# Product Selection—A Forgotten Vital Component of Program Design

*Nikhil Gandhi, Strategic Energy Technologies, Inc., Acton, Massachusetts*
*Floyd Keneipp, Summit Blue Consulting, Walnut Creek, California*
*Dulane Moran, Research Into Action, Inc., Portland, Oregon*
*Jane Peters, Research Into Action, Inc., Portland, Oregon*
*Shahana Samiullah, Southern California Edison, Irwindale, California*
*Anne West, Quantec, LLC., Portland, Oregon*

## Abstract

Energy efficiency programs promote technologies that have reported energy and demand savings, which is a primary qualifying consideration. Other technology characteristics such as the appropriateness of application, maintenance and repair considerations, customer comfort, functionality and ease of use under different operating conditions, durability, and appearance do not get as much scrutiny as energy savings. As a result, expected energy savings can fail to materialize or customers lose confidence, jeopardizing technology acceptance.

Two separate products, operating on the same principle, were selected to control air conditioner usage when the controlled area was unoccupied. One product was targeted for small hotels/motels and another for multifamily homes. The results of on-site verification found a failure rate of up to 90 percent in multifamily housing. In the case of a third product, an emerging lighting technology was chosen for retrofit application in niche markets. Despite initial challenges, the lamps appeared to fit well in outdoor applications. However, the technology did not have the range of brightness or color temperature expected for indoor applications, where the lamps "made everything look green."

These findings were unexpected, and discussions with facility personnel showed that the design of selected products was inappropriate for the application without further development and the selected products did not offer the claimed benefits under all operating conditions. This paper identifies some pitfalls of ignoring non-energy-saving characteristics of products; discusses the reasons for lack of performance; and reasserts the need to return to the basics of technology assessments to ensure savings persistence.

## Introduction

Southern California Edison (Edison) offers an energy efficiency program—Innovative Designs for Energy Efficiency Applications (IDEEA)—to solicit ideas that would use innovative marketing and/or delivery methods and apply energy-efficient technologies in new applications. The IDEEA program fills gaps in Edison's portfolio of energy efficiency programs. Edison expects third-party providers to submit ideas to implement energy efficiency in hard-to-reach market segments. A successful demonstration of an innovative approach can ultimately help mainstream that program.

The 2004–2005 IDEEA program and its 13 constituent programs were evaluated in 2006–2007. The process evaluation of the individual programs had four major subtasks: a secondary data review to examine program and project documentation and interviews with program and evaluation staff at other utilities and organizations that implemented and evaluated similar programs; interviews with project management and implementation staff, including implementation contractors; surveys of program participants and, where possible, nonparticipants; and analyses of findings. The underlying objective of the overall process evaluation was to compile "lessons learned" from the first rounds of the IDEEA solicitation, to improve the current and future solicitation process for third-party programs. Data were analyzed using "triangulation," an approach in which the multiple points of view were compared and contrasted across the different respondents to provide a comprehensive view of the program from each informant's perspective.

The overall steps of the impact evaluation studies were as follows: a review of program installation records, engineering calculations, and secondary literature (e.g., DEER database, ASHRAE documents) as needed; analysis of billing/metered data; on-site verifications when feasible; adjustment of ex-ante assumptions with verified data; and estimation of adjusted gross and net energy and demand savings.

Early evaluation findings suggest that some constituent programs appeared to be successful and some were not. Some technologies demonstrated expected performance, while others had high rates of failures. Some programs were, indeed, innovative, and those involved new market segments, implementation approaches, or technologies. Some constituent programs were unsuccessful in meeting their implementation and savings goals while at the same time demonstrating the viability of a new technology. Some programs were successful in demonstrating an energy-efficient technology to a new market segment, but savings did not persist, and in some cases, customers noticed increased energy usage. Some of these issues can be foreseen and prevented by a thorough review of a program concept, while others cannot always be foreseen.

The evaluation of three IDEEA programs—Multifamily HVAC Controls, Cool Cash Controls, and Miniature Cold Cathode Hardware—had a common theme, i.e., the selected products had the potential to save energy but some characteristics of the selected products were not appropriate for the market segment and/or applications. These characteristics were functionality and durability, maintenance and repair considerations, performance under different operating conditions, customer comfort, and product appearance. Two separate products, operating on the same principle, were selected to control air conditioner usage when the controlled area was unoccupied. One product was offered for installation in hotels/motels and another but similar product was selected for multifamily buildings. The results of verification and impact assessment found a failure rate of up to 90 percent in these programs, caused by battery failure, tampering, equipment malfunction, and lack of monitoring, and for some installations, energy usage increased by as much as 35 percent. In the case of a third product, cold cathode lamps were chosen for retrofit application in niche markets. These lamps appeared to fit well in outdoor sign and lighting applications but did not have the range of brightness or color temperature required for indoor applications. As a result, two program dropouts accounted for 30 percent of the lamps that would have been installed under the program.

A brief description of the three IDEEA programs is presented next. Then, the evaluation data demonstrating unexpected performance degradation because of certain product characteristics and application considerations is presented, followed by conclusions and recommendations to weigh in non-energy-saving considerations in selecting products for energy efficiency programs.

## Program and Product Description

### Multifamily HVAC Program

This program was designed to reduce HVAC energy consumption in multifamily housing in inland communities through a wireless occupancy sensing technology that uses a door sensor and multiple occupancy sensors throughout an apartment to communicate with a central "brain" which controls the operation of HVAC equipment by floating the set point of a thermostat higher. This control method reduces the run-time of HVAC equipment when an apartment is unoccupied, typically during peak demand periods. The technology does not require occupant involvement to save energy and accommodates residents' daily schedule changes. The wireless sensors require a battery for operation. The system can intelligently detect the low battery state and will go into a "safe" default mode, relinquishing control to the occupant so that there will never be a lapse in HVAC operability. The manufacturer expects the battery life to range from two to five years with normal usage.

The target market was primarily moderate-income customer housing (multifamily rentals) in hard-to-reach communities (outside the Los Angeles and San Diego basins) at properties with air conditioners older than five years. The program was offered for buildings with fewer than three floors that had thermostat-controlled split-system HVAC units. The property managers were asked whether residents had lifestyles that would cause them to be away during the day, since preferred tenants would be in that category.

### Cool Cash Controls Program

The Cool Cash Program, a turnkey, retrofit program, installed power controllers and occupancy sensors or an integrated occupancy sensor and thermostat control for package terminal air-conditioning systems (PTACs). These controllers and sensors reduce the energy required to cool hotel rooms, by working together to sense the presence of a guest and then set the thermostat according to occupancy. When a room is unoccupied, the PTAC unit is shut off for a limited time such that the room can be brought back to the pre-set temperature within 20 minutes after room occupancy is sensed. An unoccupied room would be cooled to a higher temperature than an occupied room, resulting in energy savings. The program was offered as an opportunity to conserve energy wasted in motels and hotels that cool unoccupied rooms. The infancy of the PTAC controller market and the volume of potential sites provided an opportunity to demonstrate this technology and stimulate interest in a “wide-open” market.

### Miniature Cold Cathode Hardware Program

The purpose of this program was to spark interest and investment in a new emerging technology—the cold cathode lamp. The cold cathode lamps offered by the program replaced incandescent lamps found in interior applications and exterior advertising signs. The operation of the exterior message signs was defined by the message being displayed and how often this message changed. The cold cathode lamps of varying wattage (3 to 8 watts) typically replaced 25- to 40-watt incandescent lamps, yielding an expected average wattage reduction of 89 percent. Cold cathode lamps have a rated lamp life of about 25,000 hours, 2.5 times longer than that of standard compact fluorescent lamps (CFLs) or long-life incandescent lamps.

Miniature cold cathode lamps were offered as a replacement for incandescent decorative lamps, particularly in applications where CFLs were not a viable replacement. They were also an attractive alternative to LED lamps in terms of price, aesthetics, longevity, and lumen depreciation. Program implementers noted that cold cathode lamps are more resilient to vibration than incandescent lamps, are dimmable without any special dimming ballast, and can withstand continuous on-off cycles or flashing. Cold cathode lamps have a cycling life of an estimated 500 million on-off cycles, whereas standard CFLs have an estimated life of 10,000–12,000 on-off cycles. Dimming or flashing of cold cathode lamps does not reduce their life. This is an important attribute because the advertising signs retrofitted in the program typically operated over 6,000 hours annually, with new messages flashing each 5 seconds on average, resulting in nearly 4.3 million on-off cycles annually. Another advantage of cold cathode lamps for interior applications is that they do not get hot, and thus they reduce the cooling load on air conditioners.

## Product Selection Issues

The evaluation findings showed mixed energy-saving performance by technologies selected for these three programs. We analyzed the findings to understand the reasons for unexpected technology performance in the field conditions and found five non-energy-saving product characteristics that explained field performance in the selected applications and target markets. Our evaluation findings related to these five characteristics—functionality and durability, maintenance and repair, operating condition, customer comfort, and product appearance— are described next.

**Functionality and Durability**

Product reliability, functionality, and durability inspire customer confidence and eventual adoption of technology. When a product fails to perform intended tasks, customers do not realize benefits they were hoping for; more important, failure to perform over time reduces the expected lifetime benefits. As part of process evaluation interviews for the Cool Cash Program, participants were asked about how the equipment worked after it was installed and about any vandalism or tampering. Among the seven interviewed participants, three reported experiencing some equipment malfunctions: in one case, battery failure, and in the other two, instances that required equipment to be reset. Two of the remaining four contacts reported "operational issues" as staff learned about equipment settings, defaults, and how the equipment worked in practice. Only one hotel contact reported sensor vandalism or tampering—in this case the equipment had been dismantled.

The process interviews did not ask contacts to estimate the portion of their sensors that were working as expected. However, on-site verifications conducted to assess the program impact showed that the portion of nonworking sensors was about 22 percent, indicating that hotel contacts might not be aware of malfunctioning sensors. Ten of the twenty-one nonworking sensors were defective and required replacement, six sensors were tampered with by removal of sensors or batteries or shutting off the wall switch, and five sensors that were not communicating with the master controller were reset to work during site visits. A majority (7 of 10) of defective sensors were the occupancy sensor and power controller combination in which the battery-operated occupancy sensor signals the occupancy status to the power controller. This product design appears less robust than an integrated thermostat and occupancy sensor combination (3 out of 10 failed) that is directly wired into a PTAC unit. The difference in the failure rate of these technologies is not statistically significant, since fewer thermostat and occupancy sensor combinations (224) were installed in the program than the occupancy sensor and power controller combination (578). Therefore, the failure rate calculated as the percentage of installed sensors is similar (1.34 percent for thermostats versus 1.21 percent for power controllers). The thermostat controllers are hardwired and more difficult to tamper with. None of these types of controllers required resetting at site, because the communication to the PTAC unit is through a hardwired signal, unlike the radio frequency signal used for the occupancy sensor and power controller combination.

Similar lack of persistence was observed in the Multifamily HVAC Program. The evaluation found that systems components (41 motion sensors and 34 wireless door sensors) were removed by tenants in 19 of 66 verified apartments. The removal rate, when extrapolated to the population, was 14.1 percent. Three reasons account for lack of measure persistence: (1) The system relied on expensive batteries to power remote sensors that may have strained technical capability and financial resources of participants, as discussed in the next subsection. (2) The appearance of the system might have caused it to be mistaken for a surveillance device. Many participants indicated that they were unaware of the energy-control function of the occupancy sensors and thought that these could have been cameras. Thus, while no participant would confirm that this was case, it is likely that some of the disconnected devices were disabled by participants out of a concern for privacy. (3) Participants or property managers had not reset the system after a power outage, disabling the AC system control. The evaluation team could not confirm that this was indeed a system failure. Tenants at 29 of the52 sites included in the onsite verifications for the Multifamily HVAC Program indicated they did not understand the way the system worked and their property managers did not have a clear maintenance policy or practice to keep the systems functioning.

Technical limitations reported by respondents of the Miniature Cold Cathode Program need further investigation: low watt limitations of older signs that required rewiring before retrofit; "fade-out" concerns when viewing the sign at different angles; lamp "flickering"; "temperature sensitivity" that led to removal of lamps during winter months; and lamp "seating" that required removal and reinstallation of lamps. These problems—primarily caused by the characteristics of this technology and its application—caused disruptions for some participants and additional labor expenses to correct. Several sign owners, because of their experiences with the program, stated they will not use the technology again. In correct applications, the technology worked and saved energy. One participant said, *"The savings were huge; in our first month the power bill was $3,000 less."* One participant reported a very positive "issue" when he received a call from his accounts payable department, *"My controller called to see what the problem was in our facility that had resulted in such a drop in the utility bill."*

**Maintenance and Repair**

The occupancy sensor and power controller combination used for the Cool Cash Program required standard AA batteries. During on-site verifications, a few instances were observed where batteries were removed or the polarity was reversed, disabling the operation of the controller. Such instances were far less serious than the battery-related issues noticed in the Multifamily HVAC Program. A major concern about this technology was that the communication between occupancy sensors and power controllers might be lost for various reasons, which happened frequently. When sensors stop communicating with each other, the PTAC unit is no longer controlled based on the occupancy status; thus, energy savings do not occur, because the PTAC unit continues to operate during occupied and unoccupied periods, depending on the temperature setting.

Hotel staff should be aware that the sensors can malfunction from time to time and know how to reset them. The program trained participants' hotel staff in detecting malfunctioning sensors and resetting them to work. Typically, hotel cleaning staff were instructed to observe the operating status of occupancy sensors in rooms they were cleaning after guests checked out. However, high staff turnover among participants made it difficult to ensure that new employees were also trained adequately and in a timely manner to reset nonworking sensors. We found 5 out of 21 nonworking sensor-controller combinations had to be reset to work during on-site verifications. This technology feature increased maintenance and training burden and placed the realization of energy savings at risk.

The control system used in the Multifamily HVAC Program deploys a wireless battery-operated occupancy sensor to signal the occupancy status to a central controller, which controls the operation of the cooling system. When a battery is depleted below the minimum voltage required to provide a reliable control signal, a blinking LED on the central controller—typically located at or near the furnace—indicates a low battery condition in one or more of the remote sensors. However, the LED on the central controller is not labeled as a 'Low Battery' indicator, and it is unlikely that many residents knew the meaning of a blinking LED. The remote sensors also had a low battery LED indicator, but this indicator was not visible unless a cover panel was removed from the sensor. It is likely that the difficulty in identifying a low voltage battery condition may have been a factor in tenants not replacing 66 percent of the depleted batteries found during field tests.

The cost of battery replacement was another barrier in the low-income housing market segment where most installations took place. The system's occupancy sensors used a CR123A battery that retailed at prices ranging from $1.99 to $11.99, with an average price of $6.89 per battery, according to a survey of five retail stores. Using this average price, the cost to replace batteries in an occupancy sensor would be $13.78, since each occupancy sensor used two batteries. The sample of verified apartments had, on average, 2.3 occupancy sensors, which would require $31.69 per apartment to replace sensor batteries. Door sensors used in the system required a CR2450 battery that retailed at prices ranging from $2.99 to $9.95, with an average price of $6.47 per battery. The sample of verified apartments had, on average, 1.26 door sensors, which would require $8.15 per apartment to replace door batteries. The total average battery replacement cost to a tenant is estimated at approximately $40 per apartment. Based on our observations on the life of batteries used, replacements would be required every six months, for an annual cost of about $80. We believe that battery replacement cost can be excessive for low-income customers and may be a barrier in this market segment. We note that the manufacturer has worked very hard to address problems with the system, including modifications to the controller and contracting with new battery suppliers to upgrade the quality. The current design, however, still may not be appropriate for the multifamily market segment.

Such recurring maintenance and upkeep cost issues were not prevalent in the Cold Cathode Program. One participant reported that its lighting maintenance company had increased the cost of the maintenance contract as a hedge against the possible high failure rate and increased labor to replace lamps. We determined, however, that failure rate for signage in operation for at least six months was only 1 percent, indicating that concerns about increased lamp replacement costs might be misplaced. Several participants did recognize the potential for significant life-cycle cost savings through reductions in energy and maintenance costs, and this indicates that large exterior advertising signs are a promising application as cold cathode lamps evolve. It is worth noting that this market also has a high coincidence factor, which offers system peak demand benefits.

**Performance under Different Operating Conditions**

The performance of energy-efficient technologies can vary under different operating conditions. When existing operating conditions are inappropriate, expected energy savings may not materialize. The technologies installed in the Cool Cash Program work best when air conditioners in unrented hotel rooms are left operating after guests check out. On the other hand, when air conditioners are shut off in unrented rooms, minimal savings may be realized because the only favorable operating condition now for saving energy is floating the temperature higher in rented rooms when occupants leave the room.

We interviewed the Cool Cash participant contacts to obtain information on the baseline practice of controlling temperature in hotel/motel rooms when a guest checks out and the room has not been rerented. Interviews with hotel contacts indicate that before learning of the program, most were already concerned about PTAC operations when rooms were unoccupied and were already taking some action. Six of the seven managers had assigned staff to turn equipment off. The low savings identified in the impact evaluation suggest that the baseline practices were already effective at saving energy and thus reduced the potential savings from the control technology (Table 1).

The impact evaluation conducted a billing analysis of pre- and post-installation usage to estimate participants' HVAC usage, which was then adjusted for the changes in weather and hotel occupancy during the post-installation period. The results in Table 1 show that five out of nine participating hotels saved energy, whereas the post-installation HVAC usage of the remaining four participants increased to varying degrees. The increase in the HVAC usage at Hotels C and I was much smaller than that for Hotels E and G. HVAC usage can also increase because of sensor failures that disable the ability of the controller to float the temperature. This could possibly explain a small increase in the HVAC usage. However, a large increase in the HVAC usage after the installation of sensors would be because of the baseline practice. Hotel E, in particular, was turning off air conditioners in unrented rooms before the installation of sensor controls. The hotel staff possibly discontinued that practice after the installation of controllers, assuming that controllers would automatically shut off air conditioners and not realizing that controllers simply allow the room temperature to rise without completely shutting off air conditioners. This would have increased the run-time of air conditioners in unrented rooms to maintain temperature. An increase in HVAC usage was an unintended and unexpected consequence of lack of knowledge of baseline practice and high staff turnover that could have made it difficult for hotel staff to keep up with training of new employees.

**Table 1: Pre- and Post-Installation HVAC Usage in Participating Hotels**

| Hotel | Estimated Pre-installation HVAC Usage (kWh) | Post-installation HVAC Usage (kWh) | Estimated Savings per Hotel (kWh) |
|---|---|---|---|
| Hotel A | 79,860 | 51,599 | 28,261 |
| Hotel B | 308,896 | 257,521 | 51,375 |
| Hotel C | 64,296 | 72,690 | (8,394) |
| Hotel D | 88,620 | 72,875 | 15,745 |
| Hotel E | 46,800 | 109,005 | (62,205) |
| Hotel F | 259,661 | 183,562 | 76,099[1] |
| Hotel G | 93,206 | 117,792 | (24,586) |
| Hotel H | 95,368 | 86,685 | 8,683 |
| Hotel I | 28,912 | 31,740 | (2,828) |

In the Multifamily HVAC Program, the system operation is highly dependent on the function of the battery-operated wireless sensors. The manufacturer expected a battery life, under average operating conditions, of about one year. For the hotel market segment, this manufacturer advises changing sensor batteries on the same schedule as that for electronic lock batteries. However, similar guidance for battery replacement in multifamily buildings was not available, possibly because of insufficient operating experience in this market segment. The occupancy pattern for hotels and multifamily buildings could be different, with likely higher occupancy rates and heavier traffic in multifamily installations that might have resulted in signals being sent from the sensor to the controller more frequently, and this in turn could have caused the batteries to deplete at a much faster rate than those seen in the hospitality industry. Higher occupancy rates and traffic would keep the air conditioners running longer, resulting in less than expected energy savings. More important, the persistence of measure savings would be at risk if tenants do not detect battery failure and replace batteries in time.

We also found two instances in the Miniature Cold Cathode Program where expected performance failed to materialize because of substantially different operating environments. One Cold Cathode Program participant experienced what is believed to be a voltage threshold problem causing an incompatibility of the cold cathode lamps with older signs. The older sign was not designed to power low-wattage lamps and as a result could not accommodate the new lamps on both sides of the sign and continue to operate properly. The contractor tried several different corrective actions, including turning down the lamp's brightness, but could not find a solution that allowed both sides of the sign to be lit at the same time. Because the participant chose not to upgrade the sign electronics, incandescent lamps were reinstalled on one side of the sign, reducing energy savings by half. The participant stated he was still very happy with the lamps, even though only half the sign could be upgraded.

Another Cold Cathode Program participant stated that some of his lamps did not sit properly and were at angles less than perpendicular to the sign surface. When this occurred, there was a perceived reduction in lumens. He removed and reinstalled the lamps to correct the problem. He also stated that the

1 Estimated savings also reflect savings from installing new PTAC units in all hotel rooms.

cold cathode signs could be identified because there was a difference in color and fade-out that occurred when looking from certain angles.

**Customer Comfort**

An energy-efficient technology gets adopted in the marketplace faster when energy savings can be realized without loss of comfort or, more generally, when perceived value benefits outweigh costs. The hotel/motel industry perhaps values customer comfort more than controlling energy costs. The technologies installed in the Cool Cash Program reduced energy consumption by allowing the temperature to drift higher during the unoccupied period and returning to the set temperature within 20 minutes after sensing room occupancy. Since hotel guests are likely to notice higher temperatures, especially during the summer months, we asked hotel contacts about their satisfaction with the technology and complaints, if any, they received from guests.

The findings from participant interviews provide some insight into the overarching concerns among hotel owners and managers regarding the reliability of product performance and resulting savings as well as concerns about guest comfort. Two of the seven participants interviewed indicated the equipment had not met their expectations, primarily due to issues with guest comfort during sleeping hours and when returning to a room that has been unoccupied, but also because of uncertainty with payback and energy savings. According to one contact, "The summer months are the same—you cannot shut off the air conditioner and the summer bill is the same. It helps in the winter but not very much . . . not nearly the cost of the equipment. It must be a 20-year payback." One participant said they run air conditioners on a low setting throughout the day to ensure that rooms are comfortable when guests check in. This practice would reduce the realization of energy savings during the summer months, but this hotel valued customer comfort over energy savings. Five of the seven participants reported the equipment was working well, though some problems were also reported, including guests becoming uncomfortable at night because of the sensors' failure to detect sleeping people. Two of the three participants that expressed these concerns reported their hotels had taken special measures to mitigate guest discomfort: one stopped using the sensors on a wing of rooms, to keep some cool rooms on hand for guests who may arrive late; the other installed ceiling fans to keep the air moving and provide some comfort as the PTAC controller began to cool a hot room.

Just over half of the participants we interviewed reported receiving complaints from uncomfortable customers following the installation of the sensors. One of the participants who reported receiving customer complaints described the volume of customer complaints to be about one customer per month. However, some of these hotels continued to embrace the technology, taking steps to overcome the technological limitations. They consulted the manufacturer to adjust settings and were happy with the results.[2]

In the Multifamily HVAC Program, about half of the participant tenants interviewed stated they manually controlled their HVAC units, overriding the sensors, for reasons of comfort and control. Tenants reported their apartments were too hot when they came home. Several participants expressed displeasure at the discomfort felt when the system may have allowed apartments to heat up at night when occupancy sensors incorrectly sensed an area as vacant while occupants slept. This was particularly problematic because most of the systems were installed in the Palm Desert area of California, where temperatures during several weeks in July 2006 never fell below 110°F at night. Occupants who understood how the system worked reported that they got up at night and motioned to the occupancy sensor to activate the AC system. Over half

2 The float temperature is preset by the manufacturer. A higher float temperature saves more energy, but it takes longer to cool the room to the user-set comfort temperature. Conversely, a lower float temperature cools the room faster upon a guest's return to the room but saves less energy. The sensor-controller combination used in the Cool Cash Program did not have the ability to set different float temperatures during the winter and summer seasons.

of the tenants said they were not involved in the decision to install the energy management system, and many did not want to relinquish HVAC control to the system.

**Product Appearance**

The evaluation revealed some undesirable effects that product appearance can have on technology acceptance and persistence of savings. The occupancy sensor and power controller combination installed in the Cool Cash Program required installing an occupancy sensor on the ceiling, approximately in the center of a hotel room, so that the room occupancy can be sensed without leaving dead spots. The location of sensor placement made its presence obvious to hotel guests. These sensors are shaped like a camera lens and include a light-emitting diode (LED) that flickers green or red, depending on whether it is functional or nonworking. The integrated thermostat sensor control, on the other hand, is mounted on a wall and has a clean flat appearance of a controller. As indicated earlier, we found 6 out of 21 nonworking controllers were tampered with in different ways. While we did not interview hotel occupants, hotel management and program staff reported that occupants were often curious about the occupancy sensor. One hotel contact reported having answered occupants' questions about the installed sensors. Program staff, the implementation contractor, and some hotel contacts thought that occupancy sensors appear to some customers as monitoring devices—a perception that might have triggered tampering to disable them. None of the integrated thermostats were disabled or reported by hotel contacts as monitoring devices.

The appearance of products was also a concern for participating tenants of the Multifamily HVAC Program. Some tenants thought the sensors were cameras or an alarm system, and one tenant put a towel over the sensor. One tenant didn't want the sensors to know when they were not at home. A number of the sensors were disabled or removed. The program provided a brochure describing sensor information in English and Spanish to participating tenants, but some complained that the information presented was unclear. The participating property managers were provided a maintenance document, but information was lost due to the high turnover of property managers and tenant turnover in apartments.

A wide range of opinion existed among participants and dropouts of the Miniature Cold Cathode Program on the acceptability of the lumen output and color temperature of the new cold cathode lamps. While a majority of the participants who stayed with the program were happy with the results, several large commercial chains dropped out because of poor color rendition or low light levels of cold cathode lamps. The program dropouts accounted for 30 percent of the lamps that would have been installed under the program. Some dropouts reported they would not install other energy-efficient lighting technologies because of this experience. Conversely, other large retailers felt the new lamps produced a better shopping environment for their clients, and satisfied sign owners felt the new lamps had "freshened up" their old signs. Color temperature and the perception of ideal light output will always be somewhat subjective; however, this was a consistent thread in the feedback from unsatisfied participants and dropouts.

Discussions with one manufacturer of the cold cathode lamps indicated it was aware of the color temperature problem and has addressed this issue. The industry overall, not just this program, has pushed manufacturers to develop other "warm" temperature lamps. Since the program's inception, one participating manufacturer has developed and marketed two additional lamps with warm color temperatures. In addition, a manufacturer reported it is developing higher-wattage lamps to address the interest in brighter lights.

## Conclusions and Recommendations

Edison selected proven products for all three programs to save energy. Consistent with the philosophy of the IDEEA program, these products were offered in new market segments in which they were not being used widely (Cool Cash and Multifamily HVAC Programs) or in new applications of a new technology (Miniature Cold Cathode Program). Innovative energy efficiency programs often experiment with new technology and unproven markets, using encouraging past performance in other markets and applications as a guide. We found that extending product application in new markets does not always guarantee success. Non-energy-saving features of products were more important to participants; some features of selected products were not suitable for the chosen market segment; products with different features were more suitable for those markets; and selected products needed more development before deployment; all these findings have a significant learning value. Edison did realize energy savings from these programs; however, expected performance suffered when non-energy-saving features were valued more by participants. We present below conclusions and recommendations to help improve the selection of products for energy efficiency programs.

**Field Performance Prediction Helps—Conduct Technology Assessments**

While field performance cannot always be predicted, we believe that the basics of a technology assessment can alert utility program designers to potential problems. The selection of a product with the right features for the right market can mitigate performance disappointments, especially when innovative programs are offered as resource acquisition programs, not R&D programs. A thorough technology assessment would review technology characteristics and performance data and provide guidance on the application of that technology. Such technology assessments would include performance under different operating conditions, market-technology match, life-cycle costs and benefits, maintenance and training requirements, durability, proprietary nature of parts replacement, appropriateness in retrofit and new construction, regulatory- and code-compliance considerations, comparison of delivered benefits with substitute technologies, installation skills, and customer and distribution channel acceptance.

**Baseline Operating Practice Matters—Select Application Carefully**

The energy-saving performance of the Cool Cash and Multifamily programs suffered when installations were made for participants whose operating environment or baseline operating practice was not ideal for maximizing controller performance. The HVAC control system installed in the Multifamily HVAC Program was originally designed for hotels, where it worked well, but did not show similar results in multifamily apartment complexes, where the occupancy pattern of tenants was different from that for hotels/motels. More tenants were found to be at home, which required the HVAC control system to run longer than expected. The baseline practice in the Cool Cash Program was to keep PTAC units turned off in unrented rooms, a practice that saves more energy than ceding temperature control to the HVAC controller. It is important to develop a screen for selection of participants that considers their baseline practices.

**High Maintenance and Operating Costs Can Deter Technology Adoption—Consider Upkeep Requirements**

In the Multifamily HVAC Program, battery replacement cost was a major issue. The batteries in the occupancy sensor depleted faster in apartments than they did in hotels. In the hotel industry, the chain of command for maintenance of control systems is clearly defined and maintenance and replacements tasks are routinely performed. This was not the case for this program's property managers, who did not have a well-defined policy for maintenance and battery replacement. Further, the product design did not provide an identifiable indication for battery failure, which probably made it difficult for occupants to locate failed batteries. Property managers noted that the high cost of batteries (estimated at $40 per apartment every six months) could outweigh the potential energy cost savings for tenants. The manufacturer reported that it has modified the system for deployment in the apartment market segment, contacted different battery suppliers, and implemented a battery test program before deployment. These improvements would be helpful in addressing the issues we noticed in this program.

The occupancy sensor and power controller combination installed in the Cool Cash Program placed an additional burden on the cleaning crew to notice and adjust failed sensors, for which they needed to be trained. High turnover in the hotel industry requires extra efforts in training and communication with maintenance and management staff who may not be familiar with the technology or specific equipment. It is likely that training will remain an ongoing issue, making it important that adequate information about system operation and troubleshooting be left with hotel staff and management. A similar training and education problem evident in the Multifamily HVAC Program underscored the need for better information presentation and dissemination. The chronic loss of institutional memory in the multifamily market may be addressed, in part, by posting permanent system operating and maintenance information in visible areas, such as near the thermostat. A centralized component-failure notification system for the controllers used in both programs would improve the participants' response time to repair failed components. For example, a label affixed on the occupancy sensor used in the Multifamily HVAC Program can inform tenants that the blinking LED indicates the need for a battery replacement. Similarly, a central computer-based system can indicate the status of sensors installed in hotel rooms.

In the Cold Cathode Program, some participants perceived "seasonality" or "temperature sensitivity" issues that led to removal of lamps during winter months and reinstallation in the summer, incurring extra labor costs to remove and replace lamps. These costs could reduce energy cost savings and add a "hassle factor." If customers are overwhelmed by the maintenance and upkeep requirements in order to realize energy cost savings, they might not install that technology or might ignore the upkeep requirements, losing the technology's benefits.

**Non-Energy-Saving Features Influence Technology Adoption—Deploy to Avoid Early Failures**

The controllers used in the Cool Cash and Multifamily HVAC programs need the capability to stop controlling HVAC equipment during nighttime hours when occupants are likely to be sleeping yet allow controllers to operate at night in vacant rooms.[3] Another desirable development would be to build capability to set different drift temperatures and cycle times for the summer and winter seasons. Allowing the room temperature to increase less during the summertime would reduce savings but increase guest comfort. Numerous failures, tampering, and the battery replacement requirement make a case for using hardwired occupancy sensors. This would increase the installation time but improve installation persistence. The appearance of sensors created suspicion among occupants, which resulted in tampering and proved to be a barrier to acceptance of the technology. Using a clean design that would not appear intrusive, eliminating blinking lights, and sending the sensor-failure signal to a remote location would help product acceptance.

Cold cathode lamps can be up to three times more expensive than "hot cathode" compact fluorescent lamps or long-life-rated incandescent lamps that have historically been used in outdoor signs, but they last 2 to 2.5 times longer than lamps they replace. The signs retrofitted through the program typically contained more than 6,000 lamps, and savings resulting from less frequent group relamping of cold cathode lamps can offset its price premium. Cold cathode lamps can have an economic advantage, but the program experience found that retrofitting them in existing fixtures was problematic in certain applications. The product requires reengineering to fit universally in intended applications. Demonstration sites or displays of the cold cathode lamps that allow potential participants to view the different color temperatures during the day and night would be helpful to customers. Addressing the concerns and improving color temperature would increase customer acceptance of this technology. Manufacturers have begun addressing the industry's need for

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3 Occupancy sensors detect movement or heat to sense occupancy. Rooms with sleeping occupants might be sensed as vacant, resulting in a higher operating temperature causing discomfort to occupants.

higher-wattage lamps, a wider color selection, and more readily available products. Edison has mainstreamed rebates for the lamps by including 2- to 8-watt cold cathode lamps in its energy efficiency lighting program.

Participants dropped out of the Cold Cathode Program because of non-energy-saving characteristics of lamps, and savings did not persist in the Multifamily HVAC and Cool Cash Programs when failed batteries were not replaced or failed sensors were not detected. While such experiences did not occur across the entire market segment or all applications, they were nevertheless significant enough to make participants cautious about future use. Selecting products with better non-energy-saving features and applying the technology in more appropriate applications during early stages of its introduction to new markets can reduce the chances of early failures that jeopardize technology acceptance and its adoption rate.

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