Free Energy, Social Norms, and Conservation: A Single Student Apartment Field Experiment

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Research Questions

- Will consumption naive households, who pay nothing for electricity, engage in conservation behavior when provided with usage information?
- Is there, and what is the level of energy conservation response by providing detailed efficient social norm information?
- Is a pure information conservation effect temporary or persistent?
- If there is a conservation response, is the response homogeneous across consumers? across weeks? across days? across hours?

Literature

- Midden (1983) - comparative feedback yeilded 18.4% reduction
- Allcott (2011) *OPower* study - ATE 2%
- Costa & Kahn (2013) - conservatives more likely to opt out of energy reports
- Delmas & Lessem (2012) - no information effect on dorm residents
- Delmas et al. (2013) - meta-analysis ATE 7.4%

Experimental Setting

UCSB Santa Ynez apartments

- Large number of observational units: 200 apartments, 800 residents
- Accurate high frequency electricity data (Smart meter technology)
- Detailed population demographic information
- Experimental units are near identical
- No compounding price effects
- Even ambient temperature

Experimental Setup

- Treatment period over the Spring academic quarter (April 1 - June 16)
- Apartments were randomly assigned to a treatment and control group
- Treatment consists of each treated apartment resident receiving a weekly email ▸ Email Example ▸ Graph Examples
- Email open and click rate carefully tracked ▸ MailChimp Report
- Pre-treatment and exit surveys

Experimental Validity

Control vs. Treated characteristics (Pre-treatment)

Apartment Demographic Info*

			Control	Treated
	Min	Max	Mean	Mean
Male apartment	0	1	0.51	0.43
Average age	20	25	21.3	21.3
Average units taken	9.2	16.6	14.4	14.5
Average GPA	2.45	3.58	3.1	3.1
Self assigned (%)	0	100	68.8	69.3
Senior (%)	0	100	39.0	42.5
International student (%)	0	43	11.7	7.8
Transfer student (%)	0	100	52.8	56.1
Freshman at UCSB student (%)	0	93	35.3	36.1
			n=95	n=95

* Only a sample of known characteristics are presented, there are over 150 covariates

Basic Regression Model

Empirical Specification: Diference-in-Diferences model
(cluster [apartment] robust standard errors)

$$Log\ (kWhrs)_{i,t} = \beta_0 + \beta_1\, Treated_i + \beta_2 Period_t + \beta_3\, Treated_i \times Period_t + \gamma \mathbf{X}_{it} + \delta \mathbf{Z}_t + \epsilon_{it}$$

$i \in \{Apartment\ number\}$
$t \in \{Quarter,\ Week\ number, Day\ of\ week,\ Hour\ of\ day\}$
$\mathbf{X} \subset \{Occupant\ characteristics,\ Apartment\ characteristics,\ Apt\ FE\}$
$\mathbf{Z} \subset \{Time\ FE\ eg: University\ Holidays,\ Finals,\ HoD,\ DoW,\ MoY,\ etc...\}$

Basic Results - Difference in Difference

Average Apartment Hourly kWhr Reading

	Treated	Control	Difference
Winter Qtr 2013	0.34	0.32	0.02
Spring Qtr 2013	0.28	0.28	0.00
	-0.06	-0.04	-0.02

This is about a 6.6% reduction in electricity use, equivalent to 3500 kWhrs or 2500 lbs of CO_2

Empirical Model Results

- Average treated apartment reduction in electricity consumption is 5%
  ▸ Table 1
- **Week of the quarter** treated electricity reduction varies between 1% and 10% ▸ Table 2
- **Day of the week** treated electricity reduction is largest at the weekend (Sat, Sun - 7%) ▸ Table 3
- **Hour of the day** reduction between 23:00 and 10:00 hrs is large (8%), and between 11:00 and 22:00 hrs the effect is smaller (3%).
  ▸ Hourly effect graph

Are treatment effects homogeneous?

- **Is there evidence for a boomerang effect?** No, just the opposite

  1st quartile (conservers) decreased consumption by about 13%***
  2nd & 3rd quartiles decreased consumption by about 2%†
  4th quartile (energy hogs) increased consumption by about 2%†

- **Do male and female apartments conserve the same?** Maybe†

  Male apartments decreased consumption by about 4.2%
  Female apartments decreased consumption by about 5.7%

* Statistically significant at the 1% level
† Not statistically significant at the 5% level

Exit survey - any behavioral responses?

Control vs. Treated responses (Post-treatment)

Individual Survey Responses

			Control	Treated
	Min	Max	Mean	Mean
Talk regularly about energy conservation? ***	0	1	0.05	0.19
Talk rarely about energy conservation? ***	0	1	0.42	0.19
Attitude moved toward energy conservation? ***	0	1	0.22	0.39
Q1 (energy conservers) **			0.19	0.38
Attitude stayed the same? ***	0	1	0.77	0.52
Attitude moved away from energy conservation? **	0	1	0.01	0.08
Q4 (energy hogs) ***			0.00	0.17
Took no effort to conserve? *	0	1	0.42	0.32
Regularly in agreement with roommates?	0	1	0.35	0.31
Used computer less?	0	1	0.18	0.14
Turn off computer regularly?	0	1	0.43	0.39
Turn lights off regularly?	0	1	0.85	0.85
Took shorter showers regularly?	0	1	0.22	0.25
			n=109	n=110

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Where do we go from here?

- What is the peer effect of the public display of energy usage, how does it compare to the *informational effect*?
- How does 'single student' apartment energy use and the *information effect compare* to family households?
- If apartments revert from paying for utilities to not paying, does their energy use change? In what ways?
- Can we use open/public bidding auctions to reveal a minimal WTA for energy use reduction?

Basic results

Back

Log(kilowatt hours)					
	(1)	(2)	(3)	(4)	(5)
Treated	0.0324	0.0324	0.0324	0.0439	.
	(0.037)	(0.037)	(0.036)	(0.029)	.
Spring 2013 Qtr	-0.0725***	-0.0724***	0.0185	-0.0418	-0.0302
	(0.022)	(0.022)	(0.038)	(0.041)	(0.028)
Treated x Spring	-0.0452	-0.0452	-0.0452	-0.0533*	-0.0507**
	(0.032)	(0.032)	(0.031)	(0.028)	(0.022)
Day & hour FE	no	yes	yes	yes	yes
Month & event FE	no	no	yes	yes	yes
Demographics & apt type	no	no	no	yes	yes
Apartment FE	no	no	no	no	yes
Observations	1,434,894	1,434,894	1,434,894	1,425,895	1,425,895
R-squared	0.003	0.23	0.24	0.34	0.44

Cluster robust standard errors in parentheses (apartment cohort)
** p<0.05, * p<0.1

Week of the quarter results

Back

Log (kilowatt hours)	(1)	(2)	(3)	(4)	(5)
Week 1 x treated	0.0259	0.0259	0.0259	0.0182	0.021
	(0.033)	(0.033)	(0.032)	(0.029)	(0.024)
Week 2 x treated	-0.0046	-0.0046	-0.0046	-0.0135	-0.0106
	(0.033)	(0.033)	(0.033)	(0.030)	(0.025)
Week 3 x treated	-0.0205	-0.0205	-0.0205	-0.0292	-0.0264
	(0.035)	(0.035)	(0.035)	(0.032)	(0.026)
Week 4 x treated	-0.0298	-0.0298	-0.0298	-0.0387	-0.0359
	(0.035)	(0.035)	(0.035)	(0.032)	(0.026)
Midterm week x treated	-0.0142	-0.0142	-0.0142	-0.0225	-0.0197
	(0.035)	(0.035)	(0.034)	(0.031)	(0.026)
Week 6 x treated	-0.0672*	-0.0672*	-0.0672*	-0.0761**	-0.0733***
	(0.038)	(0.038)	(0.037)	(0.033)	(0.027)
Week 7 x treated	-0.0608*	-0.0608*	-0.0608*	-0.0699**	-0.0671**
	(0.036)	(0.036)	(0.036)	(0.032)	(0.027)
Week 8 x treated	-0.0678*	-0.0678*	-0.0678*	-0.0759**	-0.0730**
	(0.040)	(0.040)	(0.040)	(0.035)	(0.030)
Week 9 x treated	-0.0553	-0.0553	-0.0553	-0.0635*	-0.0607**
	(0.037)	(0.037)	(0.036)	(0.033)	(0.028)
Week 10 x treated	-0.0631*	-0.0630*	-0.0630*	-0.0701**	-0.0673**
	(0.038)	(0.038)	(0.037)	(0.034)	(0.029)
Finals week x treated	-0.1049**	-0.1049**	-0.1049**	-0.1039**	-0.1069***
	(0.044)	(0.044)	(0.044)	(0.042)	(0.038)
Day & hour FE	no	yes	yes	yes	yes
Month & event FE	no	no	yes	yes	yes
Demographics & apt type	no	no	no	yes	yes
Apartment FE	no	no	no	no	yes
Observations	1,415,790	1,415,790	1,415,790	1,406,887	1,406,887
R-squared	0.004	0.23	0.24	0.34	0.44

Cluster robust standard errors in parentheses (apartment cohort)
*** p<0.01, ** p<0.05, * p<0.1

Week of the quarter results

◂ Back

Log (kilowatt hours)	(1)	(2)	(3)	(4)	(5)
Week 1 x treated	0.0259	0.0259	0.0259	0.0182	0.021
	(0.033)				(0.024)
Week 2 x treated	-0.0046				-0.0106
	(0.033)				(0.025)
Week 3 x treated	-0.0205				-0.0264
	(0.035)				(0.026)
Week 4 x treated	-0.0298				-0.0359
	(0.035)				(0.026)
Midterm week x treated	-0.0142				-0.0197
	(0.035)				(0.026)
Week 6 x treated	-0.0672*				-0.0733***
	(0.038)				(0.027)
Week 7 x treated	-0.0608*				-0.0671**
	(0.036)				(0.027)
Week 8 x treated	-0.0678*				-0.0730**
	(0.040)				(0.030)
Week 9 x treated	-0.0553				-0.0607**
	(0.037)				(0.028)
Week 10 x treated	-0.0631*				-0.0673**
	(0.038)				(0.029)
Finals week x treated	-0.1049**				-0.1069***
	(0.044)				(0.038)
Day & hour FE	no				yes
Month & event FE	no				yes
Demographics & apt type	no				yes
Apartment FE	no				yes
Observations	1,415,790				1,406,887
R-squared	0.004	0.23	0.24	0.34	0.44

Cluster robust standard errors in parentheses (apartment cohort)
*** p<0.01, ** p<0.05, * p<0.1

Day of the week results

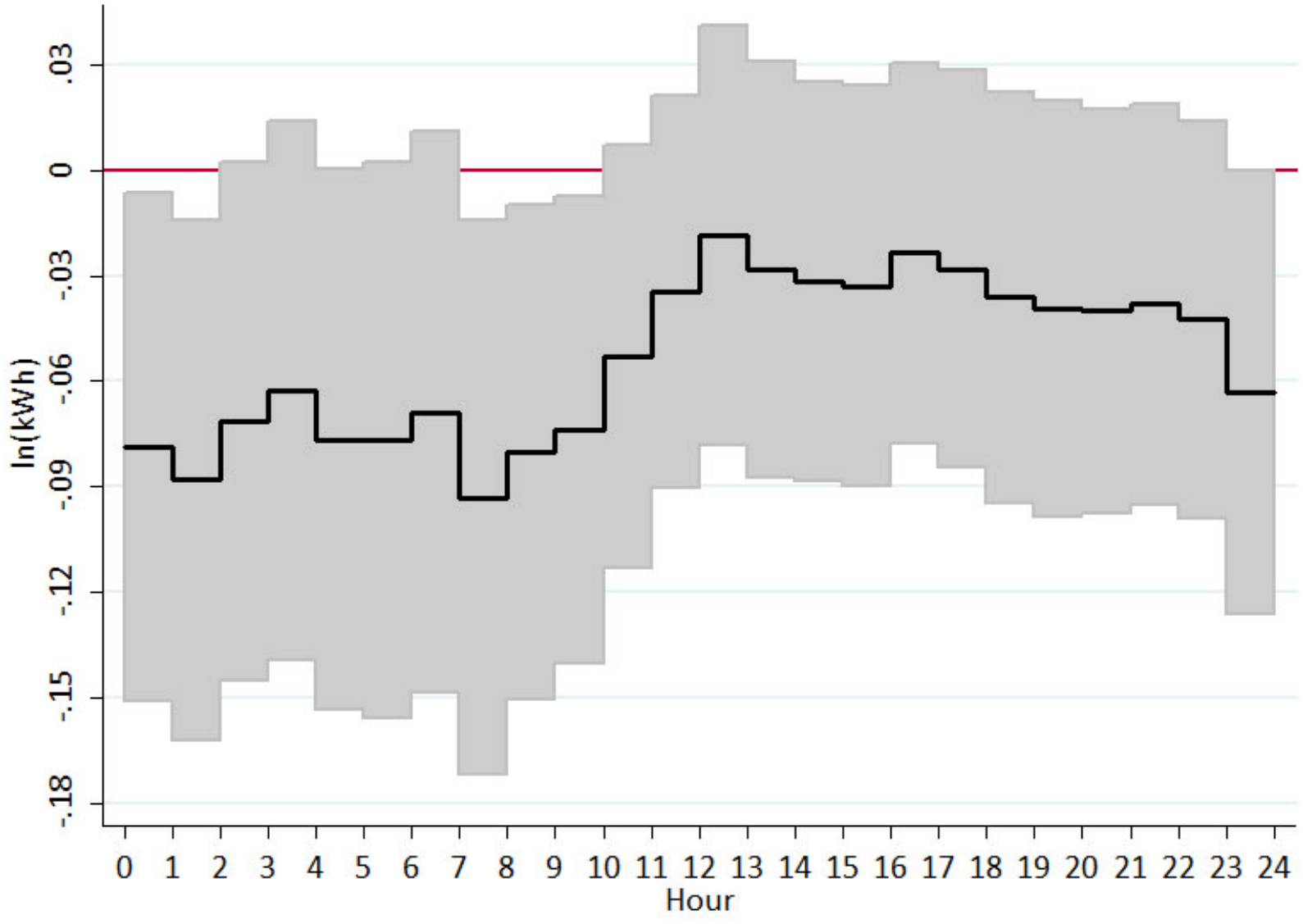
Back

Log (kilowatt hours)	(1)	(2)	(3)	(4)	(5)
Sunday Spring 2013 x treated	-0.0712**	-0.0712**	-0.0673**	-0.0741***	-0.0717***
	(0.031)	(0.031)	(0.031)	(0.028)	(0.023)
Monday Spring 2013 x treated	-0.0376	-0.0374	-0.0293	-0.036	-0.0342
	(0.029)	(0.029)	(0.029)	(0.026)	(0.021)
Tuesday Spring 2013 x treated	-0.0361	-0.0361	-0.0327	-0.0401	-0.0378*
	(0.030)	(0.030)	(0.029)	(0.027)	(0.022)
Wednesday Spring 2013 x treated	-0.0634**	-0.0634**	-0.0595**	-0.0675**	-0.0651***
	(0.030)	(0.030)	(0.029)	(0.026)	(0.022)
Thursday Spring 2013 x treated	-0.0531*	-0.0531*	-0.0493	-0.0573**	-0.0550**
	(0.031)	(0.031)	(0.030)	(0.028)	(0.022)
Friday Spring 2013 x treated	-0.0458	-0.0458	-0.0419	-0.0491*	-0.0467**
	(0.031)	(0.031)	(0.031)	(0.028)	(0.023)
Saturday Spring 2013 x treated	-0.0638**	-0.0638**	-0.0600*	-0.0669**	-0.0645***
	(0.031)	(0.031)	(0.031)	(0.028)	(0.023)
Day & hour FE	no	yes	yes	yes	yes
Month & event FE	no	no	yes	yes	yes
Demographics & apt type	no	no	no	yes	yes
Apartment FE	no	no	no	no	yes
N	1,434,894	1,434,894	1,434,894	1,425,895	1,425,895
R-squared	0.004	0.23	0.24	0.33	0.43

Cluster robust standard errors in parentheses (apartment cohort)
*** p<0.01, ** p<0.05, * p<0.1

Hour of the day results

Back



Example Email

◂ Back

Search address books

APT# 101 : 92.6 kWhrs consumed and 67 lbs of CO2 emitted.

Santa Ynez Energy Conservation Project [conservation=housing.ucsb.edu@mail128.us2.mcsv.net] on beha

Sent: Tue 6/11/2013 6:23 PM

To: Chris

View this email in your browser

Be a Green Gaucho!!

Hi Chris, your apartment consumed **92.6 kWhrs** of electricity, and emitted **67 lbs** of CO_2 this week.

Your energy efficient peers consumed **27.1 kWhrs** of electricity, and emitted **19.6 lbs** of CO_2 the same week.

The carbon emissions of your peak consumption hour was **0.7 lbs**.

How do I interpret and analyze these numbers? Please look at the graphs below

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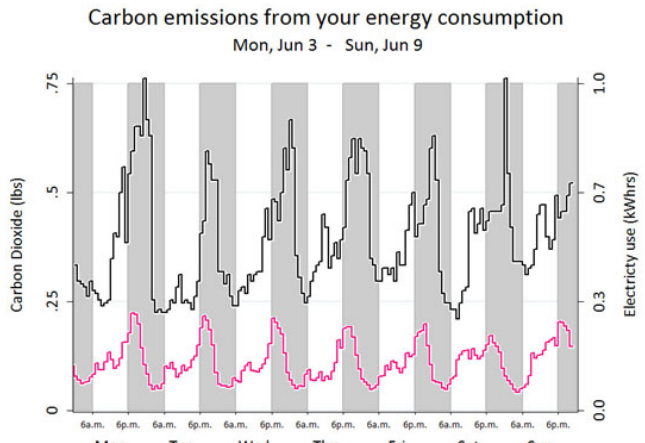
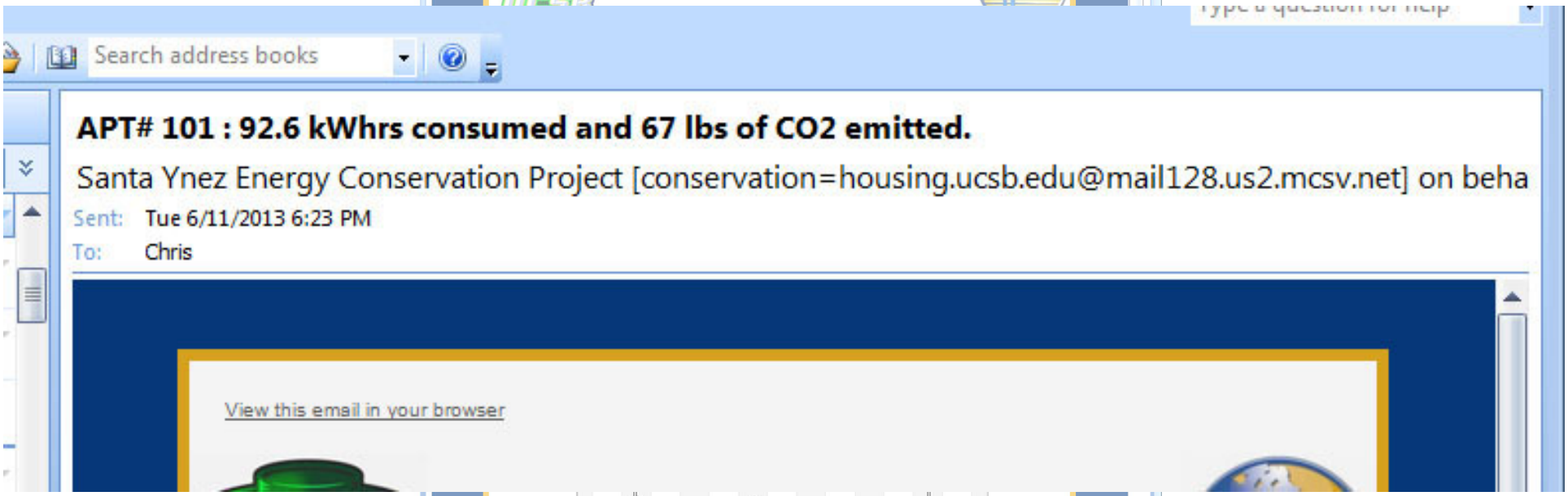


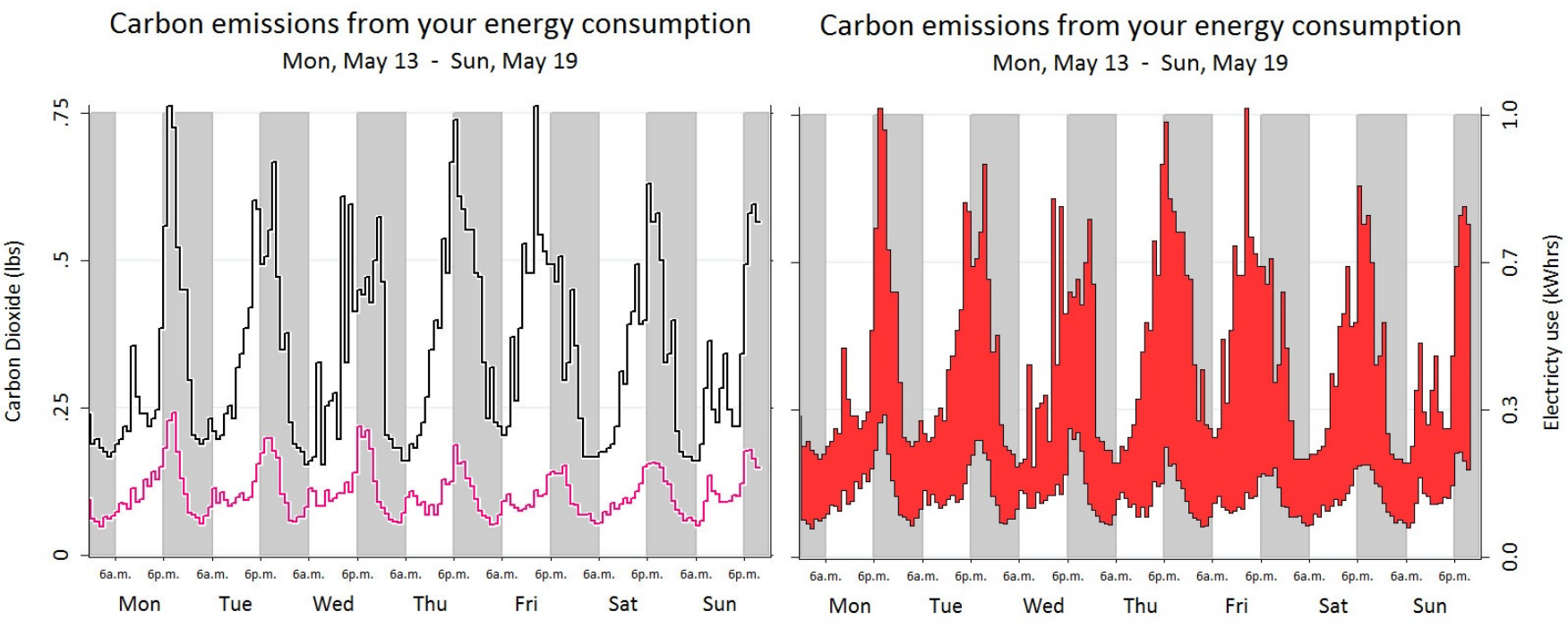
Example Email

Back



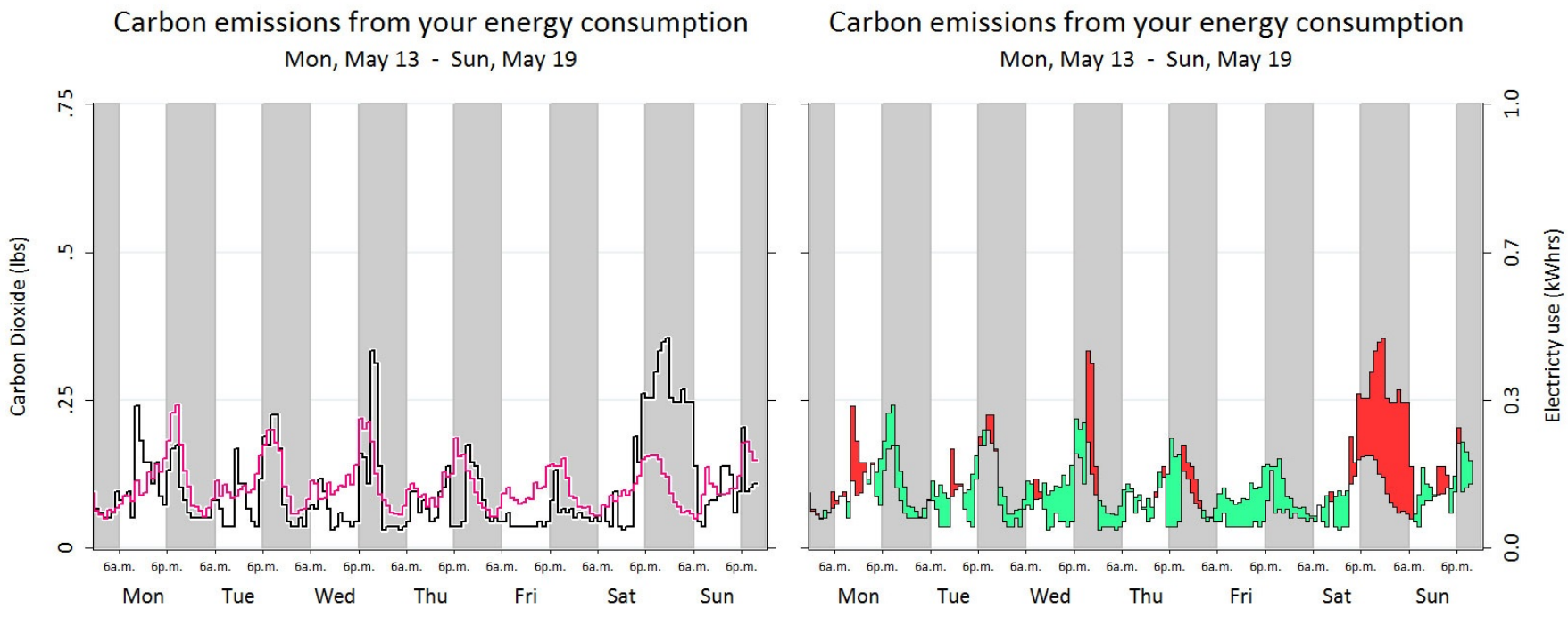
Energy Consumption Graph - Q4

◂ Back



Energy Consumption Graph - Q1

◂ Back



MailChimp Report Page

◂ Back

WK1

View Email » download print share Change Report ▾

Sent 4/8/13 8:58PM

Recipients

410

View

Sent To
List: your Santa Ynez Energy Conservation Project list

Reply-to-Email
Santa Ynez Energy Conservation Project <conservation@housing.ucsb.edu>

Subject
APT# << Test AptNum >> : << Test Energy >> kWhrs consumed and << Test Carbon >> tons of CO2 emitted.

Delivery Date & Time
4/8/13 8:58PM

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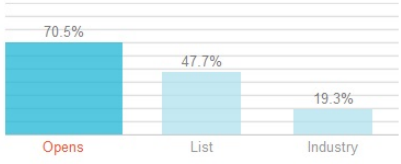

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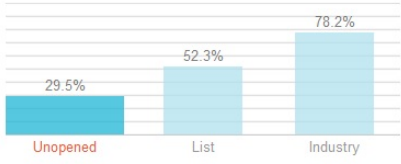

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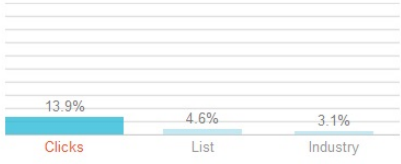

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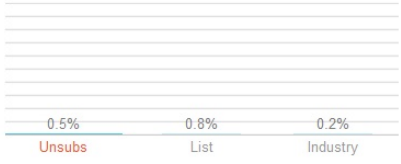

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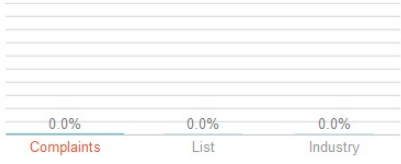

ROI **N/A**

Exit Survey Comments - Roommates

"I was really impressed with this project but unfortunately, I was the one doing all the energy conservation in my apartment. It felt as if my roommates were oblivious to the entire project."

"Either the person in the other room is leaving every light that he uses on when he leaves by his own nature or he might be reacting negatively to those energy usage e-mails resulting in me turning off all of the lights for him. Either way he is an a[][]hole."

"Honestly I think the energy project was quite useless. Although we received many emails, my roommates made no effort to conserve energy. "

◂ Back

Exit Survey Comments - Negative Attitude

"I was somewhat annoyed getting these weekly emails. At first it made me conserve energy by turning of lights more often when not in used, but as I got more of those emails i stopped turning off the lights."

◂ Back

Exit Survey Comments - Control Group

"If you charged for energy people would conserve, or even just letting people know how much they are using it could be reduced."

"I honestly had no idea that this was going on until I got these [exit survey] emails at the end of the quarter."

"Get more people involved, I wish I would have known about this. I would have made an even more conscious effort."

◂ Back

Exit Survey Comments - Treatment Group

"I thought it was very useful getting those emails each week and tuned me into how much energy was being used!"

"I thought it was a great idea to inform residents of their energy usage!"

"it was nerve wracking to receive those emails every week, and have one more thing to stress over."

"The emails were super annoying. I swear the data is wrong we all made a conscious effort to conserve every day and our numbers actually went up."

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