Occupant Energy Index: Understanding How Occupant Behavior Impacts Energy Use

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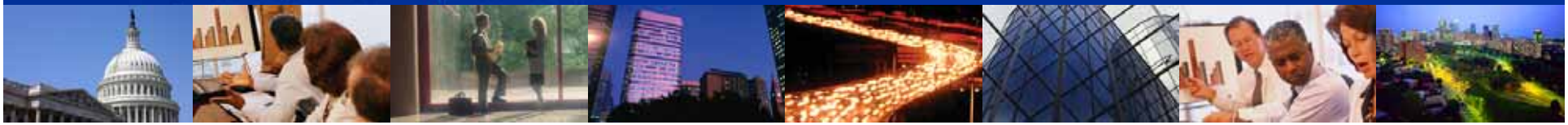


Presentation Overview

- Provide brief overview of impact of occupant behavior on residential energy consumption
- Discuss rationale for developing an Occupant Energy Index (OEI)
- Introduce the concept of an Occupant Energy Index
- Explore one example of how occupant behavior was incorporated into building analysis

Occupants are Energy Hogs…

- Residential sector ~27% of total US energy
- Increasing consumption from small appliances
- Occupant impacts include:
  - Schedules for opening and closing windows and shades;
  - Thermostat setpoints;
  - Water consumption;
  - Lighting quantity, efficiency, and usage
  - Appliance quantity, efficiency, and usage

And not all Energy Hogs are created equal…

- Studies have demonstrated that:
  - Heating could vary by 2:1 due to occupant behavior
  - Cooling could vary 5:1 due to occupant behavior
  - Similar variations for other end-uses
- Is a home with no occupants a zero-energy home?

Predicting Unpredictable Human Behavior

- Energy simulations typically involve:
  - A particular architectural design
  - A set of energy related features
  - Operating assumptions
- When ***relative*** energy consumption is of primary concern, occupant behavior can be fixed
- When ***absolute*** energy consumption is of primary concern, a single state of occupant behavior will not suffice

Introducing the Occupant Energy Index

- Goal: More accurately assess the impacts of occupant behavior
- Approach: A scale that defines the spectrum of influence from occupant behavior
- Approach: Each point on the scale represents a different profile of occupant behavior
- Benefits:
  - Ability to evaluate homes with varied occupant behavior
  - Manage consumer expectations about their home's efficiency
  - Educate consumers about their role in an energy efficient home

Evaluating Occupant Profiles

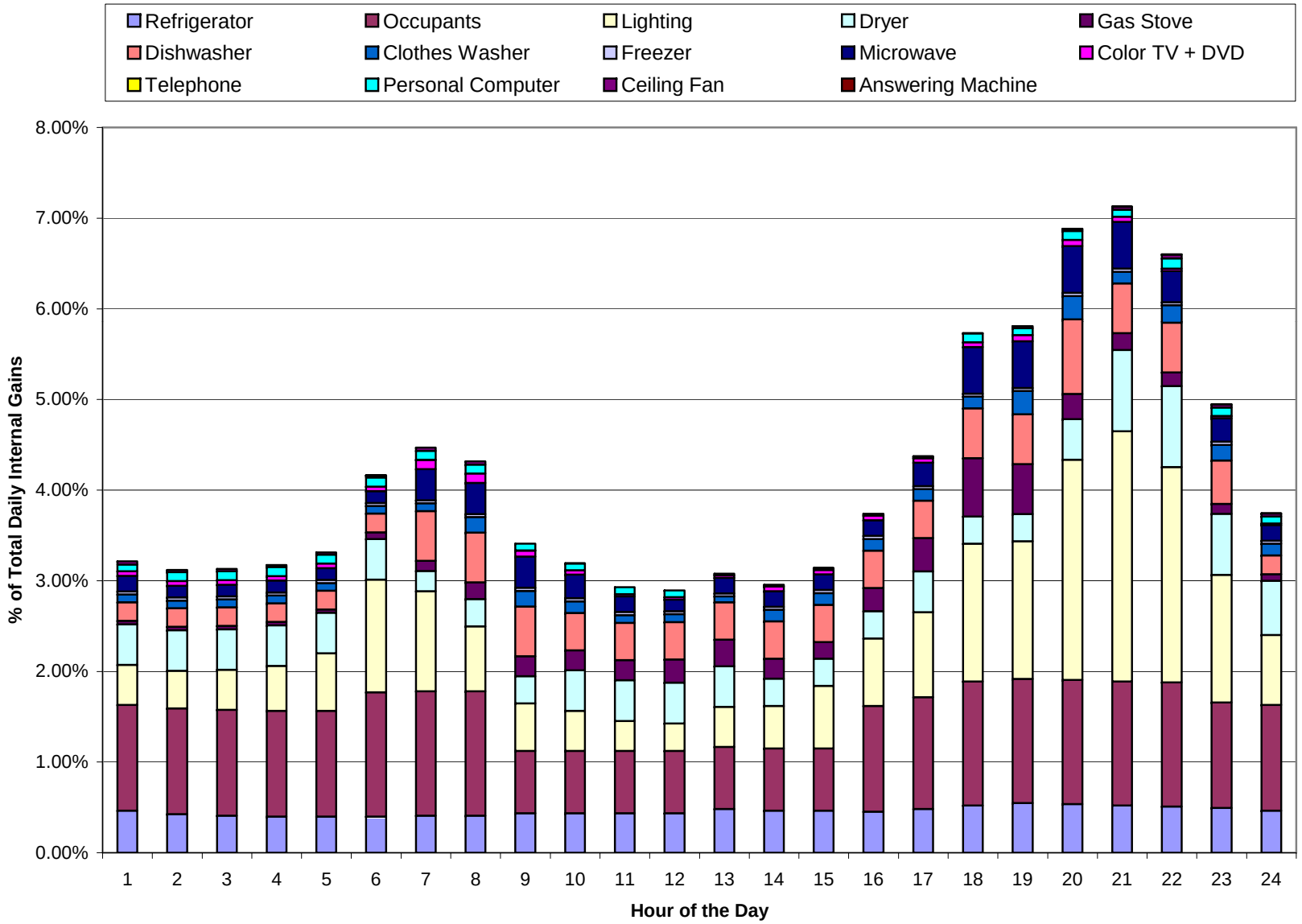
- Used energy modeling to evaluate impacts from occupant behavior
- The reference case was defined using the 2006 HERS Guidelines
- Occupant behavior was modeled using a custom internal gains schedule
- Three cities were considered:

  Houston, TX

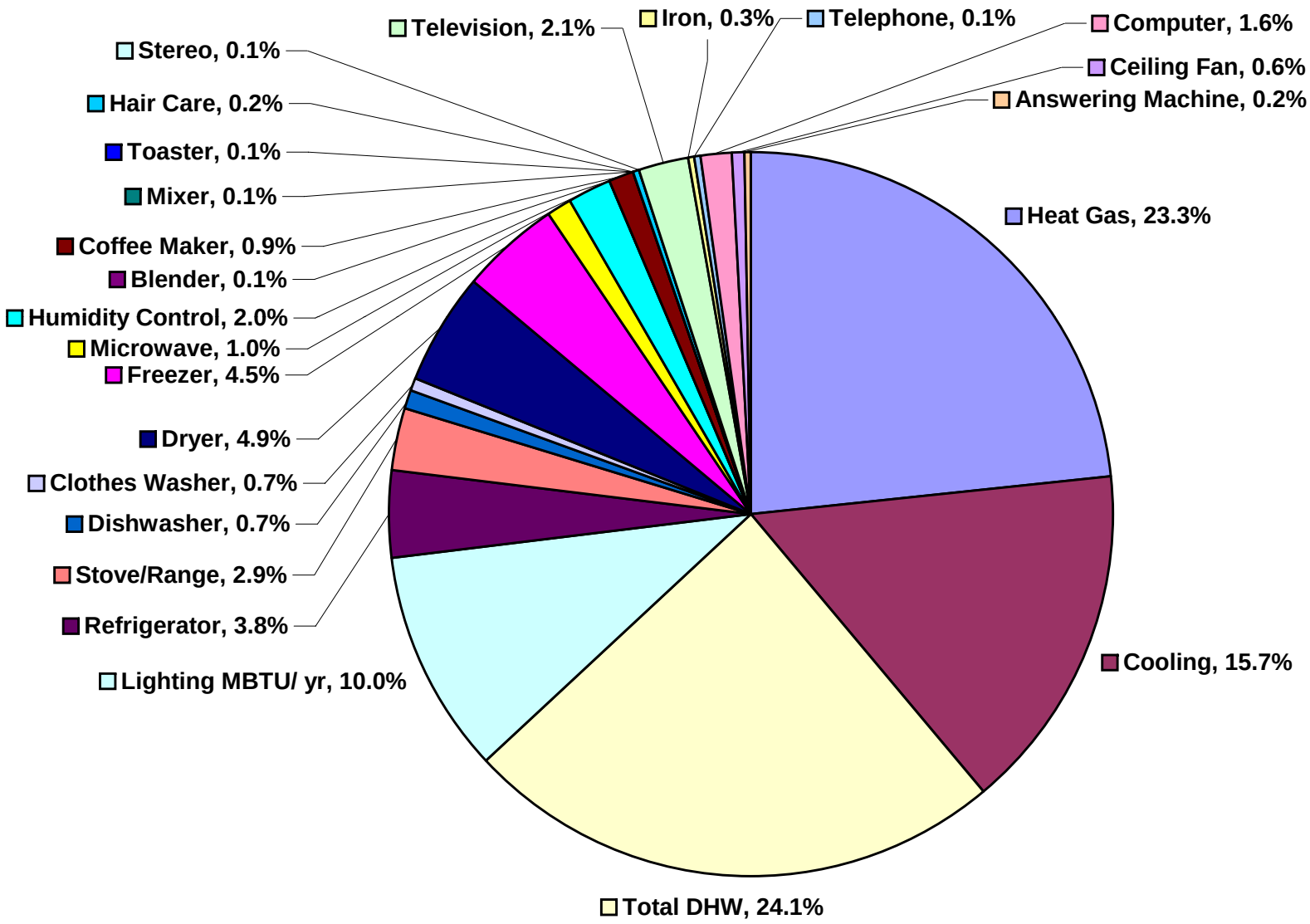
  Baltimore, MD

  Minneapolis, MN

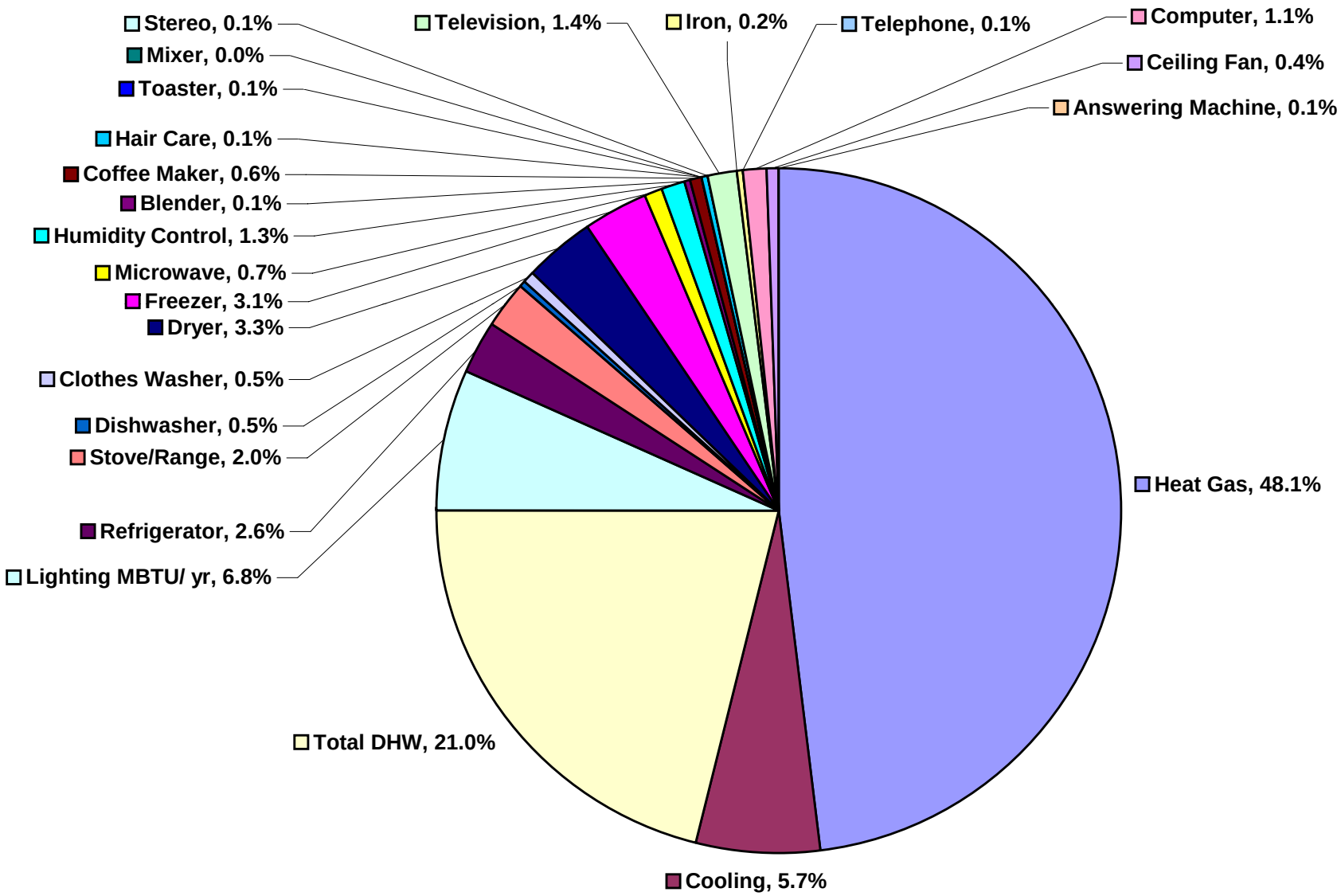
Custom Internal Gains Schedule



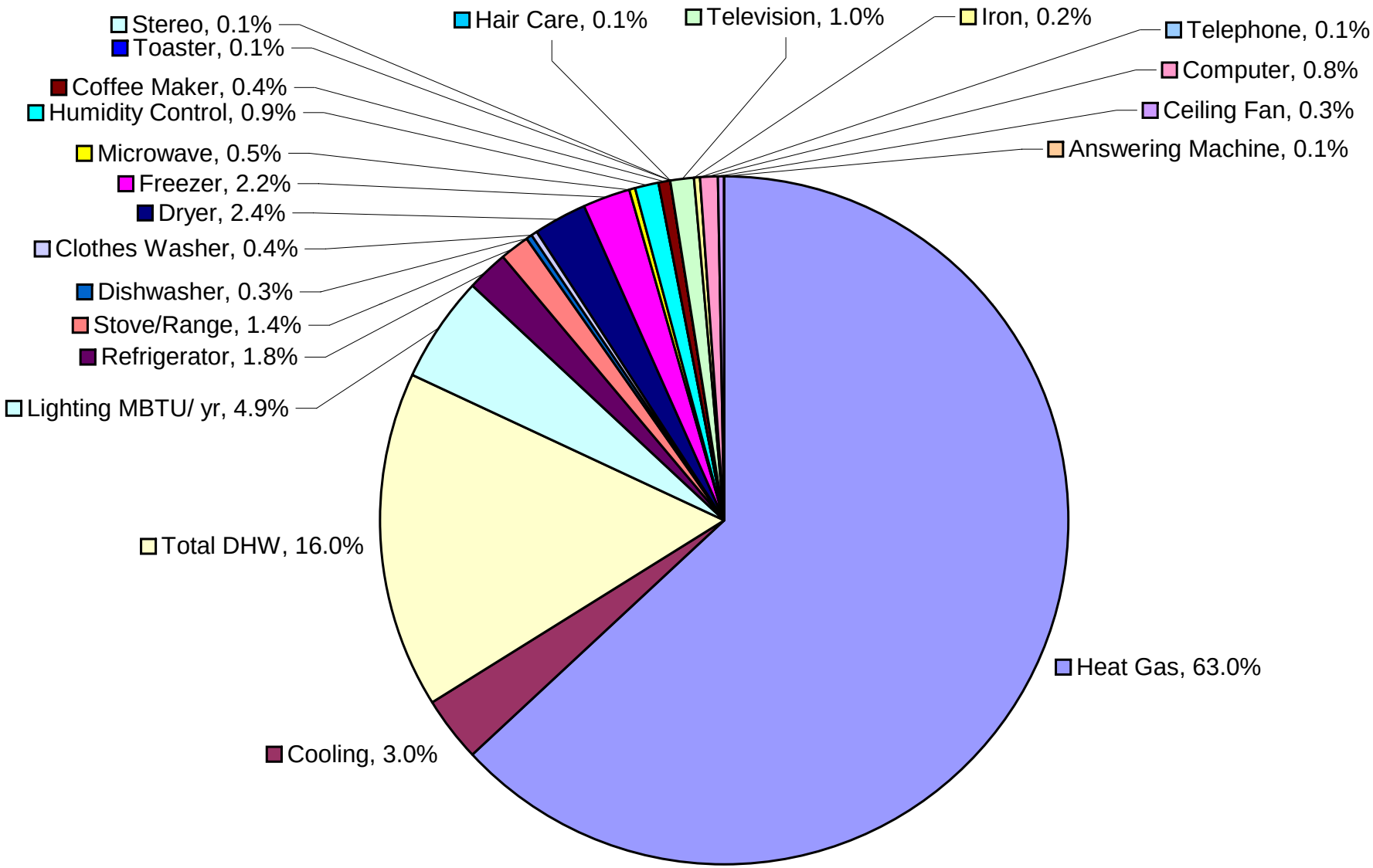
Baseline Energy Consumption - Houston



Baseline Energy Consumption - Baltimore



Baseline Energy Consumption - Minneapolis



Evaluating Individual Occupant Behaviors

- With a baseline established, mini-studies were completed to evaluate the impact of individual occupant behaviors on
  - heating
  - cooling
  - water heating
  - lighting
  - plug-loads (including appliances)

Individual Behaviors in Focus: Thermostats

Occupant Behavior Assumptions

Scenarios	Heating ^{o}F	Cooling ^{o}F
Baseline	68	78
Energy Intensive Occupant	74	72
Energy Conservative Occupant	62	84

Occupant Behavior Impact

	Purchased Energy % Savings		
Scenarios	Houston	Baltimore	Minneapolis
Baseline	0%	0%	0%
Energy Intensive Occupant	-27%	-24%	-23%
Energy Conservative Occupant	19%	18%	16%
Delta	~46%	~41%	~39%

Individual Behaviors in Focus: Lighting

Occupant Behavior Assumptions

Scenarios	% Fluorescent	Intensity
Baseline	10%	HERS Reference
Energy Intensive Occupant	10%	2x Reference
Energy Conservative Occupant 1	100%	HERS Reference
Energy Conservative Occupant 2	-	No Lighting

Occupant Behavior Impact

	Purchased Energy % Savings		
Scenarios	Houston	Baltimore	Minneapolis
Baseline	0%	0%	0%
Energy Intensive Occupant	-13%	-8%	-5%
Energy Conservative Occupant 1	5%	3%	2%
Energy Conservative Occupant 2	13%	8%	5%
Delta	26%	16%	10%

Summary of Individual Behaviors

Category	Variations Considered	Absolute Impact Houston	Balt.	Minn.
Thermostats	Setpoints	46%	41%	39%
Lighting	Fixture quantity and % fluorescent lighting	26%	16%	10%
Freezers	Equipment efficiency and quantity	12%	7%	4%
Refrigerators	Equipment efficiency and quantity	10%	6%	3%
Cooking Range	Burner efficiency and hours of use	8%	5%	3%
Dishwashers	Equipment efficiency and annual wash cycles	7%	7%	6%
TV/DVD	Equipment efficiency and annual hours of use	6%	3%	2%
Clothes Washer	Equipment efficiency and annual wash cycles	5%	4%	3%
Computers	Equipment efficiency and annual hours of use	4%	3%	1%
Microwaves	Equipment capacity and quantity	3%	2%	1%
Telehphones	Equipment efficiency and annual hours of use	3%	2%	1%
Ceiling Fans	Equipment efficiency and quantity	2%	1%	1%

Evaluating Combined Occupant Behaviors

- Four mini-studies were then completed to evaluate the impact of changes to combined occupant behaviors on
  - heating
  - cooling
  - water heating
  - lighting
  - plug-loads (including appliances)

Impact of Combined Behaviors

Occupant Behavior Assumptions

Scenarios	Lighting & Appliance Consumption
Baseline	Equal to HERS
Energy Intensive Occupant	Doubled
Energy Conservative Occupant 1	Assuming High-Efficiency Products
Energy Conservative Occupant 2	Zero

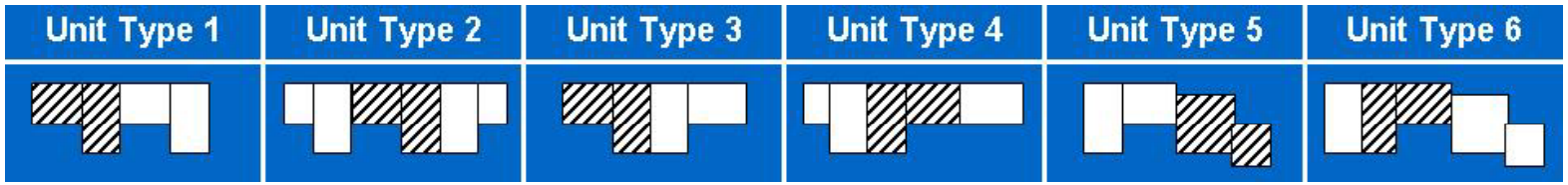
Occupant Behavior Impact

	Purchased Energy % Savings		
Scenarios	**Houston**	**Baltimore**	**Minneapolis**
Baseline	0%	0%	0%
Energy Intensive Occupant	-37%	-23%	-13%
Energy Conservative Occupant 1	20%	13%	8%
Energy Conservative Occupant 2	72%	51%	35%
Delta	~109%	~74%	~48%

Occupant Behavior & Program Design: Example

Context:

- Residential tenants provided with a monthly utility bill allotment
- Development consisted of six housing configurations, with two to sixteen units for each configuration:



- Allotments were defined by simply averaging consumption across all units.
- Residents were billed/credited for deviating from the allotment

Occupant Behavior & Program Design: Example

Challenge:

- Existing methodology did not properly account for differences in:
  - architectural characteristics
  - energy efficiency features
  - actual weather
  - occupant behavior
- Impact from anomalous energy consumers was distributed across all occupants rather than being attributed to outliers
- Existing methodology produced high tenant dissatisfaction
- Could the existing methodology be improved?

Occupant Behavior & Program Design: Example

Solution:

- Use energy modeling to create profiles of each unit type

- Account for:
  - Exact architectural characteristics
  - Exact energy efficiency features
  - Actual weather conditions
  - Allotted occupant behavior

Occupant Behavior & Program Design: Example

Solution:

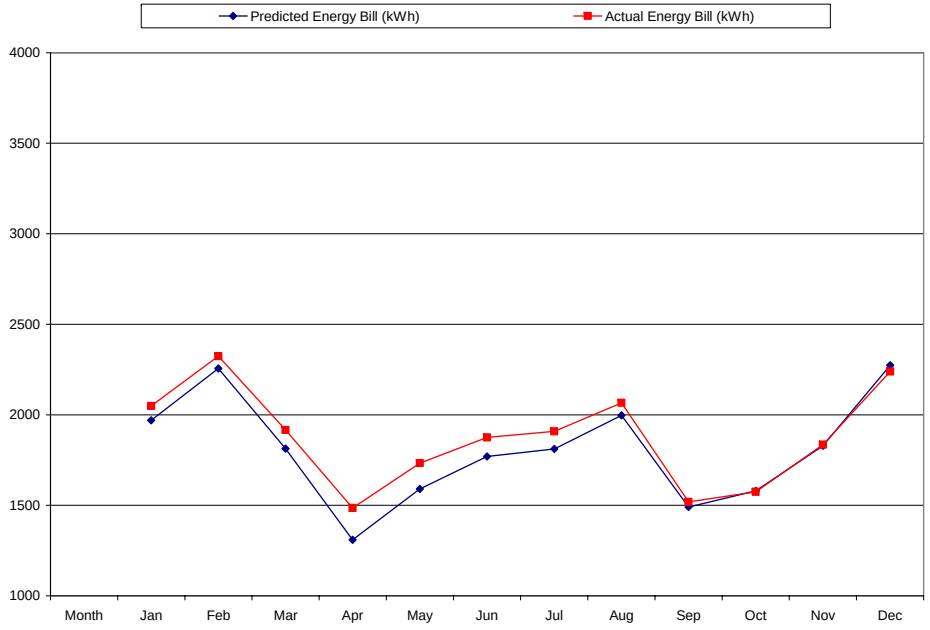
- To account for occupant behavior, define a standard set of reasonable behaviors that encompass:
  - thermostat set-points
  - hot water consumption
  - lighting and appliance quantity and usage

- Benchmark resulting profiles against utility bill data to ensure accuracy

Occupant Behavior & Program Design: Example

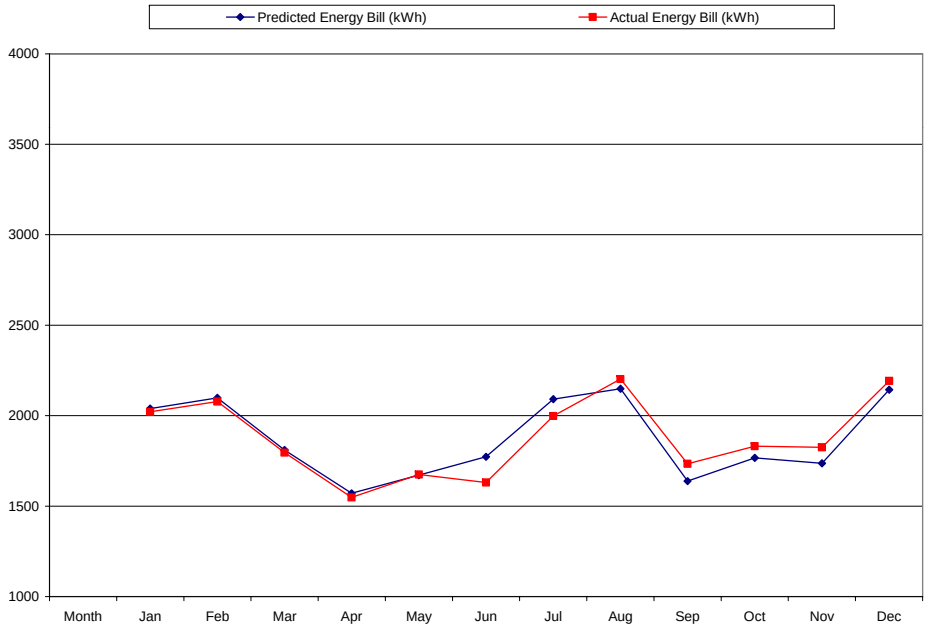
Results:

Unit Type 1 – 8 Units



Close Alignment

Unit Type 2 – 8 Units

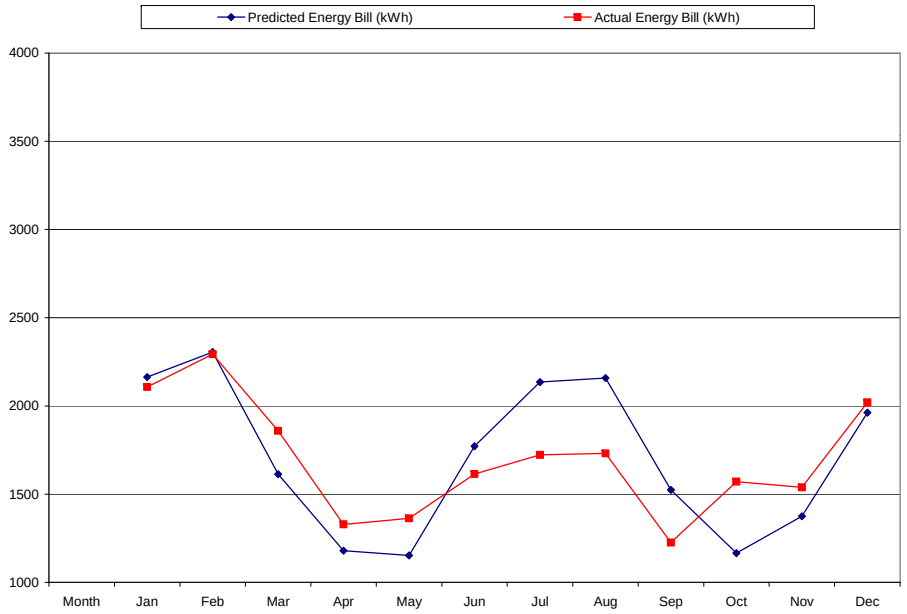


Close Alignment

Occupant Behavior & Program Design: Example

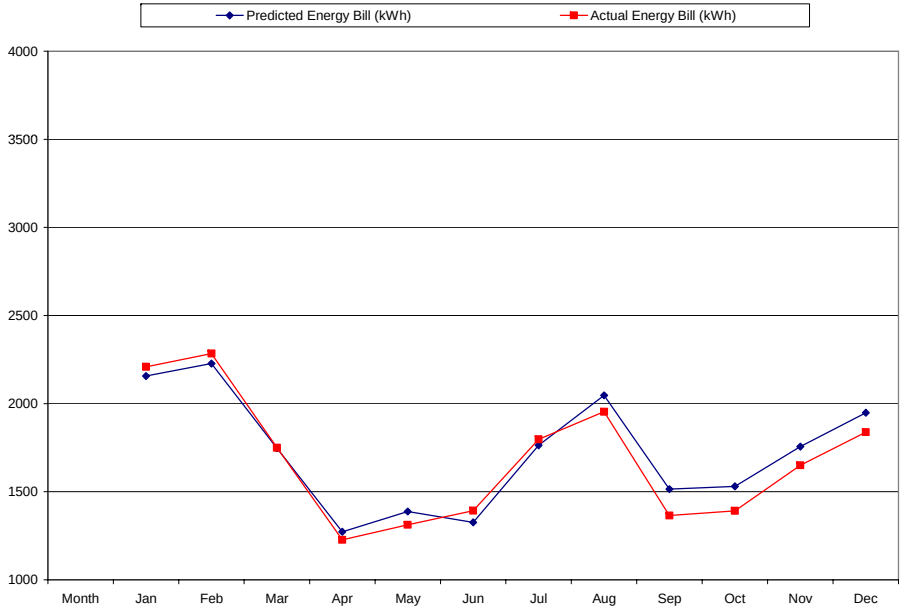
Results:

Unit Type 3 – 16 Units



Generally Close Alignment

Unit Type 4 – 10 Units

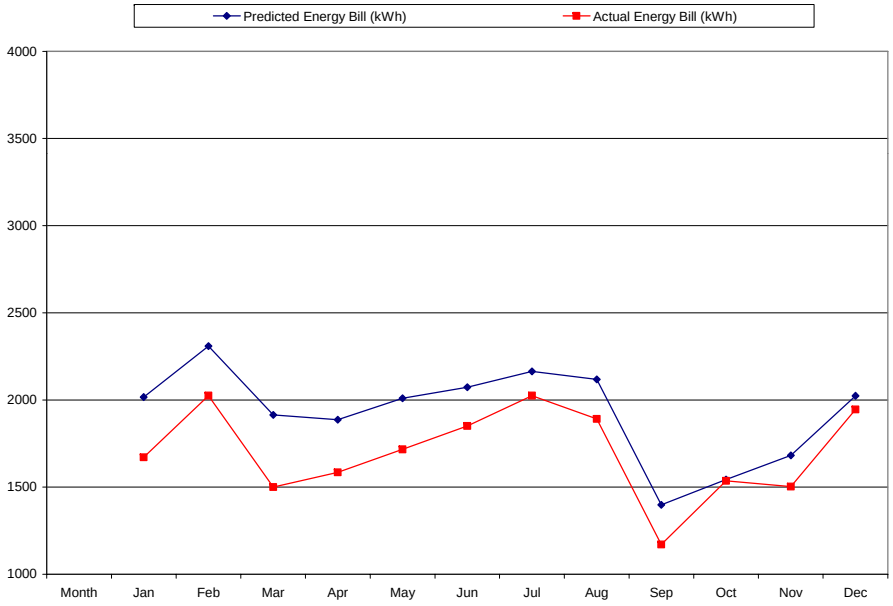


Close Alignment

Occupant Behavior & Program Design: Example

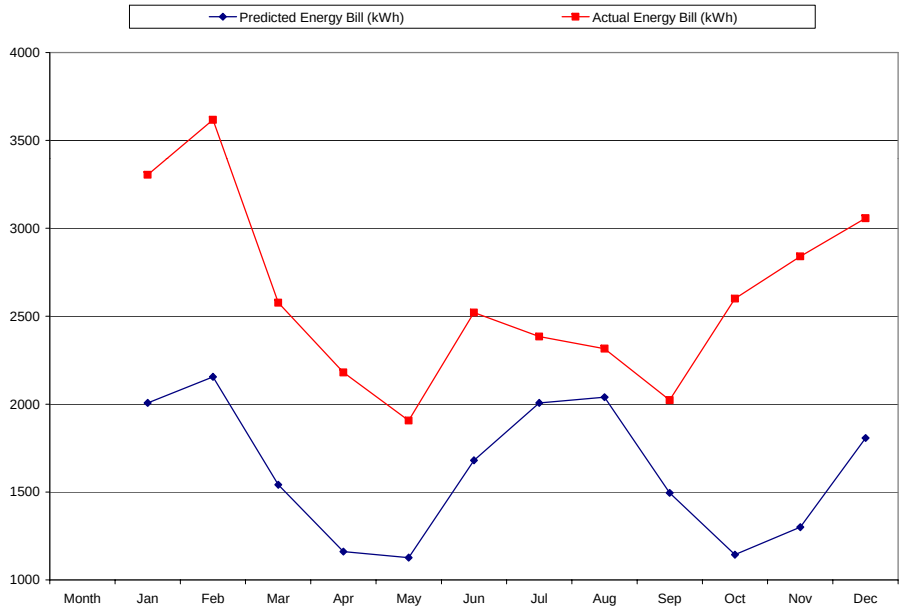
Results:

Unit Type 5 – 4 Units



Generally Close Alignment

Unit Type 6 – 2 Units

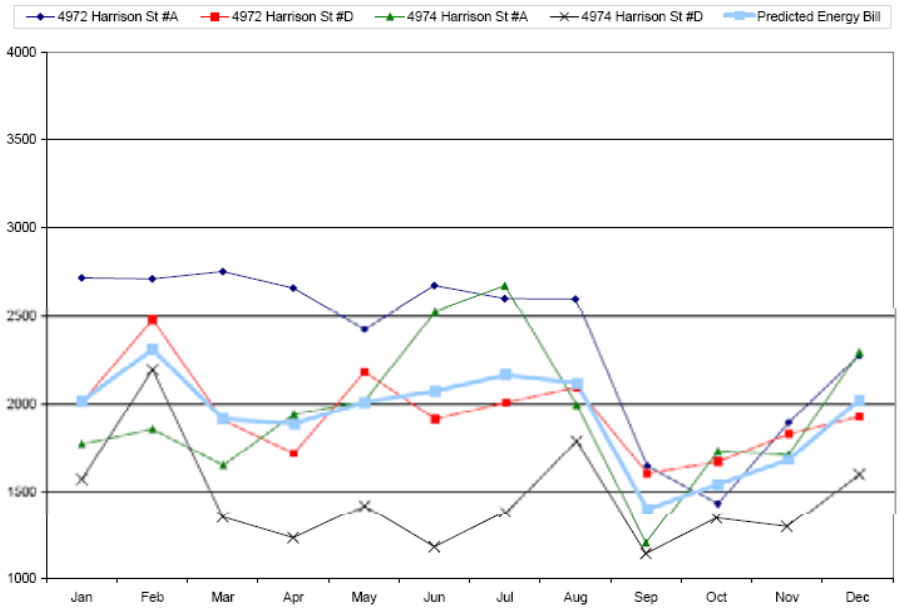


Alignment Not Close Due to One Outlier

Occupant Behavior & Program Design: Example

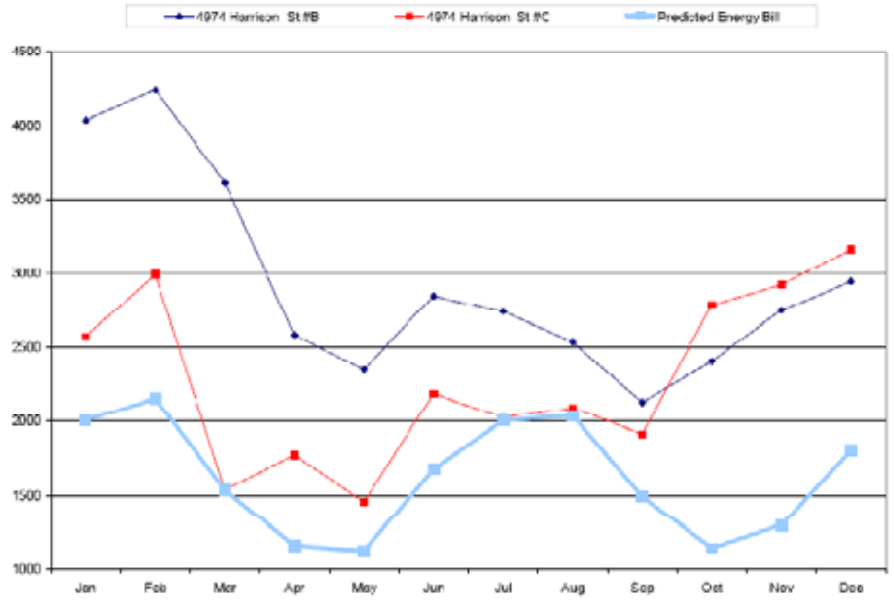
Analysis of Anomalous Results:

Unit Type 5



Actual consumption for all Unit Type 5 units

Unit Type 6



Actual consumption for all Unit Type 6 units

Occupant behavior likely cause of outliers

Occupant Behavior & Program Design: Example

Summary of Results:

	Actual Utility Bill	Energy Allowance	RECS
Unit Type 1	$2,252	$2,169	$2,359 – $2,521
Unit Type 2	$2,253	$2,249	$2,359 – $2,521
Unit Type 3	$2,037	$2,050	$2,359 – $2,521
Unit Type 4	$2,017	$2,068	$2,359 – $2,521
Unit Type 5	$2,042	$2,314	$2,359 – $2,521
Unit Type 5 without 4974 #D	$2,502	$2,314	$2,359 – $2,521
Unit Type 6	$3,133	$1,946	$2,359 – $2,521

Using a consistent set of occupant behaviors for modeling helps to identify outliers and to set more equitable allowances

Occupant Behavior & Program Design: Example

Conclusions:

- Program design can be improved by using building simulation to account for:
  - Architectural characteristics
  - Energy efficiency features
  - Actual weather conditions
  - Allotted occupant behavior
- This improved approach can help identify outliers and properly credit or charge them for their variation in behavior
- In contrast, averaging utility bills does not properly credit or charge outliers

Overall Conclusions

- Standard methodologies for evaluating residential energy efficiency mostly do not consider variations in occupant behavior
- Occupant behavior can have very significant impacts on energy consumption. Considering lighting and appliances alone, consumption can change by more than 100%
- The Occupant Energy Index, a concept introduced here, could be used to address this shortcoming
- One case study illustrates how occupant behavior can be incorporated into building analysis to improve program design