UNIVERSITY OF HAWAI‘I SYSTEM

ANNUAL REPORT

REPORT TO THE 2007 LEGISLATURE

Annual Report on

Energy Efficient Design Standards for the University of Hawai‘i at Mānoa

HCR 166, HD 1
Twenty-Third Legislature, 2005

September 2007

Energy Efficient Design Standards for the University of Hawaii at Manoa

The following is a report that was requested of the Center for Smart Building and Community Design (the Center) by the Hawaii State Legislature in 2005. The Legislature charged the University of Hawaii to develop a set of standards that could be applied to both new and existing construction to reduce the energy consumption of its building stock. The Legislature was also interested in the possible impact that a system-wide energy manager would have on energy consumption across all the campuses.

Since the request was made, however, Governor Lingle signed into law Act 96, a sweeping piece of legislation intended to encourage energy efficiency, increase the deployment of renewable energy, and thus reduce the State's dependence on imported energy. This Act validated the Legislature's original request to the Center to develop building performance standards, but at the same time rendered the activity redundant through the establishment of building performance standards for all state buildings.

This report encompasses the remaining matters that the Legislature requested the Center to address, and provides relevant updates on the current status of energy efficiency at the University of Hawaii at Mānoa campus. If members of the Hawaii State Legislature or their staff are interested in obtaining additional information on this subject, the implementation of Leadership in Energy and Environmental Design (LEED) standards, or any related subject matter, Center staff would be delighted to provide such information or arrange for a briefing by Center experts at a time most convenient for the legislative members or staff.

Background

On March 15, 2005, the Hawaii State Legislature passed House Concurrent Resolution 166 (HCR 166). This resolution directed the Center for Smart Building and Community Design (the Center) of the University of Hawaii to complete several tasks related to standards that would improve the energy performance of buildings in the University of Hawaii system.

Specifically, these tasks were:

1. Develop energy efficient design and performance standards that will:
   a. Bring about substantial quantitative and qualitative improvements to university buildings; and
   b. Include specific energy and resource conserving design and engineering methods for new construction, renovation, and retrofitting of all buildings in the University of Hawaii system; and
   c. Include criteria for life cycle cost analysis for building design and operations for new construction, renovation, and retrofitting of all buildings in the University of Hawaii system.

2. Develop these standards in consultation with University of Hawaii system administrators, various University campus chancellors and vice chancellors, the University of Hawaii Office of Capital Improvements, University of Hawaii faculty, representatives from the electric and gas companies, the American Institute of Architects, the American Society of

Heating, Refrigeration and Air Conditioning Engineers, and interested university and high school students.

3. Conduct a cost-benefit analysis and an evaluation of the benefits of establishing the position of an Energy Conservation Manager to coordinate and monitor an energy management program and to promote and modify university system energy consumption through efficient utilization and awareness of energy sources.

4. Submit a final report on the above items, plus a description of strategies for implementing the design standards to the Legislature, the President of the University of Hawaii, the Chancellor of the University of Hawaii-Mānoa, and the Director of Business, Economic Development, and Tourism (DBEDT).

Initial Progress

To meet the requirements of HCR 166, the Center established a project advisory committee (membership is provided in Appendix A.) consisting of representatives from the University system and administration and the other groups as directed by the legislature. The Center, guided by this committee, determined that these performance standards would focus on the three most achievable and effective portions of the LEED standards: These were: 1) energy efficiency, 2) water conservation 3) indoor air quality. These areas of design also represent three of the core credit areas in the LEED criteria.

On December 15, 2005, the Center submitted a report to DBEDT titled “Energy Efficiency Guidelines for Retrofitting Existing Campus Buildings.” Although this report was not expressly commissioned by the Legislature as part of HCR 166, a copy is provided as it represents significant information and discussion on addressing the building-related energy efficiency issues facing the University of Hawaii system.

Subsequent Progress

The remainder of the assignment has been overtaken by two significant events.

1. In May of 2006 the Hawaii State Legislature passed Act 96. This act mandates that all state buildings achieve a LEED Silver performance rating.

2. The University of Hawaii at Mānoa has advanced through the process of establishing an Energy Management Office under the Office of the Vice Chancellor of Administration, Finance, and Operations.

Act 96

With the passage of Act 96, the University of Hawaii was required to construct all new buildings to meet the LEED silver standard. Energy performance is the core of the LEED criteria. The LEED energy criteria are based on the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standard, ASHRAE 90.1. This particular ASHRAE standard is refined and updated every few years to improve the energy performance of buildings that are designed to comply with it. The ASHRAE 90.1- 2001 edition was the benchmark standard on which the earlier LEED version 2.0 was based. In 2005 ASHRAE adopted the upgraded design strategies in the 90.1-2004 as the new standard. Pursuant to that the US Green Building Council (USGBC), in early 2006 upgraded its version of LEED 2.0 to LEED 2.2 to comply with the new elevated ASHRAE 909.1-2004. These changes occurred during the course of the 2005 legislative session.

While lawmakers in Hawaii were debating the merits of mandating LEED Silver for all state buildings, the requirements for achieving LEED Silver were upgraded due the changes in progress at ASHRAE and USGBC. In other words, by the time the bill was voted on at the end of the legislative session, the energy standards represented in that bill had become substantially more rigorous than the initial discussion had anticipated. Therefore, state buildings designed in compliance with the LEED Silver provisions in Act 96 will be approximately 40% more energy efficient than the last building built on any University of Hawaii campus. This is a significant and commendable step toward achieving large- scale energy savings in the state.

Before the passage of Act 96, Honolulu and most of the other counties in the state mandated an energy code that was largely based on ASHRAE 90.1- 1989 with some specific upgrades to ASHRAE 90.1- 1999. Within that context, if the University of Hawaii sought to establish and commit to higher energy performance for its buildings, it needed to develop its own standards – and that is what the authors of these standards began to do within the Center in 2005. However, in the course of events described above, LEED Silver now applies to all state agencies, and the University of Hawaii as a state agency no longer needs to develop its own standards. Indeed it would obfuscate matters and be unconstructive if the University were to do so.

The Mānoa Campus's first LEED-certified building will most likely be the Frear Hall dormitory, scheduled for completion in 2008. Other campuses are pursuing their new construction projects which, similarly, will necessarily be LEED-certified.

A note on life-cycle cost analysis

Life-cycle cost analysis (LCCA) is a method for assessing the true and total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system, including maintenance and utility costs. LCCA is especially useful when comparing project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs.

LEED is a performance standard, not an accounting standard, and does not include any specific criteria that require life-cycle cost analysis. The adoption of LEED silver as the minimum standard for state buildings, therefore, does not necessarily require a calculation of life-cycle costs. However, it is precisely because LCCA was <u>not</u> applied to the many buildings on the University of Hawaii and Mānoa campus (and buildings throughout the state of Hawaii), that we have inherited a massive stock of poor quality buildings in which to educate our students coupled with unmanageable energy and operational costs (instead, principles of value engineering and least cost were typically applied to decision-making).

For this reason, LCCA should <u>always</u> be applied to and required from construction and major renovation project proposals to ensure that potential long-term savings are never sacrificed to hold a project's initial costs down, particularly when energy use is being considered. LCCA will be helpful in justifying building designs that meet LEED criteria, since many of these directly support energy savings, and protect these designs from alteration as a result of value engineering that seeks to achieve “first cost” savings while committing the State to inflated operational costs. LCCA evaluation must be more sophisticated when considering aspects of green building performance such as the health and productivity of the occupants and LCCA is not appropriate as a means to assess aesthetic, decorative, or artistic aspects of building design. For these reason, LCCA is most practical for the analysis of tangibles, such as energy and water costs, although the health and productivity benefits of green buildings are under scientific study and initial findings demonstrate significant positive financial outcomes from these buildings in the form of reduced sick days, reduced absenteeism, enhanced worker happiness, add other metrics.

Act 96 directs each agency (including the University of Hawaii) to use life-cycle cost-benefit analysis to purchase energy efficient equipment such as Energy Star products, which represent a broad range of items including light bulbs, roofing materials, windows, and air conditioning equipment among others. In the spirit of the law, LCCA will be applied by the University of Hawaii at Mānoa to construction projects as well.

Energy Management Office

In October 2006, Denise Eby Konan, Interim Chancellor of University of Hawaii at Mānoa campus, convened a day-long energy summit to discuss with the campus community how the University should increase energy efficiency on campus, reduce its energy bill and increase its long-term sustainability. One of the most important outcomes of this summit was the consensus that a full-time, professional Energy Manager was necessary to propose, prioritize, and oversee the many changes, upgrades, and programs that would be necessary to meet the energy efficiency targets that had been set forth in the summit. The Vice Chancellor for Administration, Finance, and Operations is currently in the process of recruiting a professional energy manager to fill this role at the University of Hawaii at Mānoa. A new Assistant Vice Chancellor for Facilities, to whom the energy manager would directly report, has already been hired.

The success of other universities in meeting their energy challenges has been notable, with many campuses saving thousands or millions of dollars each year in avoided energy costs. Although each institution is achieving its goals in different ways, the most successful programs each have an office or other administrative entity, highly-placed within the university administration, with a clear mandate for change and competent leadership. This person or entity is responsible for energy efficiency campus-wide, and is given the resources and authority to pursue this goal.

Based on the 2004 Mānoa Campus energy benchmarking study that audited campus energy consumption, it is estimated that an investment in the retrofit of the lighting and ventilation systems of the campus’ 20 worst performing buildings would cut a minimum of $5 million per year from its electricity bill, which this year exceeded $18 million. Hiring a professional Energy Manager to direct this process would provide a return on investment many fold. The major renovations that are required to realize the full benefits of an energy-efficiency campus demand an investment of millions of dollars. The other University of Hawaii campuses are watching the Mānoa campus closely as a potential model for their own energy conservation efforts, and is it critical that Mānoa’s campaign receives the support necessary to see it through to completion.

University of Hawaii New Building Construction

Status of Meeting Leadership in Energy and Environmental Design (LEED) Requirements

13-Jul-07

Campus/Location	Name	Type	New/Reno	Status/phase	Notes
Hilo	Hawaiian Language Building	Classroom/office	New	design/schematic	Design firms selected.
Hilo	Science and Technology Building	Lab/classroom/office	New	planning/design advertise/bid	Advertised July 17, 2007. Bid opened August 28, 2007
Hilo	Student Life Complex	classroom/office/kitchen?	New	construction	Predates the Act 96 Requirements but designed to meet LEED silver
Kapiolani Community College	Culinary Institute of the Pacific	Kitchen/classroom	New	design/schematic	Extensive discussions on energy-efficient kitchen design. Kitchen consultant hired. Plan to meet LEED as well as fulfil additional self-impose sustainability criteria
Leeward Community College	Social Science Facility	lab/classroom/office	New	planning	Planning contracts under negotiation.
Mānoa	Frear Hall Redevelopment	Dorm	New	construction	LEED consultant hired. Construction underway. LEED silver planned, but not posted on the LEED project web site.
Mānoa	Performing Arts Facility	studio/classroom/office	New	design	Contract under negotiation.
Mānoa	Waialua Agribusiness Incubator	Lab/classroom/office	New?	design	Project deferred.
Mānoa	Law School	Classroom/office	Renovation/ extension	planning	Design team selected. LEED charettes in process and target-setting underway.
Mānoa	Gartley Hall	classroom/office	Renovation	design	In consultant selection stage.
Mānoa	College of Education	Classroom/office	demolition/new	project development	Project deferred. Preliminary LEED charette held in October 2006 with users. Cost-benefit analysis completed.
Mānoa	Biomedical Sciences	laboratory	renovation/ expansion of existing	feasibility study/design	Complicated. New construction combined with several renovations and systems upgrades. Design/engineering team in preliminary stage of exploring energy efficiency measures.
Mānoa	Faculty and Graduate Student Housing	housing	New	feasibility study	In process of developing needs survey.
Mānoa	New Classroom Building	classroom/office	New	planning	In consultant selection stage.
Mānoa	Hawaii Institute of Marine Biology	Lab/classroom/office	Renovation	planning/design	In process of developing RFPs. Plan to meet LEED-EB and retrofit according to Labs21 principles for laboratory excellence.
Mānoa/System	Information Technology Center	Office/data center	New	design	In process of hiring design firm. Project manager is keen on hiring design team with LEED expereince.
Maui Community College	Science and Technology Building	Lab/classroom/office	New	planning/designing	Meetings held with users and occupants to discuss needs. Design team hired. Intend LEED rating.
West Oahu	Major Campus Expansion	Lab/classroom/office	New	planning/design	Early stages. Funding available for design. Registered as two separate projects on the US Green Building Council LEED project web site.
Windward Community College	Library and Learning Center	Classroom/office	New	planning/design	Contract under negotiation.

Appendix A

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Appendix B

University of Hawaii Energy Efficiency Guidelines
for Retrofitting Existing Campus Buildings

UNIVERSITY OF HAWAII

ENERGY EFFICIENCY GUIDELINES
For
RETROFITTING EXISTING CAMPUS BUILDINGS
Penultimate Draft

December 15, 2005

Prepared by:
The Center for Smart Building and Community Design
At the University of Hawaii Sea Grant College Program
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Sponsored by:
US Department of Energy, Rebuild America Program
Department of Business, Economic Development and Tourism, Energy Division
University of Hawaii Manoa, Office of the Vice Chancellor

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1.0 Introduction

1.1 Purpose

The Bonneville Power Administration prepared this Design Manual for the University of Hawaii (UH) under contract to the U.S. Department of Energy, Western Regional Office, with funding provided by the Rebuild America Program. The purpose of the Manual is to provide design guidelines and highlight certain energy efficiency measures (ECMs) and their implementation during the design process.

1.2 Discussion

The energy efficiency technologies were identified by UH and Hawaiian Electric Company, Inc. (HECO). At the time this Manual was prepared, the actual buildings and projects to which these technologies may apply were not specified. Therefore, they are presented generally and as guidelines during the design phase.

The intent is to provide guidance on energy efficiency and to define what is considered efficient for the included technologies. Utility rebates and incentives may be available for these technologies and the Designer is encouraged to pursue them.

The technologies contained in this document are not comprehensive and many of these additional energy-efficient technologies should be pursued.

Previous energy studies at the University of Hawaii at Manoa have identified air-conditioning as the largest single energy end-use at 52 percent of the total and lighting as the second largest end-use with 30 percent of the total. Included in the air-conditioning are all associated equipment and processes including fans, pumps, chillers, cooling towers, and de-humidification.

Our experience suggests that lighting retrofits are the most cost-effective and reliable energy-related retrofit available for commercial buildings. New lighting products allow lighting systems to be designed easily below energy code requirements. Since interior lighting energy use is directly related to air-conditioning and air-conditioning is the largest single end-use category, the Design Engineer is encouraged to aggressively pursue efficient lighting projects first in the process of evaluating building energy retrofits.

This document recognizes that engineering design is only the first step in successful implementation. It is critical to successful implementation that commissioning, testing, measurement and verification, and maintenance be incorporated into the overall construction project. A design process is specified with the goal of including steps necessary for successful long-term project implementation.

2.0 Design Process

2.1 Introduction

There are many possible approaches to a successful design process. However, in the traditional design process many significant energy saving opportunities are often missed. A structured approach to the design process can help to fully capture the opportunities in energy efficiency retrofit projects.

Specifically, a structured process can help to:

- Ensure that energy efficiency remains a focus and a priority throughout the design process;
- Provide the appropriate expertise and a setting to generate best-practice energy efficiency design concepts;
- Provide the needed coordination to successfully integrate energy efficiency with all the other project objectives;
- Document the design intent and design details to facilitate functional testing, commissioning, and verification of energy savings.

The following actions are recommended to help ensure successful implementation of energy-efficiency projects. The steps detailed here are necessarily generic, so the timing and content of each step may need to be modified to fit each individual retrofit project.

2.2 Design Team

To keep a strong focus on energy efficiency, provide the appropriate assignments and specialists.

- **Energy Design Coordinator** – Designate a member of the design team to coordinate energy efficiency design elements. This individual shall be a specialist in energy-efficient design and shall be responsible for coordinating the entire design team, utility representatives, and relevant specialist to ensure that recommended energy efficiency measures are identified, successfully installed, commissioned, and verified.
- **Energy Specialists** – Add specialists to the design team as needed to implement particular energy efficiency measures.

2.3 Pre-Design

Several specific activities need to take place very early in the design process.

- Contact the Hawaiian Electric Company (HECO) Account Manager and identify what incentives are available and what steps are necessary to qualify for incentive payments. Prepare an estimate of the possible incentive and summarize the application action items and deadlines.

- Identify and review any existing energy studies relevant to the buildings to be retrofitted. For example, the HECO Energy Assessment (2001) and the University of Hawaii Benchmarking Study (2001) provide valuable energy utilization information for specific University of Hawaii Manoa buildings.
- Identify any baseline metering requirements and ensure that baseline metering is started early enough to capture the baseline performance and to meet HECO's requirements.
- Determine if any specialized consultants are needed to properly implement the recommended energy efficiency measures.

2.4 Design Development

Design development should produce a clear definition of the recommended energy efficiency measures and provide a plan for successful implementation.

- **Energy Efficiency Design Meeting No. 1** – Hold a meeting at the beginning of design-development to coordinate the energy efficiency design elements. The meeting shall include the energy efficiency design coordinator, owner's representatives, and relevant members of the design team. Consider including utility representatives. Document roles and responsibilities. Discuss each energy efficiency measure that has been identified (see References). Determine if further measures need to be identified at this time. The relevant efficiency measure guidelines in this RFP shall be reviewed at this meeting. Design Coordinator shall at this point discuss the project with the University Facility Director to determine effective coordination between this project and any R&M schedule for the building. Determine which energy efficiency measures will require an M&V plan. Review Operation and Maintenance requirements with University maintenance staff and incorporate staff maintenance concerns into the design.
- **Evaluation of Alternatives** – Evaluate all the identified measures. The evaluation shall include, as appropriate:
  - Energy savings calculations;
  - Cost estimates;
  - Energy code compliance worksheets and calculations;
  - Research of relevant standards and best-practices to ensure that the design meets these requirements;
  - Load calculations and optimizing equipment sizing;
  - Establish and document baseline equipment and operation;
  - Life cycle cost analysis;
  - Design review shall include third party review if the design team does not have specific expertise in the proposed energy efficiency measures.
- **Integrated Design Approach** – Ensure that energy efficiency measures are developed in an integrated manner to ensure optimum efficiency and lowest first cost. The goal of integrated design is to optimize the overall building system, considering both first cost and operating costs.

- Begin with load reduction measures, including, but not limited to, lighting, window treatments, ventilation controls, envelope improvements, and motor upgrades.
- Incorporate all load reductions into HVAC selections and sizing with the goal of reducing the size, initial cost, and consumption of HVAC systems. Following design sizing requirements included in the Hawaii Model Energy Code Application Manual.
- Avoid over-sizing HVAC equipment. Over-sizing can result in poor part-load performance, excessive equipment cycling, reduced humidity control, and excessive initial costs.

- **ECM Summary** – After evaluation of each alternative, prepare a summary list of recommended ECMs with a description of what is to be done, estimated cost, estimated energy savings, and simple payback. As appropriate, add sections on Energy Code Requirements, utility incentives, M&V plan, O&M considerations, and life cycle cost calculations.

- **Measurement and Verification (M&V) Plan** – The purpose of the M&V plan is to reliably quantify the energy savings from the retrofits. M&V shall be done in accordance with ASHRAE Guideline 14, Retrofit Isolation Path. Prepare an M&V Plan that covers each of the energy efficiency measures identified in Design Meeting No. 1. The attached Measurement and Verification Template can be used as a guide to prepare a detailed M&V plan.

- **Functional Test (FT) Plan** – Functional Tests Plans require extensive HVAC and building systems knowledge to write and perform. Energy efficiency measures that rely on proper performance of controls may need a functional test plan. The main elements in the functional test plan include:
  - A discussion of the verification checks that need to be completed prior to functional testing. This is a general discussion rather than an itemized listing of test requirements.
  - Functional test procedures including related information such as:
    - Estimated cost/benefit information;
    - Information on what needs to be monitored, where and when to gather the data;
    - Recommended acceptance criteria;
    - Applicable calculations;
    - Potential problems and cautions.

- **Metering** – If not completed in pre-design phase, measure the baseline energy use for each measure with an M&V plan. Consider and include permanent metering as needed for measurement and verification of energy savings and system performance such as electric sub-meters, chilled water flow meters, and building automation system monitoring and trending capabilities.

- **Design Review** – Arrange for design review as needed.

2.5 Construction Documents

The recommended energy efficiency measures need to be effectively incorporated into the design documents.

- Incorporate the ECMs into the construction documents. The design of each efficiency measure shall include, as appropriate, drawings, specifications, a functional testing plan, a commissioning plan, and a Measurement and Verification Plan.
- **Energy Efficiency Design Meeting No. 2** – Hold a meeting to finalize the measures and communicate the results to the whole design team. Timing and content of the meeting will need to be adapted to the situation, but at least one formal meeting shall be held for the purpose of coordinating acceptance and implementation of the final design.

2.6 Construction Phase

Many energy efficiency measures seek to optimize *system* efficiency, and it is during the construction phase that individual pieces of equipment are put together to form a working system. Furthermore, most energy efficiency measures are a variation from standard practice and therefore require extra oversight for proper implementation. Potential risks include poor communication of unique design features, reversion to standard practice, value-engineering reviews, change orders, substitutions, and schedule demands.

A number of specific steps need to be taken by the design team to ensure that the energy efficiency measures successfully realize the design intent.

- Review contractor submittals to ensure the proper performance of the energy efficiency measure. For many energy efficiency measures this step is important because non-standard requirements are often not met in the initial contractor's submission.
- Provide construction inspection focused on the special features of the energy efficiency measures. For example, proper location and adjustment of occupancy sensors can make the difference between complete failure and complete success of the measure.
- Provide detailed functional testing as required to ensure that the energy efficiency measures are fully functional.
- Implement the required steps of the commissioning plan.
- Provide a complete O&M manual that gives the information for operation that will deliver and maintain the as-designed energy efficiency performance.

2.7 Post Occupancy

Several final activities need to be done after the building is occupied and fully commissioned.

- Implement the remaining requirements of the commissioning plan.
- Perform post-occupancy metering and analysis as required in the M&V Plan.

2.8 References

1. Hawaiian Electric Company (HECO) Energy Audit.

2. HECO/UH Energy Benchmarking Study.
3. Eley and Associates (for State of Hawaii DBEDT) "Hawaii Commercial Building Guidelines for Energy Efficiency." 2003.
4. E Source, Inc and Architectural Energy Group, for Southern California Edison, "Design Brief: Integrated Energy Design." 1998
5. General Services Administration, "2003 Facilities Standards (P100)."

Table 2.1 Measurement and Verification Template

Detailed Project Description

Describe specifically what is to be done as part of this project and how this project will save energy. Describe the proposed equipment performance, quantities, and locations. The extent of this description should match the scale of the proposed project.

Baseline Description

Baseline conditions must be established for energy use in all cases, and as needed a baseline must be established for production levels, weather, operating schedules, etc. For replacement of existing systems this baseline is usually the annual energy consumption of the existing equipment at its existing operating conditions. For new construction and some replacements, baseline conditions must be defined based on standard practice, code requirements, or some other basis. Describe the baseline conditions in detail.

Proposed Description

Describe the proposed post-installation equipment performance, quantities, and locations. The extent of this description should match the scale of the proposed project.

Energy Savings Estimate

The purpose of the energy savings estimate is to provide a basis for evaluation of a measure. Energy savings are the difference between a baseline condition and the condition at the completion of the project, projected over the life of the conservation measure.

Show baseline and post-installation energy consumption in kWh/year, adjusted on a per unit basis where applicable (e.g., Annual kWh per Ton of production; Annual kWh per heating-degree-day, etc.). Briefly *explain how the baseline and proposed annual estimated energy consumption (kWh/yr) were derived (e.g., theoretical calculations, field measurements, manufacturer's data, etc.), and what assumptions were made in determining the energy savings estimate.*

Table 2.1 Measurement and Verification Template (Cont.)

Measurement and Verification (M&V) Plan

The purpose of the M&V plan is to provide a basis for documenting and achieving the intended energy savings. Direct metering of baseline and post-installation energy use is preferred. Stipulated values are only acceptable if they have a well-documented bias in fact and an analysis shows that plausible errors from the stipulation will not unduly affect the overall reported savings.

Include a detailed plan explaining how the energy savings will be verified. Include the following sections:

A. Approach and Assumptions

- *Outline the approach to be used and why it was chosen.*
- *Identify the significant variables that effect energy use and categorize each as negligible, stipulated, or to be measured. For stipulated values provide an analysis of the possible range of the value and its impact on the overall energy savings.*
- *Identify the baseline and post-installation time periods.*
- *Describe how energy use will be measured or calculated for both baseline and post-installation conditions.*
- *Include and describe calculations to account for significant changes in production, weather, loads, hours of operation, setpoints, manual operation occupancy, or other factors that affect the annual savings over the expected life of the measure.*
- *Explain how short term measurements will be extrapolated to an annual basis.*
- *If measurement is not possible or practical, provide an explanation. (E.g., direct metering is not needed for straightforward measures such as lighting retrofits. Direct metering may not be cost effective on small projects that are otherwise proven reliable.)*

B. Metering Plan

- *For metered verifications, include a description of what will be measured, the measurement duration and the data sampling intervals, and the instrumentation to be used.*

C. Calculations

- *Show or describe the calculations to be used.*

D. Quality Assurance

- *Describe activities planned to insure good data and accurate calculations. Describe inspections, tests, commissioning, etc. to ensure that the proposed systems function as planned.*

3.0 Equipment Design Guidelines

3.1 Interior and Exterior Lighting

3.1.1 General

1. Exceed Hawaii Energy Code Lighting Power Allowance (LPA) requirements for both interior and exterior lighting; Design lighting systems with lower LPA's than required by Code.
2. Use energy-efficient lighting identified in Table 3.1 (page 13).
3. Specify 85 CRI (color rendering index) or above for fluorescent lamps. Higher color rendering lamps allow lower light levels and associated lower lighting power.
4. Specify the highest acceptable color temperature lamps (CCT). Specify the same color temperature lamps throughout a facility as much as possible and practical.
5. Align fixtures as much as possible over work surfaces, equipment, hallways, etc.
6. Place light fixtures as close as possible to where the light is needed. Take into consideration forklift trucks, cranes, and other potential interference problems when lowering fixture-mounting heights.
7. Look for daylighting opportunities. Evaluate fenestration retrofits to reduce direct solar radiation and glare, enhance useful daylight distribution and coordinate natural light with effective control and efficient interior lighting systems. Consider installing one-lamp fixtures or reduced-light-output-ballasts near windows instead of installing a dimming system.

3.1.2 Interior Lighting

1. Typical rule of thumb for fixture spacing in general office space and classrooms is 8 feet by 8 feet (8 feet on center). For this spacing, a metric of less than 1.00 watt per square foot is easily achieved. **The target for this 8-foot by 8-foot spacing pattern is 0.75 watts per square foot.**
2. Design the lighting system around the occupants and the tasks to be performed.
3. Look for opportunities to install new indirect/direct light fixtures or install indirect/direct retrofit kits. This type of fixture provides less harsh lighting, reduces the "cave effect," and can save energy. Typically this fixture is best suited for open environments.
4. If you know the configuration of a space and the configuration is unlikely to change over time, then position the light fixtures directly over workspaces and furniture. Where logical, position light fixtures in line with aisles, hallways, walkways, and corridors.
5. In open office spaces, align light fixtures with the centerline of cubicles as much as possible. This will provide the light where it is needed. If practical, position fixtures directly over the center of cubicles.

6. In classroom spaces, align light fixtures with the centerline of desks (if you know the desk configuration will not change). If the desks are in a straight line, then install light fixtures in a linear fashion. If fixtures are pendant mounted consider screwing or bolting the fixtures together, if applicable.

7. Consider not installing light fixtures in perimeter hallways. There should be enough outdoor light and residual light from the adjacent areas to provide enough hallway illumination. Minimal lighting in perimeter hallways may be required for nighttime janitorial functions.

8. Consider installing one-lamp fixtures or reduced-light-output-ballasts in fixtures located within 10 feet of windows. There should be enough outdoor light and residual light from the adjacent areas to provide enough illumination.

9. Consider using one-lamp 4-foot fluorescent fixtures in interior hallways. Install fixtures in line with the centerline of the hallway. Recessed CFL fixtures work in this application too, but they tend to leave dark spots. Hallway design light level should be at least 10 foot-candles.

10. Logically position light fixtures over equipment in mechanical rooms, compressor rooms, electrical rooms, computer rooms, etc. Hang fixtures from chains or cables in order to place the fixture as close to the equipment as practical. Chain or cable mounted fixtures allow easy fixture reconfiguration in case the equipment underneath is reconfigured. Specify outlets in the ceiling or on trusses for the fixtures to be plugged into. Specify plug and cord fixtures with appropriate cord lengths. Specify twist plugs and outlets to eliminate accidental disconnection.

11. In assembly or laboratory areas, position fixtures over the work. Hang fixtures from chains or cables in order to place the fixture as close to the work as possible. Chain or cable-mounted fixtures allow easy fixture reconfiguration in case the work areas are reconfigured. Specify outlets in the ceiling or on trusses for the fixtures to be plugged into. Specify plug and cord fixtures with appropriate cord lengths. Specify twist plugs and outlets to eliminate accidental disconnection.

12. In warehouse areas, position fixtures in a linear fashion directly over aisles. Use 8-foot industrial hooded fixtures. Mount the fixtures from a chain or cable if necessary. If chain or cable-mounted, do not directly connect (screw together) the fixtures. Leave a space of at least one foot between fixtures. This will allow the fixture to swing independently in case someone bumps the fixture. Install occupancy sensors or a timer at the entrance to an aisle that is capable of turning the whole aisle off. Specify program-start ballasts when occupancy sensor controls are used. Do not specify occupancy sensors in main warehouse corridors or other high traffic areas.

13. Specify 30 foot-candles at the desk level for ambient light levels in offices. In office spaces, 50 to 60 foot-candles is no longer needed due to the introduction of computers into the environment. Additionally, high foot-candle levels cause glare problems on computer screens. In office spaces where detail work, such as drafting, is being performed, then higher light levels may be required. Use separate task lighting that is controlled by the occupant and use the IES Lighting Handbook for guidance.

14. Add task lighting in lieu of increasing ambient light levels. In most cases, task lighting can be used to increase light levels directly on work surfaces.

15. Design light switches for easy manipulation by occupants. Limit control zones for open areas to 400 square feet or less. If light switches are arranged logically, and are within reach, occupants are more likely to turn lights off when exiting a room. Switching should control lighting in configurations that are parallel, not perpendicular, to window walls.

16. Design lighting circuits to take advantage of daylighting opportunities, front room lecture areas, etc. This will allow certain circuits to be turned off when lighting is not needed or turned off during a lecture or presentation. Some circuits may need to be dimmable (such as lecture areas or conference rooms.

17. Design separate lighting circuits in individual offices, classrooms, conference rooms, copy rooms, storage areas, etc. This allows occupants to turn lights off in unoccupied spaces.

18. Consider specifying wall-mounted infrared occupancy sensors in conference rooms, storage rooms, and individual offices.

19. Consider specifying dual-technology occupancy sensors in classrooms. Install a wall switch in the lighting circuit so that lights can be turned off during audio/visual presentations.

20. Do not specify high-pressure sodium (HPS) or low-pressure sodium (LPS) fixtures in interior spaces. HPS is only recommended for street and roadway lighting. LPS is only recommended for observatory lighting, or other applications where low light pollution levels are needed and color rendering is not an issue.

21. Specify pulse-start metal halide fixtures for high-bay lighting applications above 40-foot mounting heights. Specify T8 or T5 fluorescent fixtures for all high-bay applications less than 40' mounting height. T8 fixtures will work fine up to about 20-foot mounting height.

22. Specify program-start fluorescent ballasts in applications where the lights will be frequently switched (i.e., occupancy sensor applications). Specify instant start ballasts in applications where the lights will be on for 12 hours or more per start.

23. Consider improved room surface reflectances to enhance effectiveness and efficiency of lighting systems.

24. Specify LED exit signs.

3.1.3 Exterior Lighting

1. Specify photocell control of all exterior lighting. Where more than one photocell is required, such as an aboveground parking garage, specify at least one photocell per building orientation (i.e., North, East, South, West). Separate the lighting circuits to correspond with each of the orientations.

2. Specify pulse-start metal halide for area and parking lot lighting.

3. Specify fluorescent for parking garage and canopy lighting.

4. Specify compact fluorescent fixtures for wall packs and coach style outdoor lighting.

5. Specify ceramic metal halide for outdoor flag or signage illumination (spot lighting).
6. Specify strip fluorescent or "acrylic wrap" fixtures for stairwell lighting. If practical, specify fixtures with a built-in occupancy sensor that will turn lights down when the stairwell is unoccupied.
7. Specify high-pressure sodium (HPS) for street and roadway lighting.
8. Specify low-pressure sodium (LPS) for observatory lighting, or other applications where low light pollution levels are needed and color rendering is not an issue.
9. Provide maintenance schedules for exterior lighting, with particular attention to in-ground fixtures.
10. Design exterior lighting to minimize or eliminate light trespass and light pollution.

3.1.4 Fixture Retrofit

1. Clean fixture housing with environmentally benign cleanser.
2. Clean existing lenses with soapy water or replace the lens if yellowed.
3. Be careful when cleaning louvered lenses. Specular louvered lenses are easily scratched. Scratches will reduce the performance of the fixture.
4. Some fluorescent lamps are wired in series. Most of the newer fluorescent lighting technologies are parallel-wired. Therefore some re-wiring may be necessary.
5. Replace worn out lamp holders (tombstones). Worn tombstones will cause sparking, and in some cases blacken reflectors and lenses.
6. Replace worn or old wiring harnesses.
7. Properly dispose of or recycle all lamps and ballasts in accordance with applicable regulations.

3.1.5 Utility Incentives

Utility incentives are available as rebates from Hawaiian Electric Company (HECO). Currently, rebates are available for T-8 lamps with electronic ballasts, fixture reflectors, fixture retrofits, occupancy sensors, HPS lamps used indoors, and metal halide lamps used indoors.

Rebate application instructions are available from HECO. Note that rebate levels and availability are subject to change.

Utility incentives are also available through the Customized Incentives program at HECO. The incentive levels for existing buildings are: \$0.05/kWh/yr estimated energy savings and \$125/kW reduced estimated demand (peak period) savings. The incentives are limited to 50 percent of the project cost.

Some lighting projects may qualify for these incentives provided they meet additional HECO requirements including: the payback period must be greater than two years and it must pass HECO's benefit-to-cost ratio test.

The energy and demand savings are estimated first year savings with all the formulas, assumptions, and calculations clearly documented for HECO's review. The incentives are usually a one-time payment, although the payments may be made over a 5-year period at HECO's discretion.

The project must be proposed to HECO prior to construction.

3.1.6 References

1. Indirect/direct lighting manufacturer: http://www.finelite.com/
2. Illuminating Engineering Society: http://www.iesna.org/
3. International Association of Lighting Designers: http://www.iald.org/
4. Stairwell: http://www.eere.energy.gov/femp/ docs/fupwg_magden2_brooklyn.ppt
5. Occupancy sensors and timers: http://www.wattstopper.com/

Table 3.1 Efficient Lighting Specifications

Bonneville Power Administration
Conservation Augmentation: Extended Standard Offer (ESO)
Lighting Rebate Specification

General Equipment Requirements

A. All equipment shall be new.
B. All ballasts and luminaires shall be UL rated.
C. Ballast Warranty: All electronic ballasts shall be warranted against defects in material and workmanship for a minimum of 3 years. The warranty shall include either a $10.00 replacement labor allowance or complete replacement including labor by an agent of the manufacturer.
D. Lamp Warranty: Lamps shall be warranted against defects in material and workmanship for at least 2 years. The warranty shall provide for replacement lamps at a minimum.
E. Compact Fluorescent Warranty: CFLs shall be warranted for at least 1 year, or for the stated life of the CFL.
F. Starting Temperatures: All ballasts shall be capable of starting the lamps at the appropriate ambient (surrounding) temperatures. Examples include indoor heated vs. indoor non-heated vs. normal outdoor vs. cold climate outdoor.

Rebate Item Requirements

A. High Performance T8 Fluorescent Lamps and Electronic Ballasts

1. Includes fixture retrofits and new fixtures.
2. This category is primarily intended for 4-foot T8 lamps, but includes T8 and T5 linear fluorescent lamps, 2 feet to 8 feet in length, with ballast input watts from 15 to 114 watts, that meet the 95 lumens/watt requirement.
3. Lamps shall have a Color Rendering Index = 85, lumen maintenance = 95 percent, and lamp life = 24,000 hours (@ 40 percent of rated life, 3 hours per start). Four-foot F32T8 lamps shall have initial output = 3,100 lumens.
4. Ballasts shall meet the requirements of the Lighting Design Lab T8 and T5 Fluorescent Lamp Electronic Ballast Specifications current at the time of installation.
5. Lamp/ballast combination shall have an efficacy of equal to or greater than 95 lumens per watt:

$$\textbf{Lamp/Ballast Efficacy} = \frac{\text{Initial Lamp Lumens x No. of Lamps x Ballast Factor}}{\text{Ballast Input Watts}}$$

6. For this "High Performance" rebate, the application must include either the manufactures specification sheet documenting initial lamp lumens, lamp lumen maintenance, ballast factor and ballast input watts, or list manufacturer's model numbers and performance.
7. Alternate Compliance Method: In lieu of lamp/ballast efficacy documentation, lamps and ballast may qualify separately as follows:

	Ballast Type		
Lamp Type	Instant Start	Programmed Rapid Start	Lamp Lumens
1 lamp F32T8	---	BEF ≥ 2.75	≥ 3,100
2 lamp F32T8	BEF ≥ 1.6	BEF ≥ 1.47	≥ 3,100
3 lamp F32T8	BEF ≥ 1.06	BEF ≥ 0.97	≥ 3,100
4 lamp F32T8	BEF ≥ 0.81	BEF ≥ 0.75	≥ 3,100
Ballast Efficacy Factor (BEF) = Ballast Factor x 100 / Ballast Input Watts			

Table 3.1 Efficient Lighting Specifications (Cont.)

B. T8 or T5 Fluorescent Lamps and Electronic Ballast

1. Includes fixture retrofits and new fixtures. This rebate category is intended only for applications where the requirements of category A above cannot be achieved.
2. Includes T8 and T5 linear fluorescent lamps, 2 feet to 8 feet length, with ballast input watts from 15 to 114 watts.
3. Lamps shall have a CRI = 80, lumen maintenance = 90 percent, and lamp life = 18,000 hours (@ 40 percent of rated life, 3 hours per start). Four-foot F32T8 lamps shall have initial output = 2,900 lumens. Lamp/ballast combination shall have an efficacy = 80 lumens per watt.
4. Ballasts shall meet the requirements of the current Lighting Design Lab T8 and T5 Fluorescent Lamp Electronic Ballast Specifications.

C. Hardwired Compact Fluorescent

1. Includes new hardwired compact fluorescent fixtures and fixture retrofits, 15 to 99 watts (nominal).
2. Must replace existing incandescent or mercury vapor lighting.
3. Hardwire retrofits must remove screw-in lamp socket. Recessed fixtures must include a reflector designed for the new lamp.
4. Lamps shall have a CRI = 80, lumen maintenance = 80 percent, and lamp life = 10,000 hours (@ 40 percent of rated life, 3 hours per start).
5. Ballast shall have a power factor = 90 percent, THD = 33 percent, Lamp Current Crest Factor = 1.7, Class A sound rated, and provide end of life protection.
6. Lamp/ballast combination shall have a minimum efficacy of 46 lumens/watt for lamps under 30 watts, and 60 lumens/watt for lamps 30 watts or greater.

D. Ceramic Metal Halide

1. Includes new hardwired fixtures and fixture retrofits, 39 to 250 watts (nominal).
2. Must replace existing incandescent lighting.
3. Lamps shall have CRI = 80, lumen maintenance = 80 percent, and maximum color shift over life of lamp = 200K.

E. Screw-in Compact Fluorescent Lamps

1. Includes one-piece or modular screw-in compact fluorescent, 3 to 150 watts (nominal).
2. Must replace existing incandescent lighting.
3. Installation in recessed fixtures is not recommended. Lamps in recessed fixtures must include a reflector designed for the lamp.
4. Screw-in compact fluorescents must bear the ENERGY STAR label and meet the ENERGY STAR specifications for energy efficiency.
   Exception: Where ENERGY STAR specifications do not apply, substitutions may be allowed with prior approval from BPA.

F. LED or Cold Cathode Exit Signs

1. Applies to new LED or Cold Cathode exit signs.
2. Must retrofit or replace existing incandescent exit signs.
3. Exit signs must meet the ENERGY STAR specifications for energy efficiency. Input power must be less than 5 watts per face.

Table 3.1 Efficient Lighting Specifications (Cont.)

G. Induction Lamp Luminaire

1. Includes new induction lighting systems.
2. Must replace existing incandescent or mercury vapor lighting.

H. High Output Fluorescent Luminaire

1. Includes T8, T5, standard or HO, 4-foot and 8-foot lamps, 85 to 600 input watts.
2. Must replace T12 fluorescent/magnetic ballasts, mercury vapor, probe-start metal halide, or incandescent.
3. Lamps shall have a CRI = 80, lumen maintenance = 90 percent, and lamp life = 18,000 hours (@ 40 percent of rated life, 3 hours per start).
4. Lamp/ballast combination shall have an efficacy of greater than 80 lumens per watt.
5. Ballasts shall meet the requirements of the current Lighting Design Lab T8 and T5 Fluorescent Lamp Electronic Ballast Specifications.

I. Pulse Start Metal Halide

1. Includes new pulse-start lighting systems. Where possible, high output fluorescents are recommended over metal halide.
2. Lamps shall have a CRI = 65, lumen maintenance = 75 percent, and lamp life = 20,000 hours (@ 40 percent of rated life, 3 hours per start).
4. Lamp/ballast combination shall have an efficacy equal to or greater than 89 lumens per watt.

J. Occupancy Sensors

1. Includes infrared, ultrasonic, and dual-technology sensors. Wall, ceiling and fixture mount.
2. Occupancy sensor must be compatible with the controlled lighting equipment and rated for the controlled wattage.
3. Infrared sensors require an unobstructed view of targeted motion.
4. All sensors shall be tuned after installation for proper coverage, sensitivity, and time delay.

3.2 Reflective Solar Window Tinting

3.2.1 Summary

Reflective solar window tinting is a retrofit option for existing windows. In Hawaii the most important characteristic for windows is low solar heat gain coefficient (SHGC). A low SHGC can be provided through reflective films applied to the surface of the glass. In general, a SHGC of 0.45 or less is recommended for the Hawaiian climate.

Specify a window film with a SHGC to minimize life-cycle cost of the installation. A window film may not be appropriate in all cases. The specific application (existing window, shading, window-to-wall ratio, orientation) should be evaluated on a case-by-case basis using an hourly whole building energy simulation.

The other factor to consider in window film application is visible light transmittance (VLT). The window film should be selected such that the VLT is equal to or greater than the SHGC. In general a VLT of 0.65 to 0.70 is recommended for the Hawaiian climate.

3.2.2 Energy Code Requirements

The Energy Code will likely not apply for this Retrofit, as the windows are not being replaced and the window/wall areas are not changing. The energy code requires a maximum relative solar heat gain (RSHG) limit. RSHG is a function of the following four features of a fenestration system:

- Shading coefficient of the glass;
- Type of interior shading device;
- Type of exterior shading device (e.g., louvers or sunscreens);
- The size of overhangs or side-fins.

The limit is based on orientation, window-to-wall area ratio, and projection factor.

3.2.3 Utility Incentives

Utility incentives are currently available through the Customized Incentives program at Hawaiian Electric Company (HECO). The incentives levels for existing buildings are: $0.05/kWh/yr estimated energy savings and $125/kW reduced estimated demand (peak period) savings. The incentives are limited to 50 percent of the project cost. Note that incentive levels and availability are subject to change.

DCV may qualify for these incentives provided it meets additional HECO requirements including: the payback period must be greater than 2 years and it must pass HECO's benefit-to-cost ratio test.

The energy and demand savings are estimated first year savings with all the formulas, assumptions, and calculations clearly documented for HECO's review. The incentives are usually a one-time payment, although the payments may be made over a 5-year period at HECO's discretion.

The project must be proposed to HECO prior to construction.

3.2.4 Recommendations

1. Specify a window film with a SHGC to minimize life-cycle cost of the installation. A window film may not be appropriate in all cases. The specific application (existing window, shading, window-to-wall ratio, orientation) should be evaluated on a case-by-case basis using an hourly whole building energy simulation.

2. Specify window film with a SHGC of 0.45 or less and VLT of 0.65 to 0.70.

3. The window film manufacturers have recommended film-to-glass tables for use by factory-trained dealer installers. Listed are some glass types or conditions where the use of a solar control type of window film is **not** recommended:

   a. Single pane glass larger than 100 square feet.
   b. Double pane glass larger than 40 square feet.
   c. Clear glass thicker than 3/4 inch.
   d. Tinted glass thicker than 1/4 inch.
   e. Window framing systems of concrete, solid aluminum, or solid steel.
   f. Glass where sealant or glazing compound has hardened.
   g. Visibly chipped, cracked, or otherwise damaged glass.
   h. Reflective, wired, textured, or patterned glass.
   i. Triple pane glass.
   j. Laminated glass windows.

3.2.5 Long-Term Performance Issues

3.2.5.1 Maintenance

Follow manufacturer instructions for cleaning and care of installed product.

3.2.5.2 Warranty

Depending on the type and manufacturer, window film can be provided with a limited warranty of from 5 to 10 years.

The existing glazing to which the film is attached should also be checked for warranty stipulations. Window film applications may void glazing warranties.

3.2.6 References

1. Eley and Associates, "Hawaii Model Energy Code Application Manual." August 4, 1994.
2. Eley and Associates, "Hawaii Commercial Building Guidelines for Energy Efficiency." 2003.
3. International Window Film Association.

3.3 Chiller Replacements

3.3.1 *Summary*

Chiller replacement is an opportunity to evaluate chiller sizing, chiller variable speed drives, chilled water control sequences, cooling tower(s), associated valves and piping, refrigerant, and chiller equipment room safety and monitoring requirements. In all cases high efficiency chillers should be specified.

High efficiency chillers exceed efficiency requirements of the Hawaii Energy Code and, if water-cooled, also qualify for rebates from HECO. Table 3.2 below and the Utility Incentives section outline qualifying chiller efficiency levels.

Replacement of old, manually-operated chillers allows the opportunity to also install new automatic control components and incorporate operating strategies for chiller plant optimization, including staging, monitoring, and set point control. This additional work may qualify for HECO's Customized Incentives Program.

Centrifugal water-cooled chillers should be provided with variable speed drives (VSD's). VSD's improve chiller efficiency at part-load. Installation of a VSD will require modification of the electrical service to the chiller.

Chiller replacement is usually more involved than simply replacing a machine, like-for-like. Often the existing equipment is incorrectly sized for the existing cooling loads. Installing different sized chillers will probably require replacing pumps and possibly piping to match flow rate requirements.

If chillers are replaced due to age it is very likely that isolation and service valves on both the evaporator and condenser piping are in need of repair or replacement. Repair or replacement of various other chilled water equipment, piping, valves, and controls may also be warranted.

3.3.2 *Energy Code Requirements*

Table 10.1C from the Energy Code regarding minimum efficiency requirements for water chilling packages is repeated below in Table 3.2. Note that IPLV is a dimensionless number. To convert it to units of kW/ton divide 3.52 by IPLV.

Table 3.2: Hawaii Energy Code Requirements – Reproduced

Water Chilling Packages, Minimum Efficiency Requirements

Equipment Type	Size Category	Sub-Category or Rating Condition	Minimum Efficiency[b]	Test Procedure
Air Cooled, With Condenser, Electrically Operated	< 150 Tons		2.80 COP 2.80 IPLV	ARI 550 or ARI 590 as appropriate
	≥150 Tons			
Air Cooled, Without Condenser, Electrically Operated	All Capacities		3.10 COP 3.10 IPLV	
Water Cooled, Electrically Operated, Positive Displacement (Reciprocating)	All Capacities		4.20 COP 4.65 IPLV	ARI 590
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	< 150 Tons		4.45 COP 4.50 IPLV	ARI 550 or ARI 590 as appropriate
	≥150 Tons and < 300 Tons		4.90 COP 4.95 IPLV	
	≥300 Tons		5.50 COP 5.60 IPLV	
Water Cooled, Electrically Operated, Centrifugal	< 150 Tons		5.00 COP 5.00 IPLV	ARI 550
	≥150 Tons and < 300 Tons		5.55 COP 5.55 IPLV	
	≥300 Tons		6.10 COP 6.10 IPLV	
Air Cooled Absorption Single Effect	All Capacities		0.60 COP	ARI 560
Water Cooled Absorption Single Effect	All Capacities		0.70 COP	
Absorption Double Effect, Indirect-Fired	All Capacities		1.00 COP 1.05 IPLV	
Absorption Double Effect, Direct-Fired	All Capacities		1.00 COP 1.00 IPLV	

3.3.3 Utility Incentives

Utility incentives are available as a rebate for High-Efficiency Chillers from Hawaiian Electric Company (HECO). The rebate is based on chiller size in tons and equipment nominal IPLV efficiency in kW/ton. Chiller efficiency rating must be based on ARI Standard 550-98. The qualifying IPLV efficiency is 0.55 kW/ton. The rebate is based on the formula:

Rebate = {[(0.55 kW/ton – Equipment Efficiency) x $250] + $20} x Cooling Tons

Rebate application instructions are available from HECO. Note that rebate levels and availability are subject to change.

3.3.4 Recommendations

3.3.4.1 Sizing:

1. To the extent practical and possible, use historical building chiller load information to size chiller(s). If that information is not available then use observations regarding chiller loading and operating hours.
2. Select chiller sizes to optimize chiller performance at observed building loads.

3.3.4.2 Efficiency:

1. Specify high-efficiency chillers.
2. Specify factory testing to establish chiller capacity and efficiency.
3. Specify the appropriate controls and strategies to optimize chiller plant efficiency (e.g., condenser water reset, variable flow, chilled water temperature reset, …)

3.3.4.3 Ancillaries:

1. Specify variable speed drives for water-cooled centrifugal machines.
2. Specify chiller control panel interface to building control system.

3.3.4.4 Refrigerant:

1. Provide with minimum ozone-depleting refrigerant (e.g., HCFC).

3.3.5 Long-Term Performance Issues

3.3.5.1 Maintenance

1. Establish and maintain evaporator and condenser water treatment to minimize tube fouling and corrosion.
2. Perform maintenance at manufacturer recommended intervals.

3.5.2 Warranty

Chillers should be provided with 3-year comprehensive warranty including parts and labor. Extended 5-year warranty should be considered for larger machines.

3.3.6 References

1. Eley and Associates, "Hawaii Model Energy Code Application Manual." August 4, 1994.
2. Electric Power Research Institute, "Commercial Cooling Update: Refrigerant Regulatory Issues." January 1996.
3. National Institutes of Standards and Technology, "Trade-Offs in Refrigerant Selections: Past, Present, and Future." October 1997.
4. Avery, Gil, "Improving the Efficiency of Chilled Water Plants." ASHRAE Journal, May 2001.

3.4 Packaged Air-Conditioning Replacement With High-Efficiency

3.4.1 Summary

Use high-efficiency air-conditioning (A/C) equipment at the time of replacement of existing packaged A/C equipment or when installing new A/C equipment.

High-efficiency A/C equipment is defined as equipment that is more efficient than that required by the Hawaii Energy Code and qualifies for a rebate from HECO.

3.4.2 Energy Code Requirements

Hawaii Energy Code requirements for packaged A/C equipment are listed in Table 10.1A – reproduced in its entirety as Table 3.4 below.

3.4.3 Utility Incentives

Utility incentives are available as a rebate for Air Conditioning – Packaged & Split Systems from Hawaiian Electric Company (HECO). The rebate is based on A/C size in tons and equipment nominal rated efficiency, measured in SEER or EER. Chiller efficiency rating must be based on ARI Standards 210/240, 320, or 340/360. The qualifying efficiency is shown in Table 3.3 below. The rebate is based on the formula:

Rebate = {[(Equipment Efficiency – Qualifying Efficiency) x $30] + $40} x Cooling Tons

Rebate application instructions are available from HECO. Note that rebate levels and availability are subject to change.

Table 3.3 HECO Rebate Qualifying Efficiencies

System Cooling Capacity		Qualifying Efficiency at Full Load
(MBtuh)	(tons)	SEER or EER
Less than 65	Less than 5.42	13.0 SEER
65 to 135	5.42 to 11.25	11.0 EER
136 to 240	11.26 to 20	10.8 EER
Over 240	Over 20	10.0 EER

Note: Applies to Air Cooled, Unitary Package or Split System A/C Units

Table 3.4: Hawaii Energy Code Requirements – Reproduced
Unitary Air Conditioners and Condensing Units, Electrically Operated, Minimum Efficiency Requirements

Equipment Type	Size Category	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure
Air Conditioners, Air Cooled	< 65,000 Btu/h[c]	Split System	10.0 SEER	ARI 210/240
		Single Package	9.7 SEER	
	≥65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	10.3 EER[b] 10.6 IPLV[b]	
	≥135,000 Btu/h and < 240,000 Btu/h	Split System and Single Package	9.7 EER[b] 9.9 IPLV[b]	ARI 340/360
	≥ 240,000 Btu/h and <760,000 Btu/h	Split System and Single Package	9.5 EER[b] 9.7 IPLV[b]	
	≥760,000 Btu/h	Split System and Single Package	9.2 EER[b] 9.4 IPLV[b]	
Air Conditioners, Water and Evaporatively Cooled	< 65,000 Btu/h	Split System and Single Package	12.1 EER 11.2 IPLV	ARI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Split System and Single Package	11.5 EER[b] 10.6 IPLV[b]	
	≥135,000 Btu/h and ≤240,000 Btu/h	Split System and Single Package	11.0 EER[b] 10.3 IPLV[b]	ARI 340/360
	> 240,000 Btu/h	Split System and Single Package	11.0 EER[b] 10.3 IPLV[b]	
Condensing Units, Air Cooled	≥135,000 Btu/h		10.1 EER 11.2 IPLV	ARI 365
Condensing Units, Water or Evaporatively Cooled	≥135,000 Btu/h		13.1 EER 13.1 IPLV	

[a] IPLVs are only applicable to equipment with capacity modulation.
[b] Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.
[c] Single-phase air-cooled air-conditioners < 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

3.4.4 Recommendations

These recommendations are from Reference 2 and Reference 3.

1. Specify high-efficiency units.
2. Specify units that are specially designed for humid climates and have a high latent cooling capacity.
3. Do not over-size the unit. There is a performance penalty for over-sized systems. Manufacturers recommend choosing a system slightly smaller than peak load to reduce cycling and reliability problems.
4. Consider the use of variable speed fans to minimize cycling and reduce noise.
5. Specify low-noise units.
6. Specify coated fins to maintain efficiencies and extend life of equipment.
7. Specify thicker fins with wider spacing when available.
8. Specify two-stage cooling thermostats with the capability to schedule fan operation and heating and cooling set points independently.
9. Commission the system prior to acceptance through a combination of checklists and functional testing of equipment control, economizer operation, airflow rate and fan power.

3.4.5 Long-Term Performance Issues

3.4.5.1 Maintenance

1. Replace filters regularly.
2. Clean coils regularly (indoor and outdoor).
3. Check refrigerant charge.
4. Clean cooling coil condensate pan and drain on a scheduled basis.
5. Lubricate and adjust fan as recommended by manufacturer.

3.4.6 References

1. Eley and Associates, "Hawaii Model Energy Code Application Manual." August 4, 1994.
2. Eley and Associates, "Hawaii Commercial Building Guidelines for Energy Efficiency." 2003.
3. California Energy Commission, "Small HVAC System Design Guide," October 2003.

3.5 Demand Controlled Ventilation (DCV)

3.5.1 Summary

The Hawaii Energy Code ventilation requirements are based on ASHRAE Standard 62-89. This is an older version of the Standard that does not include an area component in the ventilation calculations like the newest version. In addition, the design occupancies contained in the Standard are usually much greater than those typically found in some occupancy types. These two factors result in design ventilation rates that can be excessive. Excessive outdoor air ventilation causes increased building energy use for cooling and dehumidification in Hawaii's tropical climate. Excessive ventilation will also cause increased fan energy use.

Two approaches to reducing the potential excessive over-ventilation from ASHRAE Standard 62-89 include:

1. Establish ventilation rates on actual observed occupancy densities rather than the Standard's design occupancy densities, and
2. Implement Demand Controlled Ventilation.

Demand controlled ventilation (DCV) is a control strategy that uses measurements of carbon dioxide as a proxy for number of occupants to establish the appropriate amount of outside air being introduced into the building or space. It will generally result in lowering the amount of outside air into a space when compared to ASHRAE Standard 62-1989 ventilation requirements.

Reference 5.3 notes that "For spaces that have high peak occupancies but which are only intermittently occupied, such as ballrooms, meeting rooms, and theaters, vary outside air intake rather than constantly maintaining the high rates needed for peak occupancy." For these types of spaces, which include auditoriums and classrooms, served by dedicated HVAC single-zone systems, automatic control of outside air or DCV is recommended.

3.5.2 Description

DCV applies best to single zone HVAC systems serving spaces with varying occupancy. In application at a University, these situations are likely found at auditoriums and large classrooms, but may also be found elsewhere.

For a single zone HVAC system, successful design implementation of DCV requires, at a minimum:

- one CO_2 sensor located either in the space or in the return air duct from the space,
- modulating outside air, return air, and exhaust air dampers,
- automated control system and control logic, and
- commissioning and tuning requirements.

Some publications suggest an outside air CO_2 sensor be used as a reference point for indoor CO_2 concentration with the difference between indoor and outdoor CO_2 maintained at 700 ppm.

However, the use of an outside air CO_2 sensor is not recommended because of problems with sensor drift and accuracy which are compounded when two sensors are used. Instead, it is common to assume an outdoor level of 300 ppm and set the indoor target to 1,000 ppm or less. The DCV set point should be adjustable from the control system.

3.5.3 Energy Code Requirements

The Hawaii Energy Code requires:

"(f) Ventilation.

(1) Outdoor air ventilation rates shall not exceed the minimum rates required by ASHRAE Standard 62-1989 by more than 10 percent.

(2) Exception. Outdoor air quantities may be greater if required because of special occupancy or process requirements, source control of air contamination or local codes, or if it can be shown that the additional outside air does not increase overall building energy costs."

Table 3.5: ASHRAE Standard 62-1989 Minimum Ventilation Rates

Occupancy Category	Estimated Max Occupancy (P/1000 ft^2)	CFM/person	CFM/ft^2
Auditoriums	150	15	
Classroom	50	15	
Corridors			0.10
Laboratories	30	20	
Libraries	20	15	
Locker Rooms			0.50
Office Space	7	20	
Public Restrooms			50 CFM/water closet
Training Shop	30	20	

3.5.4 Utility Incentives

Utility incentives are available through the Customized Incentives program at Hawaiian Electric Company (HECO). The incentives levels for existing buildings are: \$0.05/kWh/yr estimated energy savings and \$125/kW reduced estimated demand (peak period) savings. The incentives are limited to 50 percent of the project cost. Note that incentive levels and availability are subject to change.

DCV may qualify for these incentives provided it meets additional HECO requirements including: the payback period must be greater than two years and it must pass HECO's benefit-to-cost ratio test.

The energy and demand savings are estimated first year savings with all the formulas, assumptions, and calculations clearly documented for HECO's review. The incentives are usually a one-time payment, although the payments may be made over a 5-year period at HECO's discretion.

The project must be proposed to HECO prior to construction.

3.5.5 Recommendations

Install DCV in single-zone HVAC systems serving auditoriums, classrooms, and conference rooms that have intermittent and varying occupancy.

For Variable Air Volume applications, Reference 6 suggests that installing DCV in any space with an expected occupancy load at or below 40 ft^2/person can potentially benefit from DCV. It recommends that conference rooms use either a VAV box with a CO_2 sensor to reset the zone minimum or a series fan power box with zero minimum airflow set point.

Do not install a reference outside air CO_2 sensor. Instead, establish ambient outside air CO_2 levels and set the DCV set point to an adjustable value less than 1,000 ppm minus outside air CO_2 level.

Design ventilation rates to actual occupancy rather than Standard 62-1989 design occupancy densities.

3.5.6 Long-Term Performance Issues

3.5.6.1 Maintenance

CO_2 sensors must be calibrated on a routine basis per manufacturer's recommendations, or more frequently as needed.

3.5.7 References

1. Dougan and Damiano, "CO_2-Based Demand Control Ventilation: Do Risks Outweigh Potential Rewards?" ASHRAE Journal, October 2004.
2. "ANSI/ASHRAE Standard 62-1989," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
3. Eley and Associates, "Hawaii Model Energy Code Application Manual." August 4, 1994.
4. Warden, David, "Supply Air CO2 Control." ASHRAE Journal, October 2004.
5. Felker, Larry, "Minimum Outside Air Damper Control." ASHRAE Journal, April 2002.
6. "Advanced Variable Air Volume Design Guide," California Energy Commission, October 2003.

3.6 Conversion to Variable Air Volume (VAV)

3.6.1 Summary

Conversion of an existing HVAC system to variable air volume is a complex engineering task. There can be a significant potential for saving energy in the conversion. In some cases a VAV system could be expected to improve comfort conditions when compared to the existing system (e.g., multi-zone systems).

This Section does not attempt to identify when or how to convert a constant volume system to variable air volume. Instead selected recommendations from Reference 2 are listed along with code requirements and utility incentive options.

3.6.2 Energy Code Requirements

The Energy Code limits the power required by the fan motors at design conditions and at 50 percent of design conditions.

"(3) Variable Air Volume (VAV) Fan Systems.

(A) For fan systems which are able to vary system air volume automatically as a function of load, the power required by the motors for the combined fan system shall not exceed 1.25 W/CFM of supply air at design conditions.

(B) Individual VAV fans with motors 25 hp and larger shall include controls and devices necessary for the fan motor to demand no more than 50 percent of design wattage at 50 percent of design air volume, based on manufacturer's test data."

3.6.3 Utility Incentives

Utility incentives are available through the Customized Incentives program at Hawaiian Electric Company (HECO). The incentives levels for existing buildings are: $0.05/kWh/yr estimated energy savings and $125/kW reduced estimated demand (peak period) savings. The incentives are limited to 50 percent of the project cost. Note that incentive levels and availability are subject to change.

DCV may qualify for these incentives provided it meets additional HECO requirements including: the payback period must be greater than 2 years and it must pass HECO's benefit-to-cost ratio test.

The energy and demand savings are estimated first year savings with all the formulas, assumptions, and calculations clearly documented for HECO's review. The incentives are usually a one-time payment, although the payments may be made over a 5-year period at HECO's discretion.

The project must be proposed to HECO prior to construction.

3.6.4 Recommendations

These recommendations are from Reference 2. They were selected to be applicable to the Hawaii climate and in a retrofit situation.

1. "Specify VAV boxes with a "dual maximum" control logic, which allows for a very low minimum airflow rate during no- and low-load periods.
2. Set the VAV box minimum airflow set point to the larger of the lowest controllable airflow set point allowed by the box and the minimum ventilation requirement (often as low as 0.15 CFM/ft^2).
3. For all except very noise sensitive applications, select VAV boxes for a total (static plus velocity) pressure drop of 0.5 inch H_2O.
4. Use supply air temperature reset controls to avoid turning on the chiller whenever possible.
5. Reduce the supply air temperature to the design set point, typically about 55°F, when the outdoor air temperature is higher than about 70°F.
6. Use housed airfoil fans whenever possible.
7. Avoid using pre-filters.
8. Specify final filters with 80 percent to 85 percent dust spot efficiency (MERV 12).
9. Utilize the maximum available area in the air handler for filters rather than installing blank-off panels.
10. Use extended surface filters."

3.6.5 References

1. Eley and Associates, "Hawaii Commercial Building Guidelines for Energy Efficiency." 2003.
2. California Energy Commission, "Advanced Variable Air Volume Design Guide," October 2003.

3.7 Electric Motor Replacements

3.7.1 Summary

Electric motor replacement is an excellent opportunity to save energy and improve plant operations. These opportunities begin by evaluating motor sizing to driven load, electrical power supply, motor controllers, motor driven equipment and control methods, variable speed drives, and power transmission components. College campus applications involving electric motor drives can include ventilation loads (e.g., air handler fan), pump loads (e.g., chilled water pump), and process load (e.g., refrigeration compressors). For the remainder of this guideline, these and other applications will be referred to as motor systems.

Motor replacements are of two types: retrofit of an existing operating motor or replacing a motor that has failed or burned out. Hawaiian Electric Company (HECO) currently offers financial incentives for both types of replacements of AC, polyphase motors. National Electrical Manufacturers Association (NEMA) premium efficient motors should be specified to reduce electrical energy consumption per application.

See Table 3.6 below for outline qualifying motor efficiency levels and potential rebate values.

3.7.2 Energy Code Requirements

Table 3.6: Hawaii Energy Code Requirements & Rebate Values – Reproduced

Size:	2 Pole (3,600 rpm)		4 Pole (1,800 rpm)		6 Pole (1,200 rpm)		Rebate
(hp)	ODP	TEFC	ODP	TEFC	ODP	TEFC	per Motor
1	77.0	77.0	85.5	85.5	82.5	82.5	$15
1.5	84.0	84.0	86.5	86.5	86.5	87.5	$22.50
2	85.5	85.5	86.5	86.5	87.5	88.5	$30
3	85.5	86.5	89.5	89.5	88.5	89.5	$45
5	86.5	88.5	89.5	89.5	89.5	89.5	$50
7.5	88.5	89.5	91.0	91.7	90.2	91.0	$75
10	89.5	90.2	91.7	91.7	91.7	91.0	$100
15	90.2	91.0	93.0	92.4	91.7	91.7	$120
20	91.0	91.0	93.0	93.0	92.4	91.7	$160
25	91.7	91.7	93.6	93.6	93.0	93.0	$200
30	91.7	91.7	94.1	93.6	93.6	93.0	$210
40	92.4	92.4	94.1	94.1	94.1	94.1	$240
50	93.0	93.0	94.5	94.5	94.1	94.1	$300
60	93.6	93.6	95.0	95.0	94.5	94.5	$360
75	93.6	93.6	95.0	95.4	94.5	94.5	$450
100	93.6	94.1	95.4	95.4	95.0	95.0	$600
125	94.1	95.0	95.4	95.4	95.0	95.0	$750
150	94.1	95.0	95.8	95.8	95.4	95.8	$900
200	95.0	94.4	95.8	96.2	95.4	95.8	$1,200
250	95.0	95.8	95.8	96.2	95.4	95.8	$1,500
300	95.4	95.8	95.8	96.2	95.4	95.8	$1,800
350	95.4	95.8	95.8	96.2	95.4	95.8	$2,100
400	95.8	95.8	95.8	96.2	95.8	95.8	$2,400
450	95.8	95.8	96.2	96.2	96.2	95.8	$2,700

3.7.3 Utility Incentives

Utility incentives are available as a rebate for High-Efficiency Motors from HECO, and are shown on the far right column in Table 3.6. The rebate is referenced to motor size in horsepower (hp), minimum efficiencies for 2-, 4-, and 6-pole polyphase motors with either Open Drip Proof (ODP) or Totally Enclosed Fan Cooled (TEFC) enclosures. All applications are subject to HECO review and approval. For a specialized motor that is not listed on the rebate table, an applicant may submit specifications on a selected motor. HECO will consider these situations on a case-by-case basis to determine if a particular motor can qualify for a rebate.

Rebate application instructions are available from HECO. Note that rebate levels and availability are subject to change.

3.7.4 Recommendations

At facilities where many electric motors exist, the following guide can be used to set priorities:

- Begin by looking at the motor systems that are problematic;
- Examine systems where motors or components are due for major maintenance or replacement;
- Inventory motors and identify ones that operate at least 1,000 hours per year, and are the larger HP units on campus; and
- Examine motor systems with fans/pumps/blowers/compressors that have flow controlled by throttling devices (typically dampers or valves).

Data to gather when assessing energy consumption and performance for evaluating replacement of motors should include nameplate data on each component in the motor system, manufacturer's specifications and performance charts, process and instrumentation diagrams including the control system strategy (not always readily available), and field measurements.

Data gathering in typical motor systems should include:

- Power Supply – Input voltage, conductor size, breaker rating, transformer capacity and tap settings, switchgear rating, phase balance, power factor and peak current;
- Motor Controller – type, overload setting, starting characteristics and safety interlocks;
- Motor – type, horsepower, efficiency, manufacturer, voltage, peak current, frame size, hours of operation, model number, RPM, multi-speed capability and NEMA design rating;
- Power transmission – type, adjustable speed capability, speed ratio and torque rating;
- Driven load – type, efficiency, power and speed rating, manufacturer and model, outlet conditions;
- Process load requirements – flow, pressure, temperature, speed and hours operated; and
- Control methods – automatic, manual, measuring devices and operating techniques.

Note that before servicing or taking field measurements, disconnect the power supply from motors and use safe working practices throughout.

The purpose of data gathering is to establish specific operating points that match the output capabilities of the motor with the system requirements. Typically, motor efficiency is fairly constant from 50 percent to 100 percent of rated load, with maximum efficiency near 75 percent to 85 percent of rated load (see calculations below). Below 50 percent rated load, motor efficiency can drop off quickly. Care should be taken in leaving an adequate, but not excessive, safety margin.

Options to consider when a motor operates for extended periods of time under 50 percent loading are two-speed motors and adjustable speed drives. Occasional high load demands may require a motor that is oversized; for example, a boiler fan that must meet high demands during start-up. Without an adjustable speed drive to control the speed of the motor, these type motor systems typically use a method of throttling the fluid flow and will consume much greater amount of energy when compared to an adjustable speed drive application.

Overloaded motors can overheat and lose efficiency. While many motors are designed with a service factor that allows for occasional overloading, running the motor continuously above rated load reduces efficiency and motor life.

For larger motors, rewinding can offer the lowest life-cycle cost when a rewind facility with high quality standards ensures that motor efficiency is not adversely affected.

To estimate motor load, direct read power measurements are applied as follows:

P = V x I x PF x 1.732 / 1,000, where:

P = three phase power in kilowatts (kW)
V = RMS voltage, mean line-to-line of three phases
I = RMS current, mean of three phases
PF = power factor, mean of three phases, as a decimal

Pr = HP x 0.746 / Nr, where:

Pr = Input power at full-rated load (kW)
HP = Nameplate rated horsepower
Nr = Nameplate efficiency at full-rated load

Load = (P / Pr) x 100 percent, where:

Load = Percentage of actual power to rated power
P = Measured input three phase electrical power (kW)
Pr = Input power at full-rated load (kW)

Data logging electrical power to a motor for a time per that captures typical operations, at a time increment equal to or shorter than a utility meters reading period (typically 15 to 30 minutes), can allow for adequate motor loading analysis and prove very valuable in determining whether or not the motor is appropriately sized and/or whether a two-speed motor or adjustable speed drive installation should be considered. If data-logging equipment is not available, and the input power measurements above can be assumed fairly constant, then annual energy operating costs can be estimated as follows:

Annual Energy Usage (kWh) = P (kW) x Annual Hours of Operation (hr/year), and

Operating Energy Costs ($) = kWh/yr x Aggregate Cost per kWh ($/kWh)

Note that aggregate cost per kWh combines demand and energy usage utility charges to simplify energy cost calculations.

The above information should be applied towards a simple payback and/or life cycle cost analysis to determine whether or not a motor replacement makes economic sense.

Motor Loading Calculation Example:

An existing motor driving a boiler feed water pump is identified as a 20-hp, 1,800 rpm unit with a totally enclosed, fan cooled enclosure. Full-load motor efficiency is listed at 90.2 percent. The motor is 11 years old and has not been rewound. The motor system has been adequately maintained throughout its life, and is not considered problematic. It is one of the higher horsepower electric motors inventoried on the campus though, and operates approximately 2,800 hours per year. An electrician makes the following measurements when it is in typical operation mode:

Vab = 471V	Ia = 22 amps	PFa = 0.81
Vbc = 469V	Ib = 20 amps	PFb = 0.79
Vca = 468V	Ic = 19 amps	PFc = 0.77

V = (471 + 469 + 468) / 3 = 469.3 volts
I = (22 + 20 + 19) / 3 = 20.3 amps
PF = (0.81 + 0.79 + 0.77) / 3 = 0.79

P = 469.3 x 20.3 x 0.79 x 1.732 / 1,000 = 13.0 kW

Pr = 20 HP x 0.746 / 0.902 = 16.54 kW

Load = (13.0 kW / 16.54) x 100 percent = 78.8 percent

Without data logging equipment available, and assuming that the measurements captures typical operation, and an aggregate cost of energy equals $0.15/kWh, the annual energy usage and operating costs can be estimated as follows:

Annual Energy Usage (kWh) = 13.0 kW x 2,800 hrs/year = 36,400 kWh/yr

Annual Operating Energy Costs ($/yr.) = 36,400 kWh/yr. x $0.15/kWh = $5,460/yr

A few motor replacement options to consider exist. One could consider replacing the motor with a high efficiency 15 or 20 hp unit, but note that the existing motor loading is within the rated load where maximum efficiency typically occurs, and that based upon the measured data, downsizing to a 15 hp motor would place the motor above full load operation, and possibly require modification to the existing motor frame and pump connection. A VSD installation could be appropriate if more information regarding variation in system loading were available to adequately analyze. For now, with the available data, replacing with a 20 hp, 1,800 rpm, TEFC, 93% high efficiency motor will be considered, and calculations made below:

kW Reduction = Input Power – (Load x hp x 0.746/Efficiency of new motor)
= 13.0 kW – (0.788 x 20 hp x 0.746 / .93)
= 0.36 kW

Annual kWh Saved = 0.36 kW x 2,800 hrs per year = 1,008 kWh/yr.

Annual Savings = $0.15/kWh x 1,008 kWh/yr. = $151

With more economic cost inputs collected (including utility rebate, if available), simple payback and/or life cycle cost analysis would be appropriate at this point when considering motor replacement.

If one foregoes simple payback and/or life cycle cost analysis, the following rules-of-thumb can be applied when considering replacement of oversized and properly sized motors:

- When motors are significantly oversized and under-loaded, replace with more efficient, properly sized models at the next opportunity, such as a scheduled plant downtime.
- When motors are moderately oversized and under-loaded, replace with more efficient, properly sized models when the motors fail.
- When motors are properly sized but standard efficiency, replace with energy-efficient models that meet or exceed efficiencies listed in Table 1 above when the motors fail.

3.7.5 Long-Term Performance Issues

3.7.5.1 Maintenance

Clean motor surfaces and fan and inlet openings periodically. (A vacuum cleaner is preferable vs. use of compressed air for blowing.) A heavy accumulation of dust and lint will result in motor overheating and a shortened motor life.

Lubrication is an important factor for maintaining efficient operation of motors, and larger motors require periodic bearing greasing. Avoid over-greasing motor bearings though, as over-greasing tends to increase friction and leads to motor failure. Follow motor manufacturer's maintenance requirements.

Maintain proper belt tension and alignment, otherwise increased power consumption and a decrease in motor life will result.

Attention to increases or changes in vibration will signify a bearing problem, load imbalance, bent shaft or couple misalignment, all best caught early on and addressed prior to failure.

Check for balanced three-phase power, and over- or under-voltage conditions, as these can shorten the motor life through excessive heat build up.

Inventory motors at the facility, particularly larger horsepower units and those that operate over 1,000 hours per year. The software described below can help with this inventory.

3.7.6 Electric Motor Software

Available electric motor software can help facilities determine potential energy savings by replacing motors with high efficiency ones, as well as providing an inventory database for existing electric motors. Current available software packages for facility maintenance and engineering staff include the following:

Electric Motor Manager, EM2 – Described at the software website as "A full featured, yet easy to use motor management software, where users can enter motor nameplate data from your desk or from the plant floor and the software will help you calculate motor operating costs, compare your motors to higher efficiency motors including NEMA Premium™ motors, prioritize motors for efficiency, analyze repair/replacement options, and track spare motors." Visit http://www.drivesandmotors.com for additional information.

MotorMaster 4.0 – Developed for the U.S. Department of Energy by the Washington State University Cooperative Extension Energy Program to support motor management functions at medium-sized and large industrial facilities. It includes a large database of manufacturers electric motors, provides analysis tools for simple payback and life cycle costing for motor replacements. MotorMaster is available through the U.S. Dept. of Energy's Office of Industrial Technology's web-site http://www.oit.doe.gov/bestpractices/software_tools.shtml.

3.7.7 References

1. Canadian Industry Program for Energy Conservation "Energy – Efficient Motor Systems, Assessment Guide." 2001. Available at http://energy-publications.nrcan.gc.ca/.
2. U.S. DOE "Motor Challenge Fact Sheet" available at http://www.oit.doe.gov/bestpractices.
3. U.S. DOE "Operations and Maintenance Best Practices, A Guide to Achieving Operational Efficiency" December 2002.
4. Council on Energy Efficiency "Fact Sheet Premium Efficiency Motors" available at http://www.cee1.org/resrc/facts/motrs-fx.php3.