Replicable and Scalable Near-Zero Net Energy Retrofits for Low-Income Housing

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ABSTRACT

LINC Housing Corporation partnered with Electric Power Research Institute, BIRAenergy, Southern California Edison and Southern California Gas Company to develop, demonstrate, and document the implementation of deep, near-zero energy retrofits in low-income multifamily properties in California, through a comprehensive turnkey approach including:

- Cost-effective Very Efficient Retrofits (VERs)
- Rigorous monitoring to validate actual savings
- One-stop delivery models
- Resident education

The VERs were implemented at The Village at Beechwood, a 100-unit low-income property owned by LINC in Lancaster. The team designed solutions for and evaluated different building and unit types. Energy and demand savings were facilitated through resident engagement and installation of smart thermostats.

Launched in October 2013, the PIER Beechwood Team developed a baseline and VERs, with construction starting in 2015. Construction in the community building and implementation of emerging technologies will continue into 2016, as well as monitoring activities. One year of post-retrofit energy data is being collected from resident units. LINC's Resident Services team will work with residents throughout the process to encourage energy-wise behavior. This presentation will update initial findings presented in 2014 (Dutta, Hammon, and Narayanamurthy 2014), comparing design goals to actual results with lessons learned through the process. Presentation content will range from test data to resident interviews. The project goal was to demonstrate scalable, replicable models and provide tools for implementation to multifamily property owners. Real upgrade costs combined with estimated utility-bill savings represents a 20-year simple payoff, suggesting that this process could be scaled and maintain cost-effectiveness in the absence of grant funding.

Introduction

Residents of low-income housing in California often carry the brunt of allotting a higher proportion of their income to utility costs compared to other income groups. This is primarily because owners of low-income multifamily housing lack the ability to raise rents and reinvest in a property's energy efficiency. This hurdle is raised higher by the programmatic barriers owner's face in receiving regular funding for energy improvements. The Village at Beechwood (VAB), a 100-unit, low-income multifamily property in Lancaster, California, and owned by LINC

Housing Corporation, is one such property. The community operates with one of the highest energy indices of all LINC properties due to extreme seasonal climates (Climate Zone 14) coupled with apartment structures and HVAC equipment in need of rehabilitation and energy efficiency retrofits. As residents pay their own electricity utility bills, high costs in the summer can be financially burdensome.

In March, 2013, a strong interdisciplinary team consisting of Electric Power Research Institute, BIRAenergy and LINC Housing Corporation, in collaboration with Southern California Gas Company and Southern California Edison, received a $1.3 million grant from the California Energy Commission's Public Interest Energy Research (PIER) program. PIER supports energy-related research, development and demonstration for research not adequately provided by competitive and regulated markets. The PIER funding, in addition to leveraged funding through grants secured by LINC, was applied at the Village at Beechwood (PIER Beechwood Project) to help develop, demonstrate and document the steps and components needed by low-income multifamily property owners to make whole-house energy efficiency retrofits feasible using a replicable, straightforward process.

Research Scope and Methodology

The PIER Beechwood Project has developed a package of very energy-efficient retrofit features (VERs) and retrofitted 30 residences in an existing 100 unit low-income multifamily property. We also evaluated the opportunities to make such improvements widespread in the low-income housing market, as well as to determine the feasibility of low-income properties being retrofitted near-ZNE energy. This project looks to establish VERs that are cost-effective, scalable, and can be adopted into utility programs. This effort includes technologies that have high potential but are under-represented in the market as well as those in early development stages. Development of the VER packages provides the PIER Beechwood Team with the ability to demonstrate the technical and financial value of VERs delivery models that can be replicated and scaled as well as presented to lenders and investors.

Thirty units comprising the various unit- and building-types at the property have been retrofitted to provide for testing and evaluation of measure packages for duplex dwellings with shared water heaters, as well as multiplex units tied to central water heating systems. This project provides incentive to prioritize the production of scalable and replicable measure packages that can be applied to other LINC properties and marketed to other multifamily property owners statewide.

The PIER Beechwood Team completed the following tasks under this project: Developed baseline; Calibrated model; Collected energy-consumption data; Developed and implemented VERs package; Refined VERs package on pilot subset of residences; Retrofitted VERs on remaining set of residences to be retrofitted and evaluated in comparison to surrounding non-retrofitted (control) residences; Developed and implemented data collection program; Collected and analyzed data from both retrofitted and control residences.

Leveraged Funding and Utility Program Coordination

To approach the target of near-ZNE consumption this 30-unit PIER Beechwood Project has required sources of funding in addition to the $1.3 million PIER funding. This supplemental funding has predominately occurred through grants already awarded to LINC, who is a part of a national collaborative group that received an Energy Innovation Fund (EIF) grant from the US

Department of Housing and Urban Development (HUD). While the PIER funding has been allocated to the development and implementation of the VERs within the 30 units, the EIF grant covered the costs of implementing renewable systems including a solar domestic hot water system and a solar photovoltaic system designed to offset essentially all of the remaining electricity needed by VERs-retrofitted residences, assuming equal distribution of the generation.

In addition, LINC is using a grant through the Federal Home Loan Bank of San Francisco's Access to Housing and Economic Assistance for Development (AHEAD) program to provide community-wide wireless internet access that is critical to the success of the program's M&V component by providing a viable platform for data loggers to retrieve and transmit energy consumption data.

Utility Program Coordination

To further leverage the matching grant dollars from HUD, LINC spent considerable time evaluating the feasibility of utility incentive and rebate programs that provide direct install measures as well as dollar incentives based on overall energy savings. LINC's ideal combination of utility program offerings for the project would benefit *all* 100 units at the property in one way or another, not simply the 30 units under scrutiny as part of the PIER project. Fortunately, the use of incentives offered through partner Investor-Owned Utilities (IOUs) did not preclude the use of CEC funding nor double count the amount of funding allocated to a single measure as part of the VERs packages.

The PIER Beechwood Team was challenged with identifying which combination of available programs provided the greatest ability to leverage additional resources given the proposed scope of work for the 30 units.

Physical Property Description

The 100 units at VAB are located within 28 residential buildings comprised of four 10-plex buildings of either 1- or 2-bedroom units, two 8-plex buildings of 2-bedroom units, or 22 duplexes with a mix of 2- and 3-bedroom units. All of the buildings have two stories, and each unit is located on a single floor and ranges in size from 650 sq. ft. to 1,050 sq. ft. Water heating for each duplex is provided by a shared 40 gallon, storage gas water heater. Two groups of three buildings, one 8-plex and two 10-plex buildings in each group, are supplied with hot water by a central boiler system located between the three buildings.

The resident units have an average 12 percent glazing as function of floor area. The windows are dual pane in aluminum frames. The buildings have aged, 2" batt insulation (1970s-era R7 rockwool) in the walls and ceiling.

The built up roofs are light-colored, and each unit has its own roof-mounted package unit providing gas-furnace heating and compressor cooling. Uninsulated metal "L" connector-ducts drop from the air-handler on the roof into a duct-chase inside the building, where the return side connects to an uninsulated metal return and the supply-side to a thinly-insulated flexduct with no interior liner. The return duct drops to a floor-level plenum in the wall of the main living area; the return plenum includes a thin air filter. The supply connects to a distribution box located in a dropped ceiling area in the main hall, near the front entrance. Flexducts connect the distribution box to high-sidewall registers in the kitchen, bath, main room and bedrooms. In 2nd story units the ducts are above the 2 inch batt ceiling insulation.

Duct leakage and envelope air leakage were measured in six units. The average duct leakage was 32% of the estimated 800CFM fan-flow from the 2-ton AC units, 87% of which was to the outside (as measured at 25 Pa), indicating leaky units. The average measured return flow was 689 CFM (at 25 ACH_{50}), or 86% of the nominal 800 CFM fan flow. The envelope leakage was between 9.2 and 9.9 ACH_{50}.

Unit Selection and Energy Data

Four buildings comprising 30 units were selected based on resident tenure (one duplex used for the pilot, one 8-plex, and two 10-plexes). Participating apartment units were selected with guidance from Property and Asset Management. The property includes 28 total residential buildings, which would optimally be modeled as complete, multiunit buildings. Energy analyses were performed using BEopt[1] which at that time could not simulate a building with more than 5 bedrooms. To compensate for this, each configuration of a stacked pair (duplex or multiplex; multiplex-unit configuration: end, middle, top, bottom; number of bedrooms, floor area, and orientation) was simulated and the results accumulated according to the unit makeup. The simulations were calibrated using baseline data, collected directly from the electric meters by SCE, and the technique proved to provide results that were as accurate as possible. Resident tenure was another key consideration in identifying participating units due to implications for utility data availability and potential lower disturbance to equipment during the M&V process, including the home energy management system (HEMs).

Given the regulatory barriers to collecting aggregated utility data for properties, LINC relied on its residents to grant access to utility data by signing a utility third-party authorization form. LINC was able to collect approximately 80% of resident-paid electricity data (minimum 12 months) for the 30 units in question (representing some of the highest rates of resident data collection within the entire LINC portfolio).

VAB is master-metered for gas, for the entire complex, and individually metered for electric energy use. While the overall energy use impact of the measures can be obtained using the metered data, the PIER Beechwood Project calls for disaggregation of loads by end use to identify the impact of each measure (both individually and interactively). To this end, an objective was to obtain the energy use for gas end-uses (heating, water heating, clothes drying, and cooking) and electricity end-uses (air conditioning, lighting, appliances, and plug loads). The energy use baseline was developed using methods including building data analytics, non-intrusive load monitoring and submetering. For gas usage, individual components such as space- and water-heating are being measured by sub-metering with auxiliary gas meters.

Current In-Unit Energy Use

A detailed occupant survey was developed and administered in-person by LINC Housing’s Resident Services Studio, LINC Cares, to:

- Help characterize the small appliances and equipment requiring electricity that are plugged into wall sockets (the devices that makeup the miscellaneous electric loads or “MELs”)

[1] Building Energy Optimization energy-modeling software developed by the National Renewable Energy lab, using U.S. DOE EnergyPlus as the simulation engine. www.beopt.nrel.gov/

- Estimates of the usage of those devices, as well as other pertinent occupant behavior affecting energy-use (such as and including thermostat set-points)
- Obtaining electric utility bill information and authorization to collect and use the data for this project. The survey results were used to refine predictions of MELs and adjust other, behavior-related modeling characteristics, most importantly, thermostat settings.

The resident surveys served two purposes. In addition to gathering MEL input information for the energy models, the surveys helped to identify opportunities for resident services to tailor education programming regarding the efficient use of energy and water, based on real or at least perceptual information regarding how the residents are, or think they are really using energy and water, and where and what behavioral changes could be made, and perhaps provide the best results.

Simulation of Baseline Conditions and Calibration of the Model

BIRAenergy developed computer models of the different units as they currently exist and simulated the models in EnergyPlus, using BEoptE+ v1.3. These simulations provided a baseline for the energy use in each unit type. These baseline simulations coupled with information from the occupant surveys provided the basis for calibrating the models. The calibrated models were then used to evaluate efficiency measures and to develop packages of measures to produce very efficient retrofits. As previously described, simulations of all the permutations of a stacked-pair of dwelling units occurring in the VAB complex were performed, and whole, multiplex building energy analyses were produced by combining simulation results from all of the constituent stacked pairs. Similarly, the 8- and 10-plexes were modeled by individually simulating each pair of upstairs and downstairs units as a building, all with some adiabatic walls, each set referred to here as a “unit-pair.” Thus, there were end-units and central units, and each type was simulated as an upstairs and downstairs pair, and the results summed to produce whole building results.

The water heating was simulated as a small gas storage water heater for each unit-pair. Each of the 8- and 10-plexes was then built-up from the simulated unit-pairs appropriate to the units contained within each building. Where possible, the existing energy-efficiency features were determined by tests or inspections, including cutting into dropped-ceiling chases to view insulation and ducts. The average measured duct leakage and air infiltration were used in simulating each unit-pair. Simulated and monitored electrical uses are graphically compared in Figure 1. The annual energy use for the simulation is within 5% of actual.

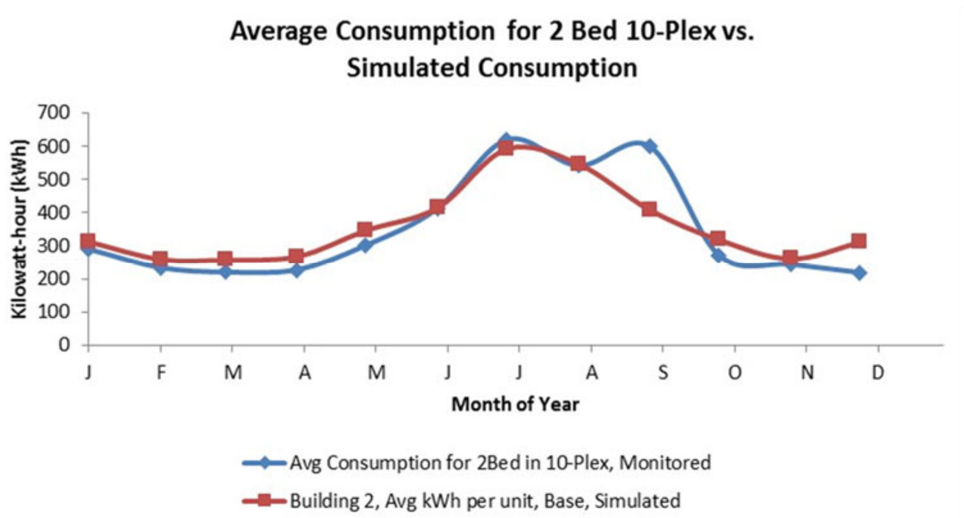

Figure 1. Comparison of BEopt simulation to actual energy use in a 10-plex apartment at The Village at Beechwood, Lancaster, CA. The average monthly deviation from the monitored data was found to be 5%. Since gas use was mater-metered for the entire complex, no comparison between simulation and actual enegy use was made for gas consumption.

Developing Very Efficient Retrofit Packages (VERs)

The energy-savings potential for each efficiency measure was first examined using sensitivity analyses where the baseline was compared to an improved case using baseline measures for all but a single improved measure. This sensitivity analysis provided an initial estimate of the impact of each efficiency measure, ignoring interactive effects, as illustrated in Figure 2, a series of stacked bars representing the energy from the various end-uses allowing comparison of total and end-use energy savings from substitutions of individual efficiency measures.

Based on the results of the sensitivity analyses, various packages of efficiency measures were analyzed to develop the optimum VERs for this low-income multifamily property, and likely others like it. The final package of energy-efficiency upgrades also included solar domestic hot water for the 8- and 10- plex buildings that share a common boiler system. In addition, solar photovoltaic systems (PVs) were installed on the awnings for covered parking. The PVs are virtually net metered so as to support both the common areas and residences. The objectives in development of VERs packages included:

- Energy savings
- Reliability and maintenance
- Availability of the measure and of trained installers
- Cost and cost-effectiveness
- Scalability into the multifamily market
- Minimizing impact of retrofitting process on residents

To develop the VERs packages, a list of potential energy-efficiency upgrades/measures for inclusion in the VERs was developed. These measures included all energy-efficiency measures that, in the consultant's experience would provide significant and cost-effective savings in these buildings, in this climate area. PVs and solar water heating were also added to this evaluation. Whole-house energy savings were determined for each measure by simulating the baseline with each improved measure, individually and one at a time, and comparing energy use to the baseline. The results of this analysis provided both the optimum cost-effective value for each measure and the relative effectiveness of each. However, since the features are individually added to the baseline model, the results did not show any interactions between measures, interactive effects of diminishing returns, nor effects resulting in cost savings, such as equipment downsizing, which occurs with the VERs case model. This analysis aims to show the maximum potential benefit from each feature. The most promising, optimized building measures were simulated in small packages of the most cost-effective measures. These features are shown in Figure 2.

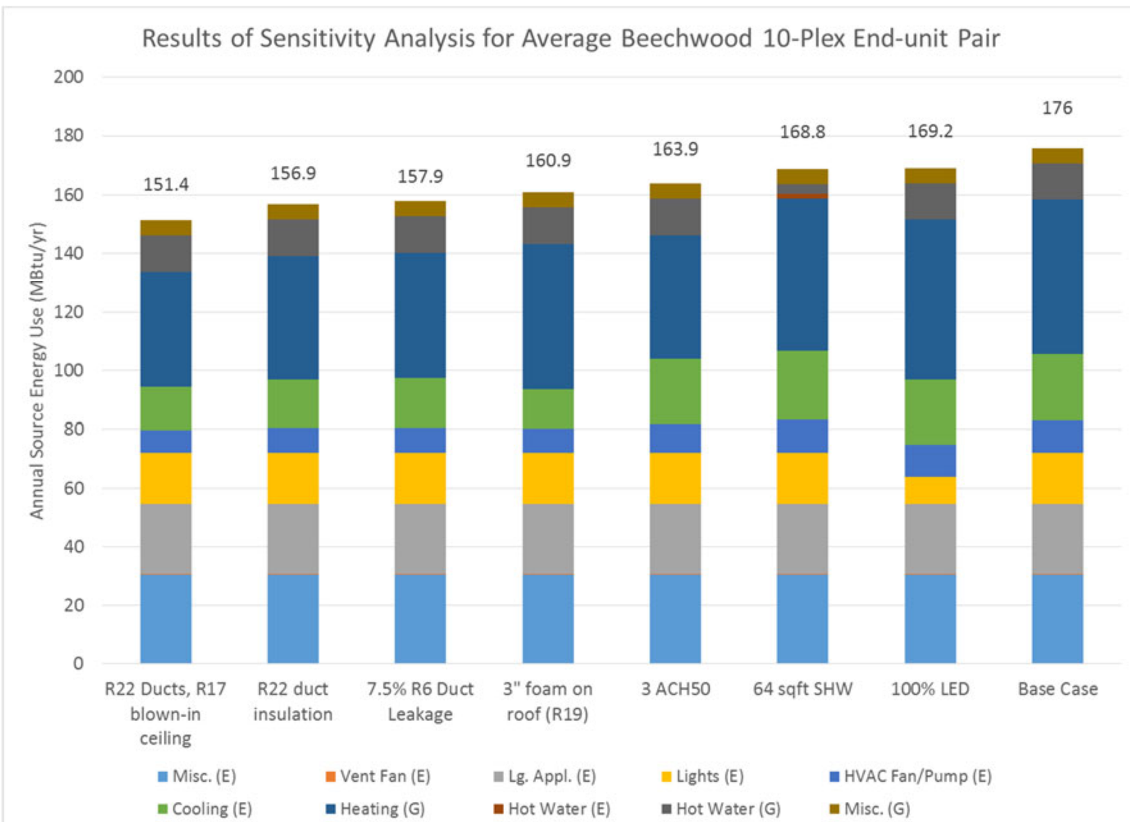

Figure 2. Example results from sensitivity analyses for an average unit from a Village at Beechwood 10-plex (end-unit), showing seven different measures used and the unimproved baseline model (SHW is solar hot water).

Given that the occupants of the housing units pay for their own electricity and that gas is master-metered for the entire facility and paid by the owner, the packages were developed in four different groups: fuel-neutral, gas, electricity, and generation. Evaluations of each measure compared to the baseline, and data collected in development of the baseline indicate that key drivers of high energy use are listed in Table 1 (not in any particular order).

Table 1. Potential measures for VERs packages based on energy impacts, with associated feasibility of installation and/or achieving modeled results.

Measure		Feasibility
1	Thermostat Set Point Management: residents tend to keep their units very warm (many heated up to 75°F or higher)	Not easily enforceable
2	Increased Building Insulation: both wall and ceiling insulation were minimal and of poor quality installation	Neither practical nor cost-effective
3	Insulation of Hot Water System Underground Plumbing: system is uninsulated from the boilers to the building	Being explored to determine cost-effectiveness
4	Replacement of Laundry Equipment: runs at relatively low efficiency	Not cost-effective
5	Replacement of In-Unit Stoves and Ovens: old and run at low efficiencies	Will be evaluated on unit-by-unit basis
6	Lighting Retrofit: opportunities to replace all incandescent lighting with LEDs or fluorescents in both resident units and common areas of property	Feasible and leading measure candidates for VERs packages
7	Replace refrigerators beyond a certain age: Coinciding and coordinated with utility refrigerator replacement program	
8	Sealing of Envelope Leakage	
9	Sealing of Duct Leakage	
10	Sealing and Insulation of Building to Make Ducts in Conditioned Space, or Replacement and Heavy Insulation of Ducts	

Pilot Unit

The VERs analyses resulted in a short list of features that should provide substantial energy savings, relatively cost-effectively and reliably. The VERs package was first tested on a pilot installation and evaluation on a single stacked-pair of units. This pilot retrofit provided a forum to test the implementation of the VERs before taking them to scale on the remaining 28 units. Table 2 shows the efficiency measures for the baseline, pilot, and final 28-unit retrofit.

The pilot consisted of a single stacked-pair and allowed evaluation of the installation of the VER package prior to full-scale retrofits. The package turned out to be quite simple in terms of measures: seal as much envelope leakage as possible using aeroseal or hand-sealing techniques (targeting 3 ACH_{50} with aeroseal, but envelope leakages ranged up to 6.7 ACH_{50}), replace the ducts with properly attached and sealed R-8 flexducts, and fill the duct chase with insulation before closing. No change was anticipated for the pilot ceiling insulation because of access problems related to asbestos. The ceiling of all units had a sound-abatement treatment containing asbestos. That limited the team's access to ceiling areas, initially thought to eliminate adding any insulation above the ceiling. However, when the duct chase containing the distribution box was opened by removing the ceiling drywall below it, the team discovered that they could access some open truss bays above the ceiling, and were able to blow insulation into an area estimated at about 25% of the ceiling area, putting about 7" of blown fiberglass over the 2" batts that were left in place. This feature was then added to the VERs, thinking that this opportunity would be universal. The refrigerators in the pilot units were a few years newer than 1999 so were not replaced per the utility program. There were also too few LEDs installed due to a low number of light-fixtures that were hard-wired and contained incandescent lamps that could be replaced by LEDs. An 84kW PV system was installed later for the community system, and a 282.225 kW system for the occupied units, all utilizing virtual net metering (VNEM). Additional efficiency measures that were evaluated separately from the pilot and the main retrofit included solar hot water (SHW) for the multiplexes, and a urethane spray-foam (XPS) roof application was installed on a 10-plex.

Table 2. Chart of efficiency measures in baseline, pilot, and final VER for 30-unit retrofit

Category Name	Base Case	Pilot	VER Case
Smart Thermostat	No	No	Yes
Ceiling / Roof Insulation	R7 batt	R7 Batt, R17 blown-in	R7 Batt, R17 blown-in, 3in spray foam (Building 3 only)
Cool Roof	No	No	Yes (Building 3 only)
Air Leakage (worst case)	10 ACH50	3ACH50	7ACH50
Lighting	100% Incandescent	100% LED	100% LED
Ducts	32% Leakage, uninsulated	7.5% leakage, R22	7.5% leakage, R22
PV System	No	No (part of VERs)	Yes - master installed
Solar Hot Water	No	No	Yes (Buildings 1, 2, 3 only)
High-Efficiency Boiler	No	No	0.95 EF (Buildings 1, 2, 3 only)
Insulated Hot Water Pipes	No	No	Yes (Buildings 1, 2, 3 only)

The major issue that increased to cost of every residence retrofitted (both the pilot and the additional 28 residences in the main retrofit) was the required abatement of asbestos in the ceiling. A hole needed to be cut in the ceiling to replace the ducts under the duct chase. This required a specialty contractor to come, remove the section of ceiling, and properly handle, remove, and depose of the ceiling materials. This added a full day to the retrofit and substantial cost not directly related to energy savings. Asbestos also limited access to the overall attic space eliminating full coverage for improved ceiling insulation, an otherwise cost-effective measure.

The VERs package was predicted to save an average of 125 Therms/yr/unit of natural gas (about 50% of the total use of the occupied units), about $212/yr/unit (averaging $0.88/therm); this savings goes to the property-owners because the gas is master-metered. The occupants of each residence would be expected to save about 902 kWh/yr/unit (about 22% of the total use of the occupied units), or about $93/yr/unit for electricity. With the property-owners saving $212/year /unit, at a VERs cost of about $4,400/unit, the simple payback is about 20 years. When the asbestos abatement is included, the per-unit cost inflates to $7,800/unit, putting the efficiency retrofit well outside any measure of cost-effectiveness.

Other than the asbestos, which was anticipated but had a dramatic effect on costs and therefore cost-effectiveness, the retrofit was both successful in installing the VERs and in determining that some ceiling insulation could be added to the VERs, estimated at 25% ceiling area insulated to about R-30. With this final VERs, the team went forward with the retrofits on the remaining 28 units.

Main Retrofit

There were measures that were installed during the 28-unit retrofit for evaluation beyond the VERs that were installed in the pilot. They are noted in Table 2 and included a SHW system for domestic use in the multiplexes, the community PV system, and a urethane spray-foam roof insulation with a cool-roof elastomeric cover. This was installed on the same ten-plex as the solar hot water system. This was done because the existing roof was estimated to have slightly less than half its useful life remaining, making it more cost-effective to re-roof before installing the solar hot water system, rather than having to remove it later to re-roof. Thus the long-lived spray-foam roof material was installed.

As previously mentioned, a large PV system was also installed. The simulations show that, with the savings from the VERs, and other use offset by the generation of the PV system, assuming the annual PV generation is equally distributed among all 100 residences, the average remaining electricity requirements of the 30 VERs-retrofitted units is 8% of the annual electricity required prior to any retrofits. To say this a different way, if all the 100 residences were retrofitted with the VERs package, and all 100 shared the PV generation equally then the total electricity used by all the residences at the Village at Beechwood would be reduced by 92% (with about 22% being due to the energy efficiency measures).

Measurement and Verification

With the project now in the post-retrofit phase of the project, the PIER Beechwood Team has installed monitoring equipment to evaluate energy use for various end-uses, as well as for individual residences. Data acquisition began at the conclusion of construction, which was initially planned for late-summer, 2014, and continue to Summer 2015 to provide long term performance analysis. Numerous problems, including problems with subcontractors, non-functioning equipment, and difficulties in relaying stored data have delayed or precluded implementation of some data collection systems and will limit the collection of the very large amount of data initially planned.

Data is now flowing from monitoring systems, and is uploaded and stored in databases that can be accessed remotely for both performance monitoring and analysis. Automated data analysis is being implemented using algorithms programmed through the relational database using existing EPRI expertise to monitor each building for *both* whole home energy use and dis-aggregated energy end-use data.

The PIER Beechwood Team also plans to use building analytics to better understand electricity and gas usage. The disaggregated instantaneous activity of common household appliances with high energy use (such as space conditioning, refrigerators, and microwaves) will be determined using load monitors. To this end, LINC will utilize its current online energy management contracts with WegoWise to provide both bill visualization tools as well as analytics for each of the 30 subject units. These tools will help establish a pre-retrofit energy use baseline and will provide for regular comparisons as data is updated on a monthly basis.

The predominate MELs consisted of appliances, electronics for entertainment, and other items including medical equipment and portable fans or heaters.

Some of the key resident survey results included the following:

- Many residents at VAB are not working and remain at home throughout the day
- Thermostats were often set quite high (74° was observed in several cases) in the cooler months
- Local climate necessitates the use of space heating throughout the winter and air conditioning throughout the summer
- The most prominently used MEL aside from kitchen appliances was a television and complementary devices (e.g. cable box), with an average of two televisions per unit being used for almost seven hours per day

The simulated electricity use for each of the unit types was compared to averages of electricity use obtained from the residents of each unit type during the surveys. The electricity use from the simulations of all the component models, averaged was within 15% of the average energy use across the surveyed models.

Energy and Demand Impacts

The impacts produced by the retrofits are both qualifiable and quantifiable. Residents in the retrofitted units have reported that their homes are cooler during hot summer afternoons. The reasons for this qualified benefit is reflected below, in the data in Figures 3 and 4, where we see the retrofit using less energy to achieve a lower indoor temperature that the pre-retrofit case. Each figure has two graphs; in Figure 3 the left graph shows the correlation between outdoor temperature and power draw of the residence's air conditioning (AC) unit. The bar graph on the right in Figure 3 is the monthly total energy consumption for the residence. The data plotted in Figure 3 are from a unit of the control group (i.e., no retrofits). Figure 4 provides the same categories of data - averaged demand vs outdoor temperature (left graph), and monthly energy consumption on the right - but Figure 4 data is from a residence of the retrofitted group. Figure 3 and Figure 4 are compared to show the results of the VERs retrofit.

The data from the left graph in Figure 4 clearly shows the impacts of the retrofits on cooling electricity demand from air conditioning. The electricity demand climbs with the outdoor temperature until July, when the retrofits were performed. Starting early July, coincident with the retrofit, the demand for power drops, while the outdoor temperature continues to rise. Once electricity demand reaches a somewhat steady-state, it is about 0.5 kW, whereas the control is about 0.75 kW (Figure 3, left).

Similarly, the monthly energy use during the summer cooling months of July - August (Figure 3, right) of over 500 kWh in the control, non-retrofitted home is substantially higher than in the retrofitted home, under 300 kWh during the same periods (Figure 4, right) is substantially lower than the non-retrofitted, control home of over 500 kWh.

This data is representative of the other retrofitted and control residences. Data has been flowing into the EPRI databases providing the opportunity to further evaluate the performance of these retrofits, which will be forthcoming in future project reports and technical papers. The data will also be invaluable to the next step in this project, which is to evaluate the economics and financing methods that could support wide-scale retrofits of low-income housing projects. Such mechanisms are very much needed by this market segment.

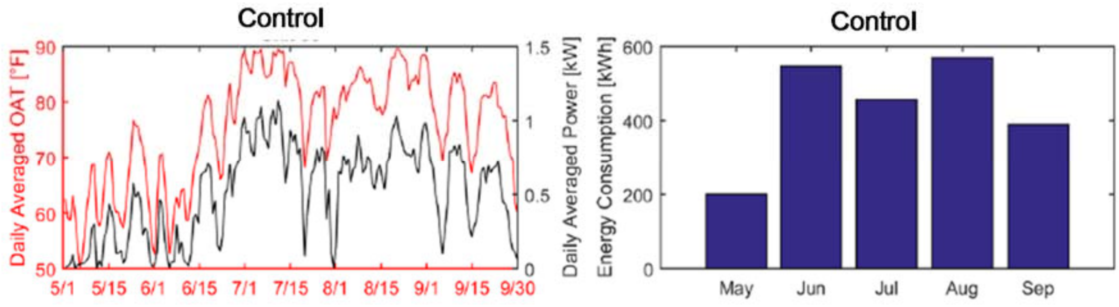

Figure 3. Control data showing the relationship between outdoor temperature and AC electric-power draw (left), and monthly energy consumption (right). Note that for this control residence, which is typical for the complex, the power draw tracks the outdoor temperature. Notice also for the columnar data that the summer months of July – August the residence used about 500 – 550 kWh.

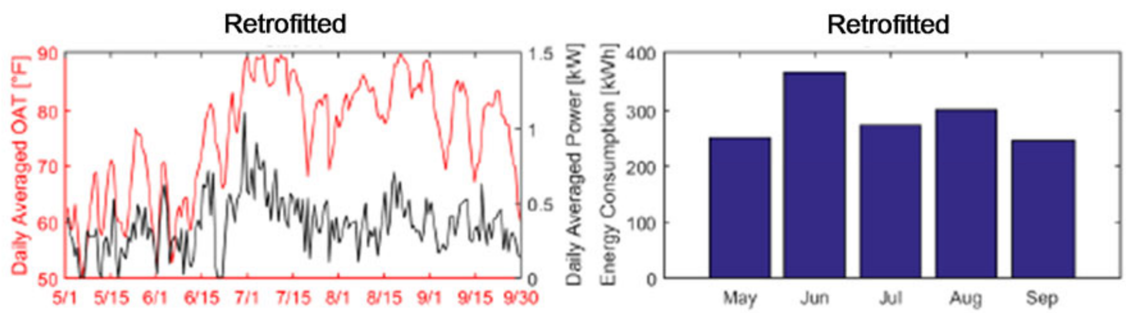

Figure 4. AC Electric power vs outdoor temperature and summer monthly energy use for a retrofitted “test” home. The retrofits were performed during the months of June and July. Note the drop in power draw from the test unit in the left graph. Also note the lower monthly electricity use for the months of July, August (about 300 kWh) compared to the control home in Figure 3 (about 550 kWh).

Financial Scalability

Development of a scalable financial model is critical to the widespread applicability of VERs and near-ZNE to the rest of LINC’s portfolio as well as the entire multifamily marketplace in California. Developing business models proves challenging for low-income multifamily property owners who pay for the cost of the property upgrades but operate as a cash flow business with very limited investment capacity. Because of its combination of individually metered (electric) and master-metered (gas) utilities at VAB, The PIER Beechwood Project enabled us to investigate the advantages and disadvantages of business models that prioritize either resident billing or master metered configurations. A true understanding of financial scalability, beyond the models, will not be available until energy savings data is made available to identify the return on investment for particular measures (which has a bearing on several of the financing tools that exist in the market).

Conclusions

This project has demonstrated and reported effective VERs packages and the integration of solar technologies in a low-income multifamily project, reducing annual electricity use by 92%, and natural Gas by 50%. This was all accomplished based on an energy model calibrated to only 5% error. The VER packages contained lighting improvements, additional roof and duct insulation, smart thermostats, and envelope sealing. Voluminous data is being collected and analyzed, and project reports are being written documenting the progress made as a result of this project, and work is needed to address the financial complexities of this market segment, some of which are unique to this market.

Low-income multifamily housing is not in the main-stream of energy efficiency practices, not to mention the push towards zero net-energy homes and communities. However, the residents of low-income multifamily projects are at least as deserving of such goals as are buyers of new homes. The PIER Beechwood project, from which this paper draws its information is multifaceted and this paper covers only part of the on-going PIER Beechwood Project. There is much to be done in finding and/or developing improved methods to make VERs like those reported here cost-effective to the property owners. The residents of Beechwood clearly appreciate the comfort benefits as well as the economic benefits of the efficiency retrofits performed. However, the barriers to widespread adoption and implementation of the practices developed and implemented at Beechwood are still considerable. These include costs, the lopsided cost/benefit values, split incentives, financing vehicles, and more. None of these have been solved by this project; but it has cast a bright light on this part of the market and painted clear pictures of the importance and what needs to be done.

In addition to these big-picture issues, there were several other lessons learned throughout the pre-retrofit stages of the project that had to be evaluated and overcome. The project team encountered challenges when attempting to utilize a community-wide Wi-Fi system to accommodate an advanced M&V need for monitoring gas consuming uses on the property. The PIER Beechwood Team will provide clarity on how they addressed these additional concerns in our project reports. They should help guide future endeavors that take on these complex technological approaches. In addition, this project is producing extensive M&V data that should be very valuable to this industry.

Retrofitting a low-income multifamily property to be near-ZNE necessitates much more than the implementation of a package of measures. This project continues to conduct the research needed to help facilitate the seamless integration between aging buildings, new technology, and the low-income residents. At project’s end in 2016, the PIER Beechwood Project will have a model for implementing whole-house energy efficiency retrofits that, at minimum, has evaluated the barriers facing low-income, multifamily owners and fully examines the efficacy of developing scalable technologies and financing models for a historically underserved market. Utilities have long struggled with making successful programs to improve the efficiency of low-income housing. Research funding has long been needed to research, develop, demonstrate and deploy the steps to successful retrofits in low-income multifamily properties. This project is designed to achieve this goal, which cannot be done without research funding. Without the focused aid of funding programs such as PIER and EPIC, energy efficiency retrofits of the existing low-income housing market will continue to languish.

References

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