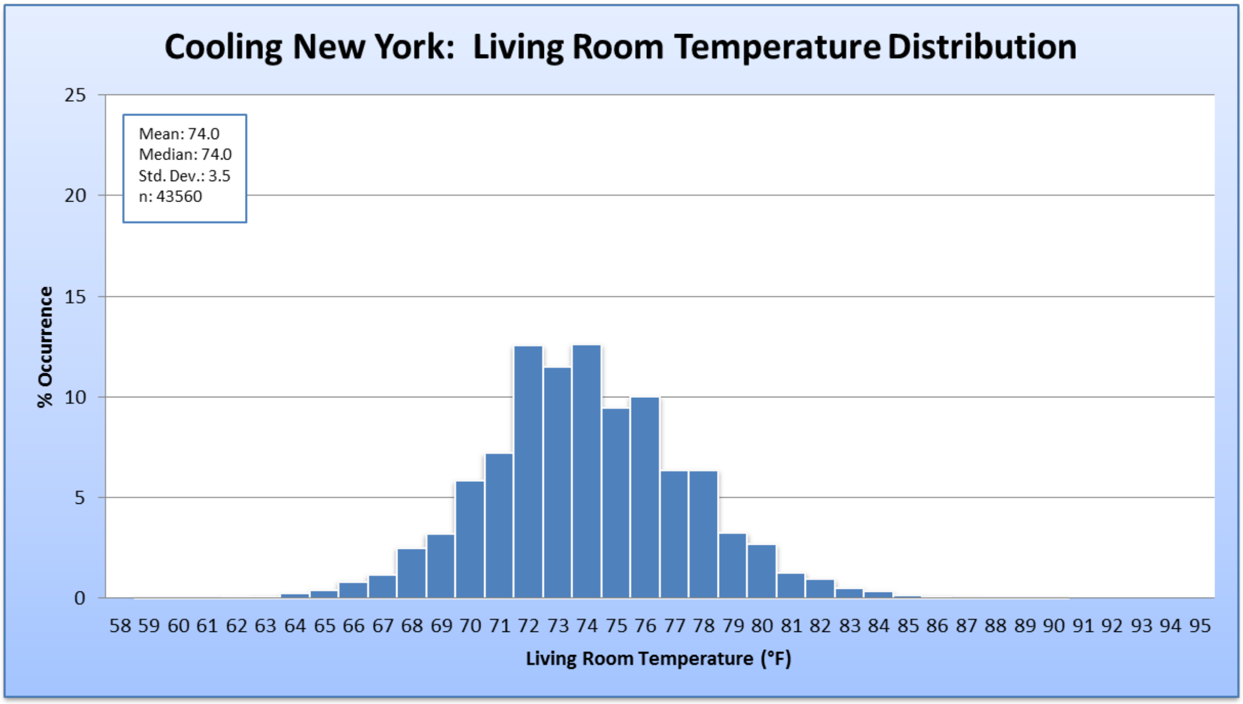


Figure 5. New York living room temperature distribution

3.2.2 Average Hourly Living Room Temperature Profiles

Figure 6 shows the average hourly temperature profile for each New York house during the cooling season. The profile shapes suggest that the living room temperatures are influenced by outdoor temperature and occupants instituting setups. Homes 25, 26, and 31 appear to use a setup in the morning when the occupants might leave for work. Homes 22, 28, 29, 32, and 37 do not have central cooling systems; however, homes 22, 32, and 37 have window A/C units and house 28 has a whole-house fan. Homes 23, 27, 38, and 40 have central A/C systems, but their temperature profiles signify that they might not use the systems or turn them off when not at home, creating a larger difference between daily maximum and minimum temperatures.

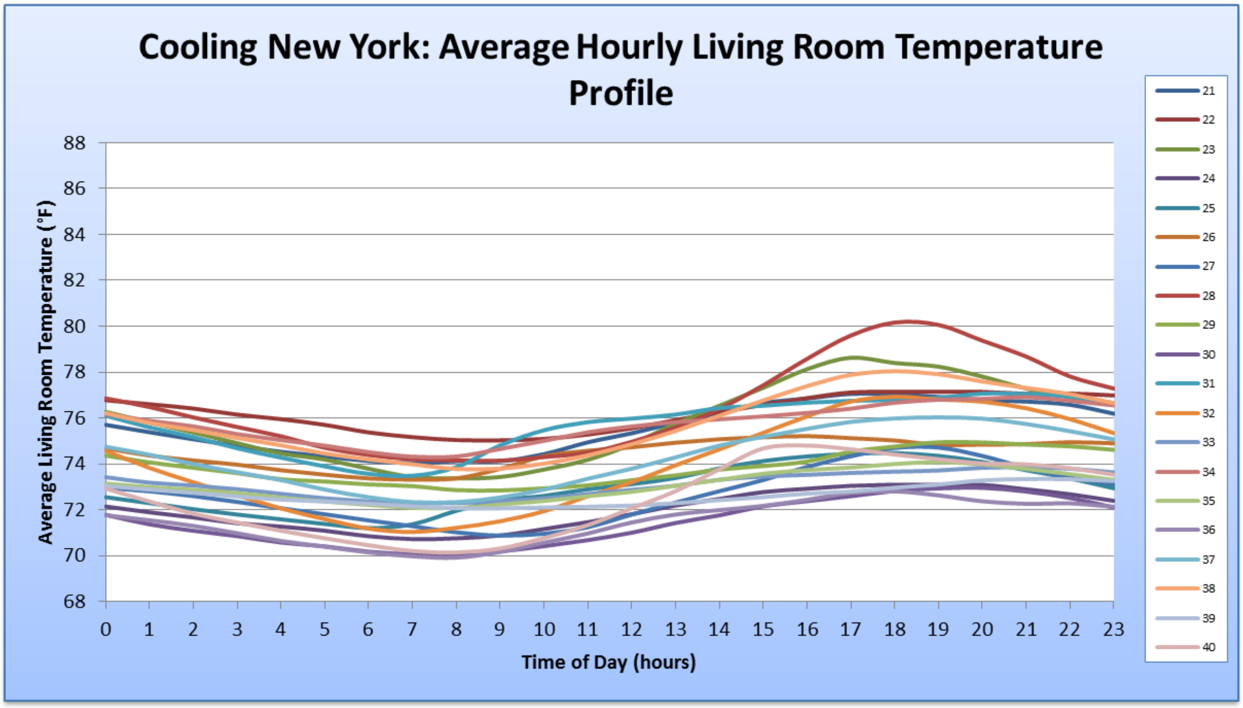


Figure 6. New York hourly living room temperature profiles

Figure 7 shows a comparison of the average weekday and weekend hourly temperature profiles for all the New York homes combined. The average living room temperatures on the weekend are roughly 0.5°F warmer than during the week. There is about a 3°F difference between the daily minimum and maximum, but the shape of the temperature profiles suggests that the living room temperature is driven by the outdoor temperature and occupants using thermostat setups during the day when they might not be home.

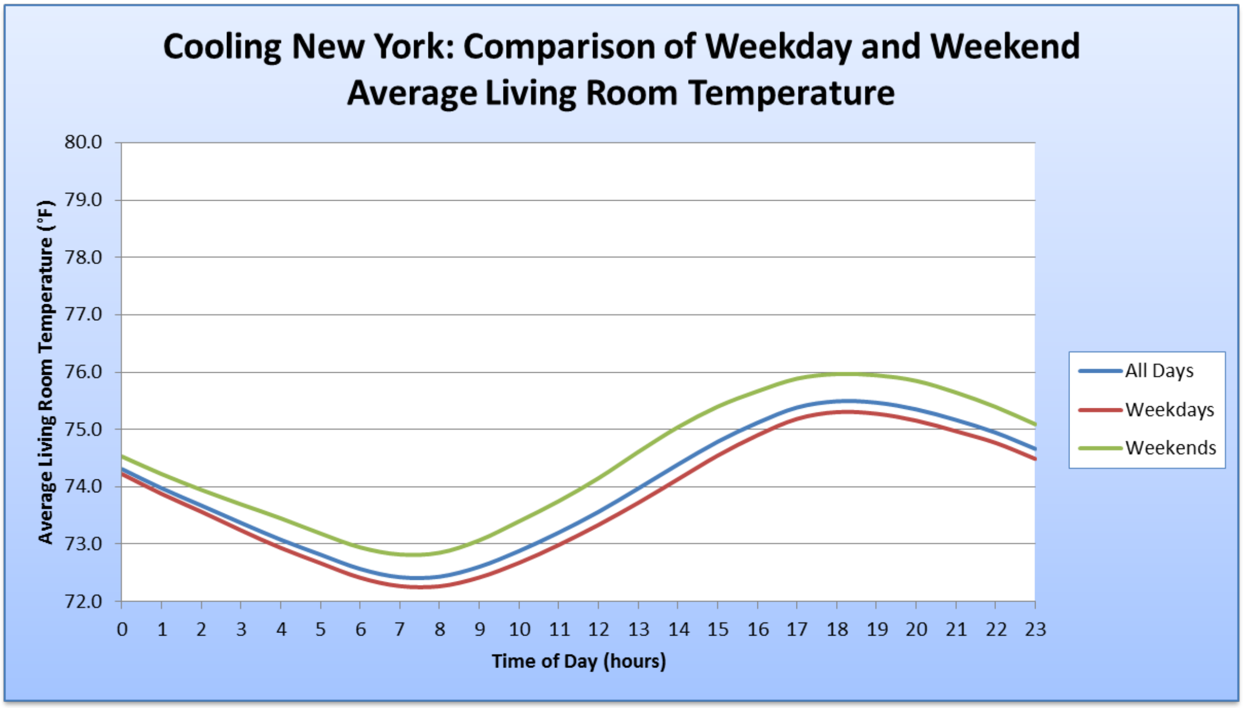


Figure 7. New York weekday and weekend temperature profiles

3.2.3 Average Daily Temperatures

Figure 8 shows the daily average living room temperature for each New York home in order of increasing mean temperature, which varies from 71.5°F to 77.0°F; the overall average is 74.0°F. Homes with larger spreads between the daily average minimums and maximums do not have central A/C systems or do not typically use them continuously.

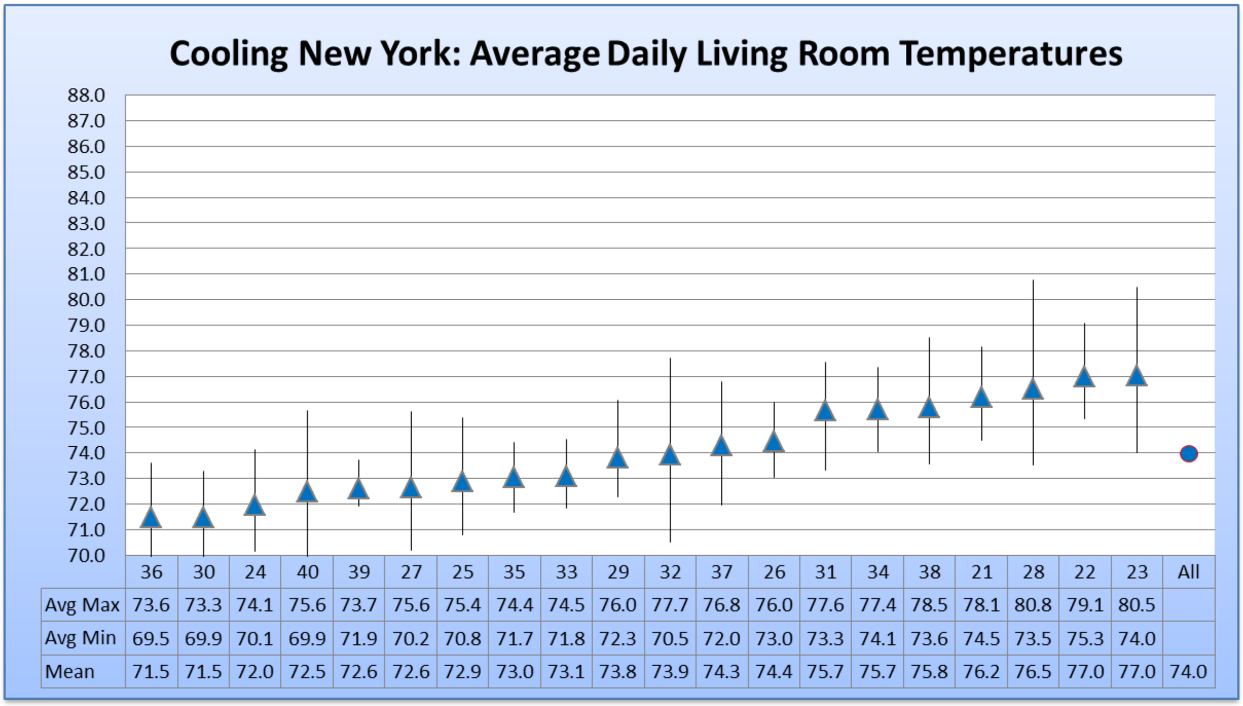


Figure 8. Average living room temperatures for New York homes during the cooling season

3.2.4 Combined Florida and New York Homes

This section compares the Florida and New York homes and examines differences between the two datasets. It also looks at the Florida and New York homes as one dataset as a way to compare the data as a whole with standards that are not climate specific. Table 3 gives a comparison of the average cooling season living room temperature calculated for the Florida, New York, and combined dataset with the different industry standards.

Table 3. Comparison of Set Point Standards and Measured Temperatures for Cooling Season

Set Point Standards (°F)	HSP	76
	IECC	75
	RESNET/HERS	78
	HEST	78/84
Measured Living Room Temperatures (°F)	Florida	78.5
	New York	74.0
	Combined Florida and New York	76.8

3.2.5 Living Room Temperature Distributions

Figure 9 shows a comparison of the living room temperature distributions for the 20 Florida homes and the 20 New York homes. The distributions show a clear difference between the

Florida and New York living room temperatures. The Florida mean temperature is 4.5°F warmer than New York and the standard deviation is 0.3°F greater for the New York homes. The Florida distribution also has a well-defined peak occurrence at 78°F; the New York distribution is flatter at its peak; temperatures of 72°F, 73°F, and 74°F have about the same occurrence.

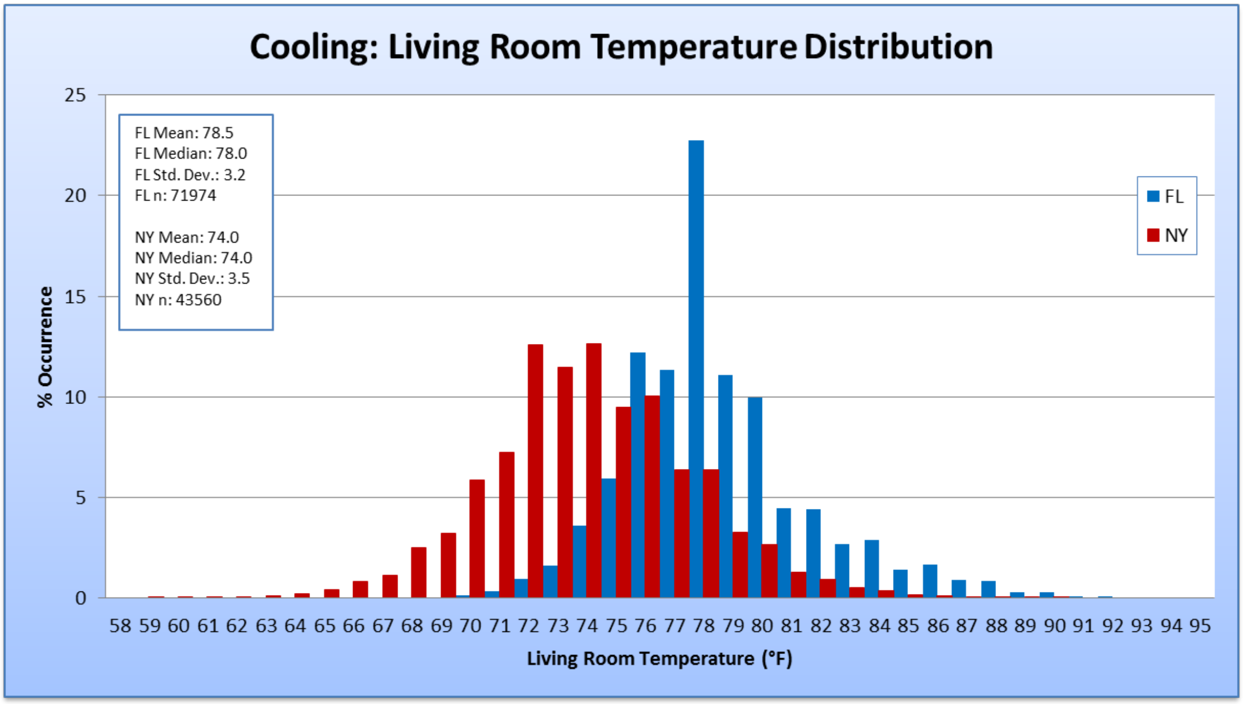


Figure 9. Comparison of Florida and New York cooling season living room temperature distributions

Figure 10 shows the living room temperature distribution for the 40 combined Florida and New York homes dataset. The distribution is dominated by the Florida homes because of the longer cooling season (62% of the data).

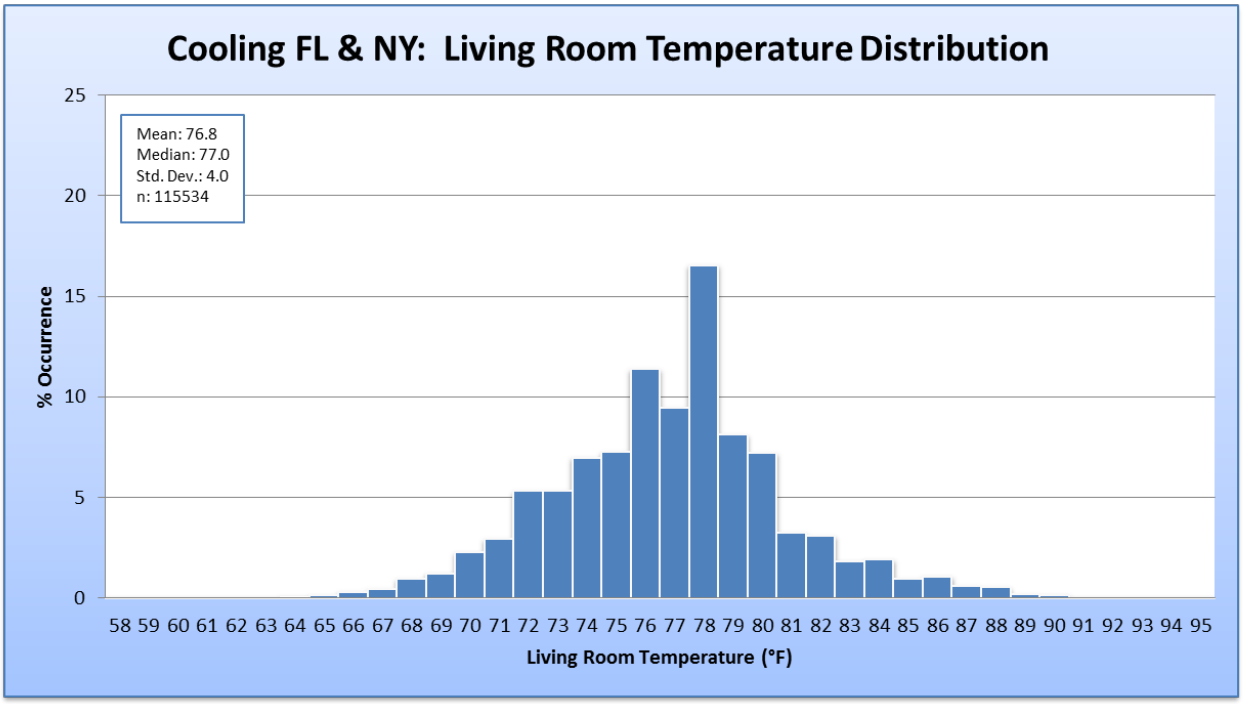


Figure 10. Living room temperature distribution for combined cooling season dataset

3.2.6 Average Hourly Living Room Temperature Profiles

Figure 11 shows a comparison of the average hourly living room temperature profiles for Florida, New York, and for Florida and New York combined as one dataset. The shapes of these profiles are similar. Florida is warmer than New York, but the difference between the daily highs and lows is smaller than it is for the New York profile by about 0.5°F.

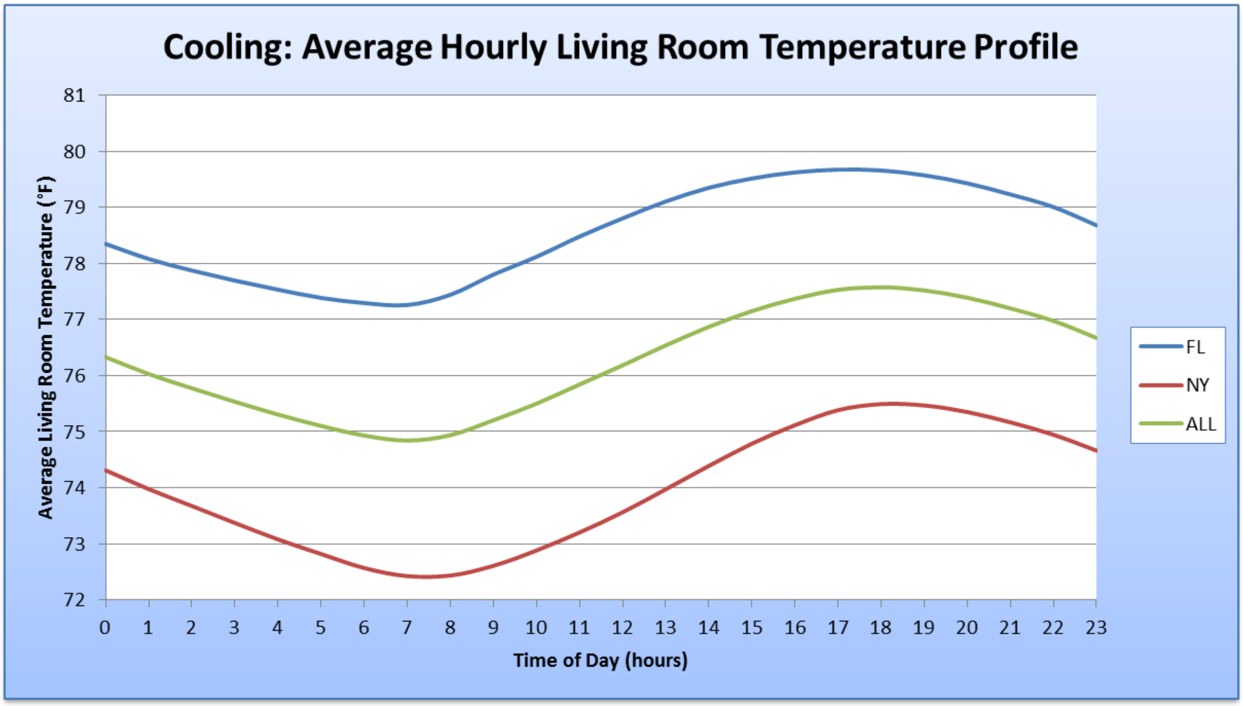


Figure 11. Comparison of hourly living room temperature profiles

4 Heating Season Living Room Temperature Analysis

This section discusses the heating season "set point" data analysis in detail. The living room temperature sensor is assumed to best represent the thermostat set point and the 15-minute data were averaged to obtain hourly data. The heating season analysis was performed for New York and Oregon/Washington homes only, because the Florida heating use was sporadic given the mild climate.

The heating season is defined for purposes of this analysis as November–March for the New York and Oregon/Washington homes.

4.1 New York

This section describes the living room temperature distribution, hourly temperature profiles, and average daily temperatures for the New York homes.

4.1.1 Living Room Temperature Distribution

Figure 12 shows the living room temperature distribution for all hours and New York homes during the heating season. The average living room temperature for the New York homes is 65.0°F with a standard deviation of 4.7°F.

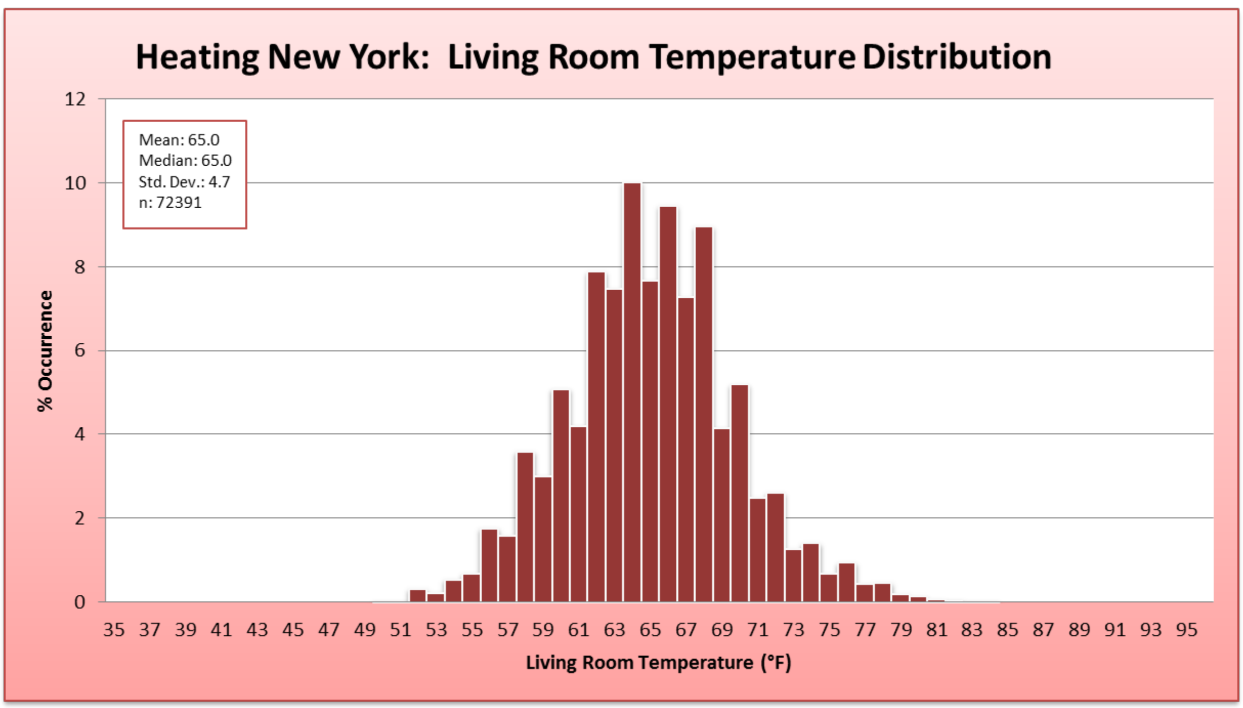


Figure 12. New York living room temperature distribution

4.1.2 Average Hourly Living Room Temperature Profiles

Figure 13 shows the average hourly temperature profile for each house in New York during the heating season. Several of the New York households appear to heat their homes at a constant set point the entire day, as their temperatures varied by about ±1°F (22, 25, 31, 35, 39, and 40).

Several New York homes either turn their heat off or use a setback in the evening and then turn the heat up in the morning after they wake up (23, 24, 26, 27, 28, 30, 32, and 34). A few homes (29, 36, and 38) appear to turn their heat up and down throughout the day, as evidenced by several peaks and valleys in their temperature profiles. Nineteen of the New York homes have either a gas or a wood fireplace, and a few temperature profiles show evidence of fireplace use in the evenings, with a sharp increase in temperature (21, 24, and 32).

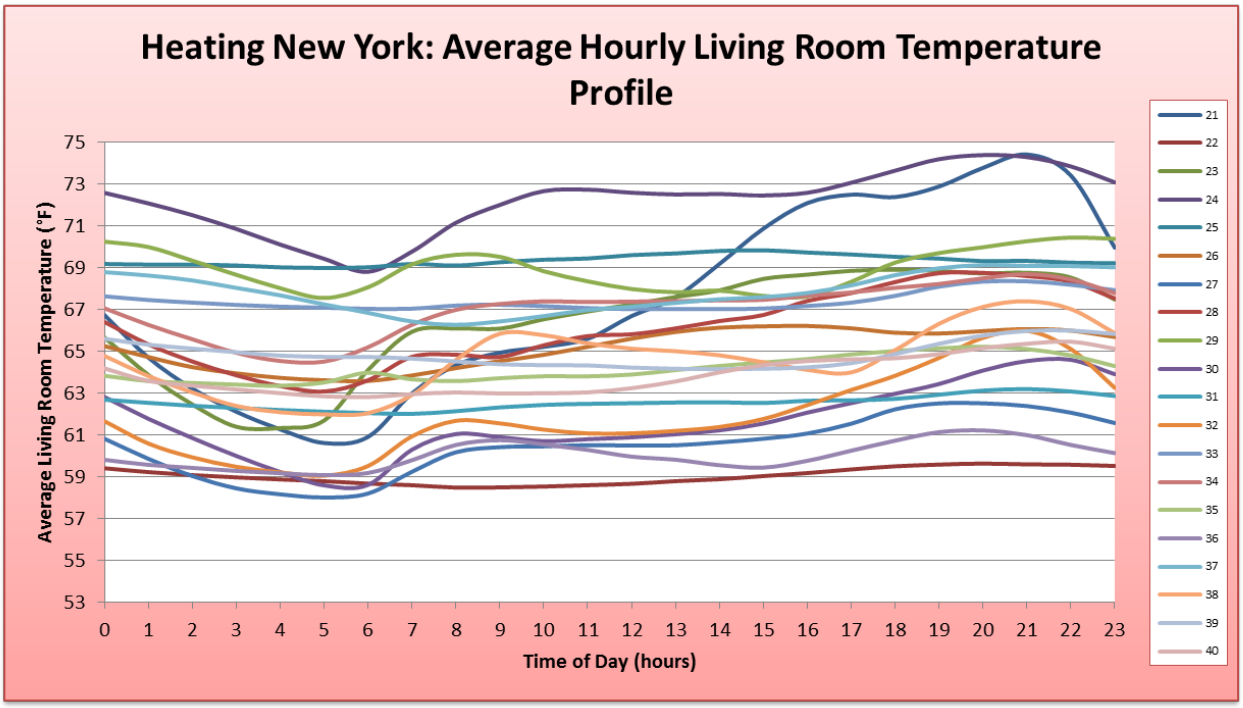


Figure 13. New York hourly living room temperature profiles

Figure 14 shows a comparison of the average weekday and weekend hourly temperature profiles. The New York homes tend to turn off the heat or use a setback in the evening and then turn their heat back up in the morning, as seen by the 4°F temperature difference between the daily highs and lows. The increase in temperature from 4:00 p.m. to 10:00 p.m. is probably driven, in part, by fireplace use, or occupants turning the heat up when they come home from work in the evening. The weekday and weekend temperature profiles show a slight difference; the weekend temperature starts to increase later in the morning because people presumably sleep in and turn the heat up later. The weekend is also about 1°F warmer during the day, which is likely caused by more people being home all day, leaving the heat on and adding to internal gain.

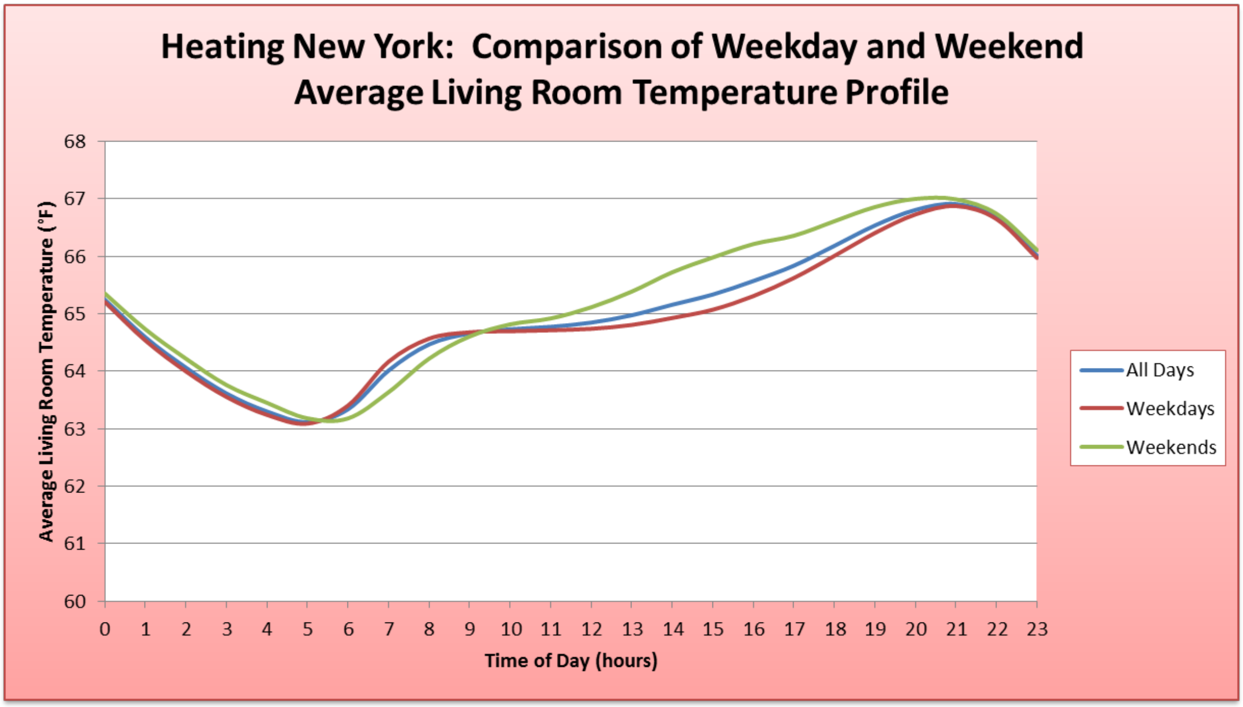
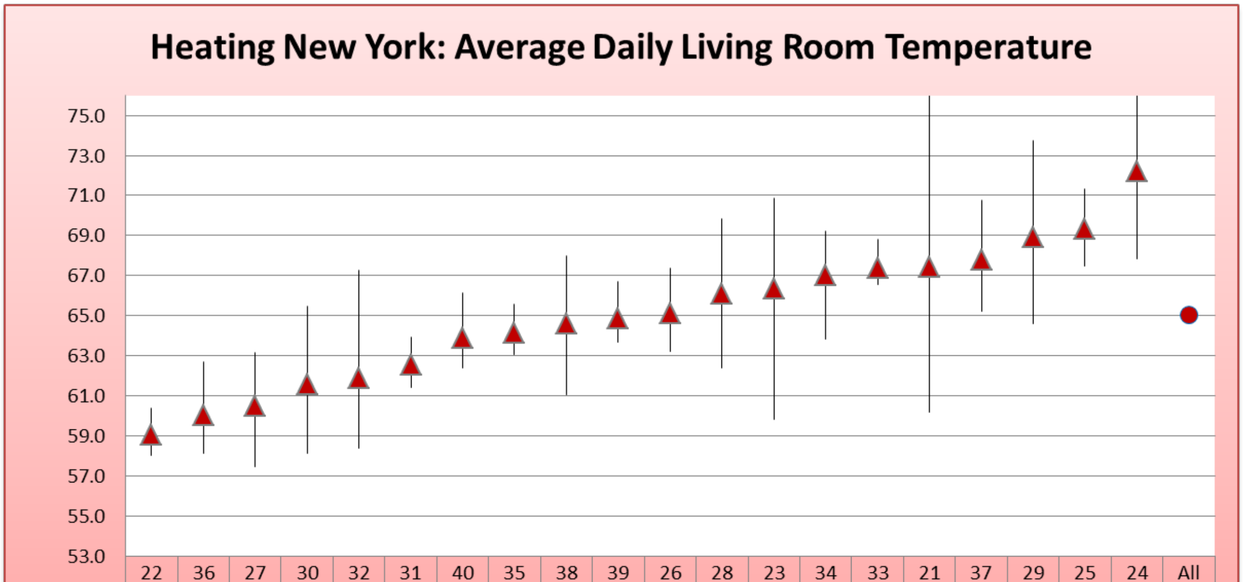


Figure 14. New York weekday and weekend hourly temperature profiles

4.1.3 Average Daily Temperatures

Figure 15 shows the daily average living room temperature for each New York home in order of increasing mean temperature. The mean temperature for all the New York homes varies from 59.0°F to 72.2°F, with an overall average of 65.0°F. Households with larger spreads between the average daily minimums and maximums may use their fireplaces frequently in the evening or turn their systems up and down instead of leaving them at the same set point throughout the day.



	22	36	27	30	32	31	40	35	38	39	26	28	23	34	33	21	37	29	25	24	All
Avg Max	60.4	62.7	63.2	65.5	67.3	63.9	66.1	65.6	68.0	66.7	67.4	69.8	70.9	69.2	68.8	76.5	70.8	73.7	71.3	76.2	
Avg Min	58.0	58.1	57.5	58.1	58.4	61.4	62.4	63.0	61.1	63.7	63.2	62.4	59.8	63.8	66.6	60.2	65.2	64.6	67.5	67.8	
Mean	59.0	60.0	60.5	61.6	61.9	62.5	63.9	64.1	64.6	64.9	65.1	66.1	66.3	67.0	67.4	67.4	67.8	68.9	69.3	72.2	65.0

Figure 15. Average living room temperatures for New York homes during heating season

4.1.4 Oregon and Washington

This section describes the living room temperature distribution, hourly temperature profiles, and daily average temperatures for the Oregon and Washington homes.

4.1.5 Living Room Temperature Distribution

Figure 16 shows the living room temperature distribution for all the hours and Oregon and Washington homes during the heating season. The average living room temperature for the Oregon/Washington homes is 63.9°F with a standard deviation of 4.9.

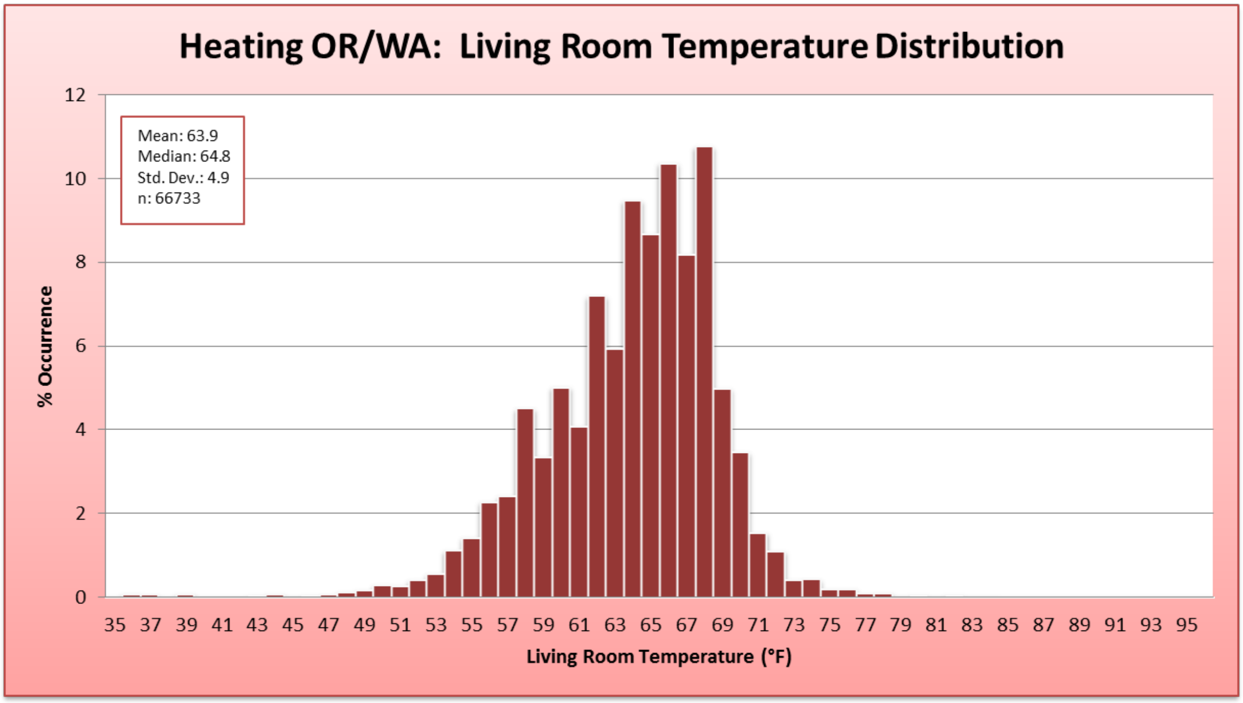


Figure 16. Oregon/Washington living room temperature distribution

4.1.6 Average Hourly Living Room Temperature Profiles

Figure 17 shows the average hourly temperature profile for each house in Oregon and Washington during the heating season. Most Oregon and Washington homes turn the heat down in the evening and up in the morning. Only two homes (46 and 55) appear to leave their heat on all day, because their temperature profiles do not fluctuate by more than ±1°F. House 53 looks unusually cold, but has only electric resistance heaters, which appear to be frequently turned down or off in the living room. House 44 has only a wood stove for heating, which explains the large difference in daily minimum and a relatively high maximum compared to the other homes. Most of the homes (17 of 20) also have fireplaces, which appear to be used frequently in the evening. Fireplace use or occupants turning the heat up in the evening when they come home could explain the increase in evening temperatures.

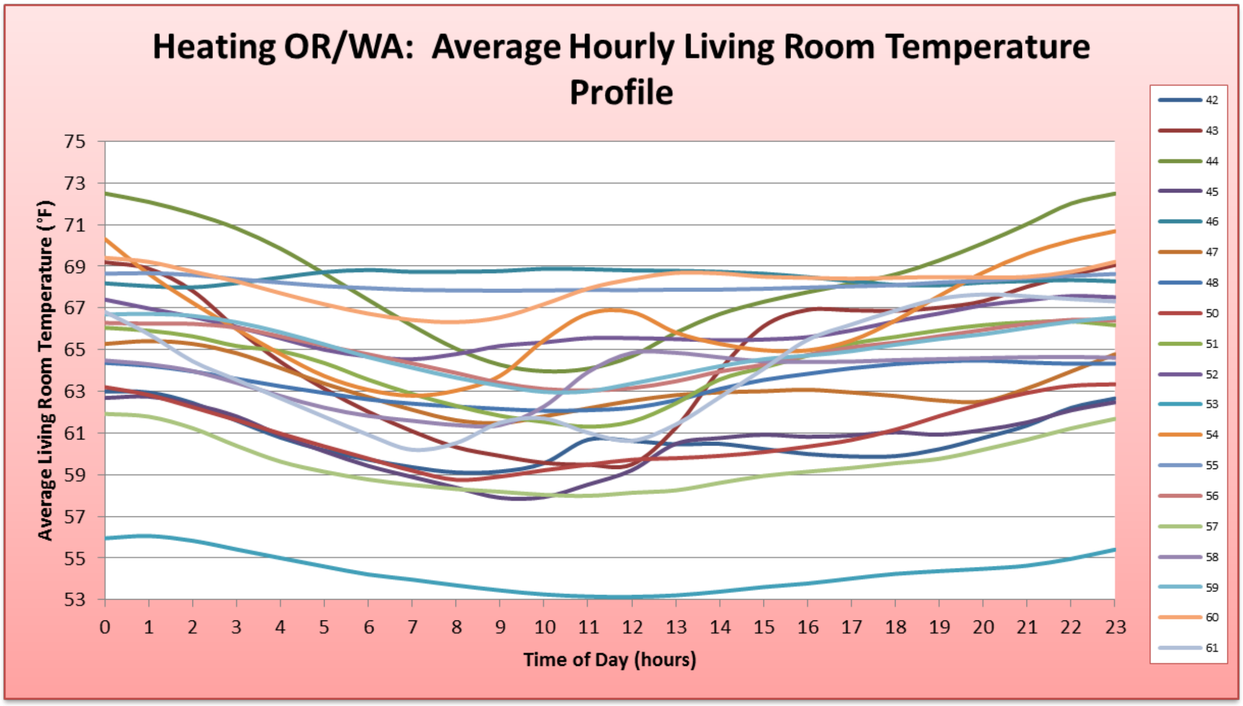


Figure 17. Oregon/Washington hourly living room temperature profiles

Figure 18 shows a comparison of the average weekday and weekend hourly temperature profiles are for all the Oregon and Washington homes combined. The Oregon and Washington households tend to turn down their heat in the evening and then turn it up again in the morning, as seen from the 4°F temperature difference between the daily highs and lows. The weekday and weekend temperature profiles vary slightly; the weekend temperature starts to increase later in the morning, presumably because people sleep in and turn the heat up later. The weekend is also about a 1.5°F warmer during the day, which is likely caused by more people being home all day and leaving the heat on, or turning up the heat.

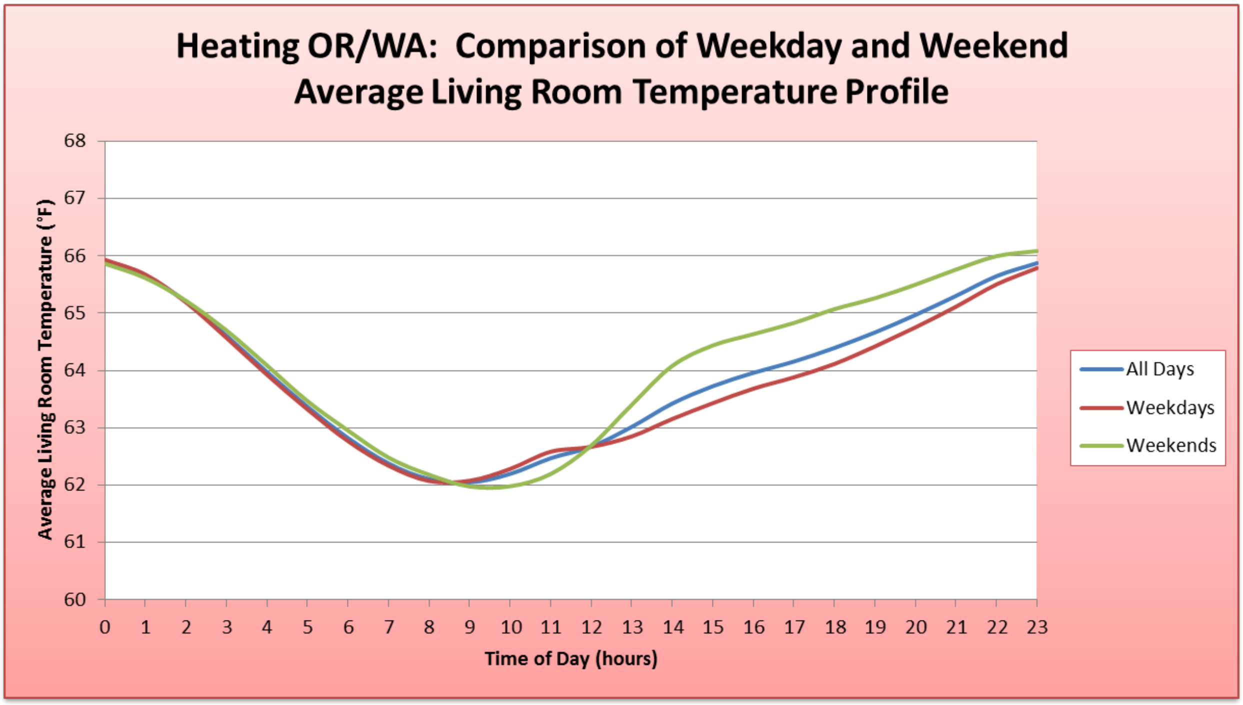
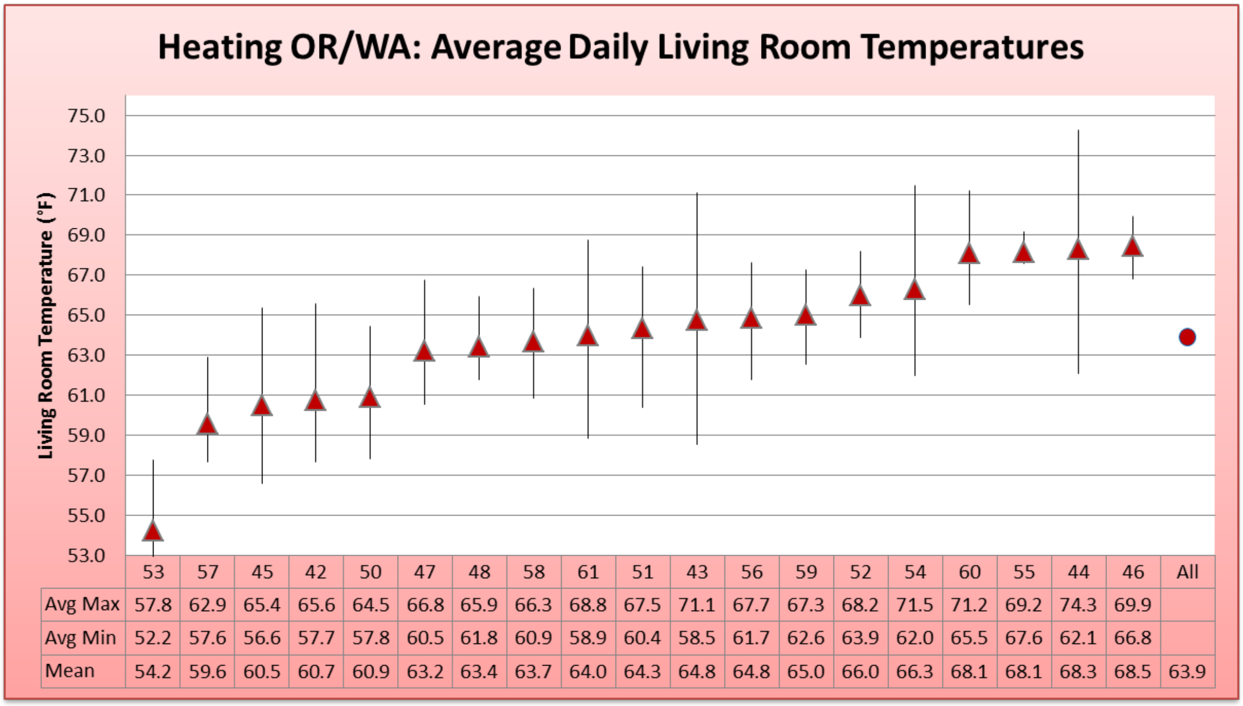


Figure 18. Oregon/Washington weekday and weekend hourly living room temperature profiles

4.1.7 Average Daily Temperatures

Figure 19 shows the daily average living room temperature for each Oregon and Washington home in order of increasing mean temperature. The mean temperature for all the Oregon and Washington homes varies from 55.0°F to 68.5°F, with an overall average of 64.0°F. Households with a larger spread between the daily average minimum and maximum temperatures typically use their fireplaces frequently in the evening or turn their systems on and off instead of leaving their heat on continuously.



	53	57	45	42	50	47	48	58	61	51	43	56	59	52	54	60	55	44	46	All
Avg Max	57.8	62.9	65.4	65.6	64.5	66.8	65.9	66.3	68.8	67.5	71.1	67.7	67.3	68.2	71.5	71.2	69.2	74.3	69.9	
Avg Min	52.2	57.6	56.6	57.7	57.8	60.5	61.8	60.9	58.9	60.4	58.5	61.7	62.6	63.9	62.0	65.5	67.6	62.1	66.8	
Mean	54.2	59.6	60.5	60.7	60.9	63.2	63.4	63.7	64.0	64.3	64.8	64.8	65.0	66.0	66.3	68.1	68.1	68.3	68.5	63.9

Figure 19. Average living room temperatures for the Oregon/Washington homes during the heating season

4.1.8 Combined New York, Oregon, and Washington Homes

This section compares New York with the Oregon/Washington homes, and examines differences between the two datasets. It also looks at the New York and Oregon/Washington homes as one dataset as a way to compare the data as a whole with standards that are not climate specific. Table 4 compares the average heating season living room temperature calculated for the New York, Oregon/Washington, and the combined dataset with the different industry standards.

Table 4. Comparison of Set Point Standards and Measured Temperatures for Heating Season

Set Point Standards (°F)	HSP	71
	IECC	72
	RESNET/HERS	68
	HEST	68/60
Measured Living Room Temperatures (°F)	New York	65.0
	Oregon/Washington	63.9
	Combined New York and Oregon/Washington	64.5

4.1.9 Living Room Temperature Distributions

Figure 20 shows a comparison of the living room temperature distributions for the New York and Oregon/Washington homes. The New York mean temperature is 1.1°F warmer than the Oregon/Washington homes. The standard deviation is large at 4.7°F and 4.9°F for the New York and Oregon/Washington homes. This could be due, in part, to common use of fireplaces in both climates, which creates a wider spread of living room temperatures.

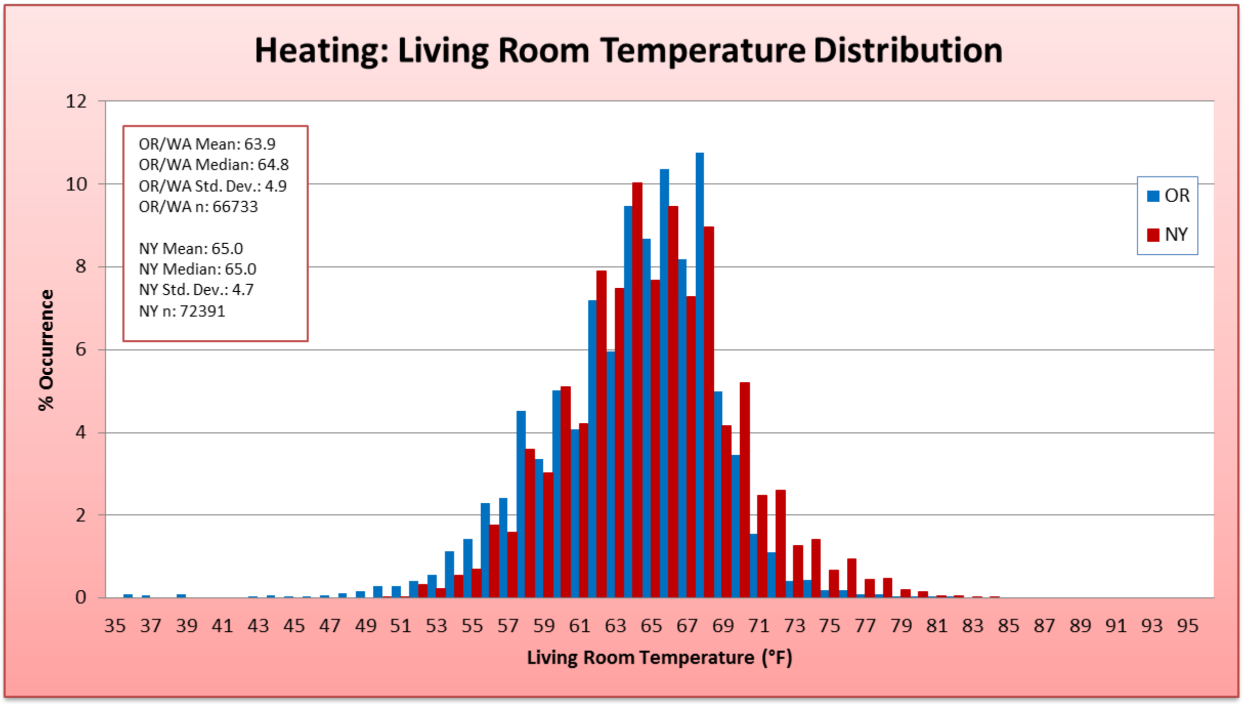


Figure 20. Comparison New York and Oregon/Washington living room temperature distributions for the heating season

Figure 21 shows the living room temperature distribution for the combined New York and Oregon/Washington dataset.

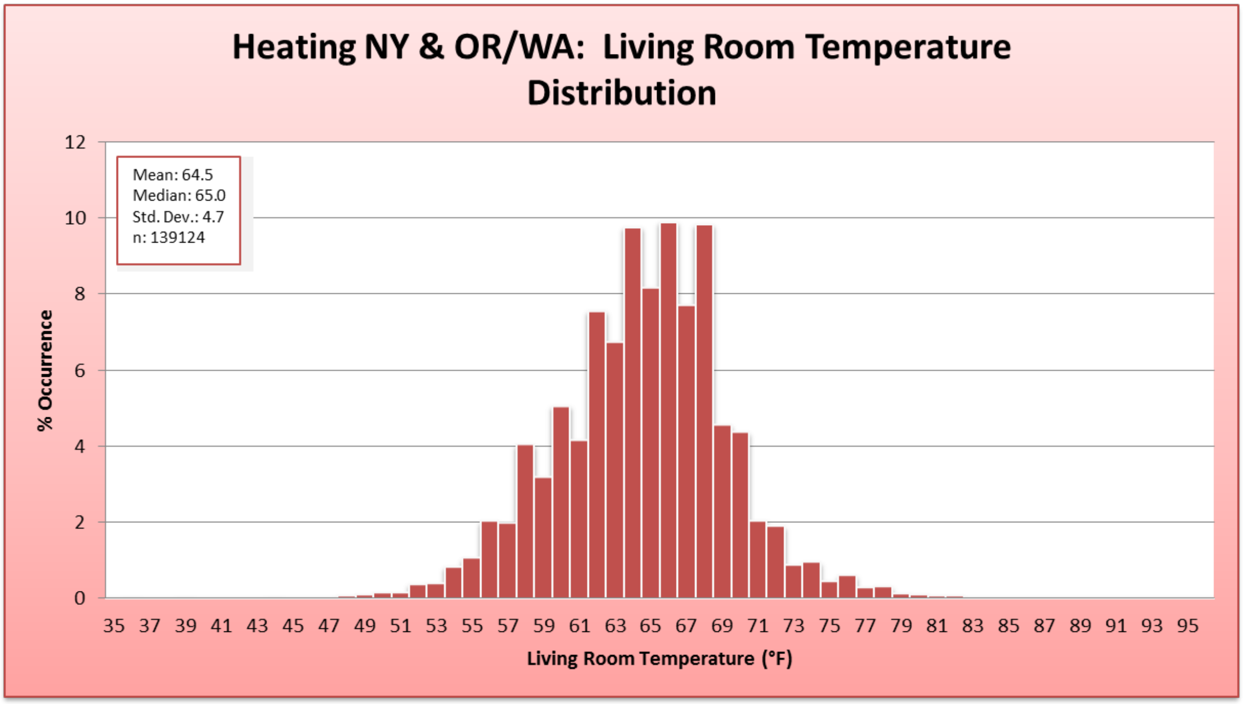


Figure 21. Living room temperature distribution for the combined heating season dataset

4.1.10 Average Hourly Living Room Temperature Profiles

Figure 22 shows a comparison of the average hourly living room temperature profiles for New York and Oregon/Washington homes separately, and New York and Oregon/Washington homes combined as one dataset. The New York and Oregon/Washington homes tend to turn down their heat at night, then up in the morning. New York homes are 1° to 2.5°F warmer than the Oregon/Washington homes during most of the day.

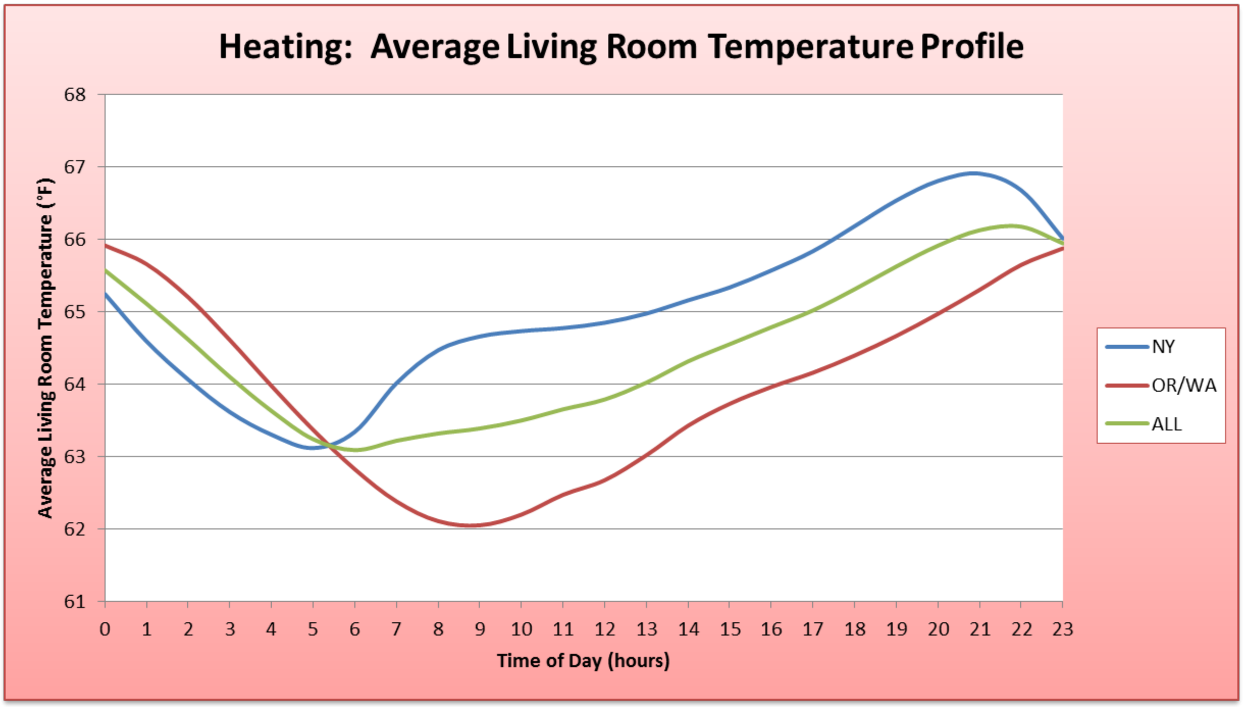


Figure 22. Comparison of hourly living room temperature profiles during the heating season

5 Cooling Season Indoor Temperature Spatial Variability Analysis

This section discusses cooling season indoor temperature spatial variability. Many home energy simulation models assume indoor air temperature is the same throughout a house. Temperatures within a house vary, however, possibly because of orientation, shading, multiple HVAC systems, HVAC supply air flow, internal loads, auxiliary heating systems, and occupant behavior.

This analysis examines the temperature differences between the living room and master bedroom for each house in Florida and New York, and provides insight into the temperature variability within each house, between homes, and between climates. The cooling season is defined in Section 3.

5.1 Florida

This section describes the indoor temperature variability distribution and average hourly temperature difference profiles for the Florida homes during the cooling season.

5.1.1 Indoor Temperature Difference Distribution

Figure 23 shows the difference distribution between the living room and master bedroom temperatures. The cooling season distribution includes all the hours in the cooling season and all homes in Florida. The Florida homes' mean temperature difference is 0.8°F—on average the living room is 0.8°F warmer than the master bedroom. The standard deviation is 1.8°F.

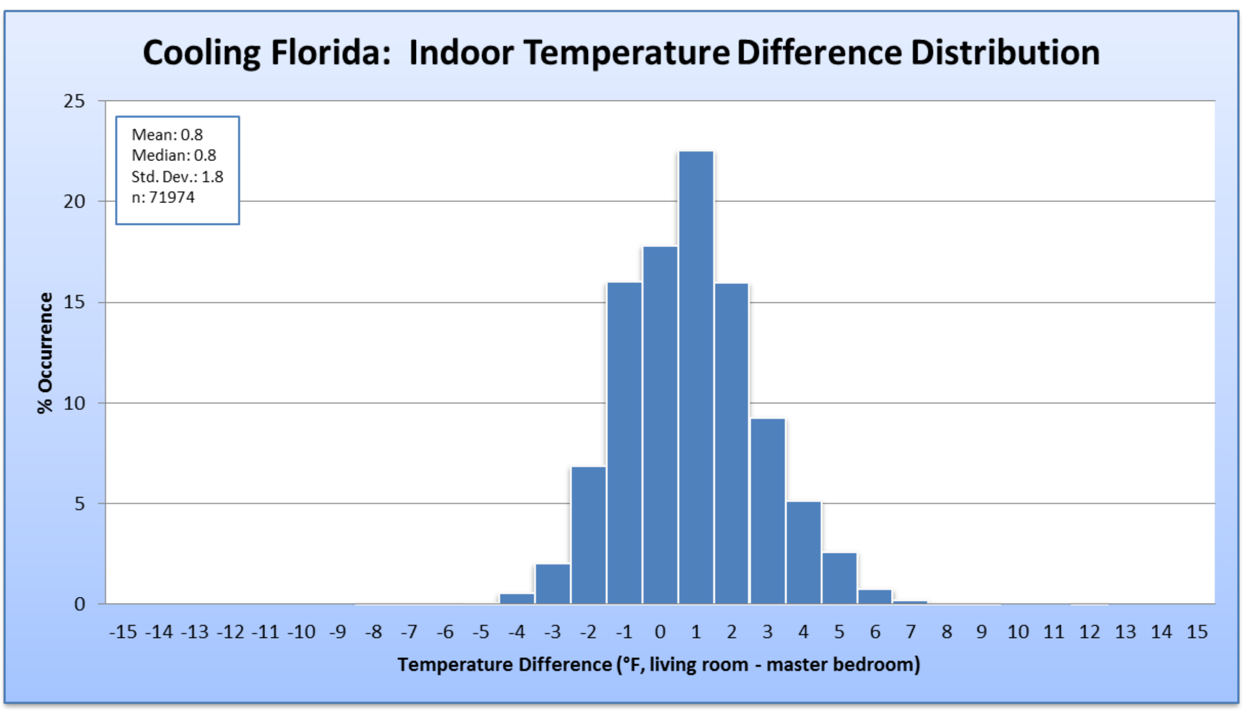


Figure 23. Florida indoor temperature difference distribution for the cooling season

5.1.2 Average Hourly Indoor Temperature Difference Profiles

Figure 24 shows the average hourly indoor temperature difference profiles for all the Florida homes. For most Florida homes the temperature difference between the living room and master bedroom fluctuates by more than ±1°F throughout the day. Homes 2, 8, and 18 temperature differences stay fairly steady throughout the day and fluctuate less than ±1°F. Homes 1, 5, 7, and 19 have multiple HVAC units, which could explain the large fluctuation in indoor temperature differences between the living room and master bedroom.

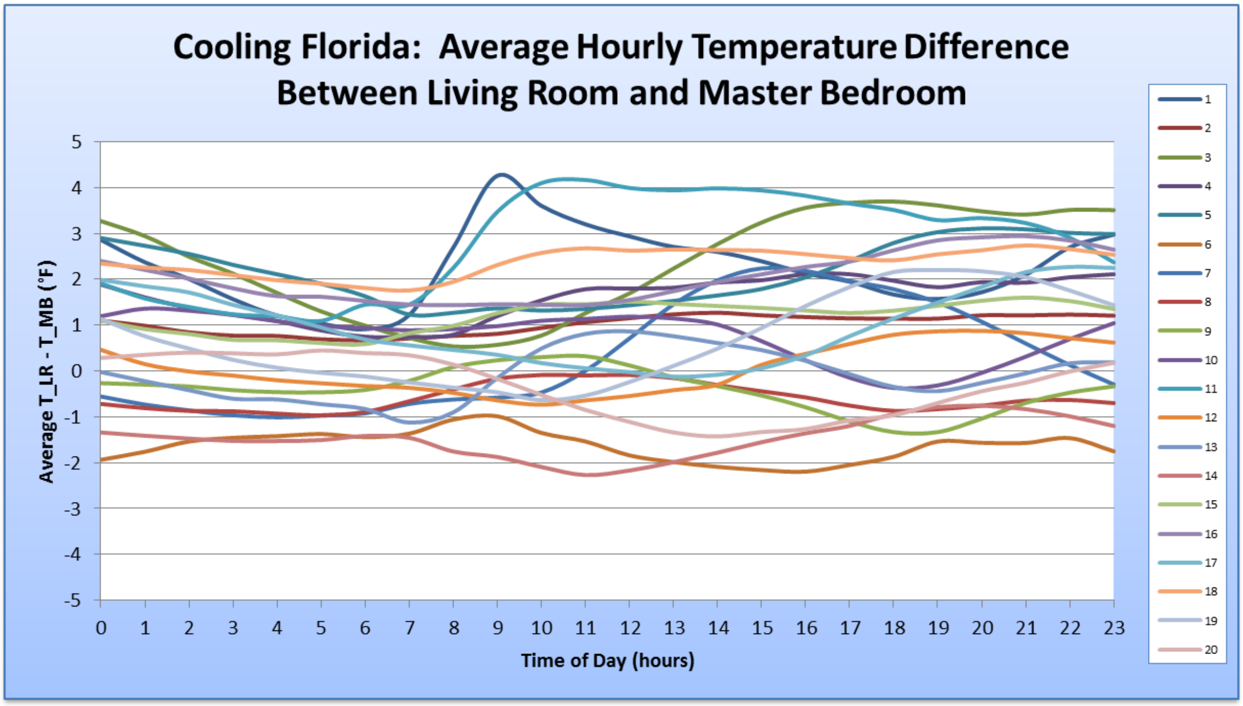


Figure 24. Florida average hourly temperature difference profiles for the cooling season

Figure 25 shows a comparison of the average weekday and weekend indoor temperature differences for the combined Florida homes. There is not a considerable temperature difference from weekday to weekend. Overall the living room is warmer than the master bedroom the entire day, and the average difference does not fluctuate by more than 1°F.

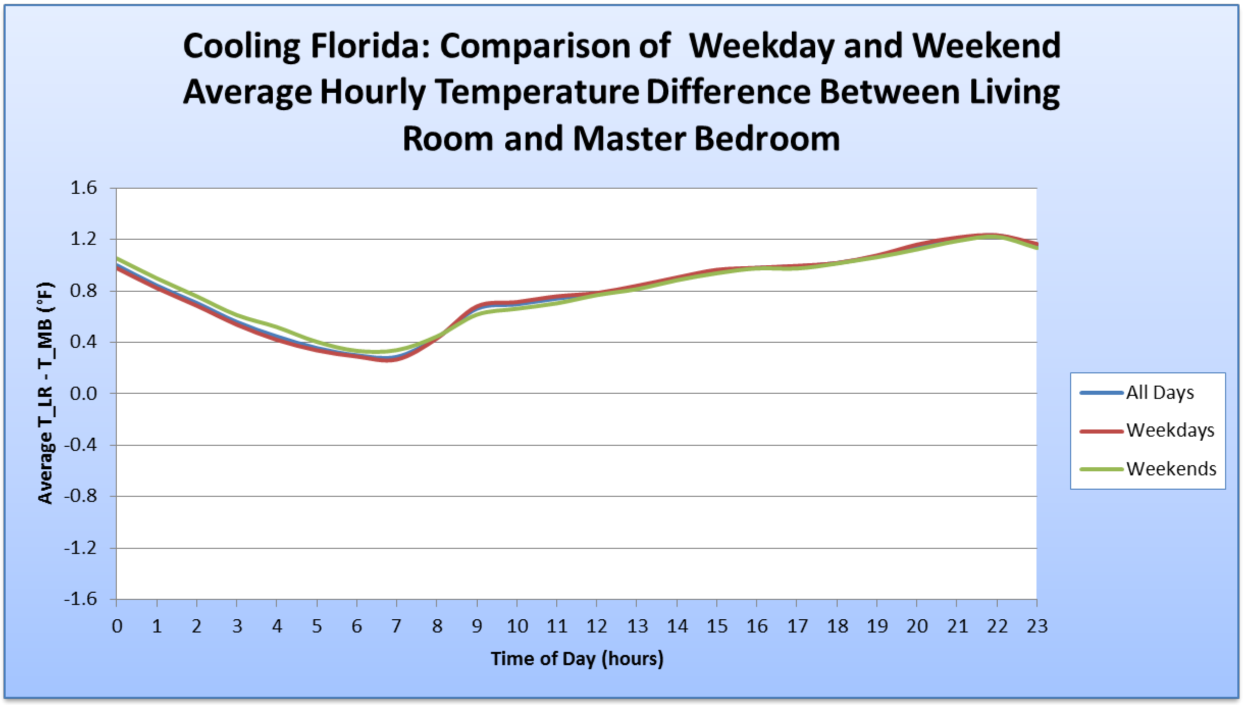


Figure 25. Florida average hourly weekday and weekend temperature difference profiles for the cooling season

5.2 New York

This section describes the indoor temperature variability distribution and average hourly temperature difference profiles for New York homes during the cooling season.

5.2.1 Indoor Temperature Difference Distribution

Figure 26 shows the indoor temperature difference distribution for all New York homes and all hours during the cooling season. On average, the living room tends to be cooler than the master bedroom by 1.0°F. The standard deviation is 2.21°F.

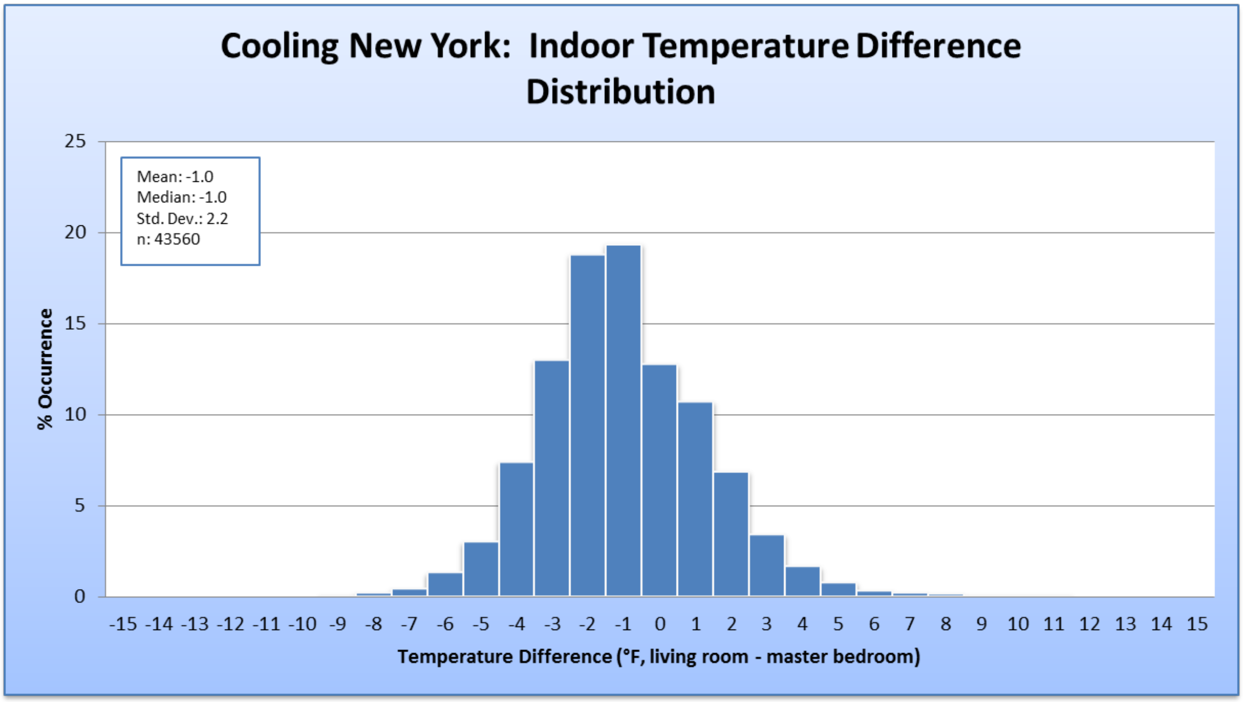


Figure 26. New York indoor temperature difference distribution for the cooling season

5.2.2 Average Hourly Indoor Temperature Difference Profiles

Figure 27 shows the average hourly temperature differences between the living room and master bedroom for the New York homes. For most, the master bedroom is warmer than the living room, and fluctuates by more than ±1°F throughout the day. In homes 24, 29, 33, and 38, the average indoor temperature difference stays relatively steady and fluctuates less than ±1°F.

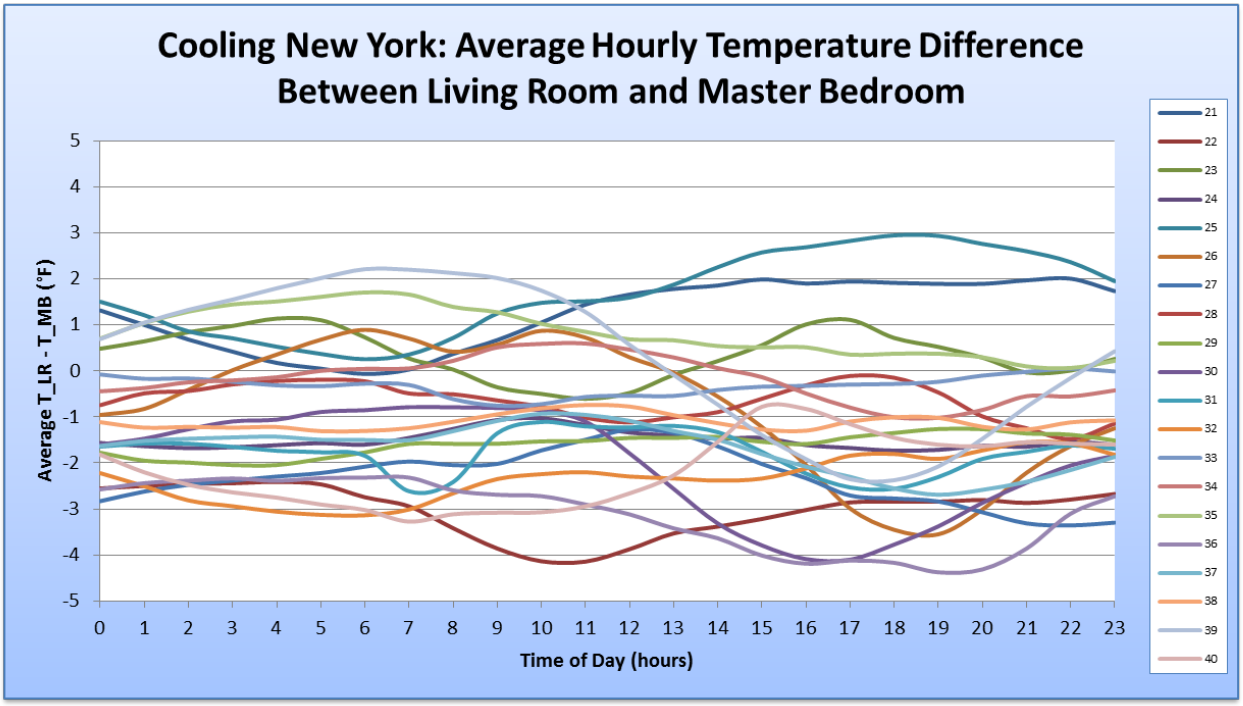


Figure 27. New York average hourly indoor temperature difference profiles for the cooling season

Figure 28 shows a comparison of the average weekday and weekend indoor temperature differences for the combined New York homes. There is not a considerable difference between the weekday and weekend profiles. Overall the master bedroom is warmer than the living room the entire day, and the average difference does not fluctuate by more than 1°F.

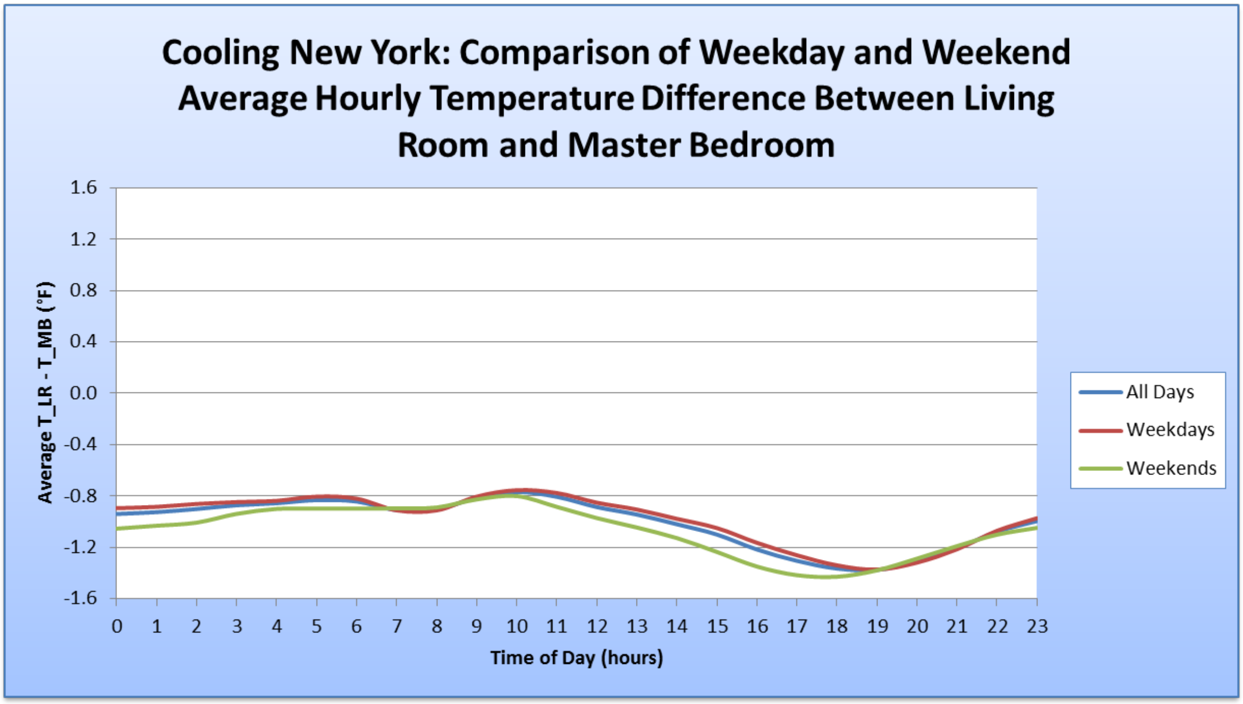


Figure 28. New York Average hourly weekday and weekend indoor temperature difference profiles for the cooling season

5.2.3 Combined Florida and New York Homes

This section compares indoor temperature differences for the Florida and New York homes and examines the Florida and New York homes as one dataset.

5.2.4 Indoor Temperature Difference Distributions

Figure 29 shows a comparison of the Florida and New York indoor temperature difference distributions. For both distributions the living room is usually slightly warmer than the master bedroom for the Florida homes and slightly cooler than the master bedroom for the New York homes.

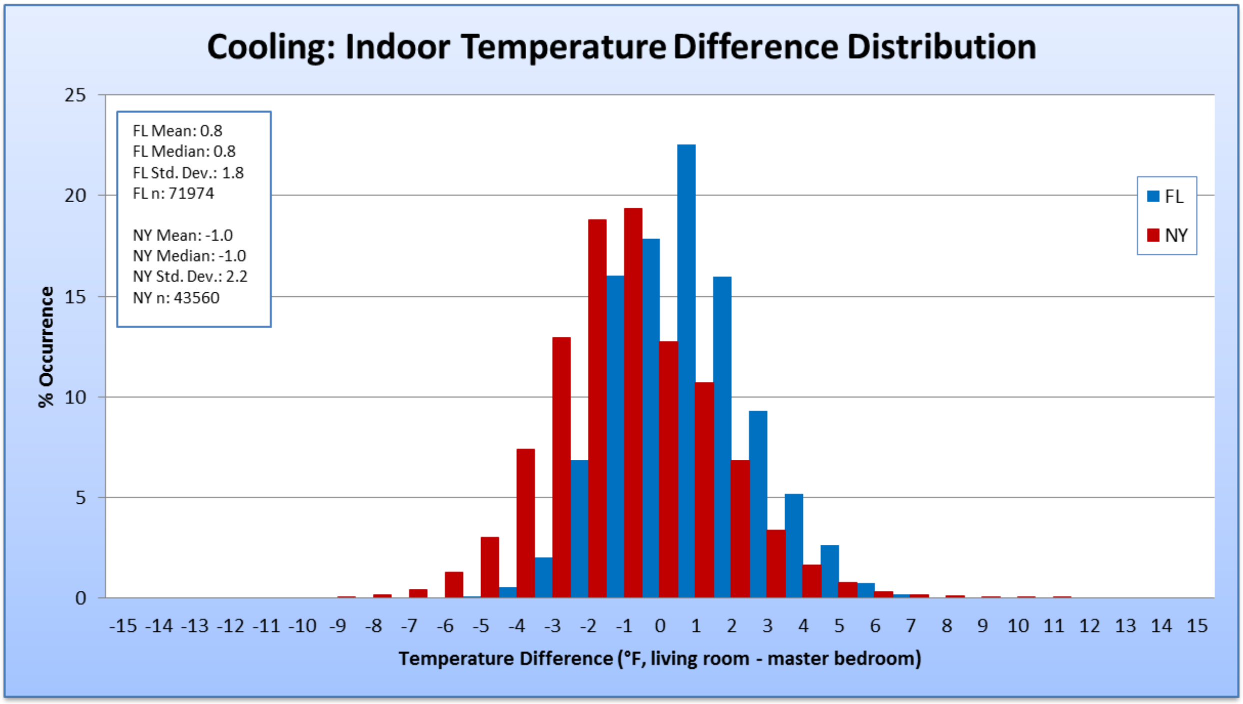


Figure 29. Comparison of Florida and New York indoor temperature difference distributions for the cooling season

Figure 30 shows the distribution for the Florida and New York homes combined into one dataset.

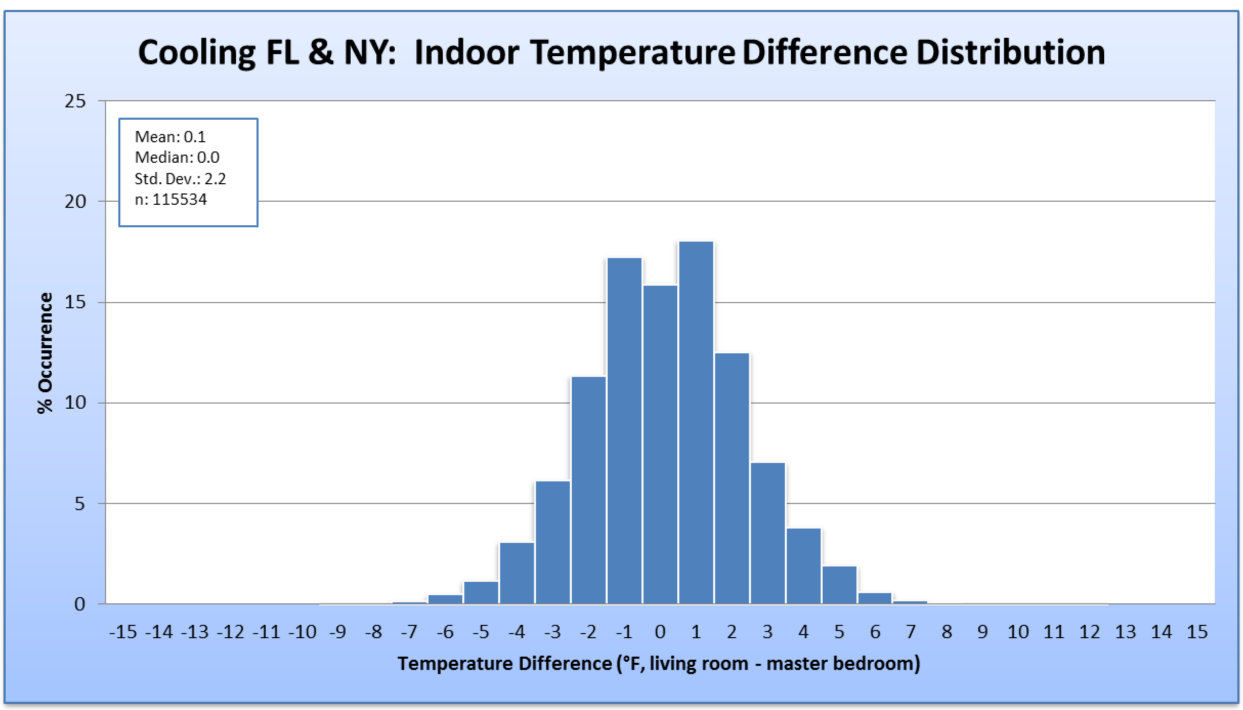


Figure 30. Indoor temperature difference distribution for the combined cooling season dataset

5.2.5 Average Hourly Indoor Temperature Difference Profiles

Figure 31 shows a comparison of the average hourly indoor temperature difference between the living room and master bedroom for Florida and New York homes. The living room is always warmer than the master bedroom for the Florida homes and colder for the New York homes. For a combined Florida and New York dataset, the living room and master bedroom are very close to the same temperature throughout the day.

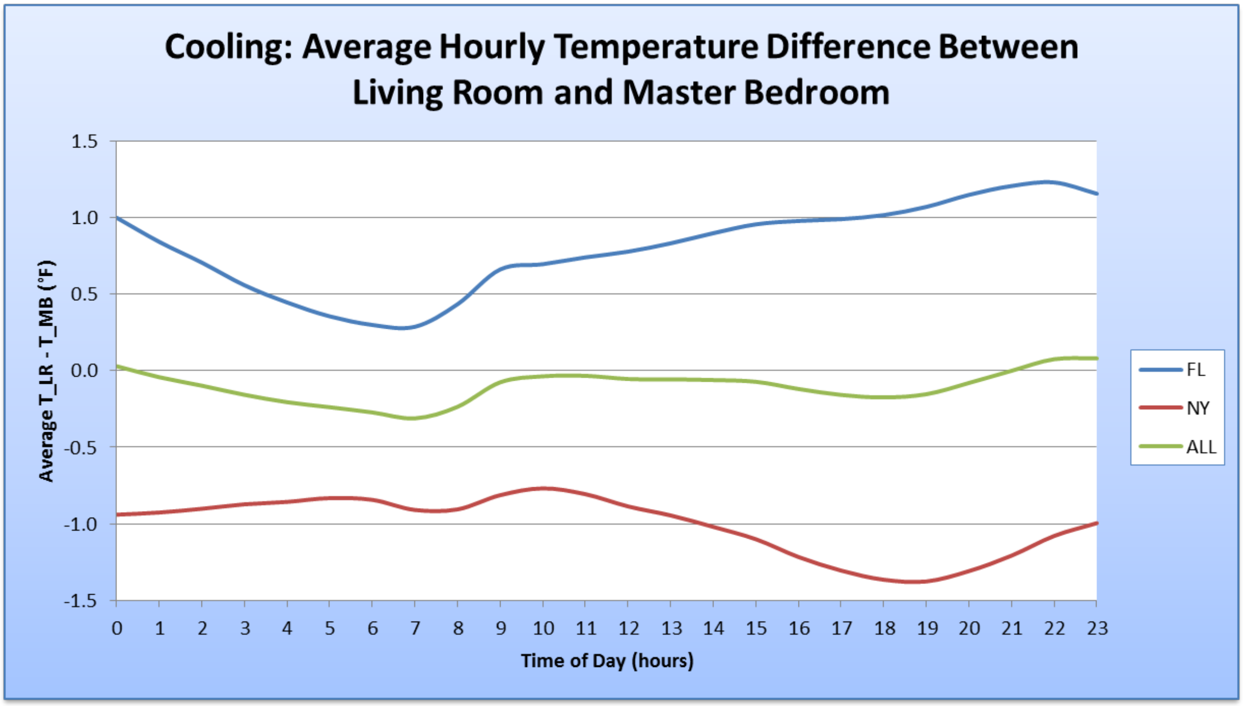


Figure 31. Comparison average hourly indoor temperature difference profiles for the cooling season

6 Heating Season Indoor Temperature Spatial Variability Analysis

This section discusses heating season indoor temperature spatial variability. This analysis examines the temperature difference between the living room and master bedroom for each house in New York and the Oregon/Washington dataset, and provides insight into the temperature variability within each house, between homes, and between climates. The heating season is defined in Section 4.

In addition to the possible causes for temperature variation within the homes mentioned in Section 5, the use of fireplaces in both the New York and Oregon/Washington datasets is likely a factor.

6.1 New York

This section describes the indoor temperature variability distribution and average hourly temperature difference profiles for the New York homes during the heating season.

6.2 Indoor Temperature Difference Distribution

Figure 32 shows the indoor temperature difference distribution for all New York homes and all hours during the heating season. On average the master bedroom tends to be warmer than the living room by 0.3°F. The standard deviation is 4.9°F. One possible explanation for this is the use of fireplaces or space heaters in separate rooms during the heating season.

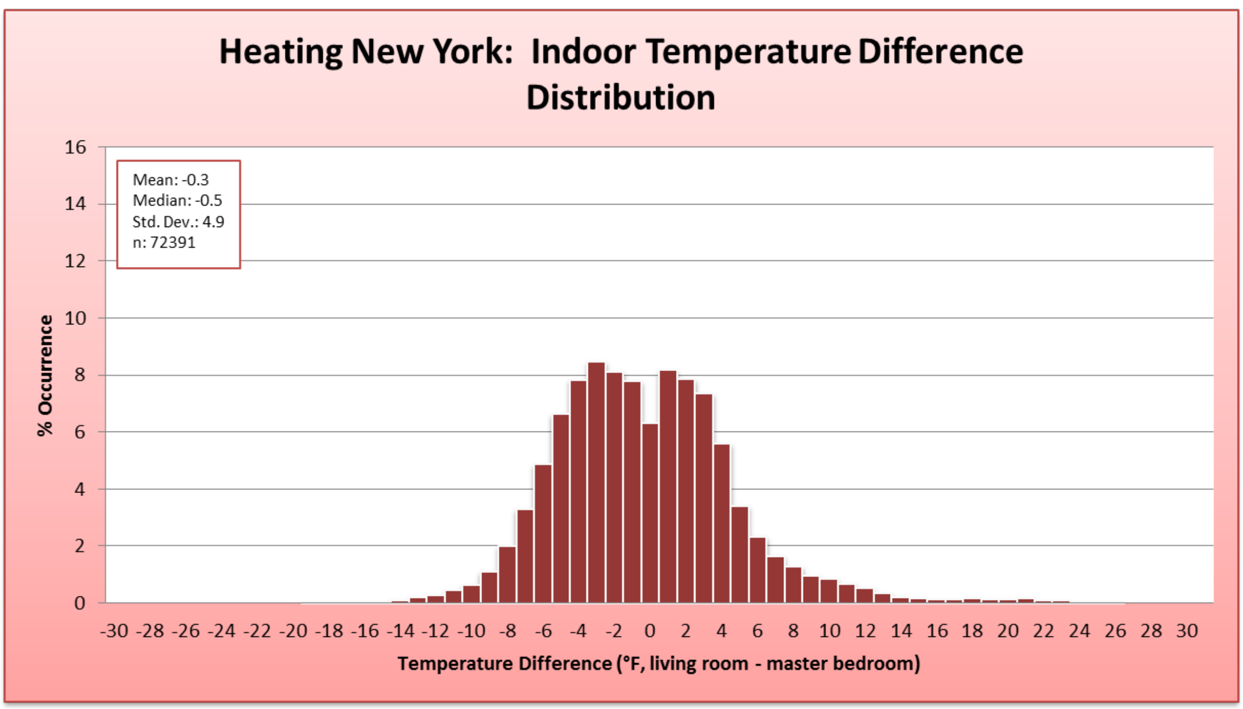


Figure 32. New York indoor temperature difference distribution for the heating season

6.2.1 Average Hourly Indoor Temperature Difference Profiles

Figure 33 shows the average hourly temperature differences between the living room and master bedroom for the New York homes. Homes 21, 24, and 32 have fireplaces, which appear to be used frequently in the evenings to heat the living rooms.

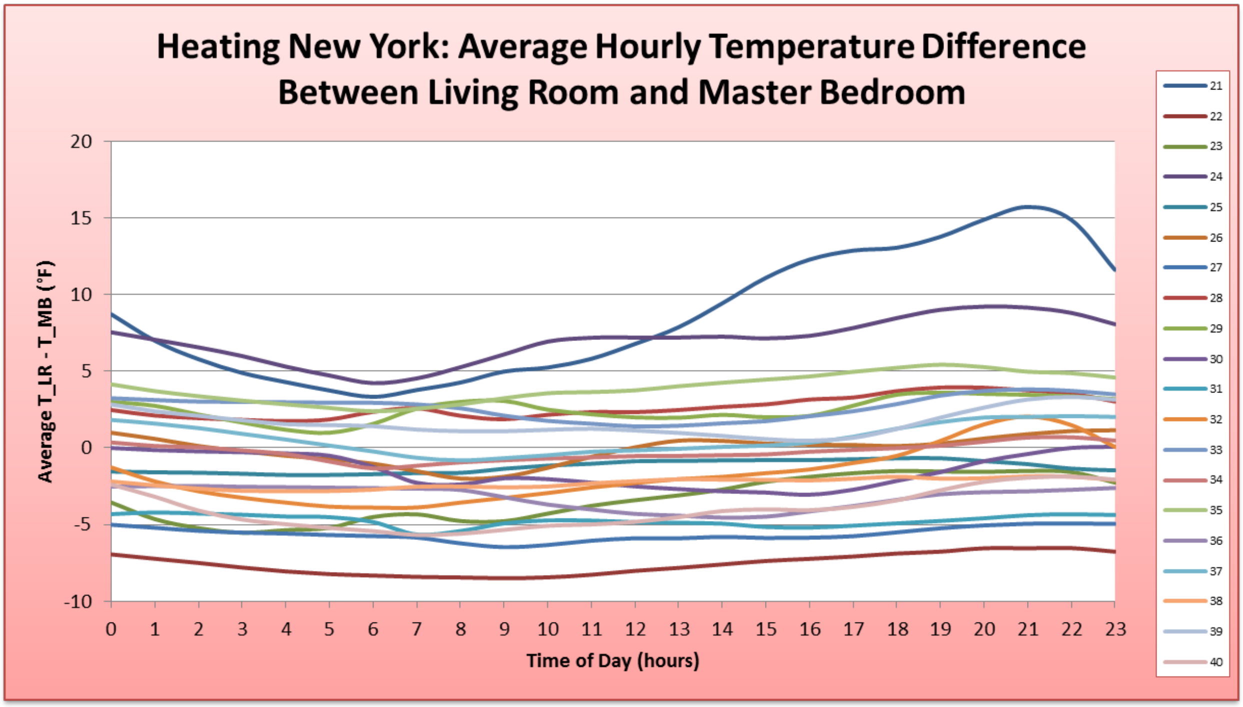


Figure 33. New York average hourly temperature difference profiles for the heating season

Figure 34 shows a comparison of the average weekday and weekend indoor temperature differences for the combined New York homes. There is not a considerable difference between the weekday and weekend profiles, except that on the weekend afternoons the living room temperature tends to be slightly warmer. Occupants may use their fireplaces more on the weekends or start them earlier in the day. Overall the temperature difference fluctuates by ±1.5°F throughout a day.

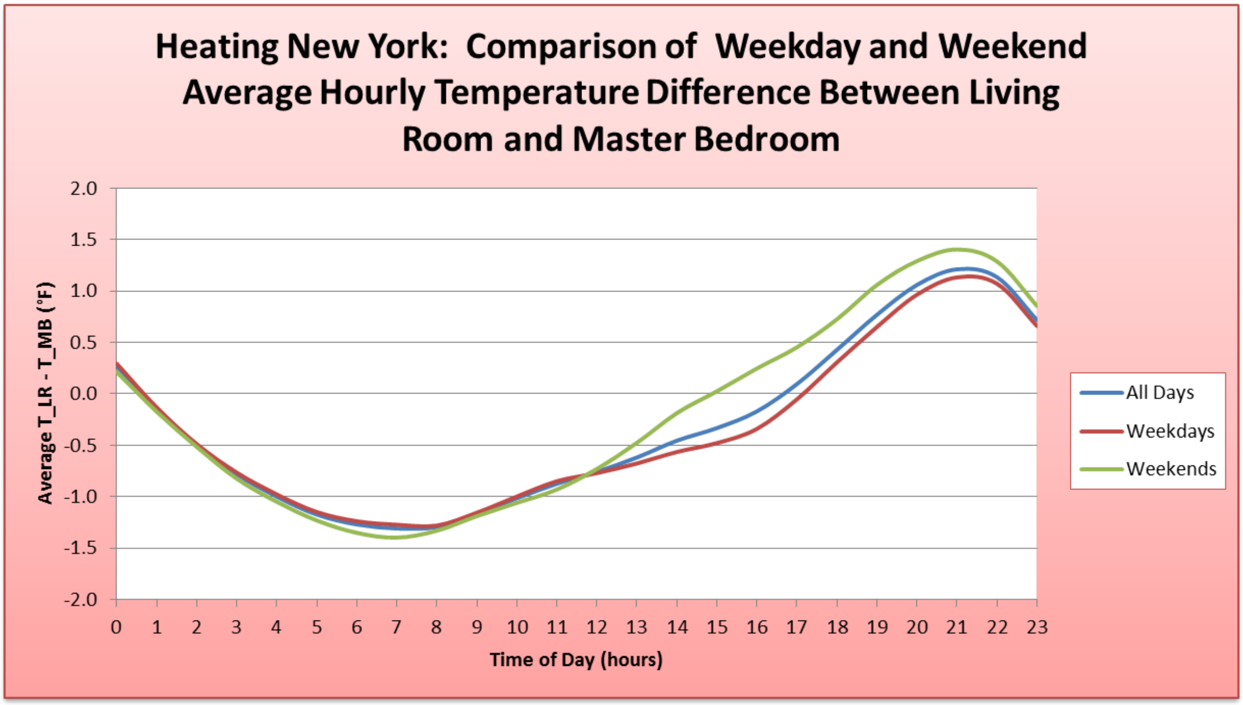


Figure 34. New York hourly weekday and weekend temperature difference profiles for the heating season

6.3 Oregon and Washington

This section describes the indoor temperature variability distribution and average hourly temperature difference profiles for the Oregon and Washington homes during the heating season.

6.3.1 Indoor Temperature Difference Distribution

Figure 35 shows the indoor temperature difference distribution for all the Oregon and Washington homes and all hours during the heating season. On average, the living room is 0.8°F warmer than the master bedroom. The standard deviation is 3.9°F. Fireplace use is one possible reason the living room is slightly warmer on average and may be responsible for the high standard deviation.

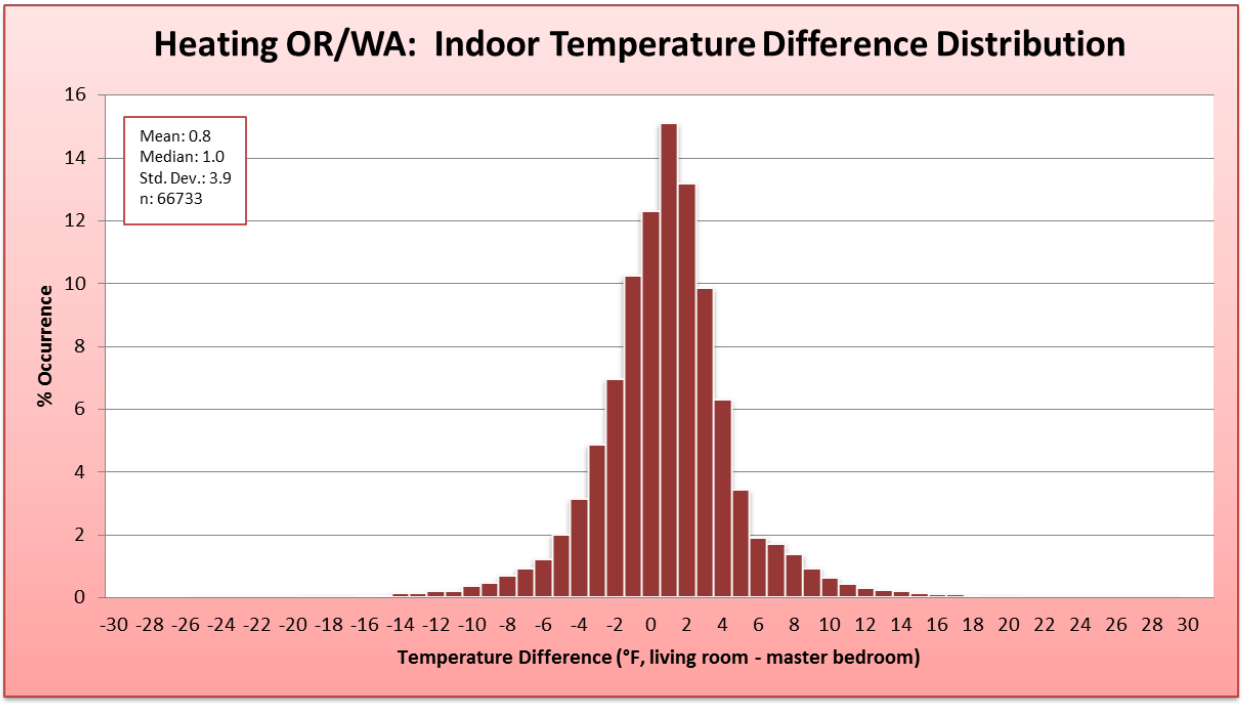


Figure 35. Oregon/Washington indoor temperature difference distribution for the heating season

6.3.2 Average Hourly Indoor Temperature Difference Profiles

Figure 36 shows the average hourly temperature difference between the living room and master bedroom for the Oregon and Washington homes. House 44 has only a wood stove for heating, which would explain why the living room is always much warmer than the master bedroom. The dip in the morning hours suggests that the occupants use the stove in the evening, allowing the living room to cool in the morning and bringing its temperature closer to the master bedroom. House 53 has electric resistance heaters that are used more often in the master bedroom. However, the house 53 profile suggests that the occupants use the living room heater mostly in the evening.

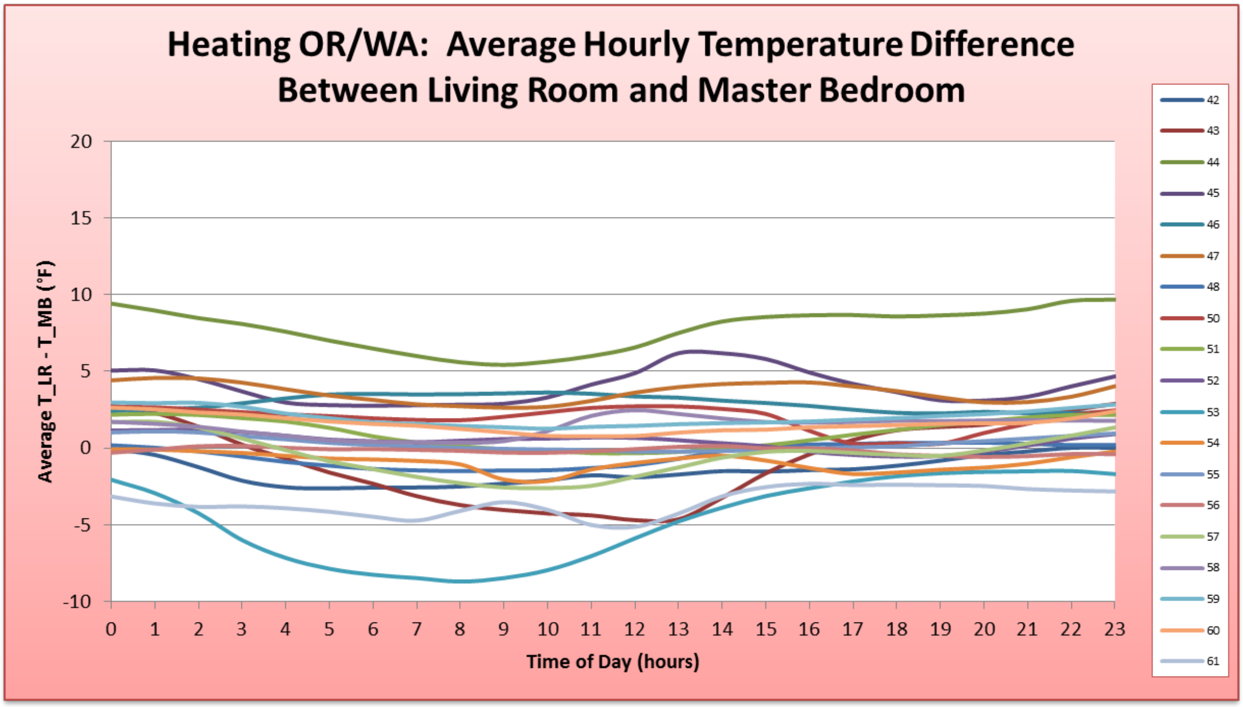


Figure 36. Oregon/Washington average hourly temperature difference profiles for the heating season

Figure 37 shows a comparison of the average weekday and weekend indoor temperature differences for the combined Oregon and Washington homes. The weekday and weekend profiles differ mostly from the time the occupants are most likely awake. The differential between the living room temperature and the master bedroom is larger during weekend daytime hours than during the weekday daytime hours. Occupants may use their fireplaces more on the weekends or spend more time in the living room, increasing internal gains. Overall the temperature difference fluctuates between –0.2°F and 2.0°F throughout a day.

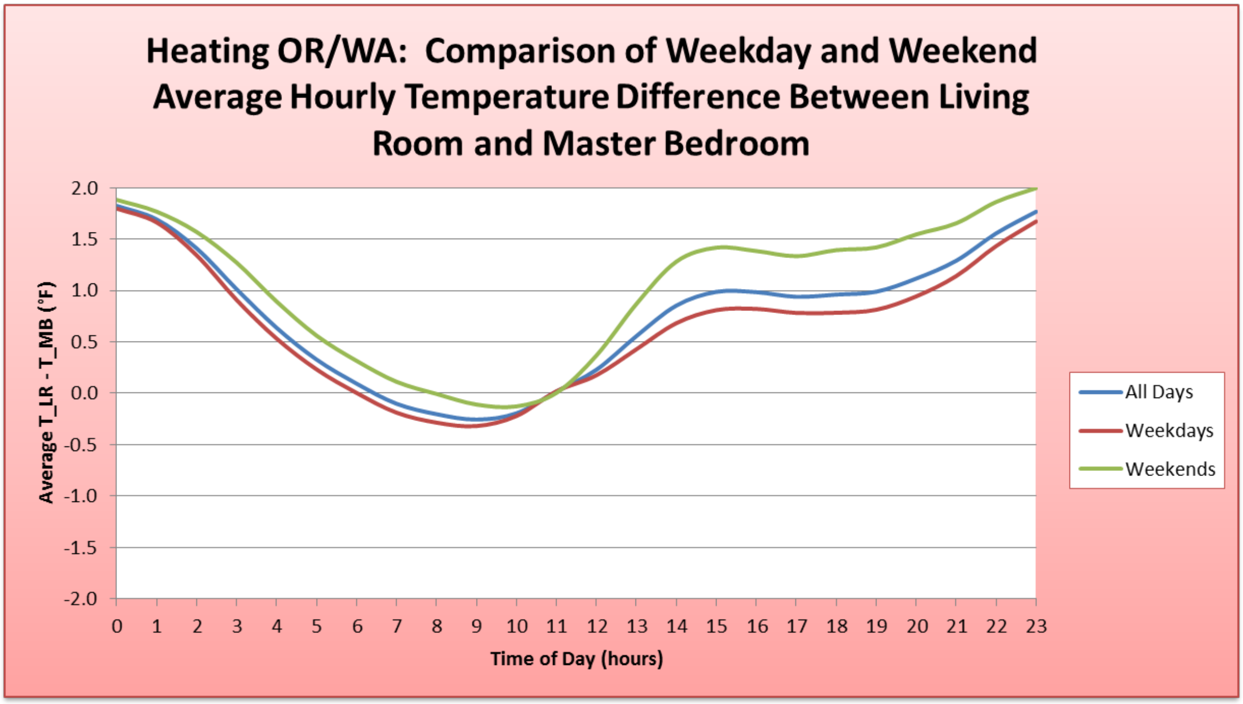


Figure 37. Oregon/Washington average hourly weekday and weekend temperature difference profiles for the heating season

6.4 Combined New York, Oregon, and Washington Homes

This section compares indoor temperature differences for the New York and Oregon/Washington homes and examines the New York and Oregon/Washington homes as one dataset.

6.4.1 Indoor Temperature Difference Distributions

Figure 38 shows a comparison of the New York and Oregon/Washington indoor temperature difference distributions. The New York distribution is flatter, having almost equal occurrence of temperature difference between 3°F and –4°F. The Oregon/Washington homes have a peak occurrence at 1°F and then drop sharply. For both distributions, the standard deviation is quite high, where the mean is close to zero.

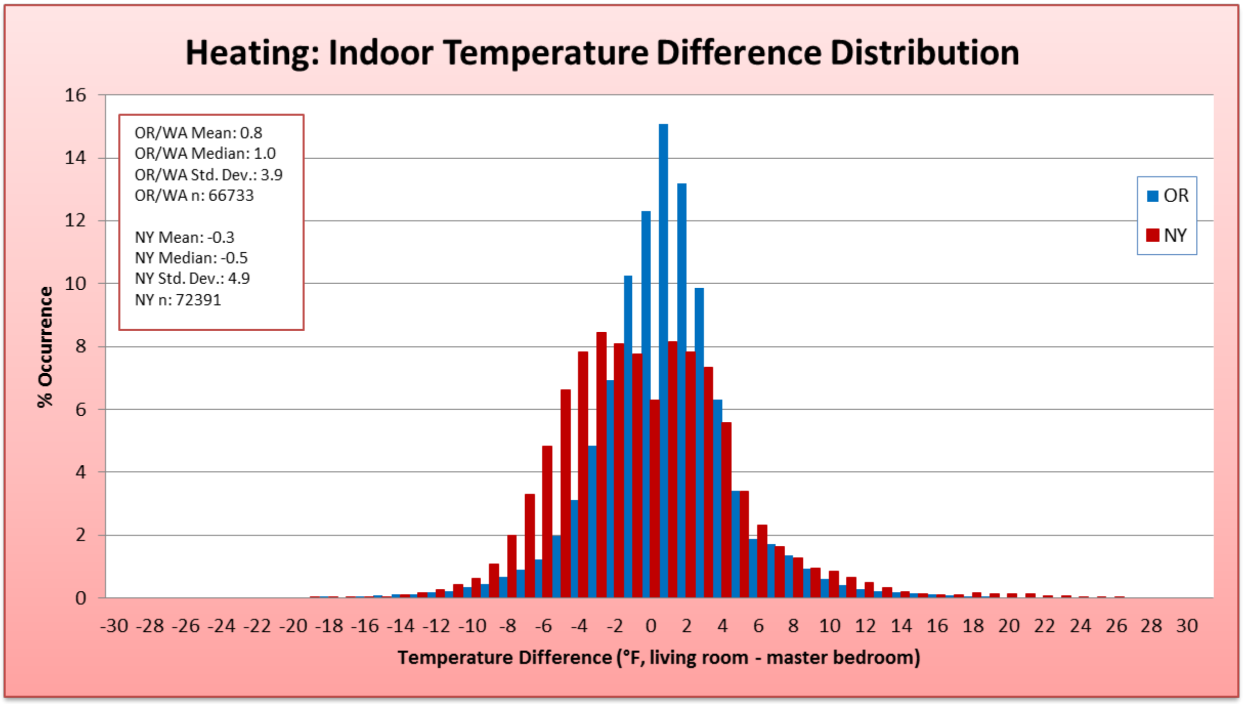


Figure 38. Comparison New York and Oregon/Washington indoor temperature difference distributions

Figure 39 shows the distribution for the New York and Oregon/Washington homes combined into one dataset. The overall mean for the temperature difference is close to zero at 0.2°F; however, the standard deviation is 4.9°F.

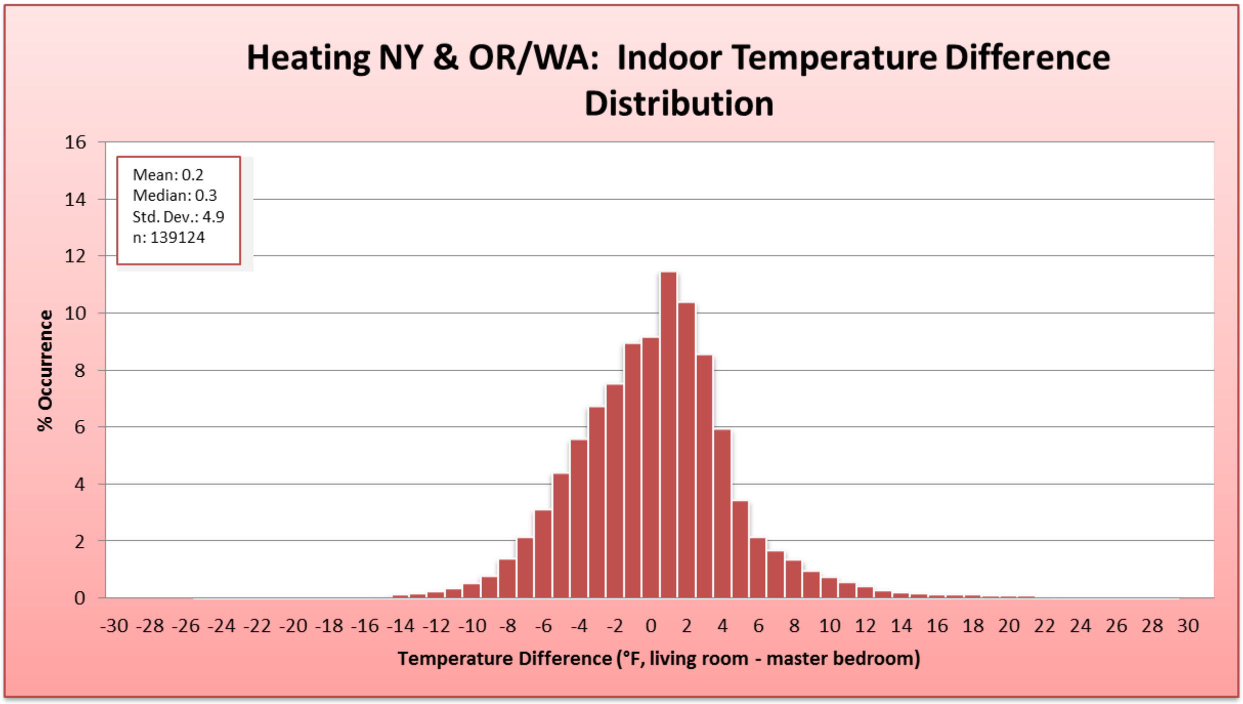


Figure 39. Indoor temperature difference distribution for the combined heating season dataset

6.4.2 Average Hourly Indoor Temperature Difference Profiles

Figure 40 shows a comparison of the average hourly indoor temperature differences between the living room and master bedroom for New York and Oregon/Washington homes. The temperature difference fluctuates between the master bedroom being warmer than the living room in the morning and the living room being warmer in the evening.

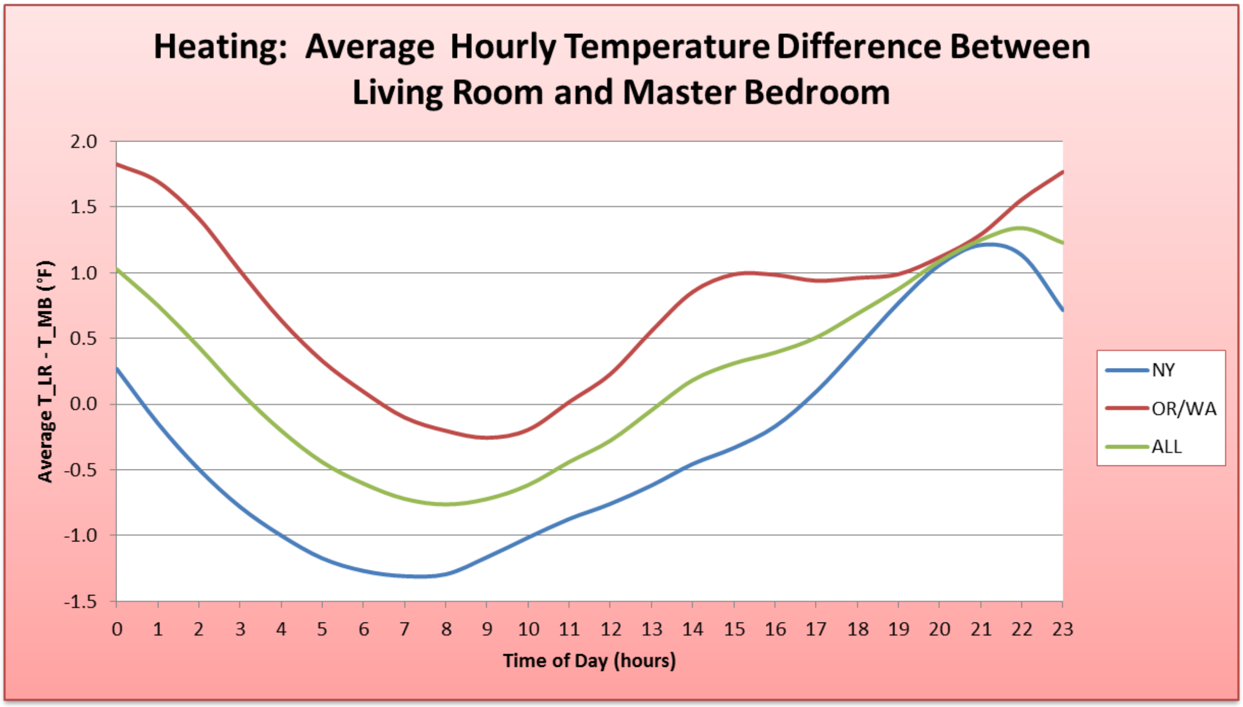


Figure 40. Comparison of average hourly indoor temperature difference profiles for the heating season

7 Case Studies

Indoor temperature variability can depend on many factors such as house characteristics and occupant behavior. This section looks at a few cases studies to show how the temperature within a house varies throughout the year and the possible causes for temperature variation within each house. For each case study the hourly temperature difference between the living room and master bedroom as a function of the temperature difference between the living room and outdoor air temperature was plotted for an entire year. A complete set of plots for all 60 homes is given in Appendix B.

7.1 Florida House 11

The indoor temperature variation in Florida house 11 (Figure 41) demonstrates the effect that solar gain can have on the temperature in different spaces. The occupants of house 11 rarely use their central A/C system and have an average living room temperature during the cooling season of 84.7°F (see Figure 4). The master bedroom temperature is higher than the living room temperature only occasionally throughout the entire year. House orientation and shading are unknown, however, given that the occupants do not actively control space temperature and the living room is almost always warmer than the master bedroom implies that the living room receives more solar and/or internal gain.

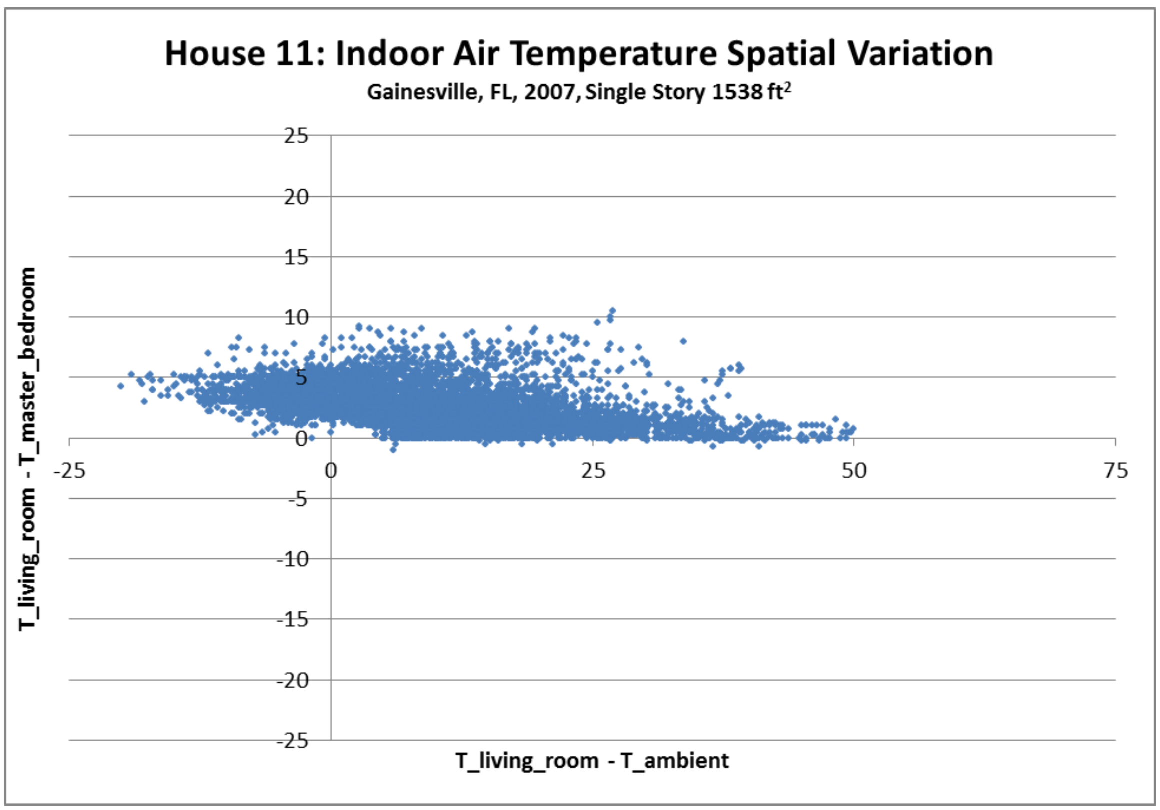


Figure 41. Florida house 11 temperature variation

7.2 New York House 21

Figure 42 shows the indoor temperature variation in New York house 21 and demonstrates how the occupants' use of the fireplace to heat the living room during the heating season can affect the indoor temperature differences. The occupants have a gas fireplace and appear to have frequently used it during the winter months to heat the living room, creating large temperature differences between the living room and master bedroom.

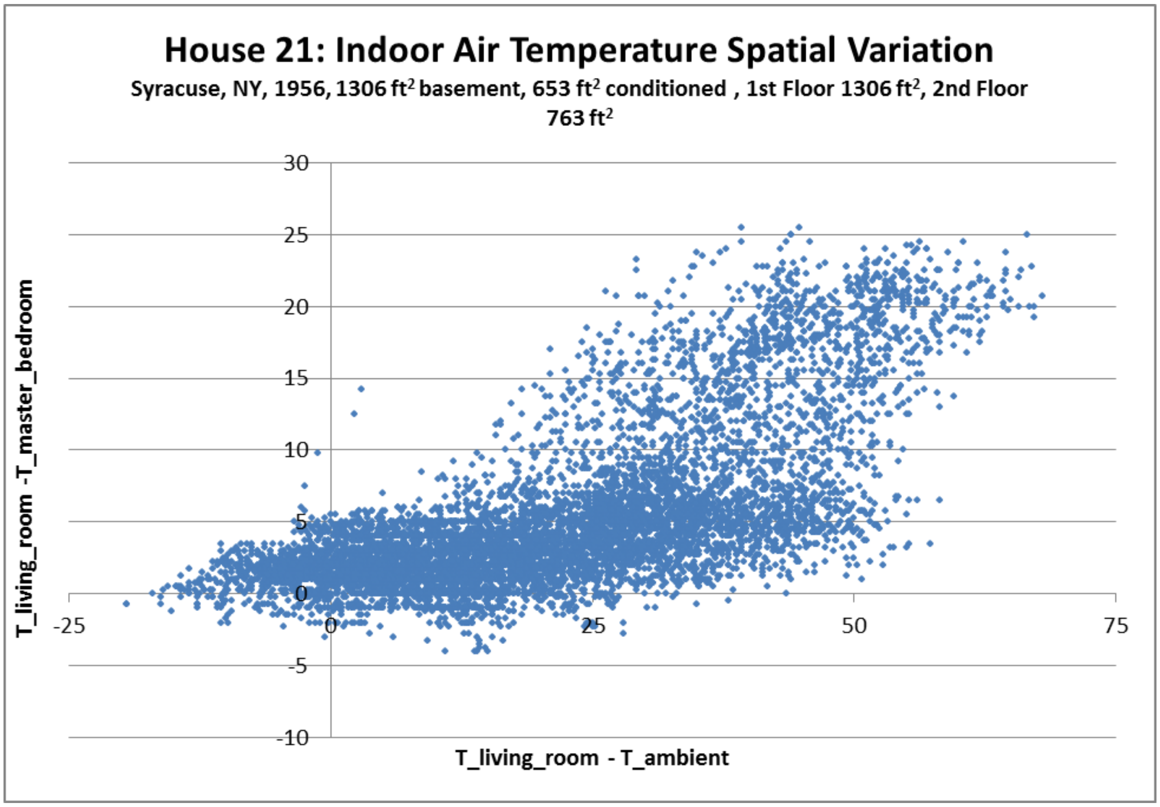


Figure 42. New York house 21 temperature variation

7.3 Washington House 53

The indoor temperature variation graph for Washington house 53 (Figure 43) demonstrates how a combination of house characteristics and occupant behavior can affect the indoor space temperature difference. House 53 is an old house that has no central heating or cooling system and has only electric resistance heaters for heating. A large number of data points show that the master bedroom is much warmer than the living room during the heating season. This implies that the occupants use the resistance heater in the master bedroom more frequently than the heater in the living room, and when using the heater in the master bedroom the heater in the living room is turned down or off. On very cold days the occupants use both the living room and master bedroom heaters, but not necessarily at the same time.

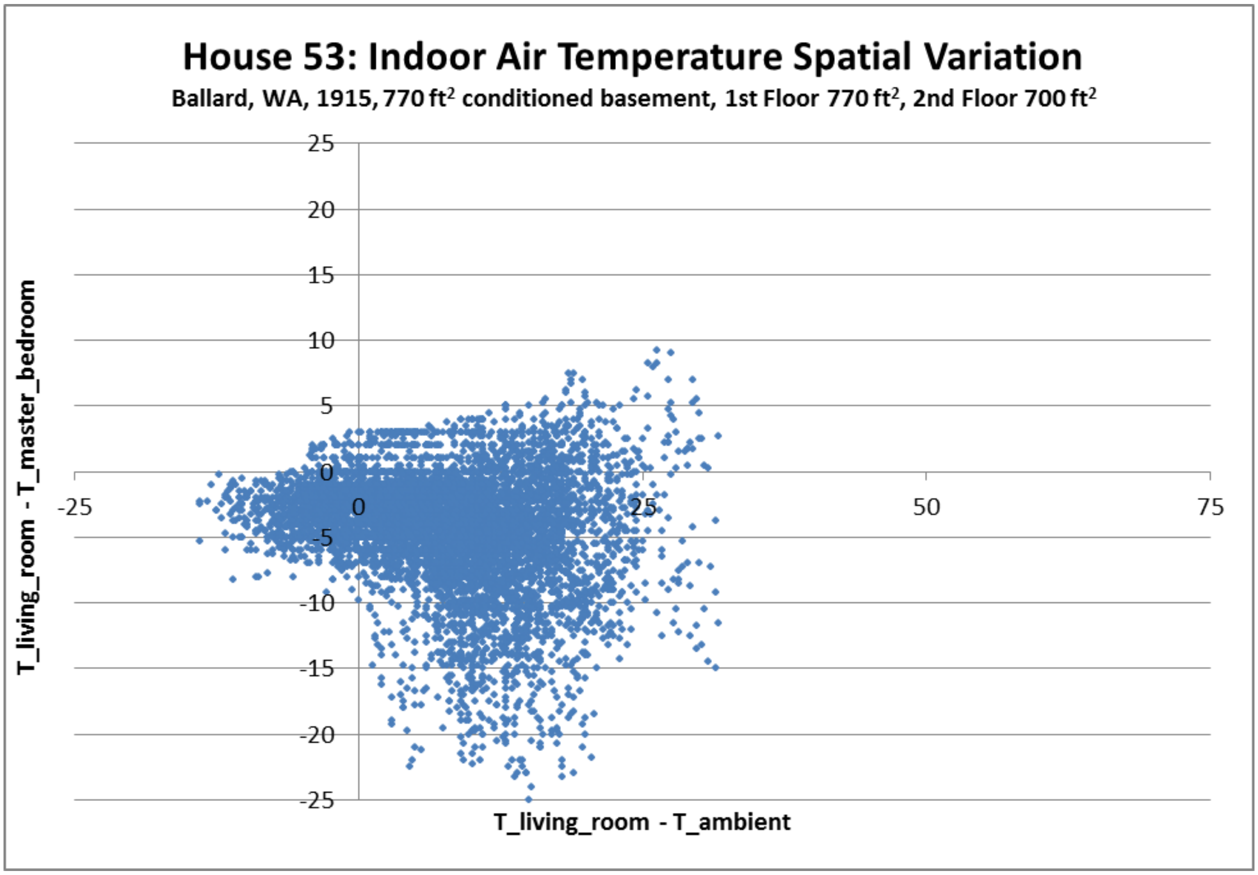


Figure 43. Washington house 53 temperature variation

8 Future Work

This section discusses continued analysis and research that could be done with this existing dataset and includes recommendations for future experiments to collect data that would help improve industry standards and modeling accuracy.

8.1 Existing Dataset

This report describes several areas of research that were completed using this dataset, but there are opportunities for continued research. For example, further examination of possible relationships between housing characteristics and indoor temperatures might provide insight into the primary drivers of temperature variations within a home.

8.2 Future Experiments

This analysis helped identify several types of information not collected during the original study that would have been useful in better understanding the drivers of indoor temperature variability and thermostat set points. The following list gives some suggestions for future experiments and additional data that should be collected along with the information that was given for this dataset.

- Collect on/off status of the space conditioning system.
- Collect thermostat settings directly from the thermostat.
- Identify the thermostat location and collect air temperature data there.
- Collect window orientation and shading information.
- Provide specific information about the placement of the temperature sensors.
- Place temperature sensors in consistent locations.
- Place a sensor near the fireplace to monitor use.
- Collect data in more rooms.
- Collect energy use data.

Collecting system status and locating a temperature sensor at the thermostat will give a better understanding of when the indoor space temperature is being controlled and what set points are being used. Adding more sensors throughout the house can provide insight into the indoor air temperatures driving heat loss or gain. Educated guesses were made in this analysis for determining fireplace use and solar heat gain influences on indoor temperature variability; placing sensors near the fireplace and gathering information about the house orientation and window placement, and ideally insolation levels at the site, will provide insight into how these factors influence indoor temperatures.

9 Conclusion

The analysis discussed in this report sought to answer several research questions pertaining to house indoor air temperature variability. For the given set of 60 homes, located in Florida, New York, and Oregon/Washington, the average living room temperature was calculated for each home, climate, and heating or cooling season. The cooling season analysis showed that the average Florida living room temperature was 78.5°F (see Figure 1), and the average living room temperature for New York was 74.0°F (see Figure 5) yielding a 4.5°F difference between the two climates. Using the Florida and New York homes as one dataset gave an overall cooling season average living room temperature of 76.8°F (see Figure 10). The heating season analysis showed that the average New York living room temperature was 65.0°F (see Figure 12), and the average living room temperature for Oregon/Washington was 63.9°F (see Figure 16), a 1.1°F difference between the two climates. Combining the New York and Oregon/Washington homes into one dataset yielded an overall heating season average living room temperature of 64.6°F (see Figure 21). These results show that set point temperatures vary with climate, and there is quite a bit of disagreement between industry standards and the heating season values calculated in this report (see Table 4), suggesting more research is needed.

This report also sought to characterize the spatial variability of indoor air temperature by looking at the difference between the living room and master bedroom temperatures. During the heating season the average indoor temperature difference was close to 0°F; however, the standard deviation was 4.9°F. This could be due to fireplace use in the winter. The standard deviation for the cooling season was 2.2°F, less than half that of the heating season. For the cooling season analysis the master bedrooms tended to be about 1°F cooler than the living room in Florida and 1°F warmer in the New York homes. The reason is unknown, but house orientation, occupant behavior, HVAC airflow variability, and other house characteristics could be factors.

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Appendix A: House Characteristics

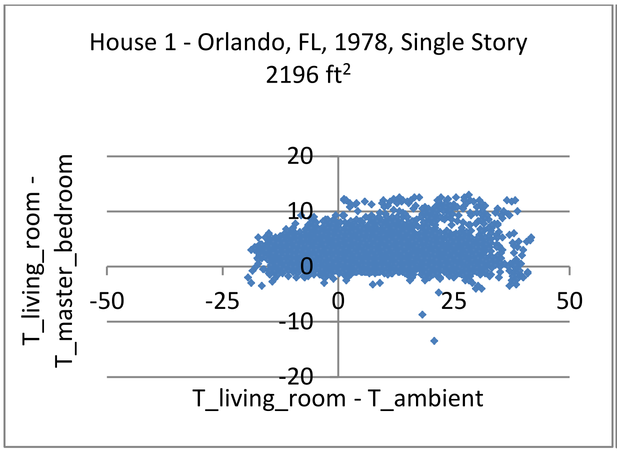
This appendix (Table 5) provides the complete list of housing characteristics that were gathered in the original study (Arena et al.).

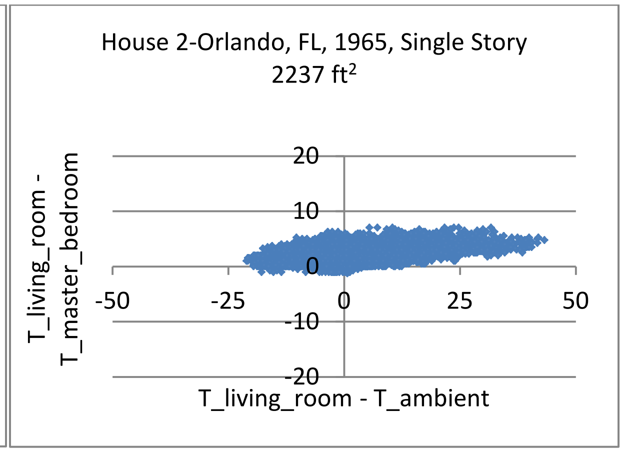
Table 5. Complete List of Available House Characteristics

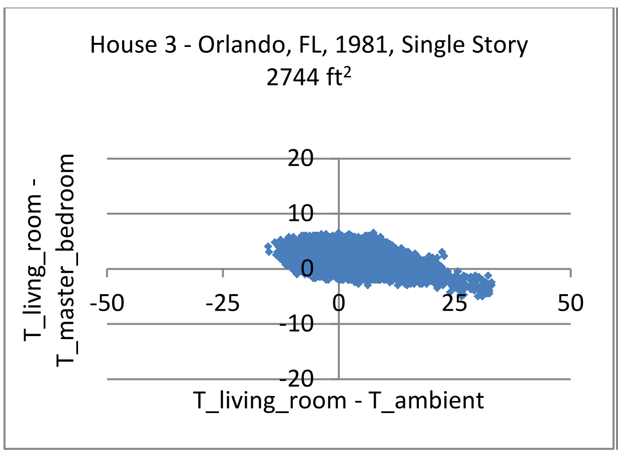
1. Zip Code	30. Window U-Value	59. Domestic Hot Water Type
2. State	31. Window SHGC	60. Domestic Hot Water Fuel
3. Year of Construction	32. Attic Insulation	61. Domestic Hot Water Venting
4. Total Basement Area	33. Attic Insulation Depth	62. Kitchen Stove Fuel
5. Conditioned Basement Area	34. Attic R-Value	63. Clothes Dryer Fuel
6. Basement Ceiling Height	35. Foundation Insulation Type	64. Fireplace or Stove
7. 1^{st} Floor Area	36. Foundation Insulation R-Value	65. Fireplace/Stove Venting
8. 1^{st} Floor Ceiling Height	37. Crawlspace Insulation	66. # Room Air Conditioners
9. 2^{nd} Floor Area	38. # AHUs	67. Room A/C Location
10. 2^{nd} Floor Ceiling Height	39. AHU Types	68. # Humidifiers
11. Other Area	40. Heating Fuel Type	69. Humidifier Location
12. # of Bedrooms	41. AHU Location	70. # Dehumidifiers
13. # of Bathrooms	42. Duct Location	71. Dehumidifier Location
14. # of Occupants	43. Heating Unit Make	72. Dryer Vented
15. # of Adults	44. Heating Unit Model	73. Bath Fan Vented
16. # of Children	45. Heating Input	74. Range Hood Vented
17. # of All-day Occupants	46. AFUE/HSPF	75. Evidence of Mold
18. # of All-day Adults	47. Cooling Unit Make	76. Location of Mold
19. #of All-day Children	48. Cooling Unit Model	77. Bath Fan CFM
20. Foundation Type	49. Cooling Output	78. Bath Fan Control
21. Moisture Sources	50. SEER	79. Blower Door House Pressure
22. Primary Floor Covering	51. Duct Leakage	80. Blower Door Fan Pressure
23. Floor R-Value	52. Central Humidifier	81. Blower Door Ring
24. Primary Siding	53. Central Humidifier Type/Location	82. ACH50
25. Structure	54. Central Dehumidifier	83. Blower Door CFM50
26. Frame Wall R-Value	55. Central Dehumidifier Type/Location	84. Blower Door Leakage Notes
27. Block Wall R-Value	56. Central Mechanical Ventilation	85. Logger Locations
28. Window Type	57. Central Mechanical Ventilation Location	86. Logger ID #'s
29. Window Frames	58. Duct Leakage Notes	87. House ID #'s

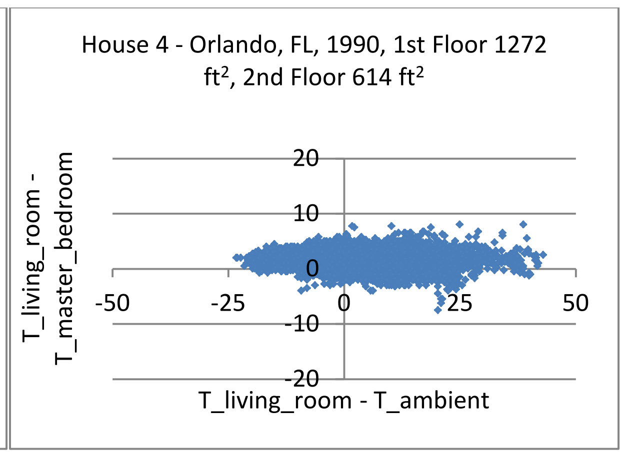
Appendix B: Indoor Temperature Variability for All Homes

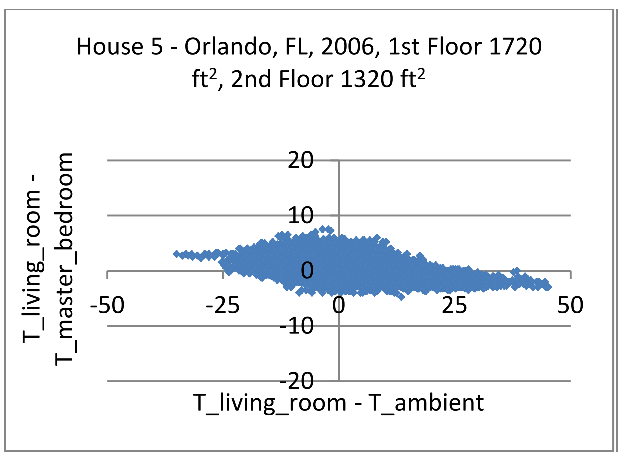
Appendix B gives the indoor temperature variation for all the homes in Florida, New York and Oregon/Washington.

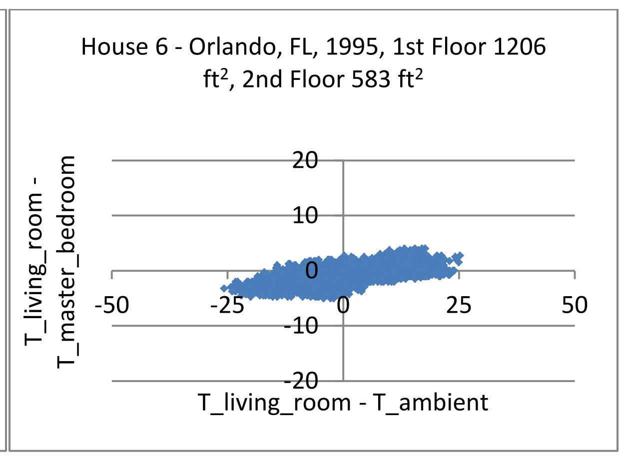


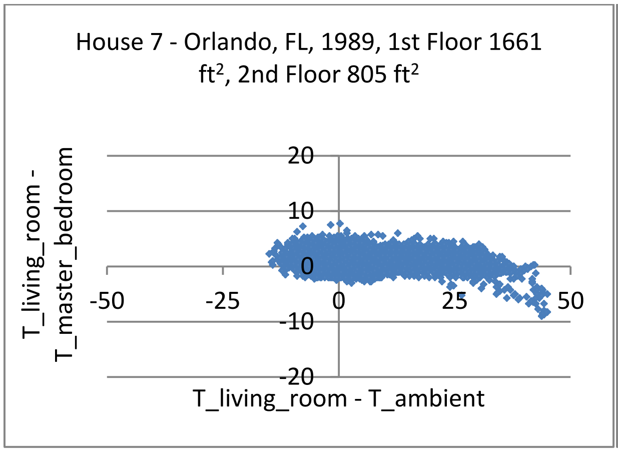


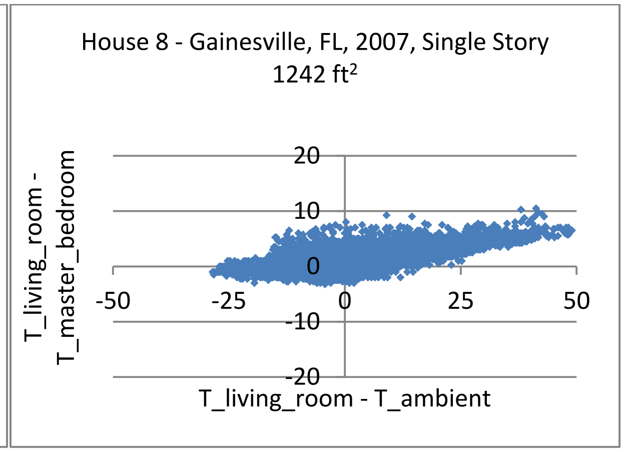


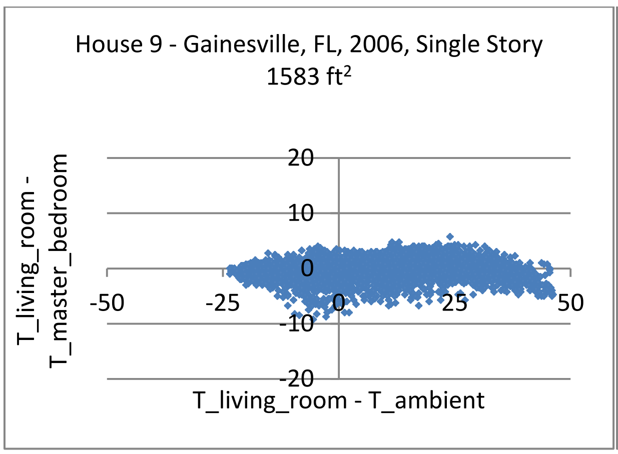


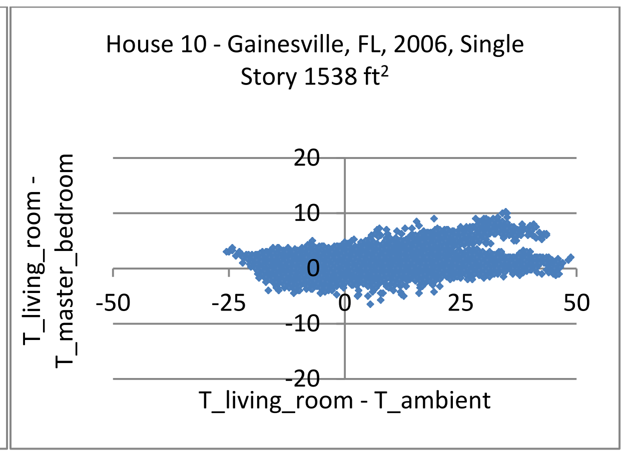


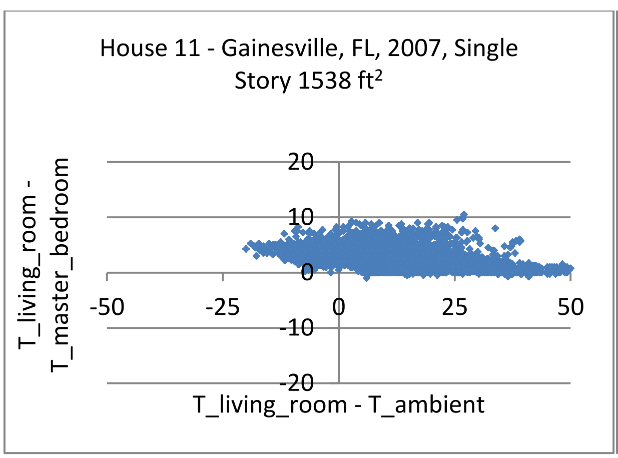


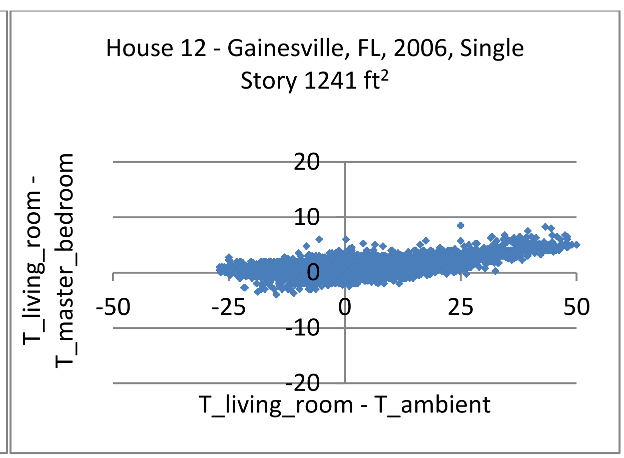

House 7 - Orlando, FL, 1989, 1st Floor 1661 ft^2, 2nd Floor 805 ft^2
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

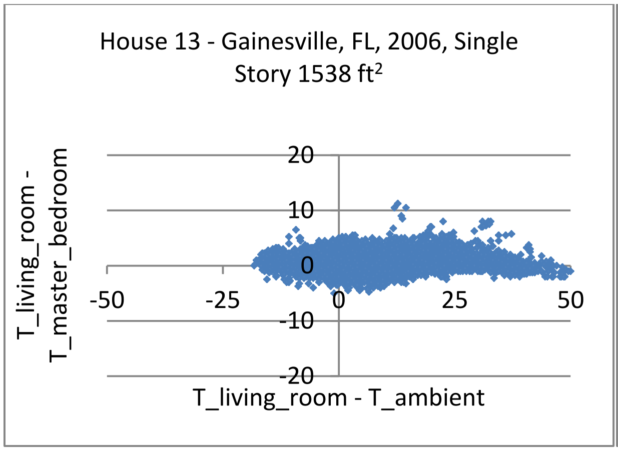

House 8 - Gainesville, FL, 2007, Single Story 1242 ft^2
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

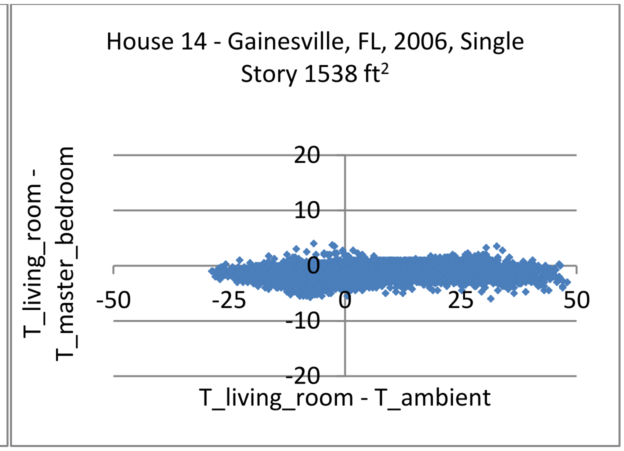

House 9 - Gainesville, FL, 2006, Single Story 1583 ft^2
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

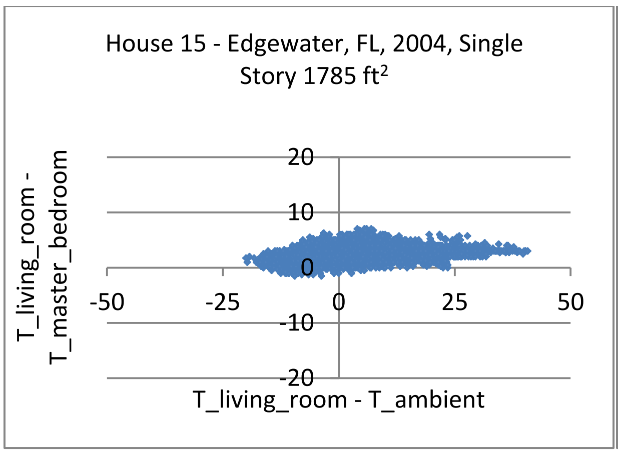

House 10 - Gainesville, FL, 2006, Single Story 1538 ft^2
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

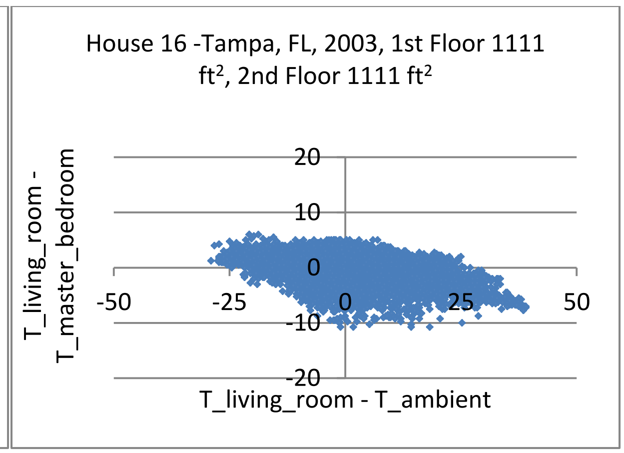

House 11 - Gainesville, FL, 2007, Single Story 1538 ft^2
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

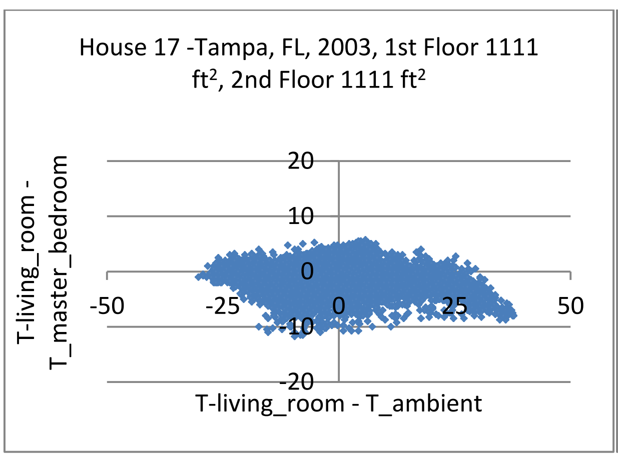

House 12 - Gainesville, FL, 2006, Single Story 1241 ft^2
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

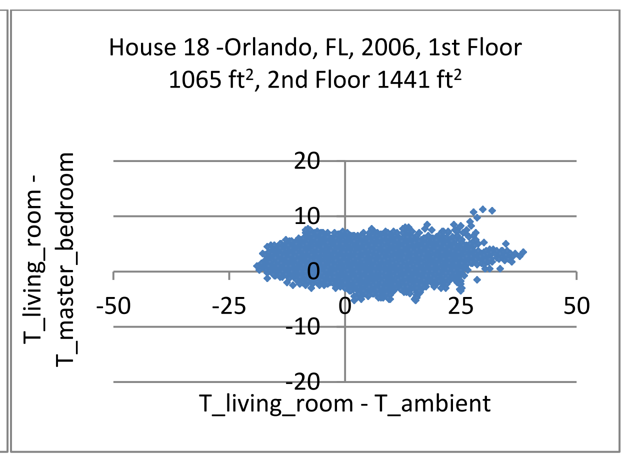

House 13 - Gainesville, FL, 2006, Single Story 1538 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

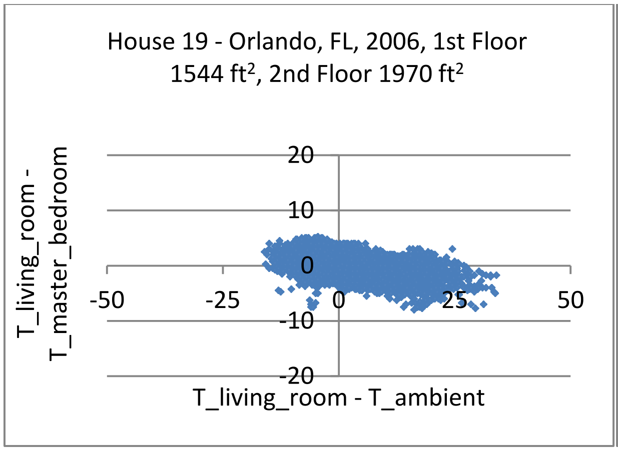

House 14 - Gainesville, FL, 2006, Single Story 1538 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

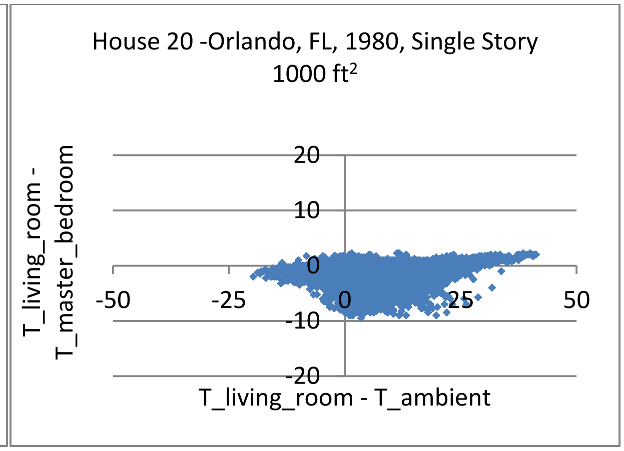

House 15 - Edgewater, FL, 2004, Single Story 1785 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

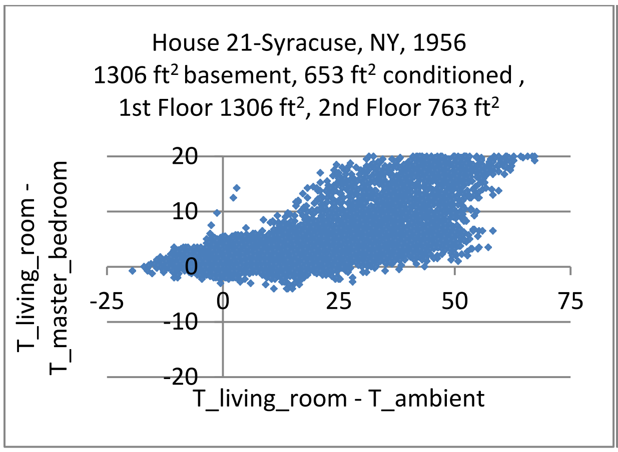

House 16 -Tampa, FL, 2003, 1st Floor 1111 ft², 2nd Floor 1111 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

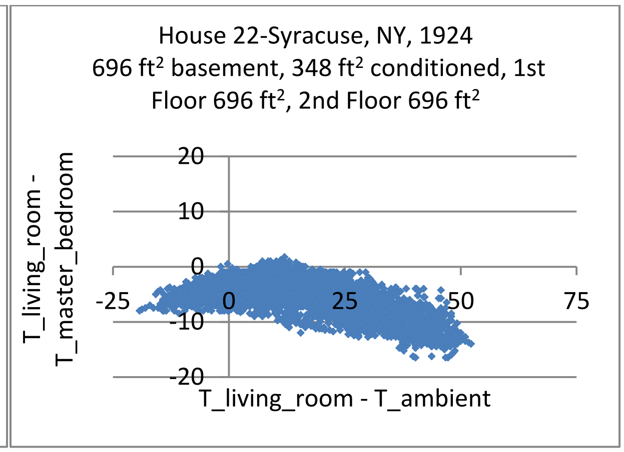

House 17 -Tampa, FL, 2003, 1st Floor 1111 ft², 2nd Floor 1111 ft²
T-living_room - T_master_bedroom
T-living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

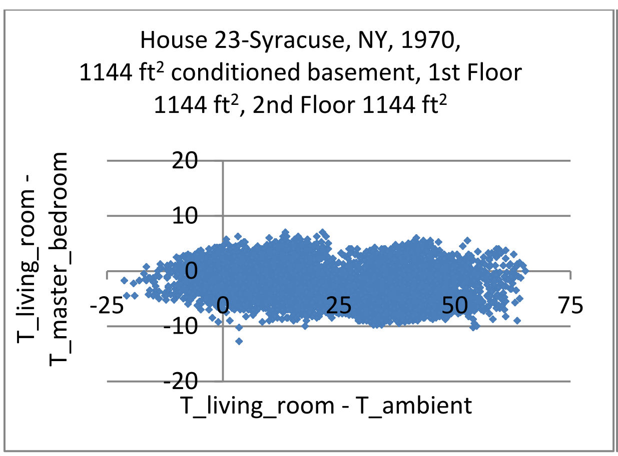

House 18 -Orlando, FL, 2006, 1st Floor 1065 ft², 2nd Floor 1441 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

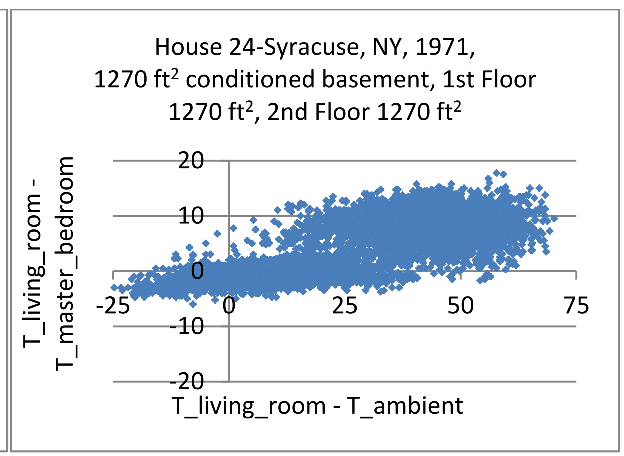

House 19 - Orlando, FL, 2006, 1st Floor
1544 ft^2, 2nd Floor 1970 ft^2
T_living_room -
T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

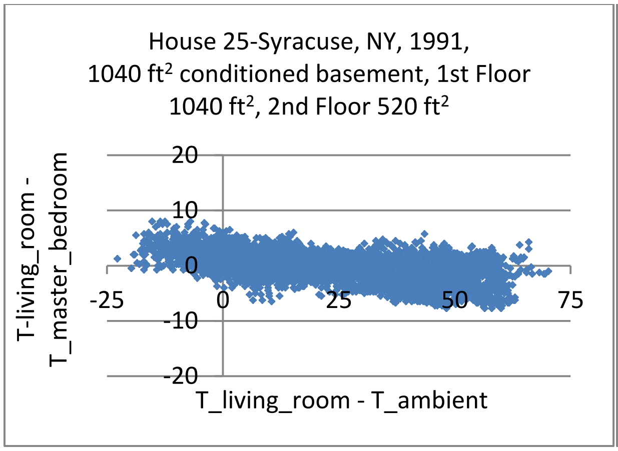

House 20 -Orlando, FL, 1980, Single Story
1000 ft^2
T_living_room -
T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-50
-25
0
25
50

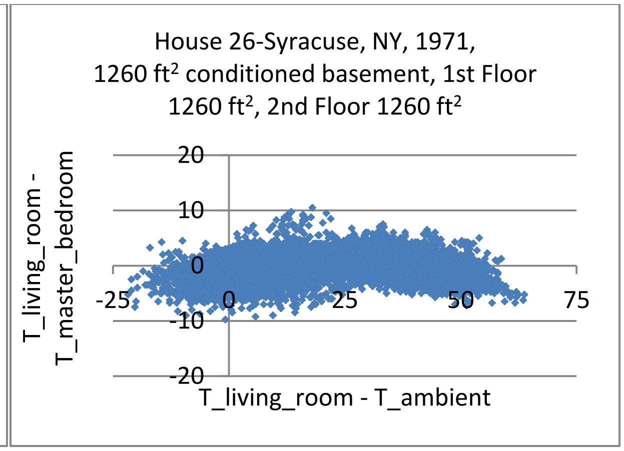

House 21-Syracuse, NY, 1956
1306 ft^2 basement, 653 ft^2 conditioned ,
1st Floor 1306 ft^2, 2nd Floor 763 ft^2
T_living_room -
T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

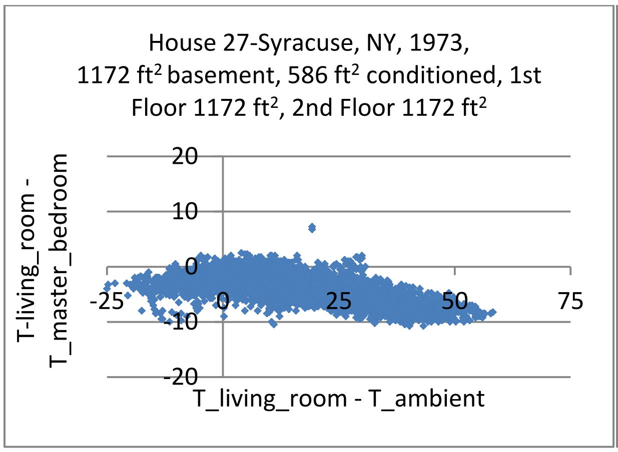

House 22-Syracuse, NY, 1924
696 ft^2 basement, 348 ft^2 conditioned, 1st
Floor 696 ft^2, 2nd Floor 696 ft^2
T_living_room -
T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

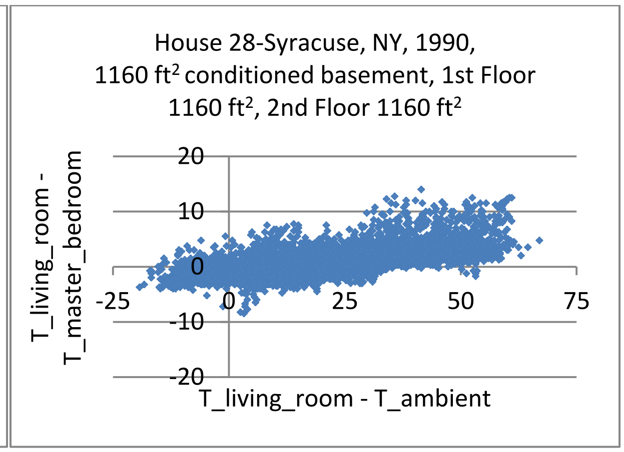

House 23-Syracuse, NY, 1970,
1144 ft^2 conditioned basement, 1st Floor
1144 ft^2, 2nd Floor 1144 ft^2
T_living_room -
T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

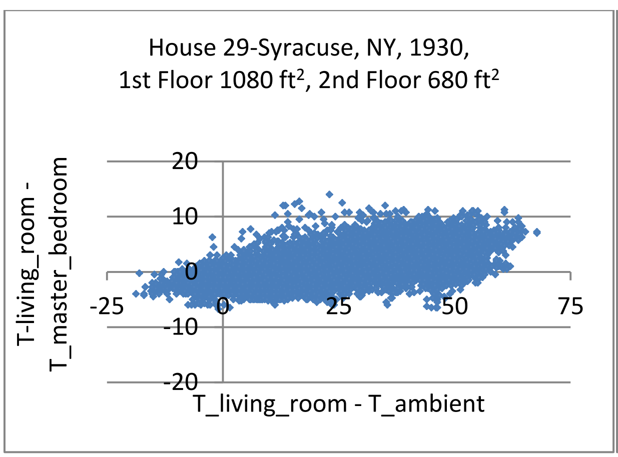

House 24-Syracuse, NY, 1971,
1270 ft^2 conditioned basement, 1st Floor
1270 ft^2, 2nd Floor 1270 ft^2
T_living_room -
T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

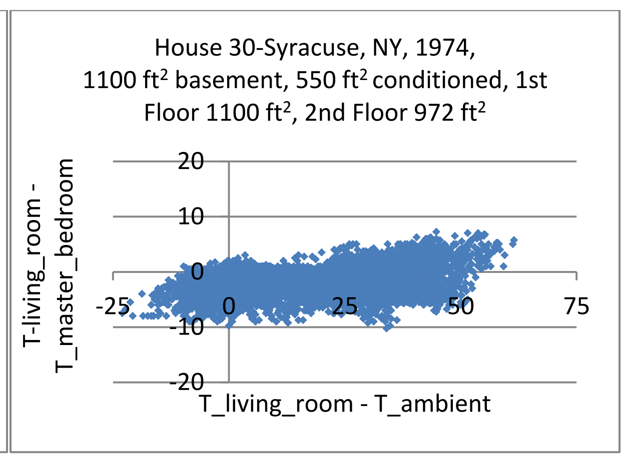

House 25-Syracuse, NY, 1991,
1040 ft² conditioned basement, 1st Floor
1040 ft², 2nd Floor 520 ft²
T-living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient

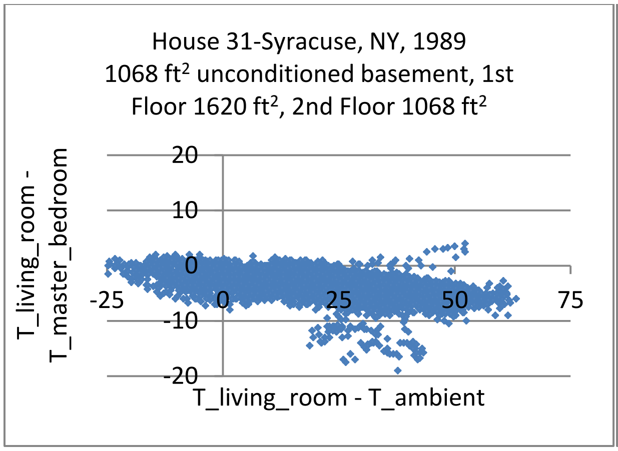

House 26-Syracuse, NY, 1971,
1260 ft² conditioned basement, 1st Floor
1260 ft², 2nd Floor 1260 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient

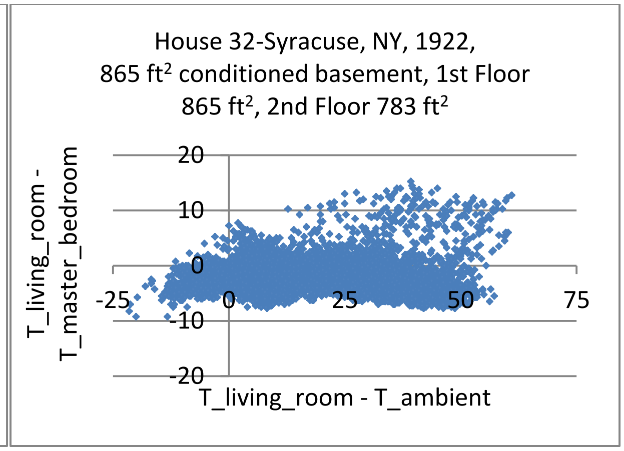

House 27-Syracuse, NY, 1973,
1172 ft² basement, 586 ft² conditioned, 1st
Floor 1172 ft², 2nd Floor 1172 ft²
T-living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient

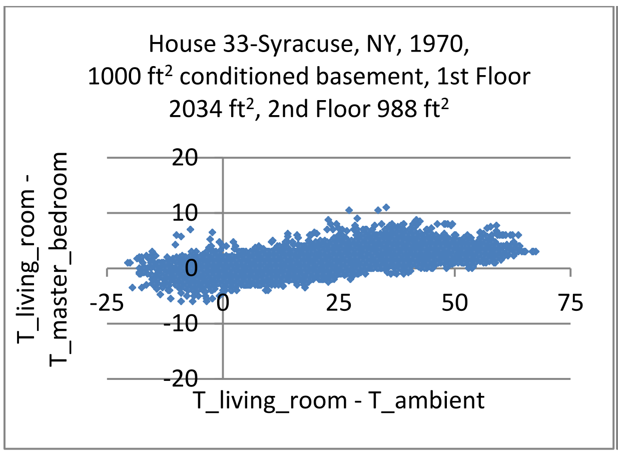

House 28-Syracuse, NY, 1990,
1160 ft² conditioned basement, 1st Floor
1160 ft², 2nd Floor 1160 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient

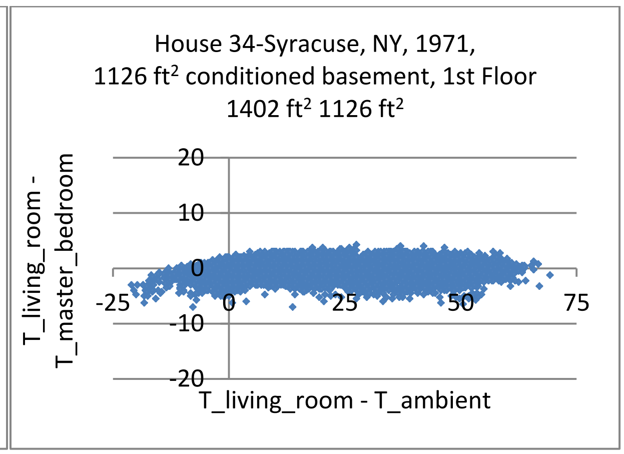

House 29-Syracuse, NY, 1930,
1st Floor 1080 ft², 2nd Floor 680 ft²
T-living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient

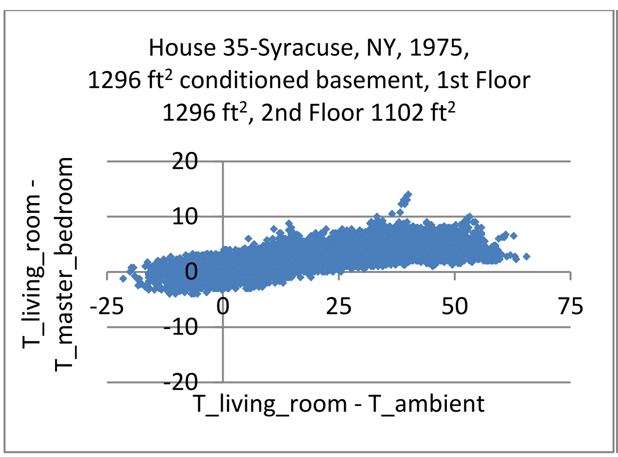

House 30-Syracuse, NY, 1974,
1100 ft² basement, 550 ft² conditioned, 1st
Floor 1100 ft², 2nd Floor 972 ft²
T-living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient

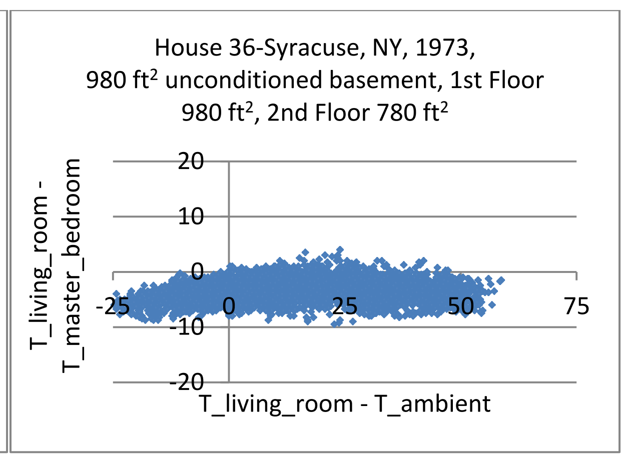

House 31-Syracuse, NY, 1989
1068 ft² unconditioned basement, 1st Floor 1620 ft², 2nd Floor 1068 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

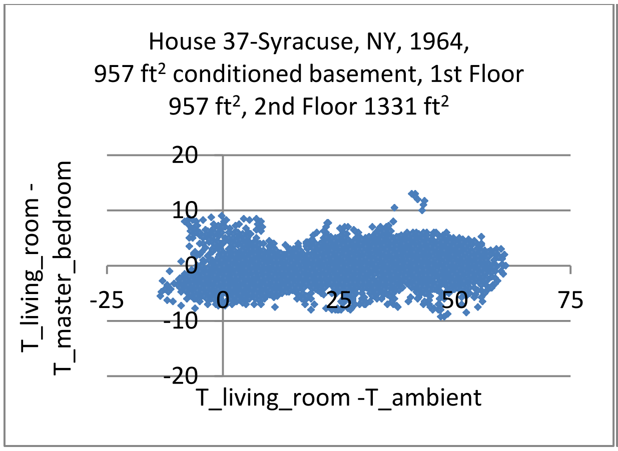

House 32-Syracuse, NY, 1922,
865 ft² conditioned basement, 1st Floor 865 ft², 2nd Floor 783 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

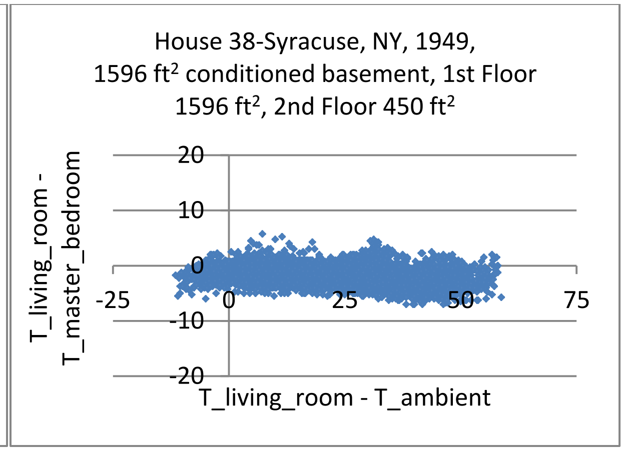

House 33-Syracuse, NY, 1970,
1000 ft² conditioned basement, 1st Floor 2034 ft², 2nd Floor 988 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

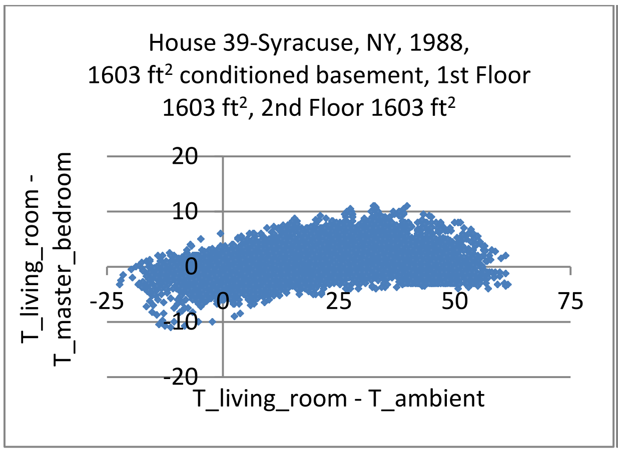

House 34-Syracuse, NY, 1971,
1126 ft² conditioned basement, 1st Floor 1402 ft² 1126 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

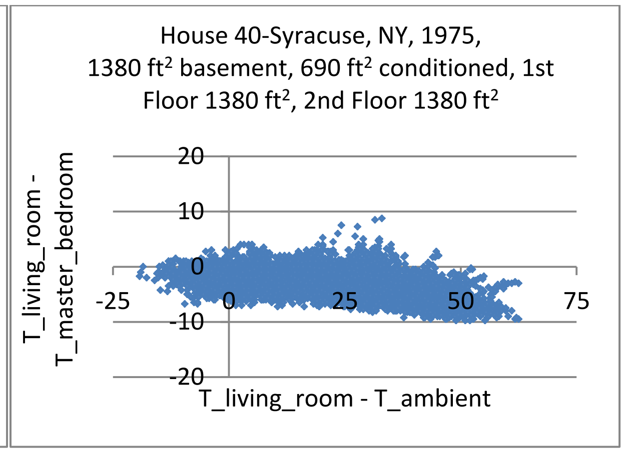

House 35-Syracuse, NY, 1975,
1296 ft² conditioned basement, 1st Floor 1296 ft², 2nd Floor 1102 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

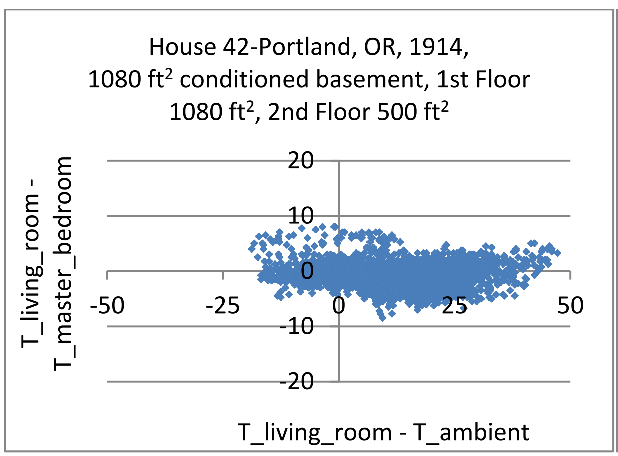

House 36-Syracuse, NY, 1973,
980 ft² unconditioned basement, 1st Floor 980 ft², 2nd Floor 780 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
20
10
0
-10
-20
-25
0
25
50
75

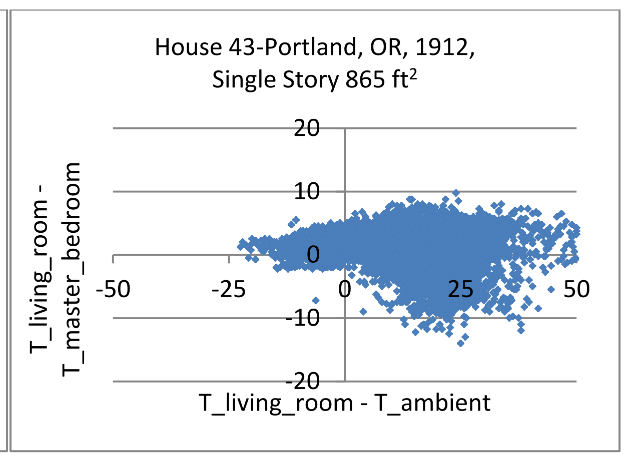

House 37-Syracuse, NY, 1964,
957 ft² conditioned basement, 1st Floor
957 ft², 2nd Floor 1331 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room -T_ambient

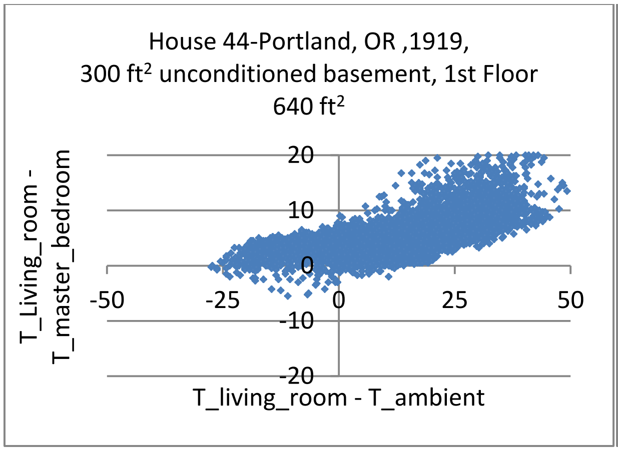

House 38-Syracuse, NY, 1949,
1596 ft² conditioned basement, 1st Floor
1596 ft², 2nd Floor 450 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient


House 39-Syracuse, NY, 1988,
1603 ft² conditioned basement, 1st Floor
1603 ft², 2nd Floor 1603 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient


House 40-Syracuse, NY, 1975,
1380 ft² basement, 690 ft² conditioned, 1st
Floor 1380 ft², 2nd Floor 1380 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-25
0
25
50
75
T_living_room - T_ambient


House 42-Portland, OR, 1914,
1080 ft² conditioned basement, 1st Floor
1080 ft², 2nd Floor 500 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-50
-25
0
25
50
T_living_room - T_ambient


House 43-Portland, OR, 1912,
Single Story 865 ft²
T_living_room -
T_master_bedroom
20
10
0
-10
-20
-50
-25
0
25
50
T_living_room - T_ambient


House 44-Portland, OR ,1919,
300 ft² unconditioned basement, 1st Floor
640 ft²
T_Living_room -
T_master_bedroom
20
10
0
-10
-20
-50
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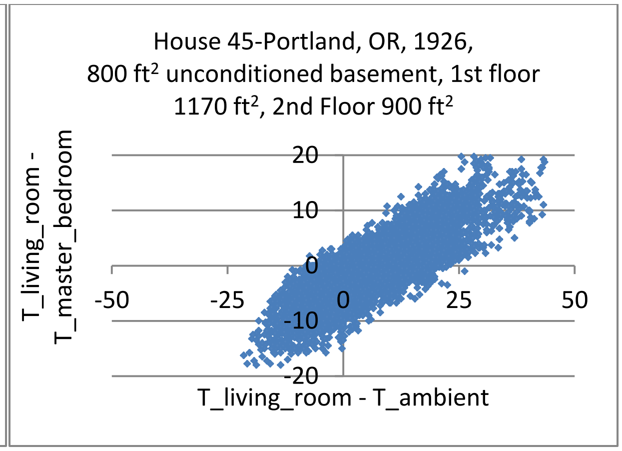
T_living_room - T_ambient


House 45-Portland, OR, 1926,
800 ft² unconditioned basement, 1st floor
1170 ft², 2nd Floor 900 ft²
T_living_room -
T_master_bedroom
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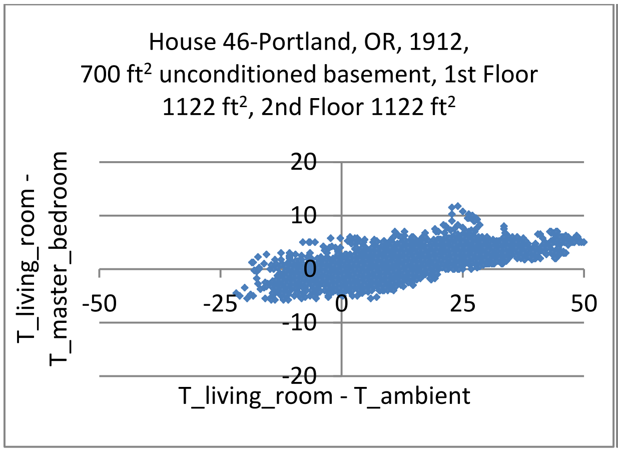
T_living_room - T_ambient


House 46-Portland, OR, 1912,
700 ft² unconditioned basement, 1st Floor
1122 ft², 2nd Floor 1122 ft²
T_living_room -
T_master_bedroom
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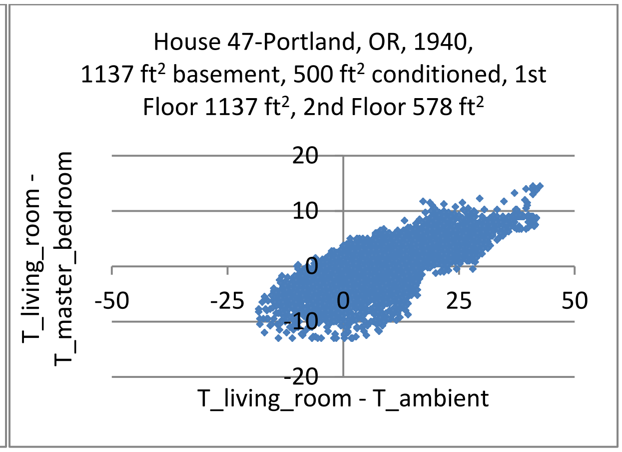
T_living_room - T_ambient


House 47-Portland, OR, 1940,
1137 ft² basement, 500 ft² conditioned, 1st
Floor 1137 ft², 2nd Floor 578 ft²
T_living_room -
T_master_bedroom
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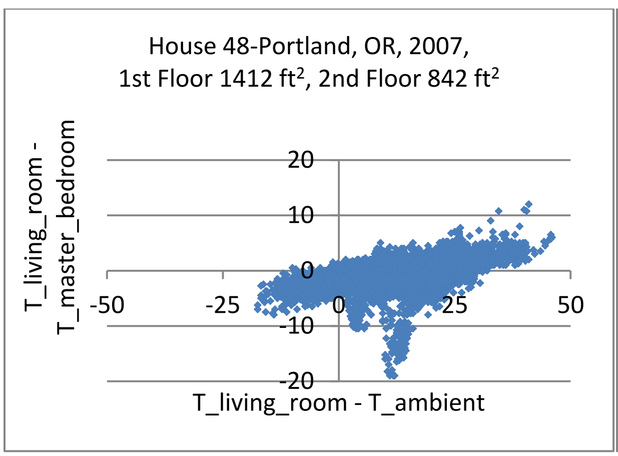
T_living_room - T_ambient


House 48-Portland, OR, 2007,
1st Floor 1412 ft², 2nd Floor 842 ft²
T_living_room -
T_master_bedroom
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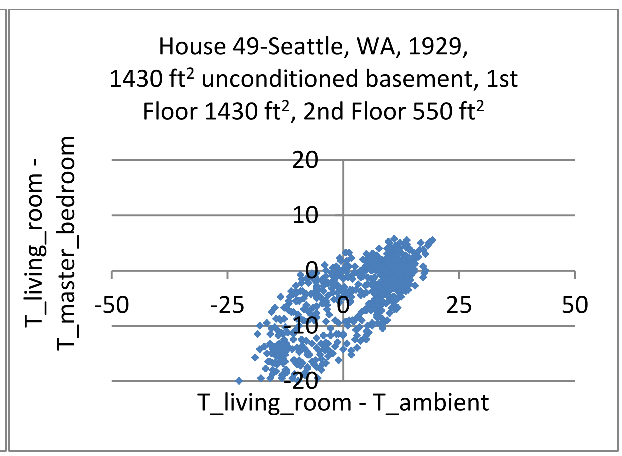
T_living_room - T_ambient


House 49-Seattle, WA, 1929,
1430 ft² unconditioned basement, 1st
Floor 1430 ft², 2nd Floor 550 ft²
T_living_room -
T_master_bedroom
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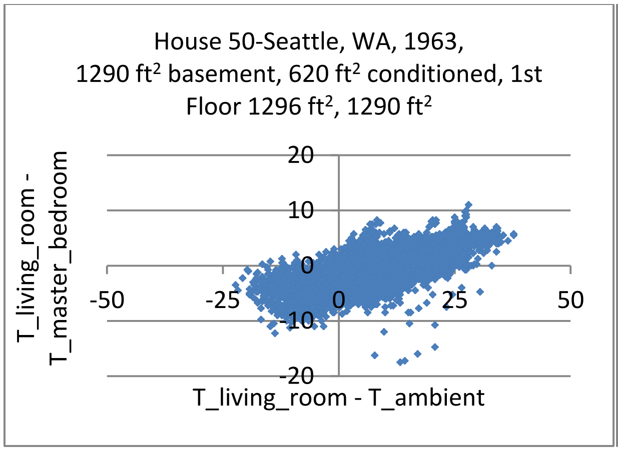
T_living_room - T_ambient


House 50-Seattle, WA, 1963,
1290 ft² basement, 620 ft² conditioned, 1st Floor 1296 ft², 1290 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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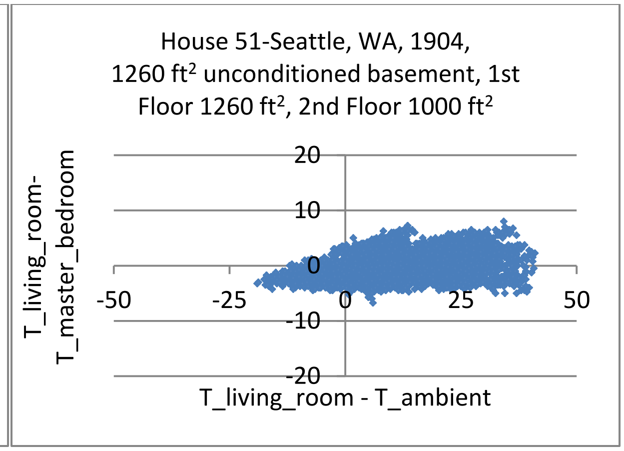
House 51-Seattle, WA, 1904,
1260 ft² unconditioned basement, 1st Floor 1260 ft², 2nd Floor 1000 ft²
T_living_room- T_master_bedroom
T_living_room - T_ambient
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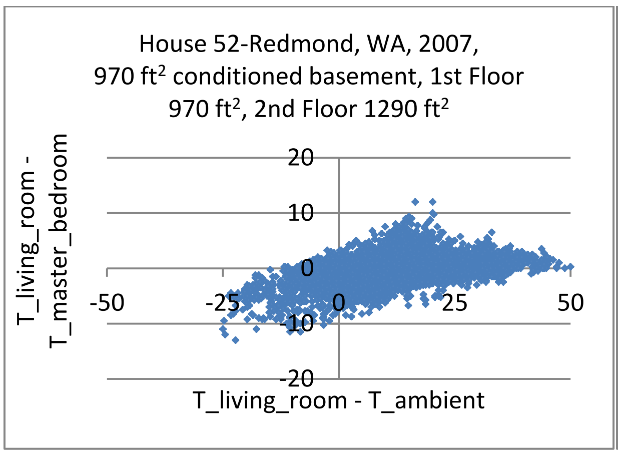
House 52-Redmond, WA, 2007,
970 ft² conditioned basement, 1st Floor 970 ft², 2nd Floor 1290 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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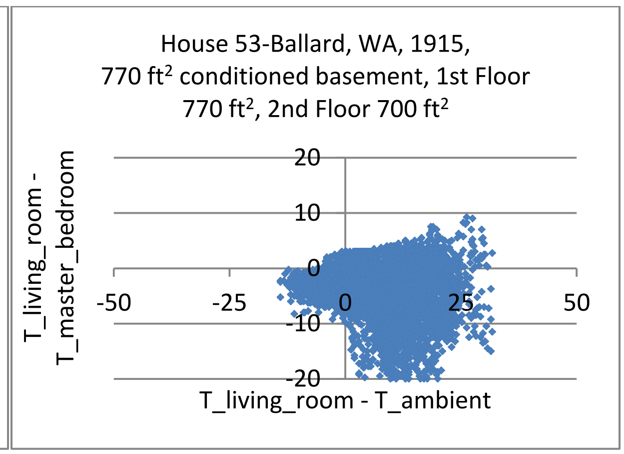
House 53-Ballard, WA, 1915,
770 ft² conditioned basement, 1st Floor 770 ft², 2nd Floor 700 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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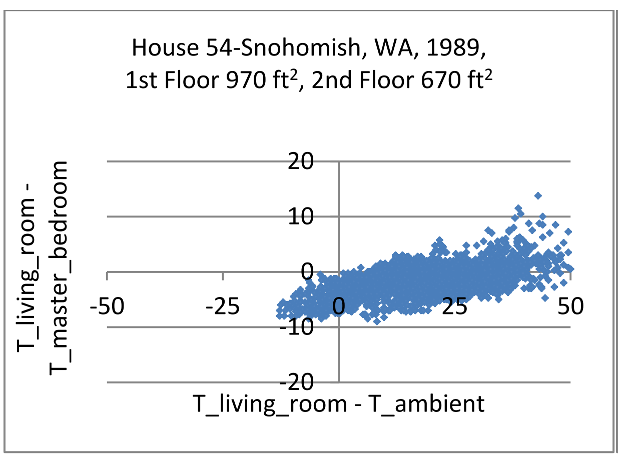
House 54-Snohomish, WA, 1989,
1st Floor 970 ft², 2nd Floor 670 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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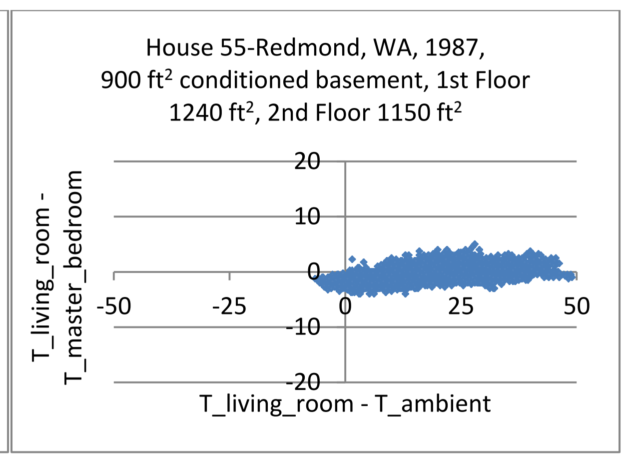
House 55-Redmond, WA, 1987,
900 ft² conditioned basement, 1st Floor 1240 ft², 2nd Floor 1150 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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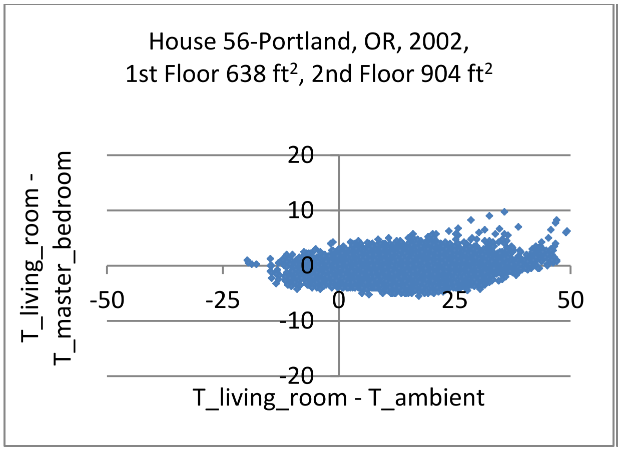
House 56-Portland, OR, 2002,
1st Floor 638 ft², 2nd Floor 904 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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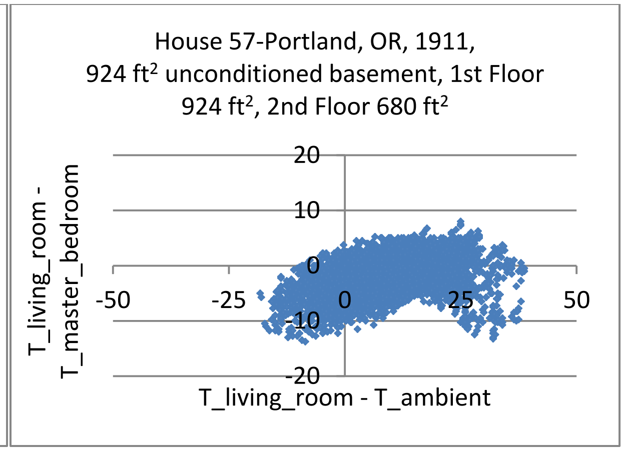
House 57-Portland, OR, 1911,
924 ft² unconditioned basement, 1st Floor 924 ft², 2nd Floor 680 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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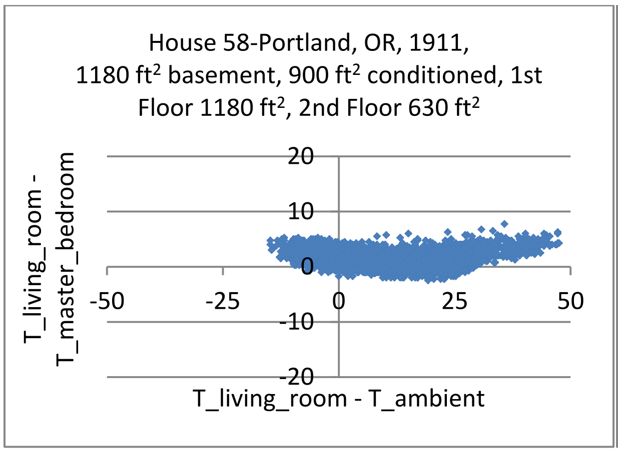
House 58-Portland, OR, 1911,
1180 ft² basement, 900 ft² conditioned, 1st Floor 1180 ft², 2nd Floor 630 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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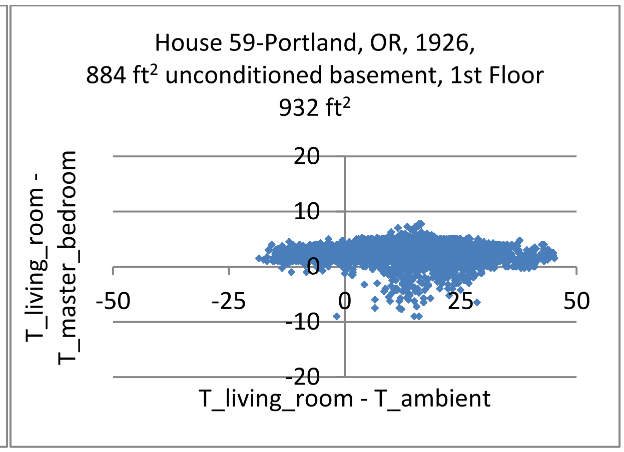
House 59-Portland, OR, 1926,
884 ft² unconditioned basement, 1st Floor 932 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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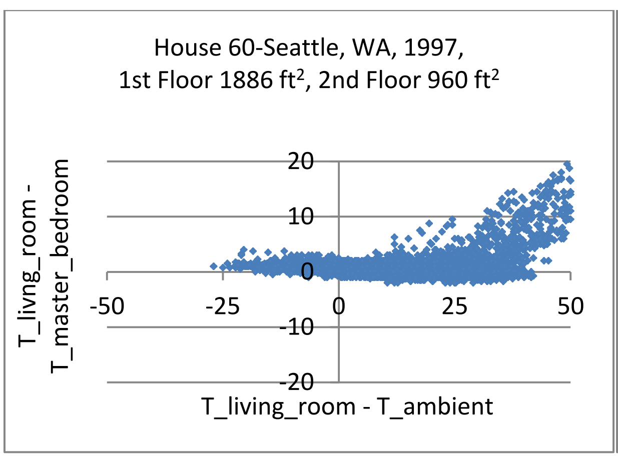
House 60-Seattle, WA, 1997,
1st Floor 1886 ft², 2nd Floor 960 ft²
T_livng_room - T_master_bedroom
T_living_room - T_ambient
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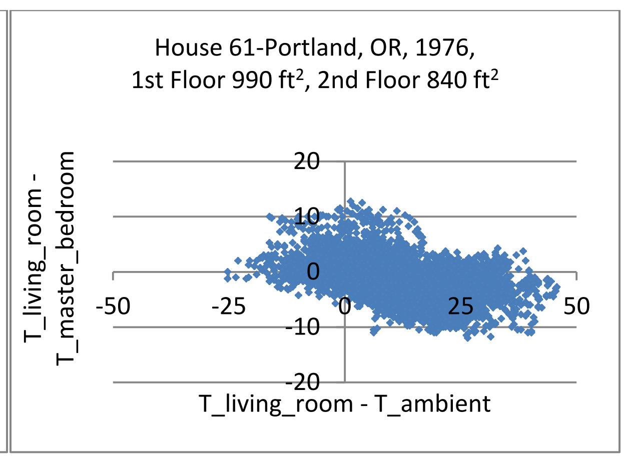
House 61-Portland, OR, 1976,
1st Floor 990 ft², 2nd Floor 840 ft²
T_living_room - T_master_bedroom
T_living_room - T_ambient
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