A New Paradigm for Retrocommissioning: Moving Building Science to Green Collar Trades

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ABSTRACT

Historically, building retrocommissioning services have been conducted by engineering staff often requires the installation of data loggers to capture trends of equipment performance. Since the introduction of the 2005 Title 24 building code, newly installed HVAC and lighting control equipment are required to undergo acceptance tests which include construction inspection and functional performance tests to assure that equipment operates according to the intent of the energy code. A significant amount of research was expended to design these tests to capture common failure modes through a short test that could be conducted by a technician. These tests are conducted by the contractor and equipment is fixed on the fly until the equipment passes the test.

This paper offers a new paradigm for providing retrocommissioning services that uses the facilities' maintenance contractors to quickly identify common problems and fix them. This new paradigm opens up the field of retrocommissioning to the much broader field of mechanical and electrical contractors, test and balance technicians and control contractors. Huge energy and cost savings, estimated to be approximately 3.4 Billion kWh/yr, 1,500 MW and $480 Million/yr in California alone creates the financial basis for green collar job opportunities that cannot be outsourced.

Background

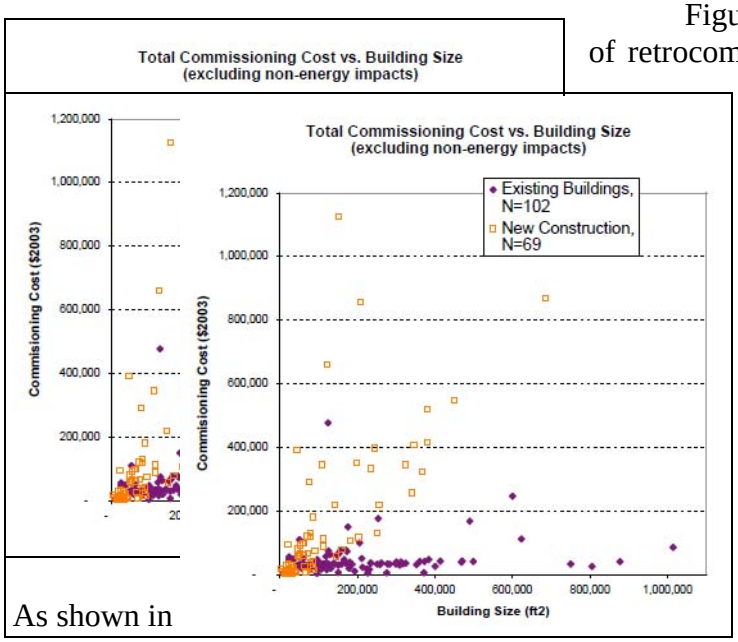
Potential Energy Savings from Retro-Commissioning

Gregerson, (1997) performed a meta-analysis of 44 retrocommissioning projects with the finding that retrocommissioning can often result in, "whole-building energy savings of 5 to 15 percent and paybacks of two years or less," This study gives one key caveat, "In most cases, either the commissioning cost or the savings were *estimated* (rather than measured).

From these results, Thorne and Nadel (2003) developed a national estimate of savings from retrocommissioning half of the US buildings larger than 100,000 sf, and assuming 10% savings are possible. With the total US building stock of buildings over 100,000 sf, consuming a total of 341 Billion kWh/yr, the savings from retrocommissioning half of these buildings would save approximately 17 Billion kWh/yr and 8,700 peak MW. This estimate is appropriate as the retrocommissioning studies reviewed typically served buildings greater than 100,000 sf.

These estimate of savings are reinforced by a later meta-analysis of 150 retrocommissioned buildings. (Mills et al 2005) This evaluation revealed a median energy cost savings of 15%. Most of the retrocommissioned buildings were larger than 150,000 sf.

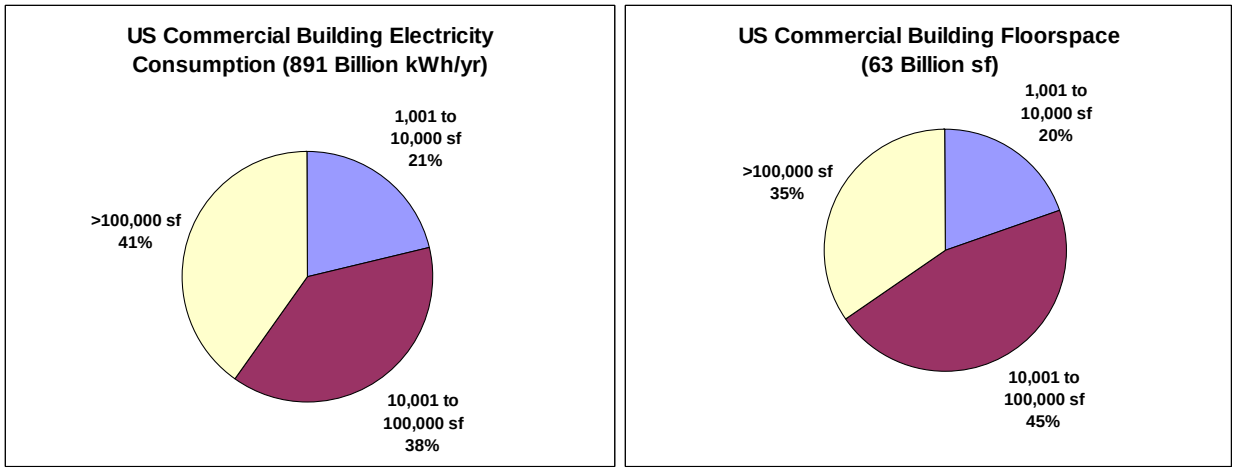
Figure 1: New and Retro-Commissioning Costs versus Building Size (Mills 2005)



As shown in Figure 1, the Mills study found that the cost of retrocommissioning was relatively insensitive to size. A similar cost plot in the Gregerson study shows that $30,000 is the market cap for retrocommissioning for most of the buildings over a range building sizes from 80,000 to 800,000 sf. This would indicate that there is a significant amount of fixed costs and thus the economics of a retrocommissioning project would favor larger sites with more potential energy savings and thus faster paybacks.

With current retrocommissioning programs primarily serving buildings larger than 100,000 sf, this limits the savings opportunity to buildings that are responsible for 41% of total nonresidential energy consumption and approximately 35% of floor space. As shown in Figure 2, if the fixed costs associated with retrocommissioning can be reduced so that commissioning can be applied to buildings with floor areas greater than 10,000 sf, more than twice the square footage of nonresidential buildings could be retrocommissioned than previously considered. This would also allow retrocommissioning programs to serve an underserved category of customer, the small commercial customer.

Figure 2: Fraction of US Commercial Electricity Consumption and Floor Space by Building Size[1]

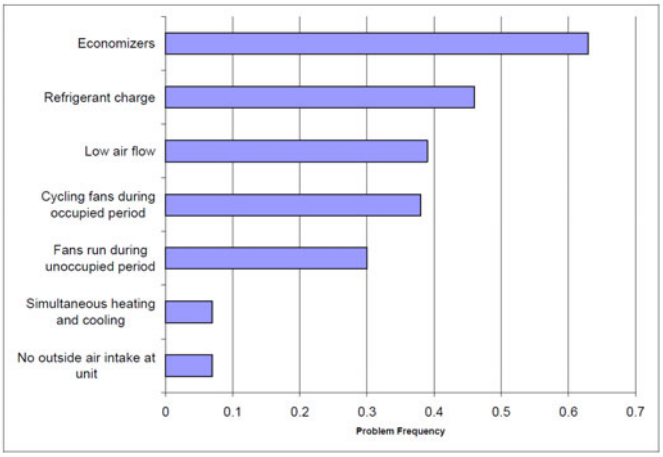


[1] Table C21. *Electricity Consumption and Conditional Energy Intensity by Building Size for Non-Mall Buildings, 2003*. **Commercial Buildings Energy Consumption Survey**. US Energy Information Agency. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set10/2003excel/c21.xls .

Common HVAC Failure Modes

The California Energy Commission sponsored Public Interest Energy Research (PIER) program surveyed 75 small commercial buildings and studied the operation of 215 rooftop units. (CEC PIER 2003). The results of this study quantified just how poorly small commercial HVAC systems are performing in the field. As shown in Figure 3, over 60% of economizers had failed (mostly in closed position), almost half of systems were over or under charged by more than 10%, and fan operation was inappropriate on at least 30% of the RTUs (either cycling during the day and not providing enough ventilation air or remaining on after hours and increasing energy consumption unnecessarily).

Figure 3: Frequency of Problems Encountered in Small Commercial HVAC Study (Jacobs et al 2003)



What was shocking about these results was that all of the participating buildings were 4 years old or less! This may imply that some of the equipment never worked from day of installation. These findings helped motivate the requirements for acceptance tests in the California Title 24 building energy efficiency.

For a study on continuous commissioning, (ARTI, 2003) commissioning experts where asked to rank the frequency and importance of failure modes for HVAC modes in all building types. The responses for small rooftop units matched those in the PIER study, with the most likely failure modes being those of improper economizer operation, poor control of outside air, controls improperly programmed etc. In addition, these experts outlined key failure modes for larger systems including those with energy management systems, chiller and boiler plants, hydronic distribution controls, and variable air volume control. These larger systems have similar problems as smaller systems (economizer control and control of setpoints) but these larger system also have more opportunities for improper operation as there are more system components (hydronic loop, fan speed control etc.).

A meta-analysis of persistence of commissioning savings (Toole & Claridge 2006) evaluated the persistence of savings from 4 studies contain a total of 27 buildings. Over time at least half of the electricity savings remained. The drop off in gas savings was more dramatic with one study of three buildings finding that none of the gas savings persisted after 4 years.

2005 Title 24 Acceptance Tests

In response to growing evidence that significant amount of newly installed equipment was not working properly and was either consuming energy unnecessarily or providing unhealthy indoor air conditions, the California Energy Commission adopted mandatory

requirement for acceptance testing of HVAC and lighting controls in the 2005 Title 24 building energy efficiency code. Acceptance tests are documentation by a "responsible person"[2] of construction inspection and functional performance tests. Construction inspection is verification that all the required components installed and all sensors are calibrated. Functional performance tests are short term tests that are specifically designed to uncover common failure modes. Acceptance testing can be considered "commissioning lite" as the acceptance tests only assure that the equipment operates according to the energy code requirements. Acceptance testing is not a replacement for building commissioning, as it does not include documenting the owner's project requirements, design document review, bid package review commissioning plan etc.

The development of these acceptance tests drew upon years of experience in the commissioning and retrocommissioning fields. These tests are designed so that they can be conducted by the technician installing the equipment. Most of these tests take less than an hour to conduct. The intent of these tests is that they indicate to the installer if there is a problem with how the equipment has been installed or adjusted. If the equipment does not pass the test, the equipment must be repaired or adjusted until it passes. These acceptance tests are required for all newly installed HVAC equipment in new and in existing buildings.

Figure 4 contains a listing of the acceptance testing that is required by the 2008 California Title 24 energy code that took effect January 1, 2010. These acceptance tests apply to every air conditioning system installed in nonresidential buildings.

Figure 4: List of 2008 California Title 24 Building Energy Code Acceptance Tests

Nonresidential Appendix Section and Test	Nonresidential Appendix Section and Test
NA 7.5.1.1 Variable Air Volume Systems Outdoor Air	NA 7.5.8 Supply Water Temperature Reset Controls
NA 7.5.1.2 Constant Volume Systems Outdoor Air	NA 7.5.9 Hydronic System Variable Flow Controls
NA 7.5.2 Constant Volume Packaged HVAC Systems	NA 7.5.10 Automatic Demand Shed Controls
NA 7.5.3 Air Distribution	NA 7.5.1.11 FDD for Packaged DX Systems
NA 7.5.4 (Air-Side) Economizer	NA 7.5.1.12 FDD for AHUS and Zone Terminal Units
NA 7.5.5 Demand Control Ventilation	NA 7.5.1.13 Distributed Energy Storage DX AC Systems
NA 7.5.6 Supply Fan Variable Flow Controls	NA 7.5.1.14 Thermal Energy Storage Systems
NA 7.5.7 Valve Leakage Test	

The Nonresidential Compliance Manual for California's 2008 Energy Efficiency Standards[3] contains the Acceptance Testing forms and the Acceptance Testing chapter. The Acceptance Testing chapter of the manual contains step by step directions for conducting the acceptance tests and filling out the forms. This "cookbook" method towards acceptance testing moves these tests into the purview of the HVAC technician, who can test and fix the equipment during the same site visit.

Anecdotal reports to date indicate that acceptance testing has not been regularly required by building departments. Efforts are underway to disseminate information to building inspectors, mechanical contractors and designers about the benefits of acceptance testing and its part in energy code compliance.

[2] A responsible party is a licensed contractor, architect, or engineer
[3] http://www.energy.ca.gov/title24/2008standards/nonresidential_manual.html

HVAC technician training and certification. The current HVAC technician training programs are centered on basic and advanced HVAC refrigeration as well as testing, adjusting and balancing/commissioning certifications. Many of the courses are offered through the utility training centers offering advance training for NATE (North American Technical Excellence) certifications. The training offered is more remedial and addressed to technicians with a good background in HVAC service. Conversely union training is offered through the industry joint labor and management training centers. These are career training programs take in individuals with little or no experience and advance them through a 5 year classroom/field application. These programs are certified by the State Division of Apprentice Training and the Federal Government. Each program leads the individual towards their apprentice completion and certification.

Traditional Model for Delivering Retro-Commissioning

Though the simple paybacks for retrocommissioning measures are often quite short, the overhead costs for delivering these programs make them less attractive. Current program delivery can take the following steps:

1) Marketing of utility incentive offerings funded by California utility customers and administered by PG&E under the auspices of the California Public Utilities Commission is conducted by a variety of utility, government partnership and third party program representatives. Having multiple channels of program delivery to utility customers has been challenging to program implementers, trade allies and especially utility customers. An additional challenge stems from analogous and sometimes overlapping measures qualifying for incentive offerings via demand response, self generation, retrofit, new construction, emerging technology projects. Customers must enroll in an incentive program by completing and signing a program application. The following describes PG&E's core retrocommissioning incentive policies and procedures and is one example of the complexity in offering of retrocommissioning incentives to commercial building owners and tenants.
2) Utility representative delivers and presents detailed study agreement to customer. Agreement provides free detailed site assessment as long as customer agrees to install all eligible and reasonable measures with less than 1 year payback. If the customer doesn't implement the <1 year payback measures, then the customer must repay the cost of the site assessment up to $25,000.[4] Customer must also provide site staff to show assessors around and install monitoring equipment. This key program requirement, the customer promising to pay for at least half of the installed cost of identified upgrades without knowing what the upgrades are is a key point of friction between the program rep and the customer. At this point, 25% of pre-selected customers drop out.
3) Traditional utility RCx incentive programs have provided qualifying customers with an independent consulting engineer's detailed investigation audit utilizing IPMVP[5]

[4] PG&E Retrocommissioning Fact Sheet. January 2009. C-1590 http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/analyzer/retrocommissioning/09%20RCx%20FS%20v5.pdf

[5] International Performance Measurement and Verification Protocol http://www.evo-world.org/

protocols. Consultant comes to the site and with the help of site staff installs monitoring equipment.

4) Monitoring equipment is left for a week and results are analyzed by consultant. Consultant looks at patterns and recommends changes to the system which are recommended in the detailed study report along with an estimate of costs, and savings.
5) Program participant receives report which includes: a project deficiency and resolution log listing recommended RCx measures with associated annual energy and cost savings estimates, implementation cost estimates and estimated utility incentives ($0.09/kWh, $100/pk kW and $1/th saved annually) for each measure. California utilities cap a calculated incentive at 50% of the measure cost.
6) Participant installs measures.
7) Consultant returns to the site, inspects installations and collects monitoring equipment and monitored data.
8) Consultant prepares post-installation measurement and verification report.
9) Results are peer reviewed for accuracy and appropriate application of program rules.

This approach is costly at about $0.15-0.20/sq ft, including the detailed site investigation, deficiency and resolution log, post implementation inspection/true up report and customer training deliverables. It is also time consuming (typ. 6-12 mo. effort) and cumbersome for all parties. Adding in the utility's pre-screening costs, peer review and post implementation inspections and documentation requirements, the programs have only been offered to and been marginally successful with the largest buildings (>100,000 sq ft).

The model for this type of program is that of the highly trained outside expert identifying control and other HVAC fixes to a relatively complex HVAC system serving a large building. This model builds upon the education experience of many of these building scientists who evaluate patterns of logged data. Thus the program relies on relatively expensive specialists, and the time commitment of collecting logged data.

Another basic assumption of this model comes from the community of industrial energy assessors who expect that savings will come from a significant capital expenditure (heat recovery equipment, motor upgrade on burn-out, lighting retrofits etc.) Thus this model has to spend a good amount of time negotiating wth the customer the key program premise, "The Energy assessment is free,* but only if the customer agrees to pay for upgrades that we are going to recommend in the report. This format requires a report presentation, essentially persuading the customer to install the upgrades and then following up with M&V measurements.

For many retrocommissioning upgrades, most of the savings are for controls adjustments, sensor replacement etc which are very low cost. The current program model spends more time and money on transaction costs than fixing the piece of equipment. Since the skill set of the program implementer is typically an engineer not a repair person, the implementer is often not qualified to make the needed adjustments or repairs.

Workforce Training for a Clean Energy Economy

In 2009 Pacific Gas and Electric and the Bay Area SMACNA/SMWIA Local 104 Training Joint Training Program established a joint working group tasked with identifying training gaps that exist between classes being taught at the PG&E Energy Center and the advanced HVAC system classes currently being provided to apprentices and journey level

technicians in the Bay Area. After hearing the elements of the PG&E RCx program many contractors explained that elements of the utility program limited attaining energy savings to large buildings. SMACNA contractors have relationships with thousands of building owners where they provide ongoing service and maintenance.

PG&E reviewed the rationale for the restrictions and determined that savings could be realized in these smaller buildings, but only if the cost of program delivery could be reduced and the fraction of surveyed buildings that implemented the measures increased. The current method of engaging engineers to prepare a master list of findings along with energy savings, costs and length of payback is only marginally cost effective in larger buildings. However, to bring benefits of retrocommissioning to a broader market, a method would have to be created to estimate deemed savings for specific fixes to problems identified by HVAC service and/or balance technicians. In addition, methods would have to be developed to reduce the overhead marketing costs as well as the fraction of building owners implementing the recommendations.

The recommendations below describe a method of program delivery that not only expands the scope of retrocommissioning programs but ultimately has the capability of transforming the training and installation practices of the HVAC industry.

"Achieving the transformational vision and goals established for the commercial sector will involve changing energy user behaviors and the supply chain of services and products that commercial end-users rely on to efficiently use energy as well as continual updating of codes and standards." (CPUC 2008)

New Model for Delivering Retro-Commissioning

We are proposing a new model for commissioning that is especially suited towards smaller buildings. This model has less overhead and can more quickly impact the energy consumption of buildings across the state. The simplest description is that the program pays contractors to conduct the Title 24 acceptance tests on existing HVAC systems and to conduct all of the low cost fixes. When the acceptance test uncovers a more expensive repair, the contractor will provide an annual estimate of savings, the cost of the repair and how much utility incentives will defray some of the cost. The key elements of this program are contractor training and certification, streamlined delivery, simpler customer decision making, direct implementation of most measures, verification of savings and spill over into energy code compliance.

Contractor/Technician Education

The primary innovation in this method of delivery is to replace highly trained building scientists with HVAC technicians. This is only possible by taking the considerable intellectual property owned by the state of California in the form of the HVAC acceptance tests and training technicians in the use of these tests and what they mean. Each acceptance test has a number of failure modes it is intended to capture. Part of the training is to help the contractors and technicians understand what is the most likely cause of each test failure and what fixes are needed to the equipment can pass the test and work appropriately. Since most of the actual testing will carried out by technicians employed by the licensed contractors, it is likely that the

technician training will be more intensive while contractor training can be more along the lines of inspector training with general oversight and observation instructions.

The training opportunities can be leveraged by making use of pre-existing HVAC training centers such as the utility training centers, sheet metal union training centers and community colleges with HVAC technician course offerings. These training opportunities also create the opportunity to teach HVAC contractors about the requirements of the energy code.

Contractor Certification

Contractor certification works in two ways: the utility certifies a contractor as capable of performing the work by employing properly trained and certified technicians, and the contractor certifies their work and the accuracy of the acceptance forms on each job.

By passing the training the program and getting certified as high performance HVAC contractors, this indicates that the contractor is able to quickly and effectively conduct the acceptance tests and make necessary repair. Thus the contractor not only knows how to apply the acceptance tests within the retrocommissioning program but also knows how to correctly apply the acceptance tests on new construction projects. Certification as a high performance HVAC contractor provides a number of benefits to the contractor including differentiation on training and quality.

The front page for each acceptance test has a required certification of the accuracy of the information on the acceptance form by the responsible party (contractor or other person with a license) and by the HVAC technician. Similar to the certification when this is filled out on a new building project, a contractor filling out one of these forms without conducting the test or inserting false data is committing fraud. Besides placing their license (and livelihood) at risk they are also creating a paper trail of financial liability. Thus it is important for the contractor to sign off on each test.

Ethics are a key component to making this training and testing viable, the Testing, Adjusting and Balancing Bureau (TABB)[6] developed a technician code of conduct that each is required to sign prior to being certified. It provides for immediate loss of certification if a technician every knowingly fills in a fraudulent form. Similarly the contractor would lose their utility certification if they are found falsifying program documents.

The contractor reaps numerous benefits for participation in the program. The contractor gets paid for conducting retrocommissioning work. This is an additional activity that results in higher utilization of trained staff during periods when regular repair work is slower (i.e. during the swing seasons). HVAC problems are uncovered which can lead to additional work that may not have been obvious before. Conducting acceptance tests render it less likely that regular equipment failure occurs for their customers with maintenance contracts – this reflects well upon the contractor. Training and expertise in acceptance testing may make the contractor more competitive when bidding for projects that include acceptance tests.

Contractors would be responsible for estimating the savings from the adjustments and repairs sponsored by the program according to utility developed deemed savings calculation methodology. These deemed savings calculations provide a reasonably accurate financial estimate of other maintenance and repair activities. This additional competence in calculating energy savings provides an added value that the contractor can put to use regardless of utility sponsorship. These deemed savings methodologies can help reduce consumer fraud.

[6] http://www.tabbcertified.org

Streamlined Delivery

The current retrocommissioning delivery protocol required a customer agreement, a field survey, installation of monitoring equipment, download and evaluation of monitored data, a report with estimates of savings and costs, and then the repair. The proposed methodology would involve a customer agreement, the equipment is recommissioned, the acceptance tests results are given to the customer. For many customers that is it. For those customers where a larger repair is identified, a proposal is made that includes the costs, savings and the utility incentive contribution for energy efficiency upgrades.

Easy Customer Decisions

The primary agreement with the customer is that the utility will pay for the contractor to conduct the acceptance test, making simple repairs and providing a summary of work done and filled out acceptance forms. If more extensive work is identified, this will be in separate report and the utility will identify how incentive they will pay on more expensive upgrades. The agreement would also include a requirement for indemnifying the utility, i.e. that any damage to equipment or business operations is between the contractor and the building owner and of course the contractor's insurance company.

What is especially attractive from the customer's position is that there is no up front requirement to agree to any expenditure for the service or for any projects identified. The customer agreement to repay the cost of the assessment if they don't undertake energy efficiency measures with claimed payback of less than a year is hard for the customer to swallow. How do they know the payback is really 1 year or less? This has been historically a problem with the retrocommissioning program and a lot of effort and time is taken to assure the customer that this is not locking them into a bad deal. This requirement for expenditure has resulted in a lot of customers dropping out of the program at the beginning.

However a no cost program that benefits the renters is something that can be taken to building owner who does not feel they have to commit to an expenditure. This format of program can expand the type of building ownership classes where the value proposition makes sense.

When the contractor has identified more extensive retrocommissioning work that requires customer expenditure, the contractor must use the energy savings calculator that makes use of a vetted calculation method or deemed savings and this calculator also gives an estimate of the maximum utility incentive for this project. The customer is not locked in, they can refuse the proposal and receive only the energy assessment and the benefit of all the setpoint adjustments and modifications that were low cost/no cost. The utility receives all of the avoided costs benefits associated with saving the energy at the customer's site. Since HVAC energy savings are often coincident with peak demand, these measures are particularly valuable to the utility.

Also the customer does not have to use the contractor who developed the energy savings proposal. The customer could use another utility certified contractor, but given the fast payback of many of these measures, the initial contractor is at a decided advantage.

Direct Implementation of Measures

Unlike many energy audit programs, the savings are not contingent on a customer decision after the majority of the program expense has been spent. Many of the measures targeted by this program are no cost/low cost measures. By relying on contractors to deliver the service, the program can rely on getting many of these measures directly implemented before the contractor leaves the building.

Verification of Savings

In verifying savings the key questions are:

1. How much energy was really saved?
2. Is the contractor cheating? (faking data and not doing the work)
3. What would have the customer done without the program?

The current program model is able to answer this question very well as all projects are conducting pre and post energy monitoring. However this is very expensive and is not a good use of ratepayer dollars. Reasonable levels of accuracy can be obtained by conducting pre and post implementation on a subsample of HVAC systems.

Though the repercussions of contractor cheating are potentially severe, unscrupulous contractors could ruin the credibility of the program. Some of the sampled pre and post measurements could be conducted without the contractor's knowledge. T.

A technical method of checking for discrepancies electronically is to require that the contractors enter the acceptance testing data in real time into a PDA (personal data assistant) or cell phone application. The data entered would be time stamped and analyzed for discrepancies related to timing, data entered and patterns in the data. The data collected from this tool could enhance next generation version of the acceptance tests.

In an ideal world this type of program would target only those customers who would never have commissioned their HVAC equipment. However, if you were going to pay to have our equipment commissioned wouldn't you be one of the first in line to participate in a utility retrocommissioning program? The main way to limit the fraction of free riders is to make it attractive to all customers and accept that there are going to be some free-riders but that there are enough true participants that the overall net total resource savings still exceed the entire program costs.

Free riders can be filtered out by asking the customers how long it has been since the equipment was last commissioned. If the equipment has been commissioned in the last 5 years, then perhaps the customer would have commissioned the equipment anyway. The rationale behind this is that a customer who has commissioned equipment before is more likely to ask for commissioning than one who has never paid for commissioning before. Also if the equipment has been commissioned earlier, it is less likely to yield as much energy savings. Thus a program rule may be to limit retrocommissioning services to those customers who have not had their HVAC system commissioned in the last 5 years.

One way to evaluate the extent of free riders is to ask the customers if they would have paid for the service on their own and how much they would have paid.

Other customers not likely to have their equipment commissioned are those who are renting their commercial space. The building owner is not likely to pay for services that increase the efficiency of the building as they do not pay the energy bill. The renter is unlikely to invest in HVAC equipment maintenance.

Spill-Over into Code Compliance

A key component of this contractor based retrocommissioning program is to use the Title 24 acceptance tests and compliance forms to identify operations problems in HVAC equipment. Training in the use of the acceptance tests and regular use of the acceptance tests for participation in the program develops a critical mass of contractor expertise. As a result this type of retrocommissioning program will likely result in more contractors using the acceptance tests as they would now be cognizant of their responsibilities and would know how to comply quickly and effectively.

With the acceptance tests being used as the basis of a retrocommissioning program, compliance or testing difficulties uncovered by the retrocommissioning program can be incorporated into acceptance test updates and thus into the Title 24 energy code. Thus interaction between the two programs can produce synergies that transform the HVAC market and the energy code.

Puget Sound Premium HVAC Service

Puget Sound Energy offers a retrocommissioning program that makes use of HVAC technicians. This program requires that the customer sign up for a 3 year service contract with pre-qualified HVAC contractors. Once signed up, PSE will give rebates to these contractors for:

- Adding economizers
- Calibrating economizers
- Refrigerant charge check
- Adjusting airflow
- Adjusting thermostat setpoints and schedules
- Replacing or calibrating sensors

This program provides great benefits for the contractor – not only does it pay incentives for certain services but it also locks in the customer into a 3 year contract with the contractor. The value proposition for the customer is less attractive as it forces a longer than typical duration of service contract. This helps assure maintained performance due to regular maintenance but provides less recourse if service is lacking.

Interaction between Code Compliance & RCx Program Savings

In the Title 24 energy code, acceptance tests are only required in new construction and when HVAC equipment is replaced.[7] Thus a retrocommissioning program could not take credit

[7] The Air Distribution acceptance test is the one exception; it is required for small single zone systems with more than 25% of the duct surface area being outdoors or in unconditioned space. This acceptance test is required if a major repair is conducted such as replacing a cooling coil or replacing a furnace heat exchanger.

for energy savings for new construction or replacement HVAC equipment. The customer would have the contractor conduct the acceptance tests anyway.

However retrocommissioning of existing equipment is clearly outside of the scope of the energy code and credit for these savings would accrue to the retrocommissioning program. In California, the investor owned utilities have Codes & Standards programs which receive credit for more stringent energy codes including acceptance testing. Thus the simplest method for addressing the spill over effects from the retrocommissioning program that result in more code compliance, is to credit the Codes & Standards program for code compliance.

Conclusions

This paper has presented a relatively novel method of expanding the scope of building recommissioning by training HVAC contractors to use the Title 24 acceptance tests for identifying poorly operating HVAC systems. These contractors are empowered to immediately fix most minor problems as a direct install program. This reduces program overhead and increases program participation. We expect that this simple form of retrocommissioning could be expanded to buildings as small as 10,000 sf.

With such a straight-forward method of delivering retrocommissioning, we expect that the potential savings are twice that estimated earlier based on only buildings larger than 100,000 sf. We expect the technical savings to be as large as 3.4 Billion kWh/yr, 1,500 MW and $480 Million/yr in California alone and ten times more in the United States.

This type of program can be ramped up fairly quickly and make use of pre-existing training resources for HVAC technicians. This type of program has the benefit of expanding the opportunity for "green collar" jobs that protect the environment, increase societal wealth while reducing the costs for delivering retrocommissioning services.

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