

ENGAGE

Behavioral Responses to Real-Time Individual Energy Usage Information (Contract 10-332)

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August 2013



ENGAGE research goals



- How do residents respond to real-time information about their energy use
- How does real time, appliance level information influence electricity usage?

Behavior change decision making



Realize that there is a problem

Identifies cost of behavior of deviation from peers

Realize possibilities to influence the problem

Identifies the impact of specific behavior change

Weigh motives vs cost of action

- Personal values
- Social norms
- Pecuniary incentives

Frame message to motivate behavior

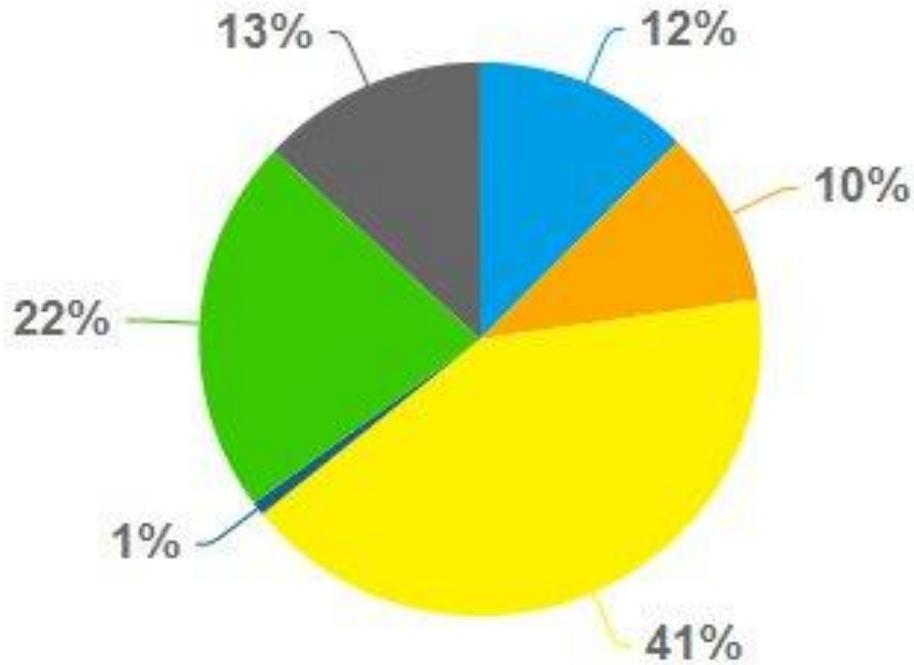
Take action

- Turn on/off lights
- Use of appliances
- Setting the thermostat

Repeated prompts to form new persistent habit

Messages

Real time appliance energy use



Click on the pie to see more details



HEATING
COOLING



LIGHTING



PLUG
LOAD



DISHWASHER



FRIDGE



OTHER
KITCHEN

Price vs Non-Price messages

Information about cost of energy use

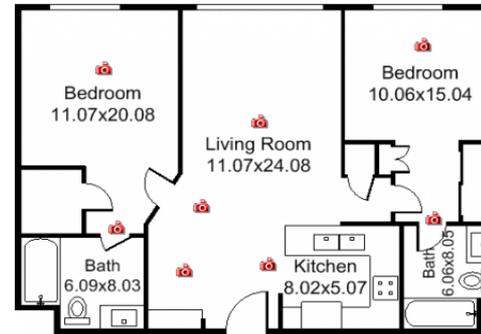


Information about impact of energy use on pollution and health



Experimental site: University Village

- 120 apartments equipped with monitoring technology
- Married/partnered graduate students
- With or without children
- Four major appliances:
 - refrigerator,
 - microwave,
 - stove,
 - dishwasher.

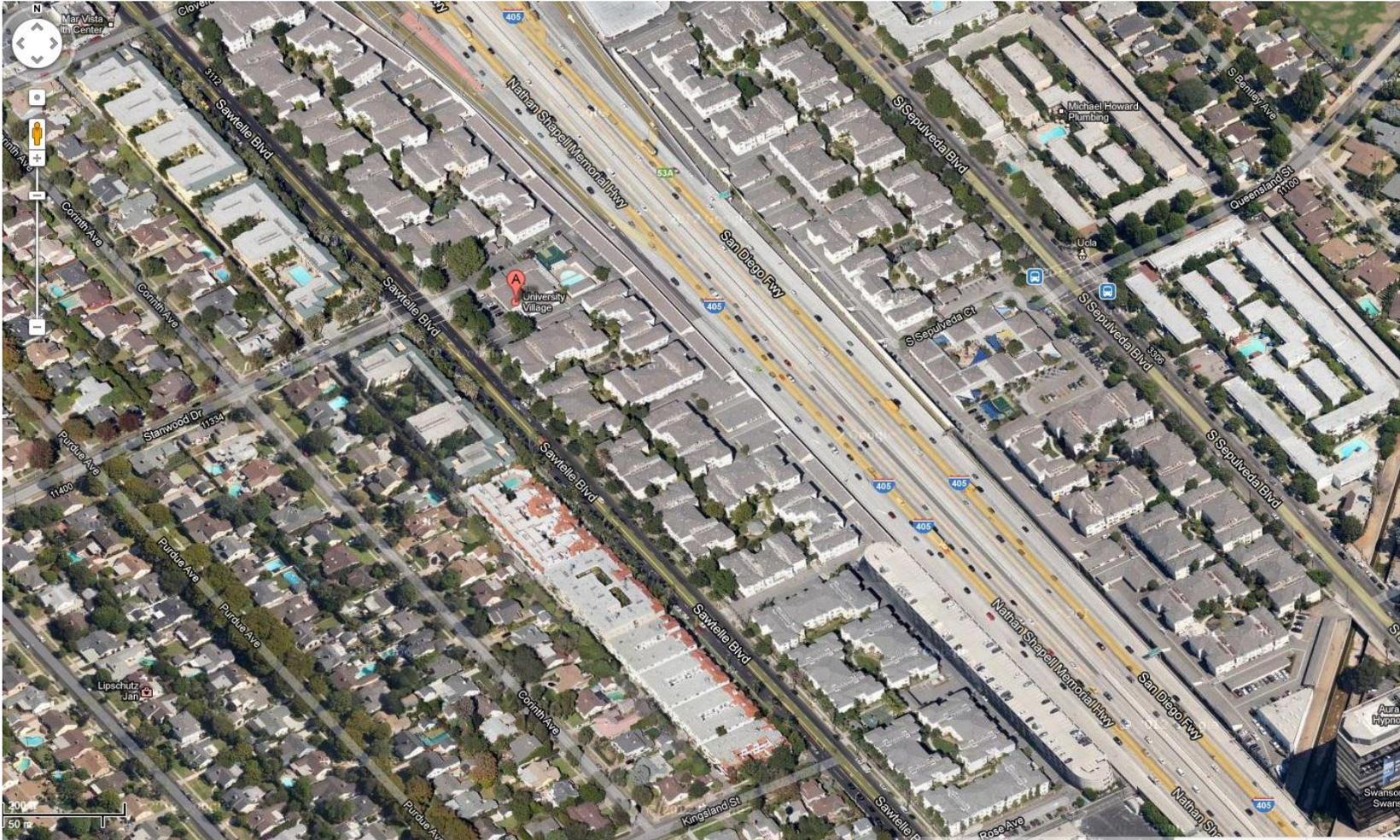


Apartment	Square Ft.	Rent
1 BR	595	\$1,143
2 BR	790-845	\$1,296-\$1,361
3 BR	1035	\$1,538

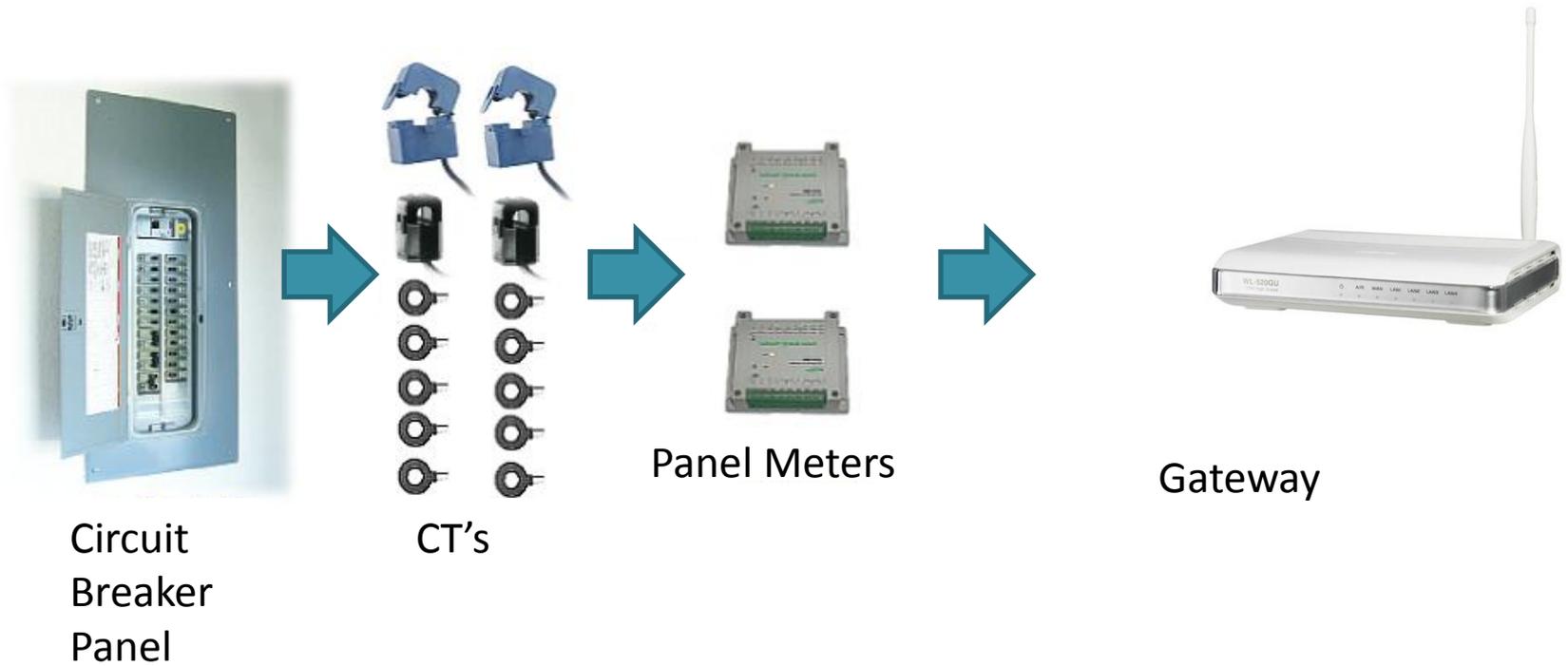
Map of Study Site & Weather Station



University Village



Energy metering system



Real-time, appliance level information



Your Impact

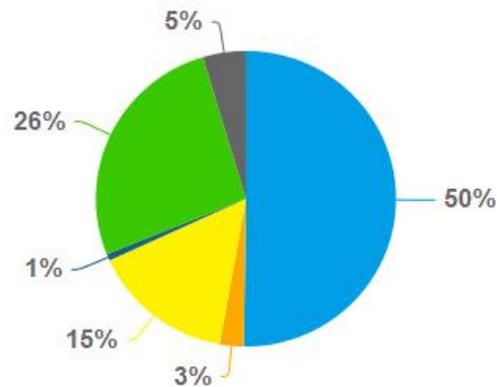
Last week you used **113% more** electricity than your efficient neighbors.
You spend **\$112 more** over one year.

[Home](#)[Month](#)[Day](#)[Now](#)

Your electricity usage for July 23, 2012 - July 29, 2012



Usage by appliance



Click on the pie to see more details



HEATING COOLING



LIGHTING



PLUG LOAD



DISHWASHER



FRIDGE

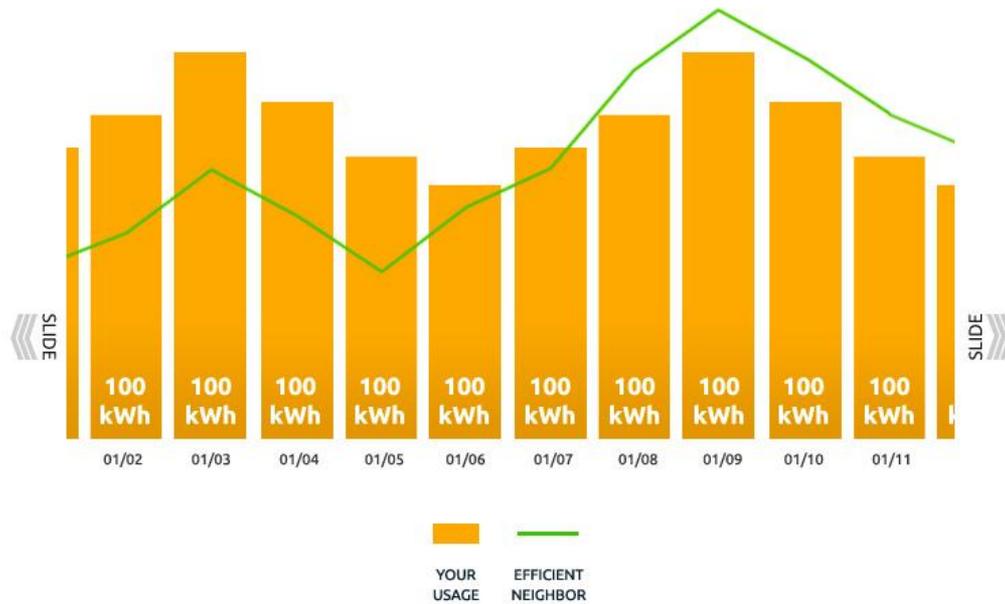


OTHER KITCHEN

UCLA Engage

- Month
- Week
- Day
- Real Time

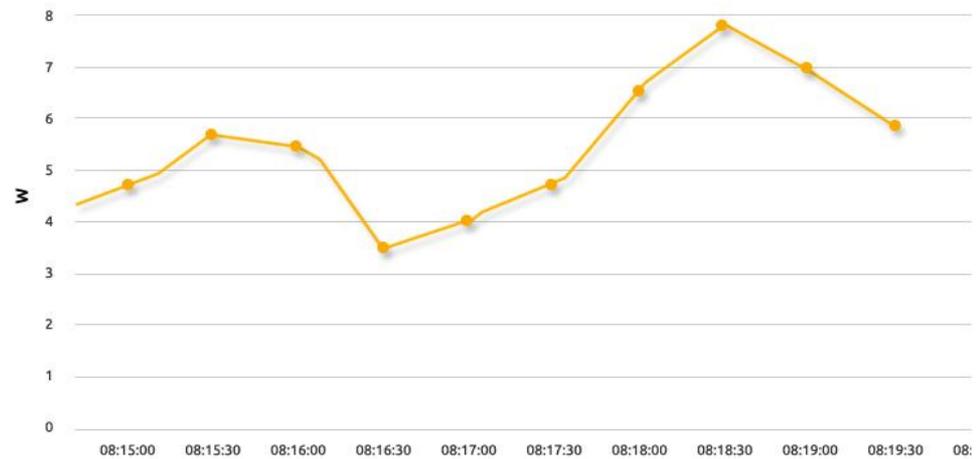
Month: March 2012



UCLA Engage

[Month](#)[Week](#)[Day](#)[Real Time](#)

Real Time



This graph shows the current rate at which you use electricity, measured in Watt (W).

Selected messages

Treatment #1



Your Impact

Last week you used **29 % more** electricity than your efficient neighbors.
You spend **\$26 more** over one year.

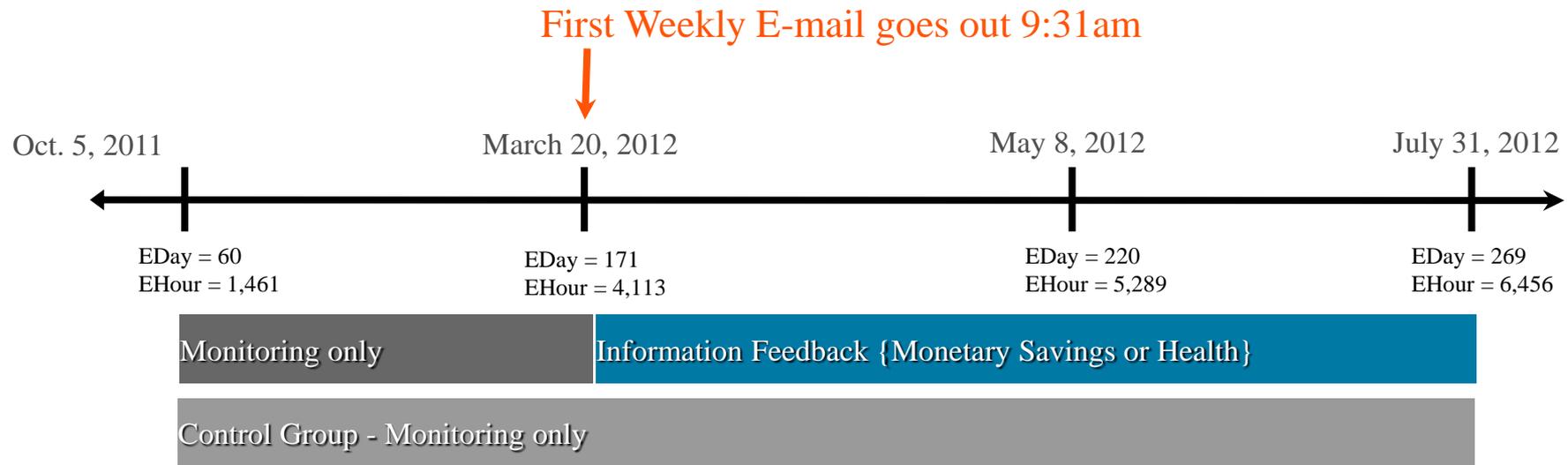
Treatment #2



Your Impact

Last week you used **29% more** electricity than your efficient neighbors.
Over one year, you are **adding 456** pounds of air pollutants which contribute to health impacts such as **childhood asthma and cancer**.

Field Experiment Timeline

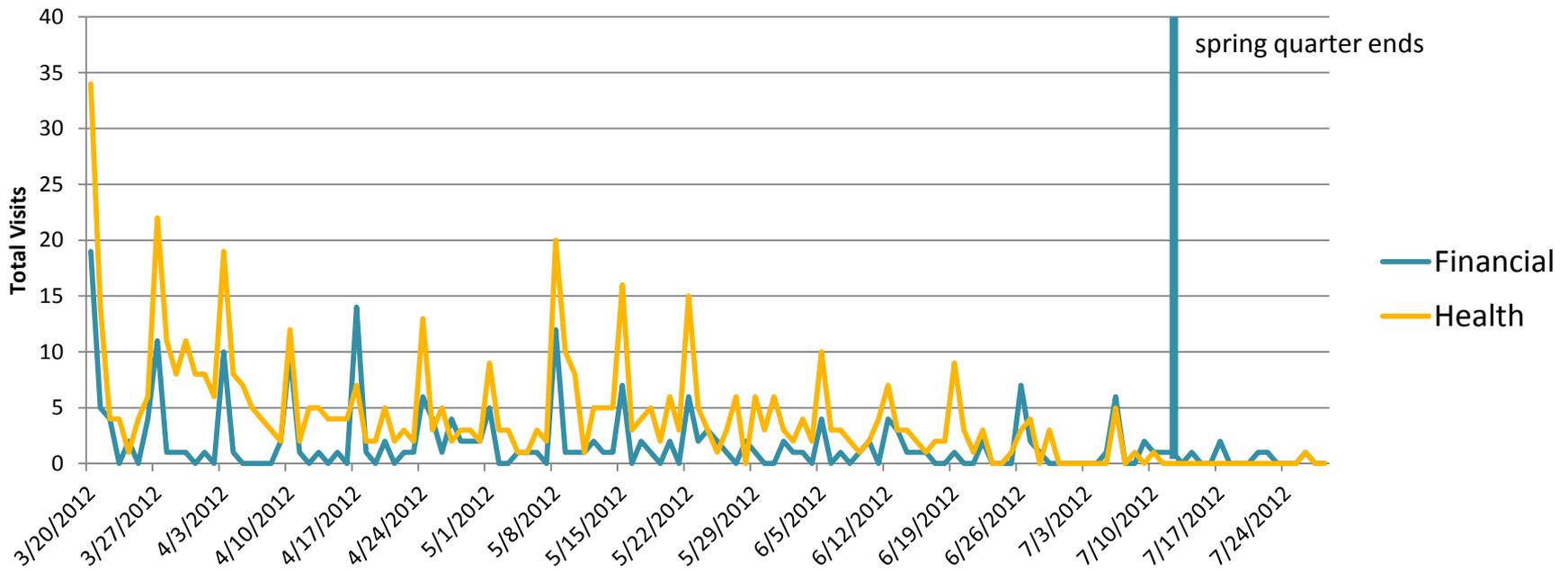


Baseline
(6 months)

Treatment period
(16 weeks ~100 days)

Google Analytics

Total Visits March 20, 2012 - July 28, 2012

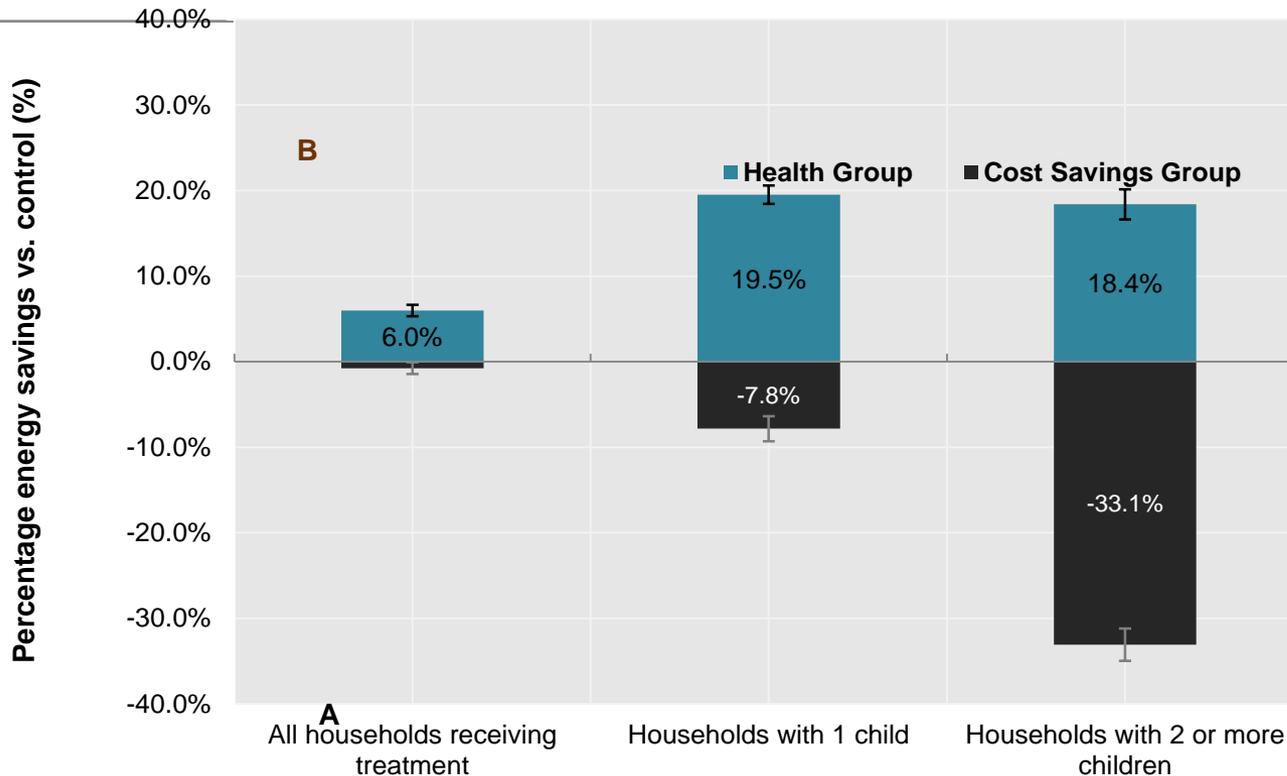


kWh Signal Decomposition

- Total electricity load for each apartment is decomposed into the following *measured* input signals:
 - Heating/Cooling
 - Plug Load
 - Lights
 - Refrigerator
 - Dishwasher
 - Other Kitchen
 - Total kWh

Appliance kWh signals are NOT derived, but experimentally measured

Main Treatment Effects



Includes controls for:

Household characteristics: Occupancy, Apartment size, Building floor, floor plan

Weather controls: heating degree hours, cooling degree hours

Time dummies: hour-by-day, day-by-week, week-by-month dummies

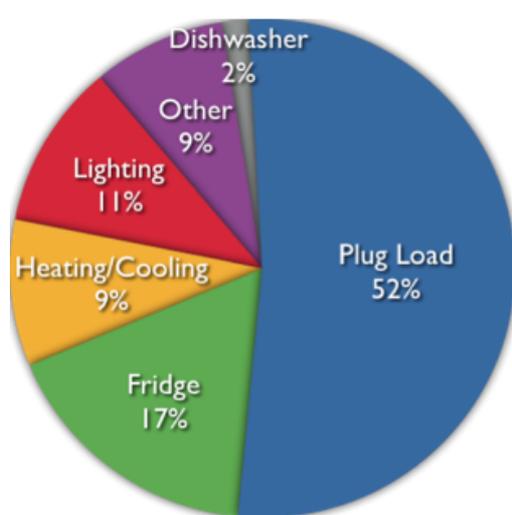
Household Environmentalist ideology: member environmental organization

Appliance Level Results

Plug load is largest share of electricity use

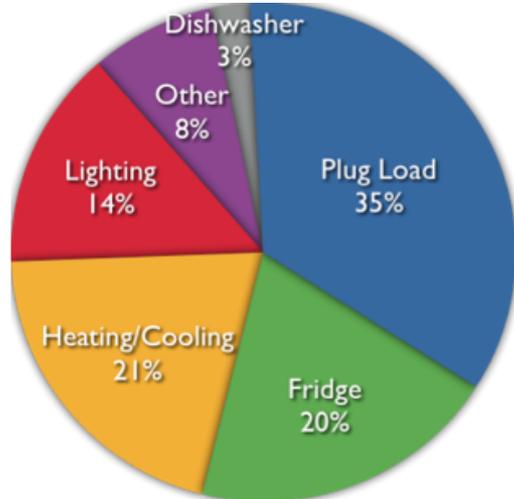
Behavioral Components {Plug load, Heating/Cooling, Lighting} ~70-72%

Major appliances {Refrigerator, Dishwasher, Other} ~ 28-31%



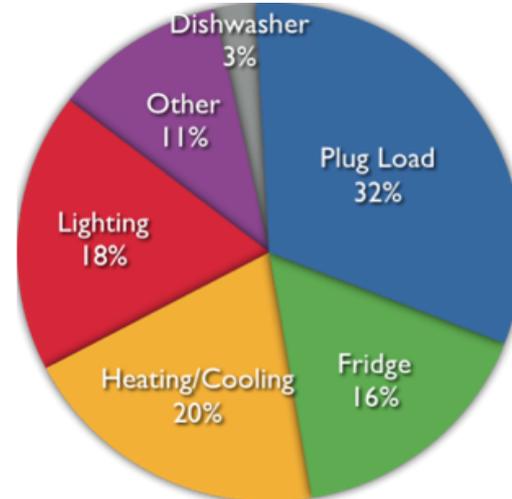
1 bedroom
~595 sq ft

(158.1 kWh/mo)



2 bedrooms
790-935 sq. ft.

(238.0 kWh/mo)



3 bedrooms
~1035 sq. ft.

(346.8 kWh/mo)

Treatment Effects by Appliance

Treatment Effects by Appliance

Study Variables	(4) Heating Cooling	(5) Lighting	(6) Plug Load	(7) Refrigerator	(8) Dishwasher	(9) Other Kitchen
Experimental						
Post-Treat*Monetary Savings Group	9.561*** (1.135)	-11.17*** (0.406)	3.754*** (0.338)	22.43*** (0.295)	21.59*** (0.782)	-2.239*** (0.650)
Post-Treat*Health Group	10.06*** (1.043)	-13.14*** (0.407)	-5.254*** (0.334)	17.72*** (0.289)	9.937*** (0.802)	-1.256** (0.632)
Observations	490,994	490,994	490,994	490,994	490,994	490,994
Number of Apartments	118	118	118	118	118	118
Wald chi-square (<i>d.f.</i> = 53)	4,382***	98,075***	50,526***	57,229***	8,770***	12,056***

Panel Data Estimation by Generalized Least Squares (GLS), errors clustered by Apartment ID.
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Includes controls for:

Household characteristics: Occupancy, Apartment size, Building floor, floor plan

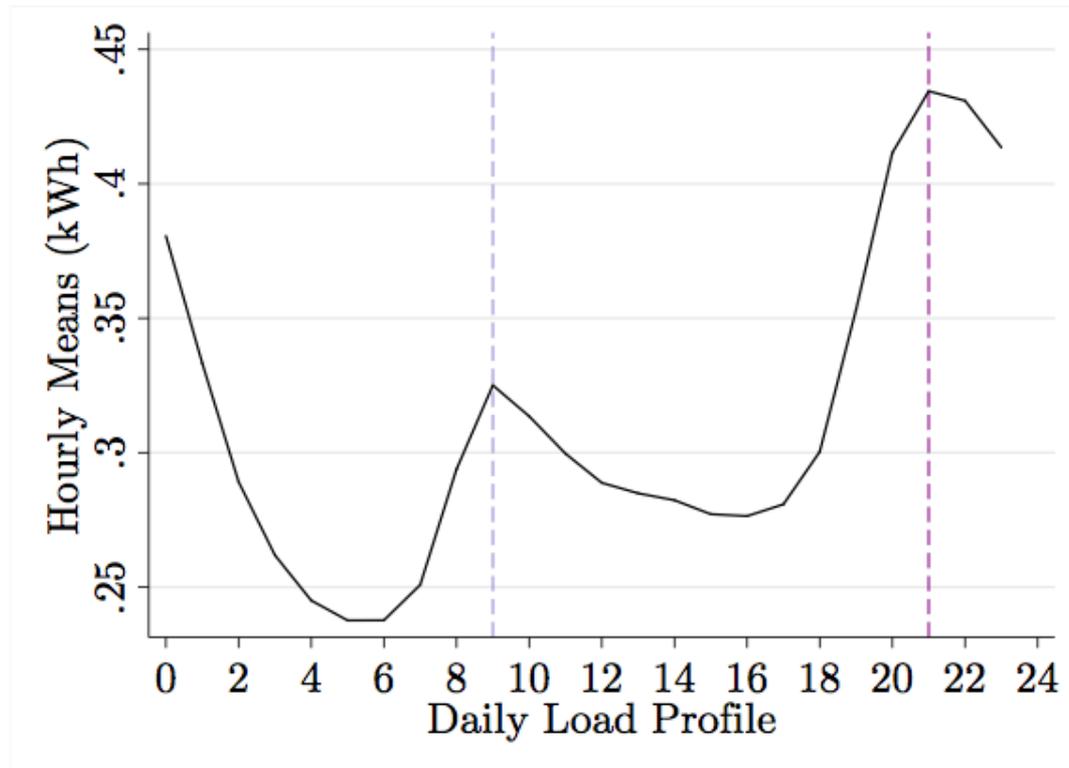
Weather controls: heating degree hours, cooling degree hours

Time dummies: hour-by-day, day-by-week, week-by-month dummies

Household Environmentalist ideology: member environmental organization

Daily Load Profile

Peak consumption occurs at 9am and 9pm



Treatment Effects by Time of Day

Treatment Effects by Time of Day

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Study Variables	Midnight - 3:00am	3:00- 6:00am	6:00- 9:00am	9:00- 12:00pm	12:00- 3:00pm	3:00- 6:00pm	6:00- 9:00pm	9:00- Midnight
Experimental								
Post-Treat*Monetary Savings Group	8.736***	5.938***	2.099***	-2.226**	-0.624	0.376	-2.577**	2.160*
	(0.925)	(0.650)	(0.734)	(0.981)	(0.933)	(0.878)	(1.139)	(1.152)
Post-Treat*Health Group	-2.418***	1.933***	-0.915	-7.769***	-7.364***	-4.825***	-11.33***	-10.18***
	(0.891)	(0.634)	(0.716)	(0.937)	(0.899)	(0.850)	(1.091)	(1.100)
Observations	60,942	60,433	61,206	61,543	61,402	61,581	61,891	61,996
Number of Apartments	118	118	118	118	118	118	118	118
Wald chi-square (<i>d.f.</i> = 32)	6,118***	4,367***	7,877***	5,593***	5,712***	6,218***	7,442***	6,530***

Panel Data Estimation by Generalized Least Squares (GLS), errors clustered by Apartment ID.
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Includes controls for:

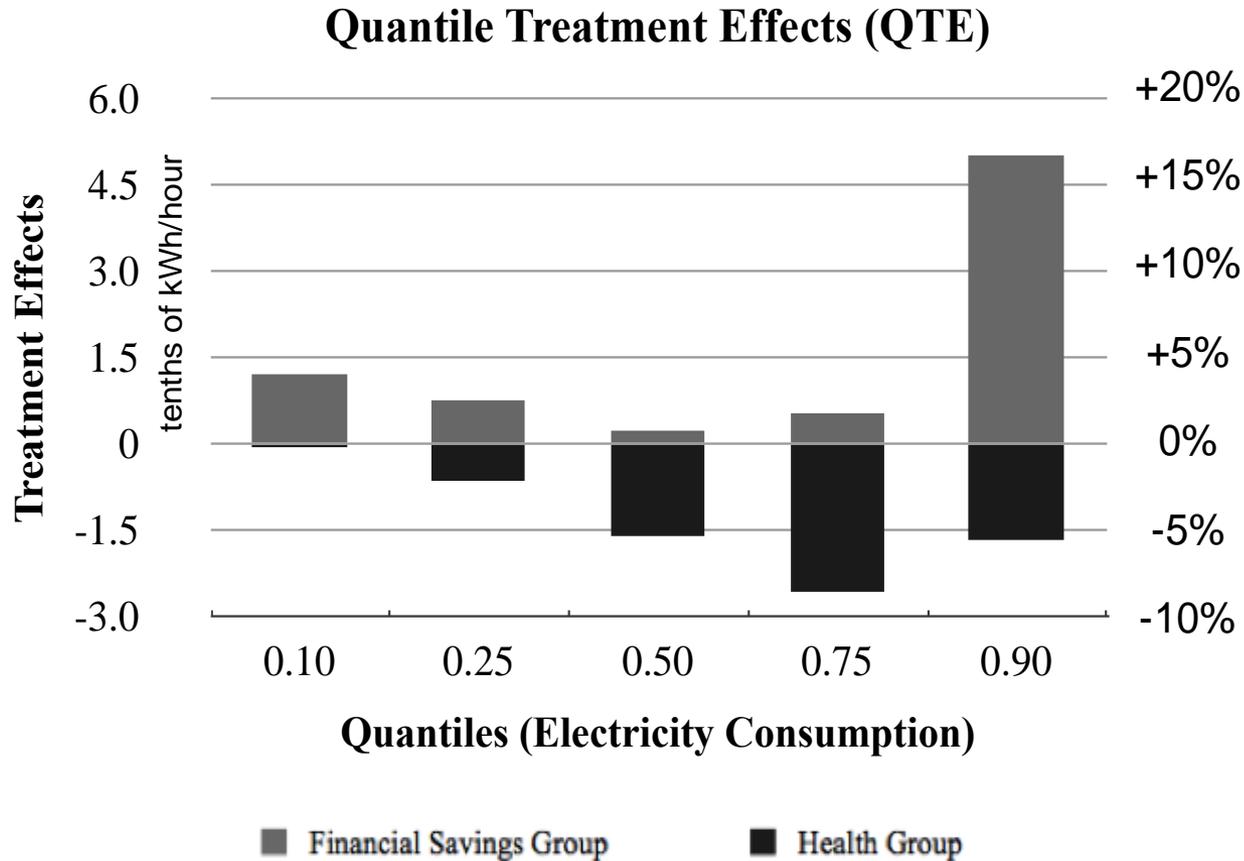
Household characteristics: Occupancy, Apartment size, Building floor, floor plan

Weather controls: heating degree hours, cooling degree hours

Time dummies: hour-by-day, day-by-week, week-by-month dummies

Household Environmentalist ideology: member environmental organization

Quantile Treatment Effects



Recap of Main Experimental Results

- Health treatment is more effective
 - Works well for families with children
 - Financial message is very ineffective for high users
- Timing of savings
 - Savings occur mostly at night
 - Some peak load savings
- Type of savings
 - Plug load

Main Results

- Environmental/Health message is more effective (7 % savings)
 - Works well for families with children (20% savings)
 - Financial message is very ineffective for high users
- Timing of savings
 - Savings occur mostly at night
 - Some peak load savings

Conclusions

- The type of message consumers receive matters
- Understanding user characteristics can help predict user interaction with technology.
- Our research provides insights on how technology and information should be disseminated to maximize conservation.

Back-up slides

Focus group

The **pie chart** had a big impact. It helped us see what the highest impact was. We started turning off the TV and the DVR. So anywhere we could change it we did that.

There was definitely a **novelty effect**. I found myself removing cereal boxes from the top of the refrigerator and we found that helped with consumption.

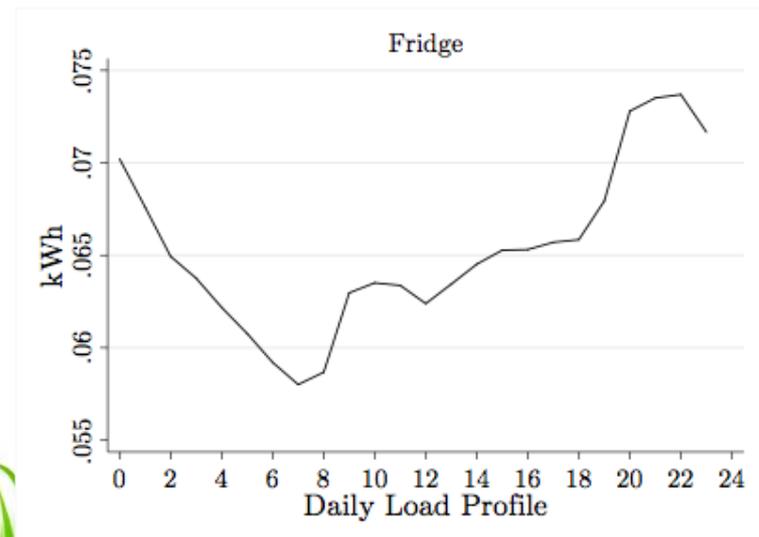
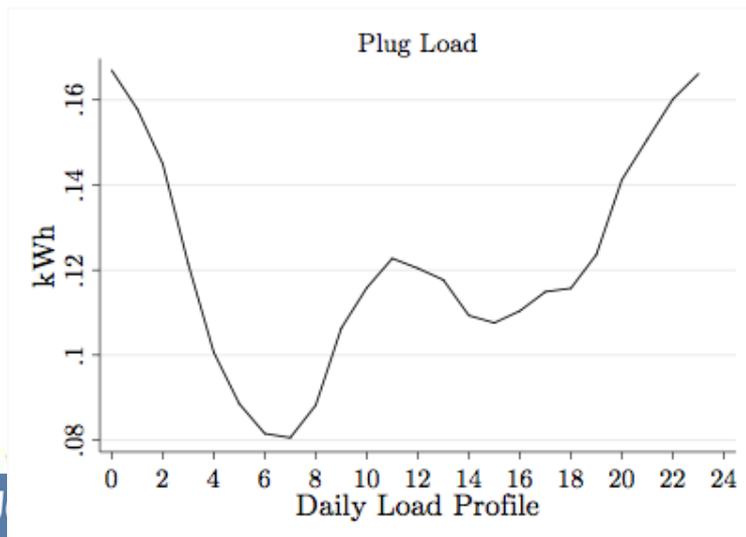
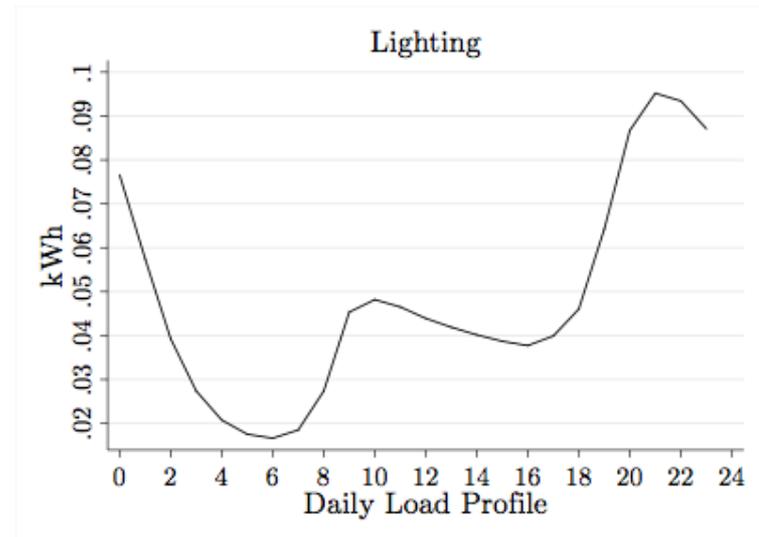
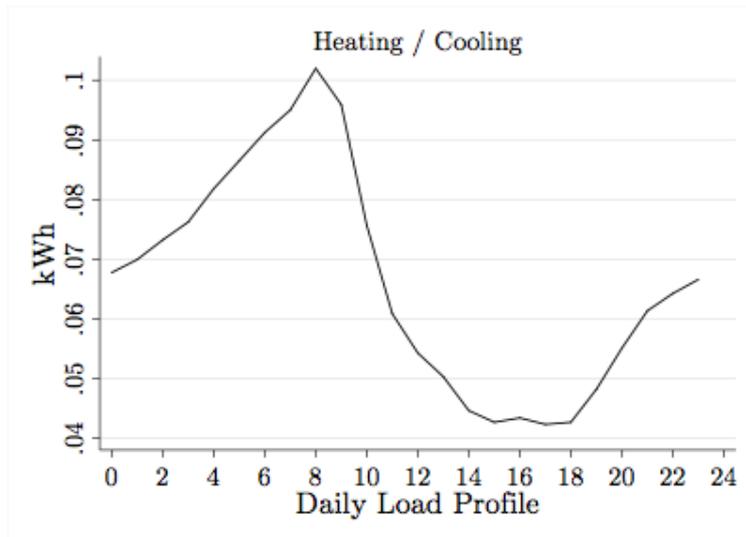
I liked the **real time** information, I realized how much energy the printer was consuming.

It really changed my **habits**. But it didn't motivate me to purchase something that was more efficient.

The **real time** data was kind of disheartening. I learned as a kid to turn the light off, but I learned that it did not make much of a difference.

I try to pull out the chargers, I try to not leave the laptop on.

Appliance level: daily load profiles



Appliance Level Loads

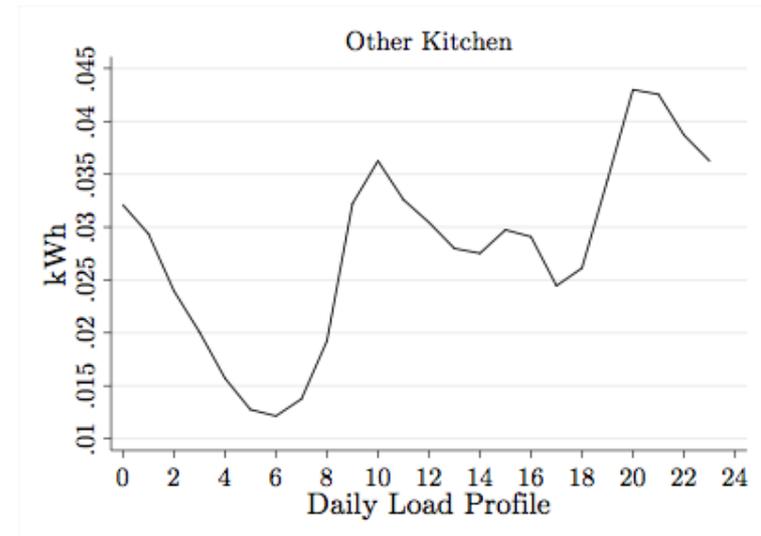
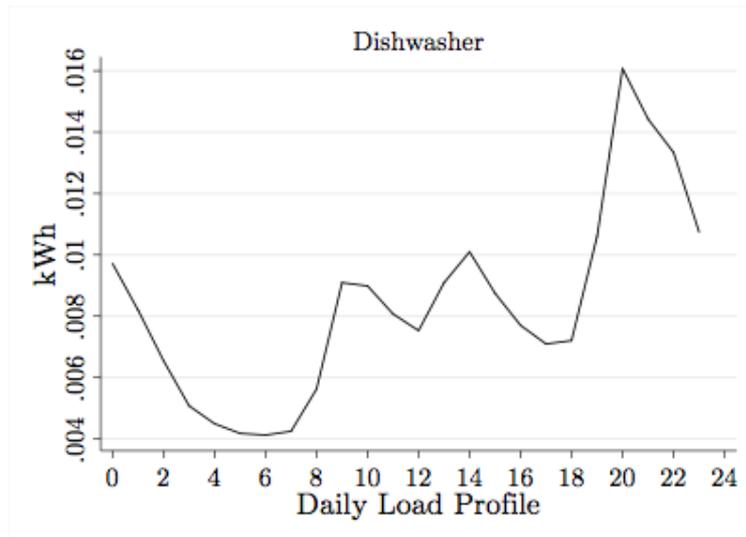


Table 3. Heterogeneous Treatment Effects on Families with Children

Study Variables	(1)	(2)	(3)
	Total kWh	Total kWh	Total kWh
Experimental			
Post-Treat*Monetary Savings Group	0.766**	-1.945***	2.423***
	(0.353)	(0.374)	(0.352)
Post-Treat*Health Group	-5.963***	-6.435***	0.851**
	(0.342)	(0.343)	(0.389)
Post-Treat*Monetary Savings Group*Children=1		7.834***	
		(0.751)	
Post-Treat*Monetary Savings Group*Children=2 or more		33.08***	
		(0.966)	
Post-Treat*Health Group*Children=1			-19.51***
			(0.545)
Post-Treat*Health Group*Children=2 or more			-18.39***
			(0.900)
Children=1		15.20***	20.32***
		(0.264)	(0.275)
Children=2 or more		23.90***	32.73***
		(0.385)	(0.400)

Estimation by Generalized Least Squares (GLS). Errors clustered by Apartment ID.

Standard errors in parentheses
 *** p<0.01,
 ** p<0.05,
 * p<0.1

Household Characteristics

Adults	-3.884***	-2.562***	-3.162***
	(0.357)	(0.366)	(0.365)
Children	12.67***		
	(0.132)		
Apartment Size (No. of bedrooms)	29.86***	31.19***	31.89***
	(0.536)	(0.539)	(0.544)
Floor Plan (Nominal square footage)	-0.0171***	-0.0217***	-0.0219***
	(0.00180)	(0.00180)	(0.00182)
Building Floor	7.166***	7.682***	7.195***
	(0.117)	(0.119)	(0.119)
Ideology			
Member Environmental Organization	-4.993***	-3.900***	-5.436***
	(0.312)	(0.310)	(0.312)

Weather Controls

Heating Degree Hours	0.968***	0.957***	0.967***
	(0.0275)	(0.0274)	(0.0273)
Cooling Degree Hours	0.0417	0.0387	0.0379
	(0.0563)	(0.0562)	(0.0561)

Time Dummies

Hour-by-Day, Day-by-Week, Weekly	Yes	Yes	Yes
Constant	45.33***	42.95***	42.17***
	(1.151)	(1.176)	(1.171)

Observations	490,994	490,994	490,994
Number of Apartments	118	118	118
Wald chi-square (<i>d.f.</i> = 53, 56, 56)	71,422***	72,459***	73,631***