BUILDINGENERGY NYC

OCTOBER 15, 2015 AT TKP NEW YORK CONFERENCE CENTER

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Understanding and Influencing Resident Energy Behaviors: Two Multifamily Case Studies/Three Perspectives

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Course Description

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“Understanding and Influencing Resident Energy Behaviors: Two Multifamily Case Studies/Three Perspectives”

- Provide an overview of energy and building occupant satisfaction and behavior as predictors of building resource use.
- Explore how “occupant green” can be expanded to include programming that encourages behaviors that improve both health and building performance.
- Discuss the role of income in energy use, and reasoned versus habitual behavior.

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand synergies/conflicts in green and affordable building typologies and impacts on occupant health

2. Understand trade-offs of ventilation and energy use, and how comfort findings may raise health concerns

3. Understand role of “income effect” in energy use and occupant behavior

4. Increase familiarity with reasoned versus habitual behavior theory and applications

Source: NYTimes.com

Multiple Case Study Building Comparisons 2011-13

Source: RCGB archives

METHODS: MULTIDISCIPLINARY SURVEYS, INTERVIEWS, APARTMENT LEVEL MONITORING OF IAQ & RESOURCE CONSUMPTION

Building 1

1. 1.Energy Star Certified
2. 127 apartments (400 residents)
3. Individual window unit AC
4. Households pay electric utility
5. No air filtration systems
6. Kitchen & bath exhaust fans
7. 88 % of residents < $ 20,000 annually

Building 2

1. LEED Certified
2. 293 apartments (700 residents)
3. Central AC included
4. Households pay electric utility
5. 100% outdoor air filtration
6. Kitchen & bath exhaust fans
7. 20% of residents < $200,000 annually

Study 1: Longitudinal, Quasi-experimental Post-occupancy evaluation n=40 (Building 1 'intervention study')

Study 2: Longitudinal Post-occupancy Buildings 1 (n=15) & 2 (n=18)

Objective 1: Conflicts and Synergies in Green, Affordable, Health-Promoting Buildings

<u>Data and Measures in Building 1:</u>

- Plug load and utility bill data for 29 apts
- HEAL questionnaires & interventions for 32 apts
- IAQ data for 31 apts
- Aggregate HH kWh data and kWh data for 13 apts
- Interviews and surveys with 15 residents
- LL84 whole-building EUI

Carbon dioxide
Carbon monoxide
Temperature
Humidity

Airborne particle mass and size

Viable bacteria and mold, x3

Total mold, x2

Mass of small particles (24 hrs)

VOCs badge (24 hrs)

Real-time mass of small particles (24 hrs)

2-inch Petri dish with filter (3 months)

Formaldehyde badge (48 hrs)

Highlights of HEAL and EE Interventions
Building 1

Objective	Intervention	Findings Highlights
↑ Water Consumption	Refillable Water bottles	• Of 28 comments, 25 were positively related to use of water bottles over time • Often shared with children • Observations included bottles out in open
↑ Physical Activity	Pedometer, Tips Manual, Community Resources Info	• Less positive / more limited use (e.g., immediately following intervention) • Some participants had physical limitations
↑ Roof Top / Veggies	Tips Manual, Community Resources Info	• Observed veggies brought in from roof top • Participation in sampling from cooking demos • Garden coordinator is key for some • Children are "picky" but respond to food demos
↑ Energy Efficiency	Line Loggers, Power strips, Tips Manual	• Fans are being used, can be an economic issue to purchase • Using power strips, less microwave use reported • Effect strongest during intervention, not persistent

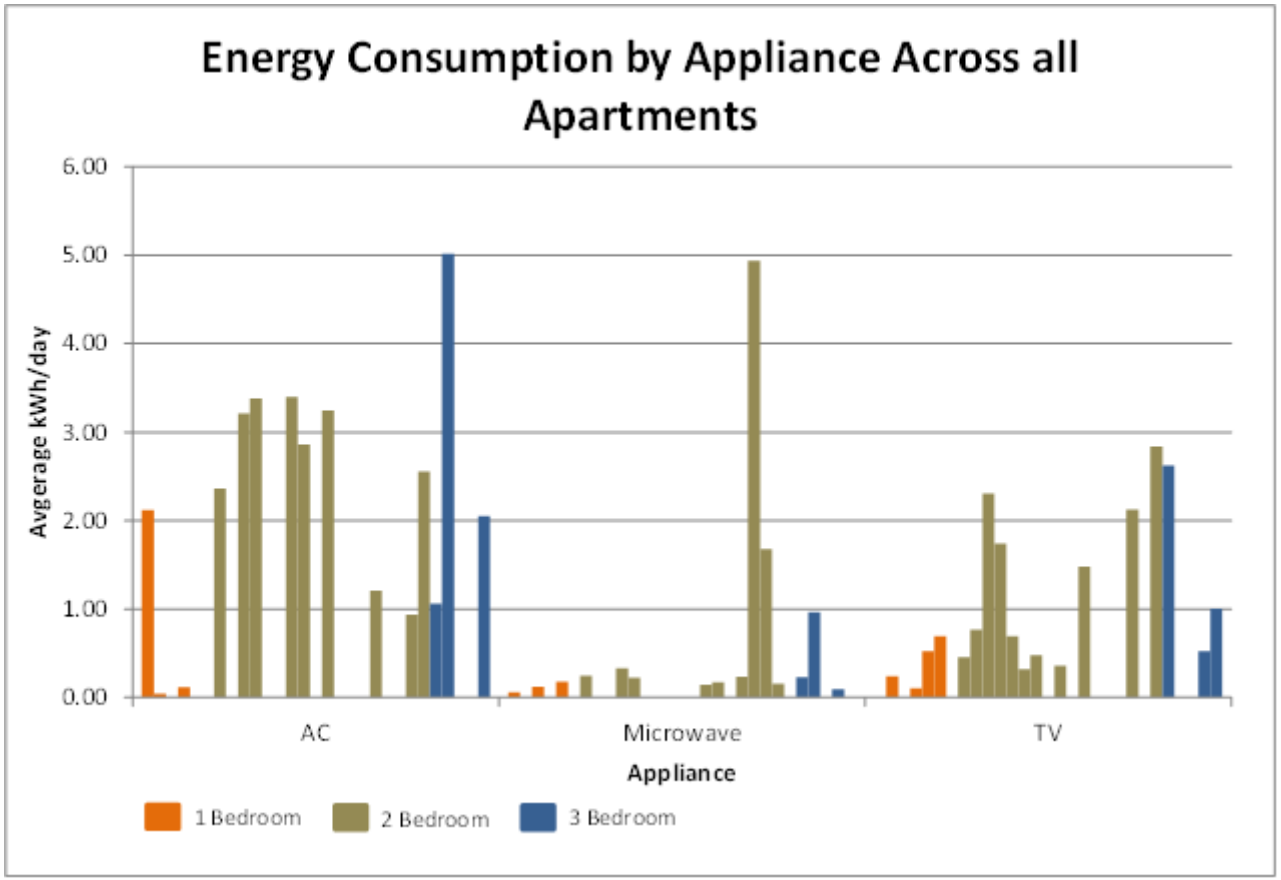
"The follow-ups were a responsibility because we had to respond (to reinforcement questions)."

"We love the roof top garden, we have several plots, where we grow peppers, cilantro, watermelon…"

Building 1 Intervention Study

Apartment Type	Apts with plug load intervention
One Bedroom	6
Two Bedroom	18
Three Bedroom	5

Kill A Watt EZ



A pilot study to fit home appliances with plug load meters was undertaken as part of this project. Readings were used from 29 participating apartments in this process between July to November 2011. The graph shows variation in appliance use by apartment size.

The graph represents a sample of line loggers / plug load meters used to monitor apartment appliances. Not all apartments had the same appliances monitored.

Building 1 Intervention Study

Random Effects Panel Regression Analysis of Household Characteristics on kWh usage

Regressor	Monthly kWh	Monthly kWh Percentages
CDD	**0.735****	**0.173****
HDD	0.027	-0.002
Number of Kids	-4.153	-3.266
Number of Occupants	**57.264***	**16.675****
Number of A/C units	**57.587****	**14.793****
Number of Bedrooms	-22.585	3.311
EE and HEAL Interventions	**-52.035***	**-8.692***
IAQ Intervention	-22.397	-10.597
Number of Observations	632	632

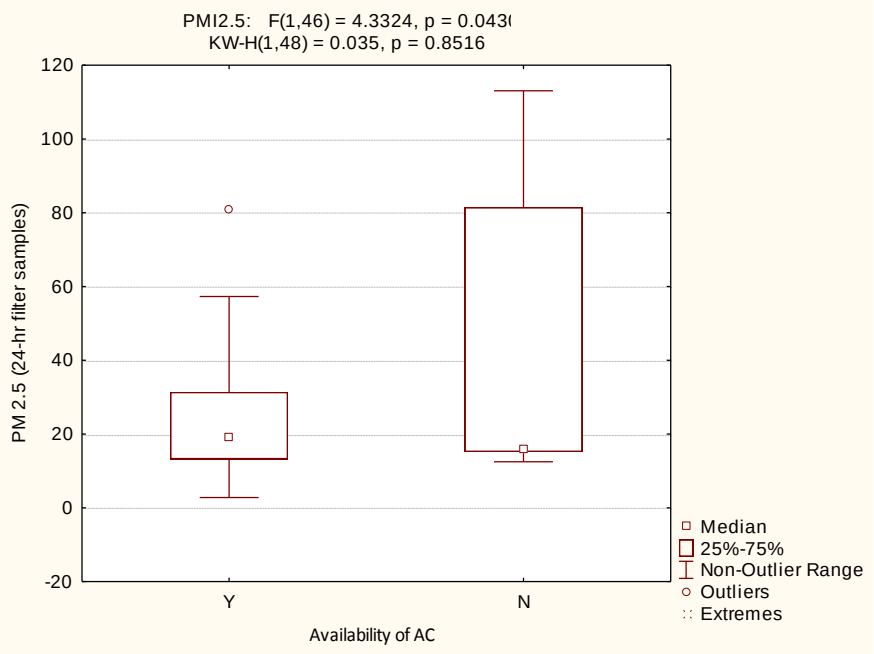
The dependant variable is the kWh usage per month. Not included are time and intercept measures. The individual coefficient is statistically significant at the *5% or **1% significance level using a two-tailed test.

There was a significant reduction in kWh consumption during the time of the intervention

Building 1 - Presence of air conditioners

<u>Where NO air conditioners reported:</u>

- Significantly higher indoor/outdoor ratios of total particle mass (1-hr),
- Significantly higher indoor/outdoor ratios of large particle number concentrations (1-hr)
- Significantly higher indoor/outdoor ratios of certain chemicals (1-hr)



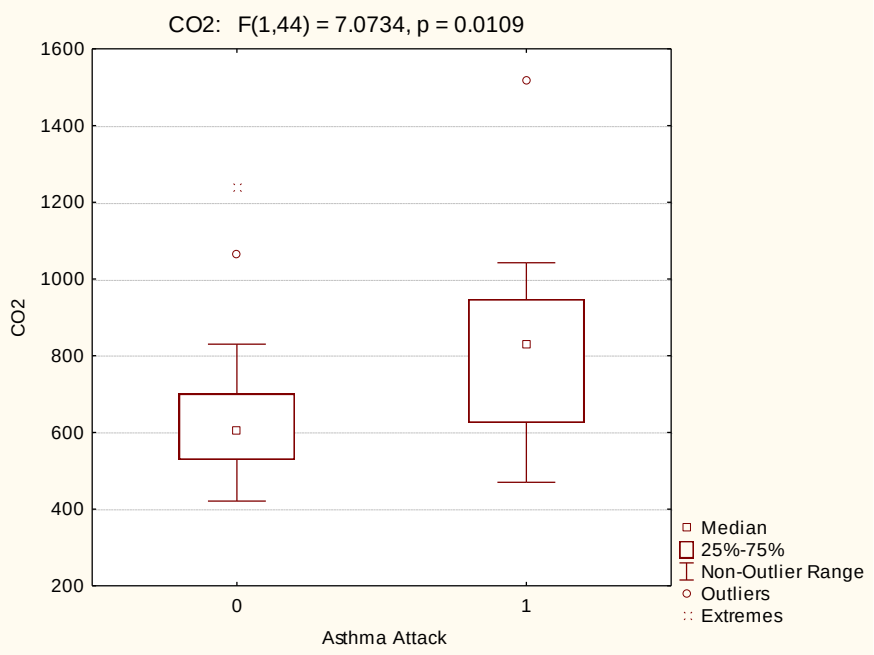
Building 1 - IAQ Factors & Asthma Attacks (1) Associated with Higher Apt CO_2

- Significantly higher concentrations of CO_2 in households where an asthma attack in the past 9-12 months was reported

(813 vs 640 ppm, p=0.011)

- Significantly higher indoor/outdoor ratios of CO_2 in households where an asthma attack in the past 9-12 months was reported

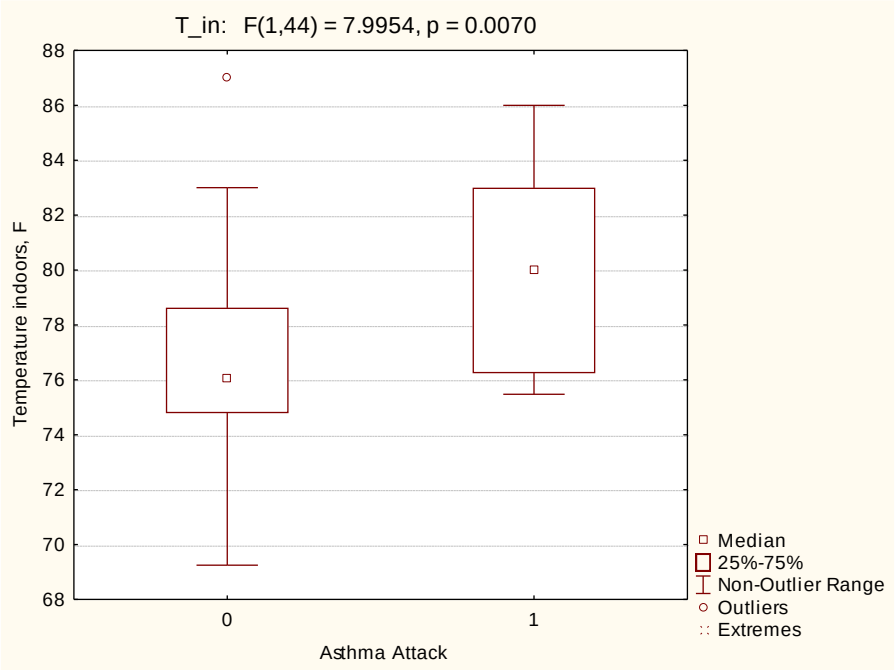
(2.24 vs 1.78, p=0.014.)



Building 1 - IAQ Factors & Asthma attacks (2)

- Significantly higher temperature in households where an asthma attack in the past 9-12 months was reported

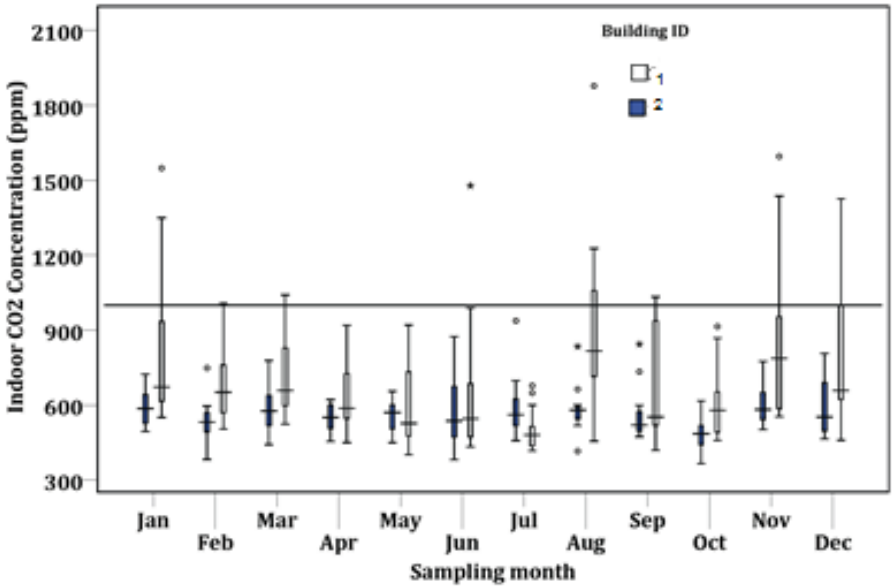
(80 vs 77 F, p=0.007)



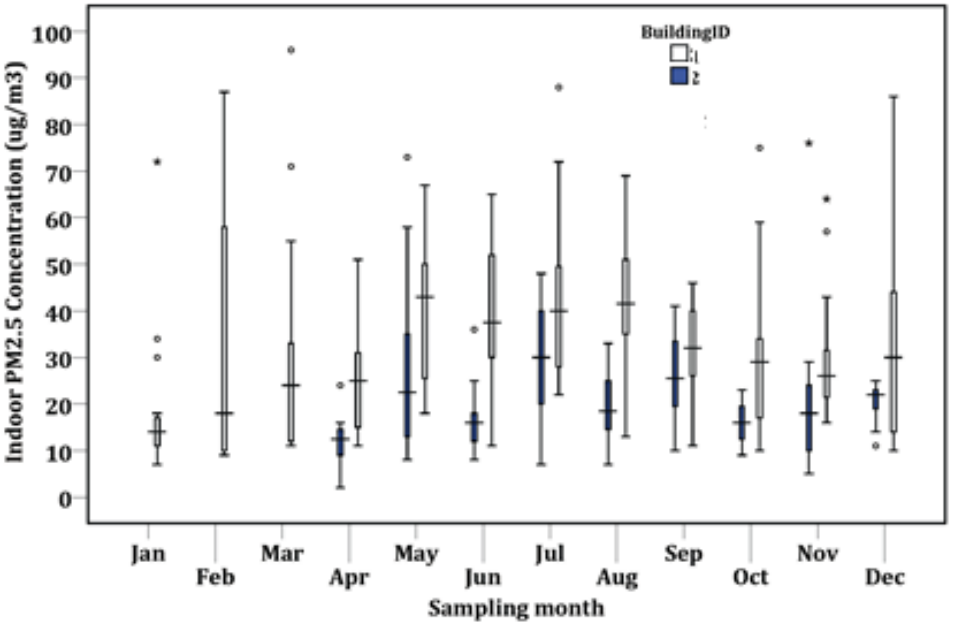
Focus on Humidity, Temperature: Comfort Factors – Building 1

- Higher particles mass concentrations detected by multiple instruments in households where response to question “is it too humid” was 3 or higher.
- Statistically significant for PM2.5 mass measured for 24-hr by a direct reading instrument (37 vs 17 $\mu g/m^3$). EPA outdoor limits 35 $\mu g/m^3$
- Significantly higher concentrations of viable bacteria detected in households where response to question “is it too humid” was 3 or higher. (860 vs 280 CFU/m^3).
- Significantly higher indoor/outdoor ratios of PM1, PM2.5 and PM10 for 1-hr direct reading instrument (2.3-2.6 vs 1.2-1.3)

Bldgs 1 & 2 IAQ Comparisons: Ventilation Differences



Higher CO_2 Readings in Building 1 compared to Building 2



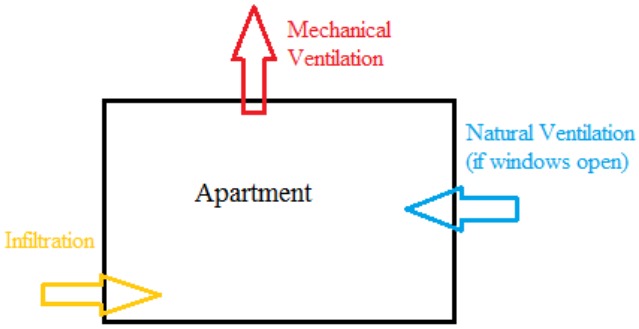
Higher overall PM 2.5 ug/m^3 readings in Building 1 compared to Building 2

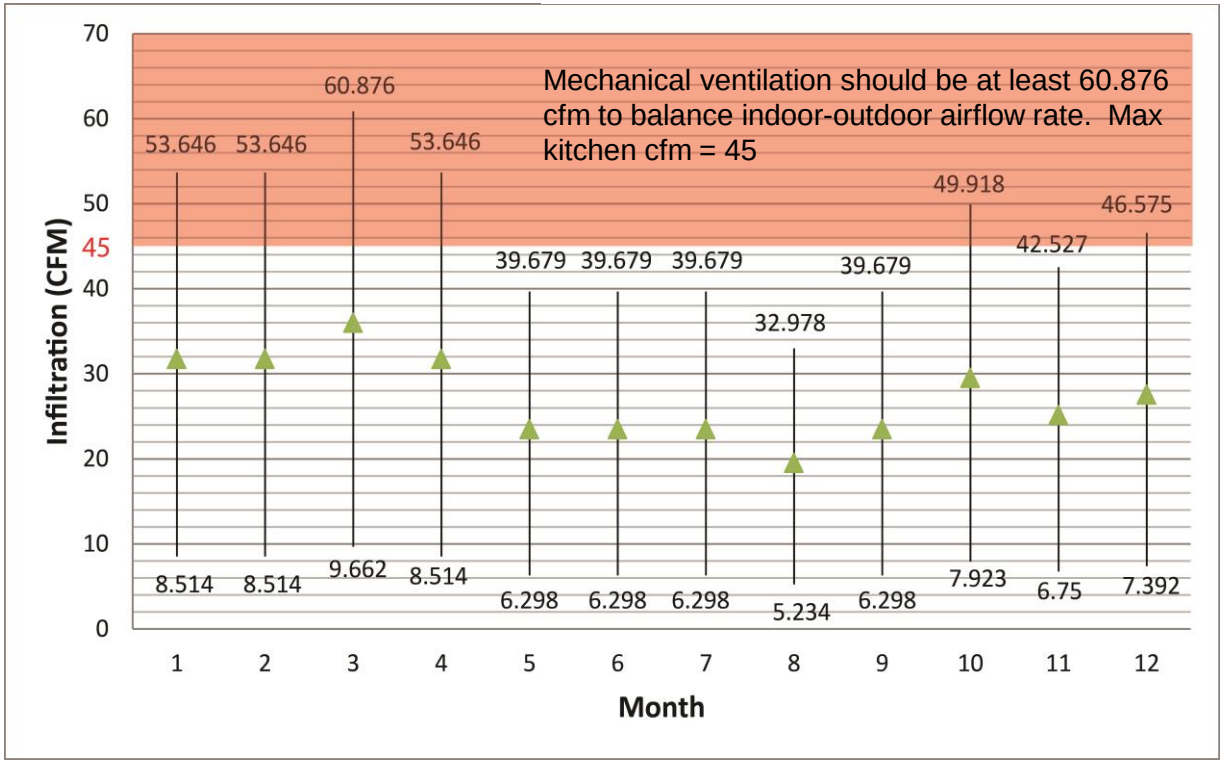
(45 min spot sampling)

Apt	Kitchen	Bathroom
A	9.79	43.44
I	29.01	57.93
C	0.73	4.05
E	28.65	30.89
F	25.02	49.43
Q	23.93	53.10
D	0.36	0.19
N	29.73	15.45
P	42.79	41.51
U	31.18	44.02
T	26.47	47.31
L	26.47	60.24
G	44.96	66.42
J	33.36	47.69
B	4.35	7.92
Average	23.79	37.97
Stdev	13.92	21.32
Rel Stdev	58.51%	56.14%

Mean cfm for exhaust fan flow rate measurements, 5/13. Ventilation rates reduced to 25 cfm kitchen & 20 cfm bath.

Ventilation estimates based on modeling of minimum & maximum infiltration and actual measurements (South Bronx).

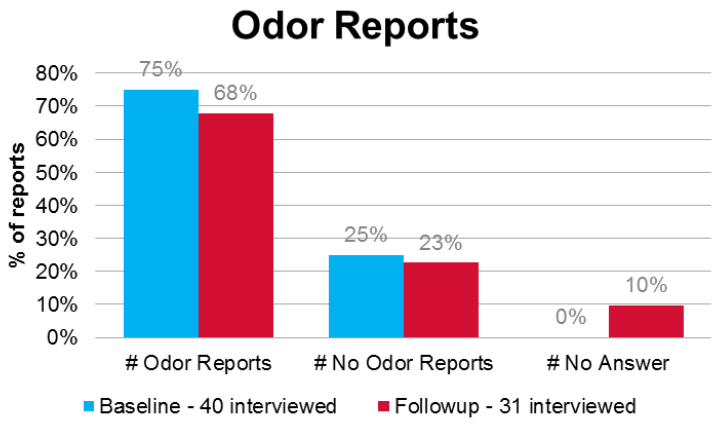


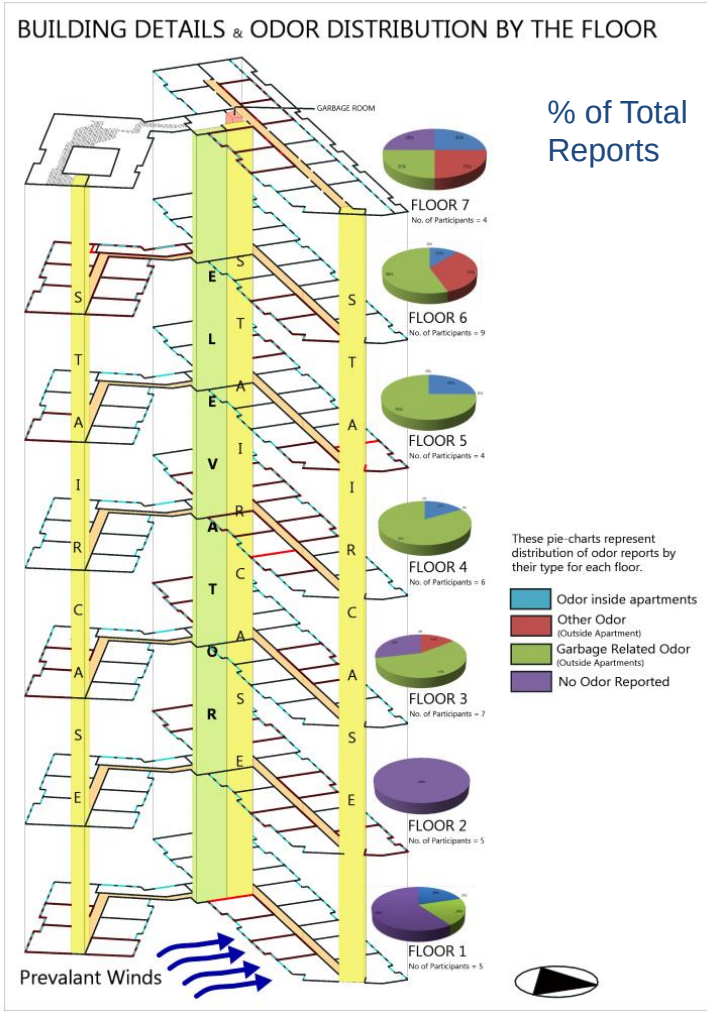


Building 1 Self-Reported Air Quality

Mapping of participant-reported odors on 3-D perspective of building (Baseline responses)

Floor	# Participants	# Reports	Garbage related odor	Odor outside apartment (other than garbage)	Odor inside apartments
1	5	3	1	0	1
2	5	5	0	0	0
3	7	2	4	1	0
4	6	0	5	0	1
5	4	0	3	0	1
6	9	0	5	3	1
7	4	1	1	1	1





Distribution of odor complaints by floor

Conflicts and Synergies: Recommendations & Discussion

- Encourage / support systematic, scale-up study of ventilation and IAQ in new and retro-fitted affordable housing construction
  - ✓ Revisit requirements in building code for IAQ, CO_2 monitoring.
  - ✓ Set parameters for trade offs between IAQ & energy efficiency programming
- Consider support for AC affordability and green cleaning programming to help improve IAQ in apartments for vulnerable populations.
- There is a need for cost-effective methods for detecting and mitigating health & safety hazards in affordable housing

Objective 2: Income Effects on Energy Use

RESULTS: Aggregate Energy & Electricity Findings

	2013 EUI (kBtu/ft^2)	Average kWh per apartment/per month	Average kWh per person/per year	Average kWh per SF/per year
Building 1 *	120	303 kWh	1,093 kWh	5.7 kWh
Building 2**	202	428 kWh	1,888 kWh	10.2 kWh

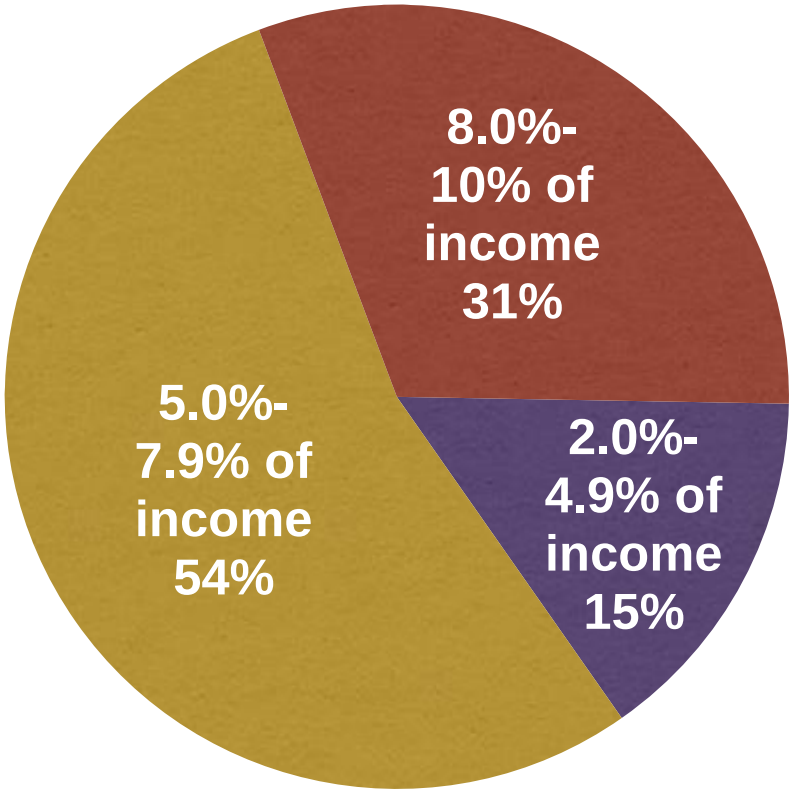
Significantly higher consumption in Building 2 at the whole-building AND household level despite LEED Platinum rating and many efficiency features

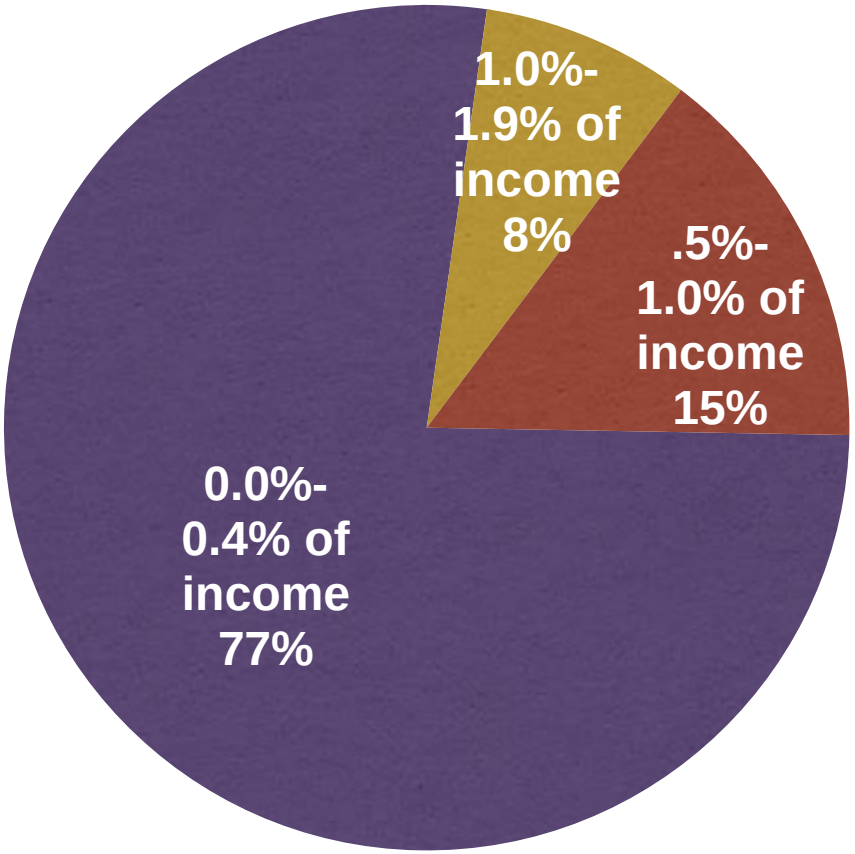
*13 apartments and LL84 whole building EUI

**293 apts and LL84 whole building EUI

Income Share for Electricity

Building 1: Share of annual income for electricity





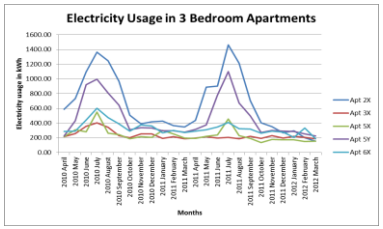
Building 2: Share of annual income for electricity

Key Takeaways (Objective 2)

- Income can override both efficient building features AND highly centralized building operations

- Low income individuals live in less energy-consumptive apartments AND often have higher level of attention to price signals which together = less energy use\

- High income individuals live in higher-amenity apartments and ignore weak energy price signals which together = much higher energy use



Objective 3: Reasoned & Habitual Behavior

Problem

Many daily behaviors that lead building residents to conserve or consume electricity are likely to be habitual in nature.

Research Question

Will behaviors that are hypothesized to be habitual be poorly predicted by Stern's (2000)[1] Values-Beliefs-Norms (VBN) framework?

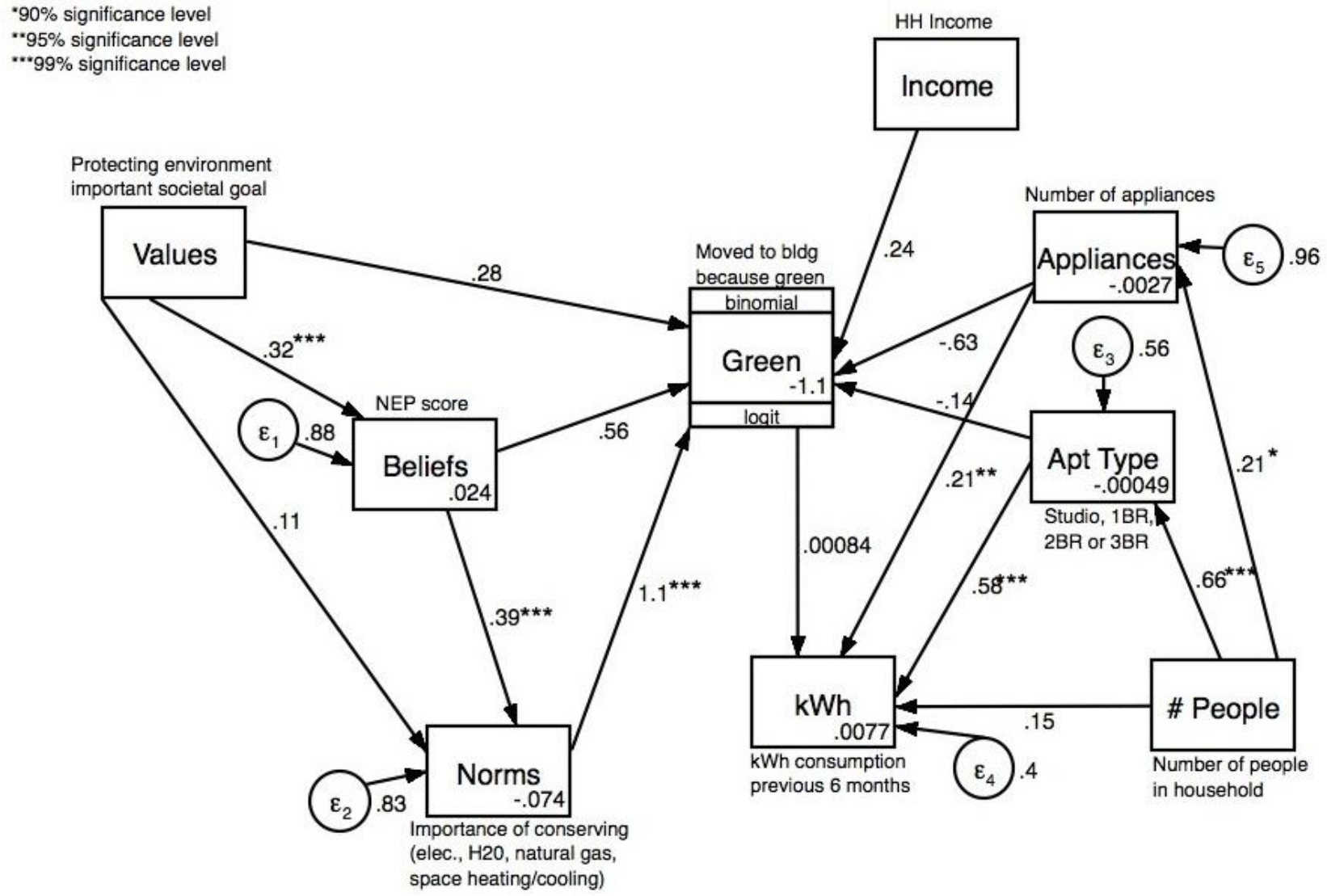
Goal

Advance knowledge of habits in the context of pro-environmental behavior.

[1] Stern, P. C. (2000). Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues*, *56*, 407–424. doi: 10.1111/0022-4537.00175

Reasoned & Habitual Behavior

Results – Building 2



Building 2 Results – in other words…

Path analyses confirmed primary hypotheses regarding reasoned and habitual behavior

- Household behaviors suspected to be fully or partially habitual or non-reasoned were poorly predicted from the causal variables of the VBN framework
    - kWh consumption
    - Loads of laundry
    - Dishwasher usage
    - Lightbulb choice

- A suspected reasoned behavior (moving to the building because it is green) was well predicted by the VBN framework

Reasoned & Habitual Behavior: Discussion

Difficult to ***prove*** with certainty that behaviors are habitual, but findings ***do*** demonstrate that behaviors are not ***reasoned or values-based.***

- Leads to the follow-up Q: How do we activate norms to encourage energy efficiency behavior?
- Design implications: Are some features unintentionally targeting habit-based behaviors? Should buildings be more automated?
- Where are the opportunities for habit intervention? Look to transition points

Manuscripts, Reports, & Publications Available

Hewitt, E.; Andrews, C.; Senick, J.; Wener, R.; Krogmann, U.; & MaryAnn Sorensen Allacci (2015). Distinguishing between green building occupants' reasoned and unplanned behaviors. Building Research & Information. DOI: 10.1080/09613218.2015.1015854

Patton, A.; Calderon, L.; Xiong, Y.; Wang, Z.; Senick, J.; Allacci, M.; Plotnik, D.; Wener, R.; Andrews, C.; & Krogmann, U. Airborne particulate matter in two multi-family green buildings: Concentrations and Effect of Ventilation and Occupant Behavior. Submitted manuscript.

Zuocheng, W.; Calderon, L.; Patton, A.; Sorensen Allacci, M.; Senick, J.; Wener, R.; Andrews, C.; & Mainelis, G. (2013). Comparison of Real-Time Instruments and Gravimetric Method Used To Measure Particulate Matter (PM) In a Green Building

Thank you!

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