ABSTRACT
Since 2004, the County of Los Angeles have retrocommissioned over 4 million square feet and additional RCx work is underway. The scope of the HVAC retrocommissioning (RCx) involved systematic investigation of mechanical, electrical and controls components/systems to diagnose and resolve root causes of operational deficiencies. During the implementation phase, new energy efficiency measures were installed, sequence of operations were optimized and functionally tested. System-level benchmark models for HVAC systems were developed based on optimized runs of eQUEST energy models and parametrically integrated into the County owned web-based Enterprise Energy Management Information System (EEMIS) with Itron/Silicon Energy EEM Suite® backbone for the purpose of monitoring the operations of the HVAC systems. The paper and presentation describes the HVAC RCx process to optimize operations, cost and savings associated with this project and key operational changes to sustain optimized operations without sacrificing tenant comfort.

RETROCOMMISSIONING PARTNERSHIP
Under the auspices of the California Public Utilities Commission (CPUC), the Southern California Edison Company (SCE), the Southern California Gas Company (SCG) and the County of Los Angeles (County) entered into a two-year program partnership commencing in 2004 that included building retrocommissioning (RCx). The program is further extended for 2006-2008 period to retrocommission additional County facilities.

Since the County had already accomplished significant lighting and heating, ventilating, and air conditioning (HVAC) retrofit in the past, the RCx project was targeted to optimize HVAC systems. The County desired to accomplish the following objectives through the RCx project:

- Benchmark the HVAC systems’ optimized performance
- Manage sustainable, optimized HVAC system performance utilizing the County’s EEMIS
- Train building technicians on the retrocommissioning process and the new HVAC system operating parameters
- Provide comprehensive documents for the County’s Operations & Maintenance
- Meet or exceed the energy and demand savings goals filed with the CPUC

RCx TO ENHANCE HVAC OPERATIONS
The adapted RCx process is graphically depicted in Figure 1. It illustrates the rigorous retrocommissioning approach for 11 County buildings covering over 1.7 million gross square feet. The County had metering and controls points on the EEMIS so that the systems could be monitored remotely through the internet. Sustainability of RCx benefits would not be attainable for the County buildings without first going through the RCx process described here.

Benchmarking Phase
The RCx provider was furnished with facility as-built documents, weather input data “*.bin” files formatted for eQUEST input containing dry-bulb, wet-bulb temperatures, humidity, dew point, enthalpy, etc. for specific sites, electric and natural gas bills for the most recent three years. This information was used to establish the pre-RCx benchmark performance information. Spreadsheets and Cal-Arch, an energy benchmarking software program, tools were then used to determine electric energy density metrics (kilowatt-hours per gross square foot (kWh/GSF/Yr), therms, and British Thermal Units per gross square foot per year (kBtu/GSF/Yr) for the facilities under the contract. These energy density calculations established the basis for savings estimates and validated the County’s energy utilization index (EUI) values for the selected buildings. This step is considered very important as it can be a good indicator of potential savings expected out of the RCx process.
**RCx Planning Phase**

The contracted RCx provider visited each site with the ISD mechanics and received an orientation on the maintenance and operations aspects and issues of the building HVAC systems. The County technicians shared their system knowledge, history of modification and trouble issues, and expected solutions with the RCx Provider. Armed with available as-built drawings, preventive maintenance logs, and occupant complaint logs, the RCx provider audited each facility and submits a planning report for each building containing comprehensive building information collected including operational and maintenance status of HVAC system. Report also includes list of observed deficiencies and issues with proposed strategies to address them. If paid enough attention, one can create budgets for potential EEMs and associated savings with it using variety of industry sources. This phase may be smartly utilized to make any portfolio changes depending on the needs of a client.

**Pre-functional Testing or Investigation Phase**

During the pre-functional phase, major field activities were performed to identify specific operations of each HVAC system. The RCx provider, along with their subcontractor teams, performed a thorough examination including review of existing sequence of operations, Point-to-point controls testing, calibration of controls components/sensors, diagnostic airflow and temperature measurements, eQUEST Modeling baseline energy usage of the HVAC system, development of scope of work and cost proposals for recommended optimization measures, or energy efficiency measures (EEMs).

**Correction of Deficiencies**

The single most important action item was to correct the deficiencies identified primarily during the pre-functional phase and after functional performance test phase. Without correcting the deficiencies, it would not have been possible to optimize the scheduling of the equipment in the buildings.

**eQUEST Modeling of Energy Efficient Measures**

Equipment, system and occupancy data collected during the investigation phase was utilized to develop an eQUEST model. Power draw of every major HVAC equipment, AHU, pumps trended over two-
weeks; air flows were measured by AABC protocols; annual data, were available, was analyzed to build the robust model based on trended/measured date. Performance curves of equipment were utilized wherever data was available. Lighting retrofit records and hours were recorded for model input and power density of 1.15 W/SF (adjustable) was applied at different facilities. Office equipment power density of 0.75 W/SF was derived based ASHRAE research articles and adjusted sample field survey. The simulated model was calibrated per IPMVP/FEMP protocols to the utility bills within 5%. Proposed EEMs were then evaluated to estimate the energy benefits of each EEM. A cost proposal was submitted. ISD chose the EEMs that impacted the operations of the buildings. Emphasis was placed on upgrading hardware, and software changes to the existing systems to automate the operations of the HVAC systems and to receive the alarms at the central operations command BEAS. One example of eQUEST model output chart is depicted in Figure 2. One of the measures installed was control program change to reset the supply or discharge air reset from 55°F to 60°F based on return air temperature 71°F to 76°F. The other energy saving strategy adapted was to shut-down (or lock-out) the hot water pump when outside air temperature past 75°F. All these temperature values are now operator adjustable without changing the program.

The following describes the EEMs that were implemented at one or more of the 11 facilities:

- HVAC System Start/Stop for AHUs, chillers and boilers.
- Outside Air Economizer sequence based on OSA or enthalpy.
- Minor Boiler Tune-up.
- Hot Deck / Cold Deck Reset (adjustable).
- Discharge (DAT) / Mixed Air Temperature (MAT) Reset.
- Adjust Condenser Water Temperature.
- Testing and Balancing of full facility was performed at two building.
- Mixing Box Repair.
- Hot Water Pump lock-out.
- Chilled Water Pump OSAT Enable at 57°F, delaying the use of chillers on colder mornings.
- Garage Exhaust Fan Carbon Monoxide Control by installing sensors throughout the garage and programming the exhaust fans to run when high level of CO to be detected.
- Hot Water Supply Temperature Reset strategy based on OSAT.

**EEM Implementation**

Selected EEMs were then implemented by one of two methods. In some cases, the County used in-house resources to implement a measure. In other cases, a change order was issued to the RCx provider enabling them to implement the measure. During this phase, the County’s M&O and Energy Management Division staff implemented many EEMs recommended by the RCx provider. Most of these measures involved HVAC control set-point and schedule changes. Other recommendations, many involving control programming changes, were contracted out to the RCx provider who subcontracted much of the work to local mechanical and controls contractors.

**Figure 2. eQUEST Energy Savings by EEM.**
• Night Purge Control strategy to flush the inside air when OSAT found to be lower than interior temperature beyond the comfort zone of 68°F to 74°F.

Functional Performance Testing

Functional performance Test (FPT) procedures were conducted in all facilities on the entire HVAC systems that included new EEMs. The RCx provider began functional testing of the HVAC systems during the unoccupied hours with the assistance of their controls subcontractors. During this phase, more deficiencies and optimization measures, though fewer in number, were discovered, reported and corrected, in most cases. All the change order related measures were successfully commissioned and demonstrated to County M&O staff for field training purpose. Functional performance test logs with master list of findings were submitted by the RCx provider. The RCx provider then remotely monitored the optimized system, with emphasis on the EEMs, with the County’s EEMIS.

Training and Documentation

The RCx provider prepared an RCx Training Manual to be used primarily by the County’s Maintenance & Operations (M&O) staff. The contents of the manual include an overview of the retrocommissioned HVAC systems and a description of the optimization measures implemented during the RCx project. The measure descriptions include background information, reasoning behind the measures, verification process used to ensure sustainable results. The RCx provider also provided classroom and on-site training to the mechanics to familiarize them with the new HVAC measures.

RCx Final Report

RCx Final Reports for each building contained records stating the optimized state of the HVAC system in terms of equipment operating schedules and optimized sequence of operations, chiller and HWP lock-out temperatures, HWST reset schedules, CDT and HDT reset schedules, economizer sequencing and other operating parameters. The County now has at its disposal equipment-level benchmark charts based on a combination of trend data of points that provides proxy to optimized state of HVAC operations. As evident from the Figure 2 based on eQUEST model output, at Bellflower Courthouse facility, the largest projected savings are from chiller, AHU, and boiler pump start/stop schedules to meet the needs of the respective facility. Most of the systems were enabled by 5:00 PM and disabled by 10:00 PM. Extended hours were granted for selective equipment where cleaning crews stayed longer. The economizer control settings and the change in the discharge temperature of cold and hot deck also provide some additional savings. (It is unknown at this point if CDT/HDT resets and economizer contribute towards maintaining comfort and improve indoor air quality (IAQ) in the building.) This observation has allowed the County to prioritize efforts to work on keeping the run-hours of the equipment as short as needed by the occupants. Any technical difficulties that extend the run-hours of the facility operation are given highest priority to resolve the issues ensuring sustainable operations.

Another level of oversight is based on final output from the eQUEST that defined the performance of the calibrated building in terms of monthly energy usage that can be used to track the bills and monitor the building operations from an energy perspective.

Finally, eQUEST output allowed the development of system-level benchmarks, based on multiple input points, for each system such as ventilation, cooling and heating system energy usage per GSF, run-hours, ton-hours or Btu-hrs delivered, chiller demand based on OSAT, etc., to monitor the performance in run-time or when thresholds are crossed. The system-level benchmarks are being programmed into EEMIS for persistence of savings. The County can now utilize EEMIS, over the internet, to efficiently monitor equipment operations, analyze energy billing data and trend system-level benchmarks for sustainable optimized HVAC operations.

RCx SUSTAINABILITY ROADMAP

The retro-commissioning project revealed greater insight to the facility HVAC operations. It defined which points/parameters were important to monitor and allow operation of the HVAC systems in the optimized state.

Upon completion of RCx training, activities stepped up at the County to initiate new monitoring procedures using EEMIS. Monitoring of facility operations is now handled with a three-prong approach as illustrated in Figure 3.

First, creating a monitoring team, that consists of controls technicians, refrigeration mechanics and electricians from Systems Section of the Energy Management Division that observes and studies weekly customized graphs from EEMIS. At the equipment level, optimized state was defined in terms
of occupancy schedules, set-points for ventilation, heating and cooling systems. It was understood that as long as implemented EEMs and schedules remained intact (or adjusted per the requirements of tenants), the retro-commissioned facility could sustain the optimized operations and thereby energy savings could persist. Most important lesson learned was that the monitoring system needs to track deviation from optimized state operation and give prompt attention to resolve the root cause of operational problem because failure to do so may lead to inefficient system operations, replication of discomfort in other locations and it will jeopardize the anticipated energy savings. A team of controls/refrigeration/electric technicians promptly diagnose the root cause of customer complaint and resolve issues to ensure the persistence of sustainable energy savings.

In the second approach, a team of analysts is tasked to analyze utility bill data from EEMIS to gauge the performance of the facilities at the whole building level and compared with the utility benchmarks derived from eQUEST final run. Although, lighting and plug loads are not measured separately, utility analysis of the trends can pin point major deviations that could be further investigated. Variables such as weather, plug, elevators, and lighting loads were not designed to be monitored; however, HVAC operations could be kept under control by targeting select parameters in a systematic manner.

Third, ISD have contracted with Itron to program select system-level benchmarks in terms of run-hours, ton-hours, Btu-hours, kW demand, kWh electric consumption and therm gas consumption to gauge the HVAC performance of the facility in numerical terms. Upon completion of this phase some of the manual workload from the other two phases is envisioned to be reduced through electronic alerting modules. These email notifications will be sent out to facility operations manager along with the energy manager.

COSTS AND ENERGY SAVINGS INDICES

Not discounting the fact that with RCx there is occupant comfort and M&O benefits, gains in operational efficiency are measurable. As seen in
Figure 4, the projected annual combined electricity and natural gas savings range that has been reported ranges from $0.10/GSF through $1.10/GSF. It is also reported that 80% of facilities can deliver $0.35/GSF and $0.18/GSF in electricity and natural gas savings, respectively. Similarly, 80% of the facilities running at current optimized state may deliver up to 3.82 kWh/GSF and 0.21 therms/GSF, respectively.

Note that most of the maintenance and repair work related to correcting system deficiencies, as well as much of the building engineer operator level controls work, was accomplished by the County’s M&O staff.

Estimated energy savings are expected to range from $0.11/GSF to $0.85/GSF. The average cost (including retrocommissioning service, EEM implementation by contractor, and County M&O services) and savings are observed to be $1.27/GSF and $0.57/GSF, respectively. The simple payback is estimated to be 3.1 years. One should be cautioned that range applies to the entire portfolio containing 11 buildings totaling 1.7 million GSF. Individual results may vary.

A wide variation in energy savings was observed for the portfolio of project buildings. The greatest savings, 5.32 kWh/GSF, was achieved where malfunctioning variable frequency drives (VFD) resulted in the drives being placed in manual operation at full speed.

The smallest savings, 0.15 kWh/GSF, were estimated for the building where existing control sequences functioned smoothly. It must be noted that optimized Start/Stop requires rather close watch on the systems operations and expedient response by building mechanics to resolve malfunctioning equipment or components.

SYSTEM-LEVEL MONITORING

The team was created and further trained to specifically monitor the sustainability of energy efficiency measures and operation schedules of equipment. The staff was familiarized with training manuals and EEMs specifics to each facility. Graphs were created using customize features of EEMIS and saved as favorite reports. Figure 5 graphically represents the configuration of the monitoring system. (Itron Inc. software application, formerly Silicon Energy, was purchased in 2001 at a cost of $600,000.00. During the course of the next five years electrical meter equipment, Cutler-Hammer, was installed in approx. 125 of the largest County
facilities. Installation costs for meter hardware and labor was $800,000.00 over this time period.)

Furthermore, the staff was trained to study the graphs weekly and observe if EEM strategies were still intact. Most common features that were tracked were scheduling or air handlers/chillers, CDT and HDT resets, hot water pump lock-out temperature, chiller lock-out temperature, VFD operation, etc. Any compromised system deviation from optimized state was discussed and resolved with building mechanic.

**Ventilation System**
Monitoring of ventilation systems revolved around watching equipment run-hours for weekdays and weekends, cumulative weekly, monthly and annually. Periodic sampling of cold and hot deck temperature graphs are examined to verify that reset strategy was

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**Figure 5:** County of Los Angeles Enterprise Energy Management Information System (EEMIS) configuration.

**Figure 6:** Weekly Fan Operation.
Cooling System Monitoring

Although there are many pieces of equipment that is part of a given cooling system, chillers by far consume the most energy in a given power plant. Monitoring chiller operating schedules may tell most of the story. Attention must also be paid when the equipment is running on variable frequency drives.

Chiller Schedule.

A weekly monitoring of the chiller start/stop graph, as shown in the Figure 7, can reveal simple confirmation that the equipment is ON for only weekday operation. In this example, it was discovered that the chiller stayed ON for few hours on a Saturday as well. In the weekly reports it was determined that a fixed Saturday schedule was programmed in the controller instead of a one time special scheduled event.

Chiller Lock-out based on OSAT

Economizer cycles were restored to working order and it was now possible to take advantage of cooler outdoor air. To shorten the operating hours of the chiller, a chiller OSAT lock-out strategy was implemented. Lock-out temperature was set at 58 °F (adjustable) based on experience. A weekly report of chiller amps or kW and OSAT on timescale as shown in Figure 8 can easily verify that strategy is indeed working. It may be noted that on a cooler morning chiller start may be delayed until 11:00 AM on weekdays.

Heating System Monitoring

Heating system monitoring is based on periodic sample of customized reports from EEMIS to observe if the HWP turns ON/OFF based on OSA Lock-Out temperature excluding scheduled OFF days on weekends. In addition, customized graphs have been developed to observe monthly HWP run-hours to compare against the benchmarks.

Figure 7. Chiller Operating Schedule.
Another strategy that is being monitored is study trends of OSAT and Hot Water Reset Supply Temperature (HWST). Heating system optimization is first achieved by implementing a hot water supply temperature reset based on OSAT. This strategy resets the temperature from a high of 180 °F to 120 °F. When there is lower demand, boiler fires less frequently, thus saving on natural gas utilization. Note the dip in HWST when OSAT peaks in Figure 9 from EEMIS for verification that the strategy is working.
The figure illustrates the fact that the building demand is essentially the same over each day of the week, even though the daytime temperature peaks vary from 67 °F to 77 °F. It can be expected that if the OSAT rise above 90°F the building demand may jump to a measurable difference. In any case, building demand behavior may be observed if kW and OSAT are depicted on the same chart.

**Figure 10. Hot water pump OSAT lock-out.**

**Hot Water Pump Lock-out based on OSAT.**

Hot Water Pump run-time plays a vital role in controlling excessive heat into the county buildings. First of all, excessive heat can create hot spots in the building due to combination of terminal box and thermostat deficiencies. Secondly, where system components work properly, cool air compensates for hot air and thus energy penalties are realized. The Figure 10 illustrates the strategy where HWP is shut-off at 72 °F (adjustable) to cease the heat supply to the building thus avoiding many “hot calls”. In fact, in a double duct system, HDT stays at the MAT and terminal mixing boxes may use the air to temper the cold air to discharge optimum air to the zones. The figure illustrates the working strategy where HWP may turn on two or more times, during morning and evening hours, when OSAT falls below lock-out temperature during occupied hours. Furthermore, in Figure 10, HWP lead/lag maintenance strategy is also verified.

**Whole Building Monitoring**

Operations personnel monitor the whole building utility metrics such as building demand shown in Figure 11. The illustrated chart clearly shows the normal operating building. The building demand peaks between 220 to 225 kW and it has a night demand flattens to about 30 kW. Such chart helps the staff to detect any anomalies.

Cooling Schedule.

Even though building demand is essentially doesn’t vary with OSAT, it is quite obvious that chiller would react to the load imposed by OSAT. The scenario is illustrated in the following Figure 12. Chiller demand peaks at about 125 amperes when OSAT is about 85 °F and the demand peaks at 92 amperes when OSAT peaked at 75 °F. An anomaly was noted by the staff on a chiller that operated unintentionally on a Saturday during evening hours. Further investigation revealed a programming error that lead to such behavior. Since then the issue has been corrected.

Meter-level benchmarks are usually less precise as it is hard to separate the effects of lighting and plug load draw. However, it could be a good indicator to document the changing operating conditions in the building. It is best if sub-meters could be installed and monitored for lighting and HVAC systems.
Figure 11: Building Demand (kW).

Figure 12. CHWP ON Over Weekend.
Utility Bill Analysis

Electric Performance.
Utility benchmarks in terms of kW, kWh, therms and dollars can be very useful in an ongoing effort to register deviation in energy consumption of a given facility. Using the front-end capabilities of the software, analyst can detect any anomalies on monthly basis and notify the operations staff to investigate further. One such example is shown in the Figure 13, where bill amount is compared against the benchmarked year to verify the persistence of savings.

Gas sub-metering Performance.
At some facilities boiler load is sub-metered. Knowing that over 90% of the billed therms get utilized in the boilers for space heating, it’s easy to compare the bill with metered values to verify, as shown in Figure 14 against metered values as well as against benchmark therm usage.

Figure 13. Whole building measured kWh consumption compared with eQUEST benchmark

Figure 14. Whole building measured gas consumption.
Meter-level benchmarks are usually less precise as it is hard to separate the effects of lighting and plug load draw. Also, bill data do not indicate the weather variation. However, it could be a good indicator to document the changing operating conditions in the building.

Automated System-level Benchmarks
The County is now capturing the benefits of persistence in RCx savings by fully utilizing the capabilities of its EEMIS system. By integrating benchmarked data from eQUEST simulations and measured data through the data acquisition system, the County can efficiently analyze various data sets and present information in a systematic manner to support the persistence process. Traditionally, such analyses would involve manual computation of performance matrices of gas and electric EUI, kW per ton and ton-hours for chiller, Btu-hrs for boilers, and other parameters, by using spreadsheets on limited sample data. Figure 15 illustrates a sample benchmark how the EEMIS approach allows the County to tap into the capabilities of the automated real time analyses of EEMIS data through customized computer algorithm. The process will efficiently gauge the performance of the facilities compared with system-level benchmarks, some of which are weather adjusted. These benchmarks are being programmed to serve as an alerting function to initiate notification to facility managers when threshold is exceeded.

During the retro-commissioning project, system-level benchmarks for performance were developed based on eQUEST output data, which was post-processed to create temperature bin data and brought it into the spreadsheet. Some benchmarks are cubic equations and some could be linear or quadratic. Appropriate equations were selected based on best fit value and observing the end points such as at high OSAT chiller kW must increase. Another equation was developed to define the upper limit of the equation at 2-standard deviation. The Red band denotes 2-standard deviation equation above the regression equation in Figure 15. If it is observed that too many real-time data points cluster above the red band, it would indicate that threshold is crossed and will require further action.

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Numerical values of these benchmarks are calculated based on real-time values registered by sensors and post-processing within the Itron module called Universal Calculation Engine Plus as shown in Figure 15. The system-level benchmark (equations) integration requires customized programming by Itron engineers. One example of system-level benchmarking is monitoring the cooling system based on observing chiller tonnage delivered against OSAT in real-time. The equation $y = f(x)$, where $x$ is OSAT is programmed into the Itron software. Value $x$ is obtained from a sensor at 15-minute interval. Software calculates value $y$, say chilled water tons, and

Figure 15. RCx persistence process using Universal Calculation Engine Plus (UCE+).
FIRST YEAR VALIDATION OF RCx SAVINGS

Gains in operational energy efficiencies are measurable. Data is directly taken from the utility bills. Combined annual energy savings are little over $425,000 that translates to approximately 3-year payback on monies spent on the RCx project that included comprehensive RCx services, as noted in the earlier section, and implementation costs incurred by subcontract work. Contributions from ISD in the form of correction of deficiencies and project management support are not included in the payback calculation.
An interesting observation is that gas savings are substantial, contributing up to one-third of the total savings. From an operation point of view, excessive heat in the buildings was actually penalizing the electric side before retrocommissioning as it is much costlier to extract the heat out of the building. Hence, keeping tab on heat supply to the building is to be kept at minimum. Electric and gas savings, in terms of kWh and therm respectively, are also reported lower than previous years on monthly basis as shown in the Figures 17, and 18. It is interesting to note that kWh savings is higher in non-summer months, October through May, and gas savings is much greater in the winter months. The explanation could be that there was cooling equipment that didn’t need to operate as much to maintain comfort in the buildings.

**CONCLUSION**

It has been observed that the retrocommissioning for existing buildings is an effective solution to achieve energy savings beyond the typical replacement of equipment and to adapt a process that is applicable to a large entity like the County of Los Angeles that has its own HVAC M&O division. In addition to energy savings there is improvement in tenant comfort and M&O can concentrate on preventive maintenance to operate the system in optimized state. Furthermore, valuable lessons were learned in the procurement of qualified RCx providers, improved coordination for the implementation of EEMs and integration of field intelligence with energy management technology to detect inefficient HVAC system operations.

The RCx process, as adapted by the County, defined the optimized operational parameters for each facility in terms of equipment run hours and verification of energy efficiency strategies that contribute to energy savings. These benchmark reference parameters, as illustrated in the Final RCx Reports, formed the roadmap for the County operations staff to systematically and periodically review EEMIS charts and verify confidently that the facilities are indeed operating in the optimized state. Monitoring the system in this manner constitutes a proactive approach, serving as first line of defense against inefficiency creep, to quickly identify and resolve issues.
In summary, after 12 months of tracking the performance of these 11 buildings, it may be concluded that comprehensive HVAC RCx process indeed does save measurable energy and improves operations of the buildings. Based on utility bills, on portfolio basis, one can expect a reduction in electric EUI of approximately 2.5 and gas EUI of approximately 0.144 in Southern California Edison and Southern California Gas territory, respectively. Whole building EUI can be a good indicator of potential savings subject to how much rigor is placed on the RCx process. The County staff is now equipped with a functional process that will ensure persistence of RCx benefits by giving the facility staff a tool to quickly acknowledge and act upon equipment and operational difficulties. Automated benchmarking process is yet to be adapted across the board to reap the benefits of EEMIS UCE+ to target only those facilities that deviate from the benchmarks. Meanwhile, periodic observations made by the facility staff based upon semi-automatic charts will keep the facilities operating in a sustainable manner.

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Howard Choy currently directs Los Angeles County's energy management division which operates a budget of around $200 million per year. This includes purchases and sales of electricity and natural gas, operation and maintenance of power plants, energy efficiency projects, and implementing the County's newly approved Energy & Environmental Policy. He is a Mechanical Engineering graduate of the University of California at Berkeley.

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