Pepperwood Apartments: A Case Study in Assessing Energy-Efficient Affordable Housing Renovations

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Presentation Outline

- How Study Came About
- Study Purpose and Scope
- LINC and Project Description
- Electricity Analysis Methodology
- Electricity Findings
- Water Analysis Methodology
- Water Findings
- Conclusions

How This Came About

- What Quantec does
- Lunch in the exhibitor hall……
- LINC and their needs

Study Purpose & Scope

- Analysis
  - Energy and water savings of a multifamily, affordable housing green retrofit
  - Short-term analysis
  - Analysis after one year—compare to short-term results
  - Compare actual savings to predicted
- Scope
  - Planned to analyze natural gas and electricity energy impacts
  - Assess changes in water consumption
  - Comparison of pre and post retrofit periods
  - Translate savings into economic impacts

LINC Housing Corporation Description

- Goal: Provide housing for people underserved by marketplace
- Originated by Southern California Association of Governments
  - Meet housing needs of groups (e.g., retired teachers, service sector personnel, young working families) faced with escalating land prices
  - Formed as nonprofit Corporate Fund for Housing, 1984
  - LINC—Limited Income Communities: name change in mid-1990s and scope expanded statewide

LINC Projects

- Innovative approaches
  - Enhance lives of people and communities
  - Utilize sophisticated financing strategies
  - Work with city partners
  - Provide comprehensive services: development, resident services, asset management, accounting
- More than 6,000 units valued at $1B
  - Cover all of California
  - Nearly 60 projects
  - New construction, acquisition/rehabilitation, mixed-use and re-use

Study Project Overview

- The Pepperwood Apartments
  - In Rancho Cucamonga, CA: fast growth and rapidly rising costs
  - Acquired 2006
  - 230 units
    - 52 studios, 128 one-bedrooms, 50 two-bedrooms
    - 7 buildings
  - Convert market-rate units to affordable homes → tenants changed in all but 20 units
  - Retrofits phased in
- Financing
  - $43M
  - City of Rancho Cucamonga, Citibank, Century Housing

Project Green Features

- Home Depot Foundation provided funding
- Increased affordability for tenants by lowering operating costs
- Measures
  - Upgraded insulation levels: roof R-19→R-38
  - More efficient water heaters, furnaces, air conditioners (SEER 7.5→12), and appliances
  - Double-paned windows (U-value 1.28→0.38), doors, and weather stripping
  - Compact fluorescent lights (CFLs)
  - Low-flow toilets

Projected Impacts

End Use	Pre-retrofit, kBtu/sf-yr	Post-retrofit, kBtu/sf-yr	Projected Savings
Space heating	5.41	1.91	65%
Space cooling	31.63	15.43	51%
Fans	4.29	2.55	41%
Hot water	27.84	21.78	22%
Total	69.16	41.67	40%

- Estimates are from EnergyPro California energy code compliance software
- Lighting and plug loads are not included
- No estimates of projected water savings were available
- LINC predicted 20% energy savings

Electricity Analysis Methodology

- Data collection
  - Occupancy information: number of occupants after retrofit; move out/move-in dates
  - Daily temperature data from nearest weather station
  - Billing data for each unit: Jan 2004 through Dec 2007

- Data preparation and cleaning
  - Calculate heating degree-days (HDD) and cooling degree-days (CDD) for each day using 65°F reference temperature
  - Convert billing data, HDD, and CDD to calendar month values
  - Clean data
    - Remove obviously erroneous data
    - Identify vacant periods and remove
    - Select post-retrofit period

Electricity Analysis Methodology

- Time period
  - Pre retrofit period ~ two years
  - Post retrofit period
    - ranged from 3 to 11 months in first (**short-term**) analysis
    - averaged 11.3 months in second (**long-term**) analysis
- Pre and post periods were matched for each unit, e.g.

  Feb-Dec 2007 ⟺ Feb-Dec 2005/Feb-Dec 2006
- Considered screening based on raw savings
  - Compared raw percent change in use between pre and post periods
  - Common practice is to remove observations with >50% savings
  - Results suggested no screening justified

Electricity Model

$$ADC_{it} = \alpha_i + \beta_1 * POST_{it} + \beta_2 * AVGCDD_{it} + \beta_3 * AVGHDD_{it} + e_{it}$$

Where for customer *i* and month *t:*

ADC_{it} is average daily consumption during pre or post period

α_i is apartment intercept; represents base load in pre and post period

β_1 is average daily savings, after accounting for weather differences

$POST_{it}$ is 1 in post period, 0 in pre period

β_2 is cooling slope in pre or post period

$AVGCDD_{it}$ is average daily CDD for pre or post period

β_3 is heating slope in the pre or post period

$AVGHDD_{it}$ is average daily HDD for pre or post period

Electricity Model

- Fixed effect model (α_i) used to capture unique, constant base load consumption for each apartment
  - Minimizes heteroscedasticity (non-constant variance)
  - Reduces effects of apartments with large consumption on estimate
- POST variable coefficient provides estimate of monthly savings by apartment
- Other models including floor area and number of occupants were examined, but rejected

Electricity Savings, Long-term

Unit Type	% of Units	Pre Annual Usage, kWh	Savings, kWh/day	Annual Savings, kWh	Savings as % of Pre Usage	t-test	Precision @90%
Studio	21%	3,079	0.6	207	7%	-3.69	45%
1 Bedroom	56%	4,174	3.2	1,167	28%	-20.83	8%
2 Bedroom	23%	5,749	3.5	1,292	22%	-10.24	16%
Overall	100%	4,308	2.7	973	23%	-22.35	7%

- Absolute and relative savings increase with apartment size
- Savings coefficient is statistically significant in all cases
- Savings estimated for studios are not very precise
- Results for all apartments combined agree well with individual apartment type estimates

Short- vs. Long-term Savings Estimates

Unit Type	Estimated Savings, kWh/day		Estimated Savings, kWh/year		Precision @ 90%	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
Studio	0.6	0.5	207	199	45%	53%
1 Bedroom	3.2	2.8	1,167	1,027	8%	9%
2 Bedroom	3.5	3.7	1,292	1,337	16%	14%
Overall	2.7	2.4	973	890	7%	8%

- Agreement reasonably good between short- and long-term estimates
- Short-term savings estimated with very limited summer month data
- Estimated overall savings increased with long-term data
- Precision improved, in most cases, with long-term data

Aggregate Energy Savings

- Savings for entire complex ~ 212,000 kWh/year
- Equivalent to about $32,000/year or $140 per apartment on the average
- Analysis of natural gas savings will be conducted later

Water Analysis Data

- Obtained billing data from water company, May 2005—November 2007
  - Billing periods are approximately every two months
  - Short-term analysis included only one 2-month post-retrofit bill
  - Long-term analysis included 8 months post-retrofit
- Nine accounts
  - One for each of 7 buildings, but no pre data for 1
  - Two for irrigation
- Data provided as printout showing meter reading and date
- Reported in 100 cu.ft. (748 gallons)

Water Analysis Methodology

- Analyzed each building separately
- Compared consumption for billing period in 2007 to same period in 2005
- Divided by number of days in period to normalize to usage/day
- Computed changes in consumption by building

Water Findings, Long-term Data

Building	Change in Avg. Building Daily Usage, 100 cu.ft.	Avg. Change in Usage/Apartment, gals/day	No. Apartments in Building
1	0.0	0.5	42
2	-1.6	-30.0	40
3	-0.8	-24.1	24
4	-1.0	-28.9	26
5	-1.0	-22.3	32
6	-0.7	-21.1	34
Overall Change in Usage			
% Change	Avg. by Apartment, gals/day	Annual water savings, gal.	Annual bill savings
-14.3%	-19.9	1,670,537	$ 2,970

- Usage increased slightly in one building
- Overall usage decreased more than 14%
- Savings by apartment average about 20 gal/day
- Annual bill savings were almost $3,000

Water Findings

- Absolute savings were highly correlated with apartment size
- Estimates based on short-term (2 months) billing data agreed well with long-term results at aggregate level
  - Within 5% across all buildings
  - Within about 30% at building level

Conclusions

- Impacts
  - Significant electricity and water savings were achieved
  - Comparison with projections was not possible—modeling issues
  - Costs of electricity and water decreased $35,000/year
  - Natural gas savings need to be analyzed
  - Cost effectiveness was not analyzed
- Methodology
  - Obtaining billing data can be a challenge
  - Short-term analysis can provide reasonably accurate estimates of long-term savings, especially at aggregate level
  - Analysis can be conducted with modest effort