U.S. DEPARTMENT OF ENERGY

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Building Energy Audit Report for Pearl Harbor, HI

DR Brown
WD Chvála, Jr.
MI De La Rosa
DR Dixon

September 2010

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

An assessment of energy efficiency opportunities at Pearl Harbor, HI was performed by a team of engineers from Pacific Northwest National Laboratory (PNNL) under contract to the Department of Energy/Federal Energy Management Program (FEMP). The effort used the Facility Energy Decision System (FEDS) model to determine how energy is consumed at selected Pearl Harbor buildings, identify cost-effective energy retrofit measures, and calculate the potential energy and cost savings.

A team of engineers from PNNL visited Pearl Harbor January 19-29, 2010 to collect data for the FEDS assessment. During this visit, PNNL engineers collected energy-related information and data from six buildings selected by Pearl Harbor personnel for input into the FEDS model.

The economic results presented in this report are based on the use of two different sources of capital funds to implement the energy projects; appropriated funds (25-year project life and 3% real discount rate), and alternative financing (e.g., Energy Savings Performance Contract [ESPC]). The alternative financing economic input assumptions (10-year project life and 10% real discount rate) are for generic ESPC financing to illustrate the differences that the source of capital makes on the technology choices. The results are only based on direct construction costs, i.e., they do not include allowances for design and construction management (SIOH) costs. The FEDS software is capable of performing the comprehensive assessment using other sources of capital (e.g., utility financing) with their distinct economic inputs as well as adjusting the cost estimates to include additional items such as design, SIOH, and contingency. Thus, the site is encouraged to re-run the FEDS software using site-specific alternative financing options and cost estimating assumptions, and then reassess the results.

This report documents the findings of the FEDS assessment and model results for appropriated funds and alternative financing sources of capital for the projects. A complete list of the 72 cost-effective energy- and cost-reducing retrofit measures is included in Appendix B-1 for projects funded using the appropriated funding source of capital. The complete list of 38 cost-effective energy- and cost-reducing retrofit measures is included in Appendix B-2 for projects funded using the alternative financing source of capital.

Table ES.1 summarizes the results of the energy assessment by retrofit category for the appropriated fund source of capital. Table ES.2 summarizes the results of the energy assessment by retrofit category for alternative financing source of capital.

For the appropriated funds source of capital in Table ES.1, Pearl Harbor can save 13,704 MMBtu/year and $663,410/year if all 72 cost-effective retrofits are implemented. The results change significantly if alternative financing is pursued. For the alternative financing source of capital shown in Table ES.2, Pearl Harbor can save 9,446 MMBtu/year and $374,929/year if all 38 cost-effective retrofits are implemented.

Table ES.1. Summary of Potential Energy and Cost Savings for Pearl Harbor Using the Appropriated Funds Source of Capital

Retrofit Category	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR	Simple Payback (yr)
Envelope	2,158	76,742	413,561	894,072	3.2	5.4
Cooling	3,893	197,942	1,254,765	1,023,281	1.8	6.3
Hot Water	447	21,551	26,796	81,554	4.0	1.2
Lighting	7,206	367,175	1,729,252	4,413,720	3.6	4.7
Total	**13,704**	**663,410**	**3,424,374**	**6,412,627**	**2.9**	**5.2**

Table ES.2. Summary of Potential Energy and Cost Savings for Pearl Harbor Using the Alternative Financing Source of Capital

Retrofit Category	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR	Simple Payback (yr)
Envelope	1,719	84,592	202,462	400,639	3.0	2.4
Cooling	911	36,355	155,552	124,378	1.8	4.3
Hot Water	429	12,443	22,397	98,301	5.4	1.8
Lighting	7,206	241,539	1,588,073	694,921	1.4	6.6
Total	**9,446**	**374,929**	**1,735,131**	**1,218,460**	**1.7**	**3.4**

In addition to this report, the Pearl Harbor energy manager will receive a complete record of the FEDS input and output files. The FEDS input files consist of the relevant building and equipment data collected and the assumptions made to perform the complex engineering analysis. The FEDS output files contain considerably more detail in support of future project development.

Emissions Reduction

Implementing all the cost-effective building retrofits using appropriated funds will result in a 18% reduction in greenhouse gas emissions. These reductions are summarized in table ES.3 and included for each building in appendix C.

Table ES.3. Emissions Reduction from Cost-Effective Retrofits

Greenhouse Gas	Reduction
Sulfur Oxides (lb)	42,561
Nitrogen Oxides (lb)	20,354
Carbon Monoxide (lb)	35,023
Carbon Dioxide (tons)	4,314
Particulate Matter (lb)	843
Hydrocarbons (lb)	10,088

Job Creation

The jobs created from implementation of all the cost-effective retrofits using appropriated funds total 37 job-years. One job-year is equal to $92,000 in capital spending for implementation.

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Description of ARRA program

On February 13, 2009, Congress passed the American Recovery and Reinvestment Act (ARRA) of 2009 at the urging of President Obama, who signed it into law four days later. A direct response to the economic crisis, the Recovery Act has three immediate goals:

- Create new jobs and save existing ones
- Spur economic activity and invest in long-term growth
- Foster unprecedented levels of accountability and transparency in government spending.[1]

The U.S. Pacific Command (USPACOM or PACOM) is facing significant energy challenges and has identified the need for a comprehensive and integrated approach to addressing these challenges. In a letter dated March 30, 2009, the PACOM Director of Resources and Assessments requested the support of the Department of Energy Federal Energy Management Program (DOE FEMP) in specific assessment, analysis, and training tasks to work toward the accomplishment of PACOM's energy security strategy. An integrated set of ARRA proposals for FEMP assistance requested national laboratory support for the execution of the identified tasks. The resulting 2009-2010 FEMP PACOM scope of work includes renewable energy and efficiency assessments, energy manager training and development, smart grid and islanding feasibility studies, alternative contracting assistance, and technology demonstrations.

In a competitive grant approach across the services and commands, the national laboratories were awarded over $3,000,000 from DOE FEMP to support PACOM needs. The funds are dedicated to technical assistance projects aimed at bringing the most advanced energy efficiency, renewable power generation, and microgrid assessments and analyses to DOD installations in Hawai`i and throughout the Pacific region.

This comprehensive building energy efficiency assessment represents a single task (Task 2.1, FEMP project 237) in the larger PACOM, ARRA-funded energy program.

[1] http://www.recovery.gov/

Background

The United States' oldest combatant command, U.S. Pacific Command (PACOM) has been a force for peace and a committed partner in the Asia-Pacific region for more than 60 years. With an area of responsibility (AOR) that includes more than 3.4 billion people and encompasses about half the Earth's surface, the Command remains a significant stabilizing influence in the world. PACOM is supported by four component commands: U.S. Pacific Fleet, U.S. Pacific Air Forces, U.S. Army Pacific, and U.S. Marine Corps Forces, Pacific. These commands are headquartered in Hawaii and have forces stationed and deployed throughout the region.

On an average day, U.S. military forces in Hawaii require 3 GW of electricity, representing approximately 10% of the total electricity needs of the islands. A map of military sites on Oahu is included in Figure 1 below. Facilities on other islands include: Pacific Missile Range Facility (PMRF) on Kaua`i, Pohakuloa Training Area (PTA) and Kilauea Military Center (KMC) on Hawai`i Island, and the Maui High Performance Computing Center (MHPCC) on Maui. In addition to most of these sites, the FEMP PACOM program tasks are performing work in Alaska, Guam, and Japan.

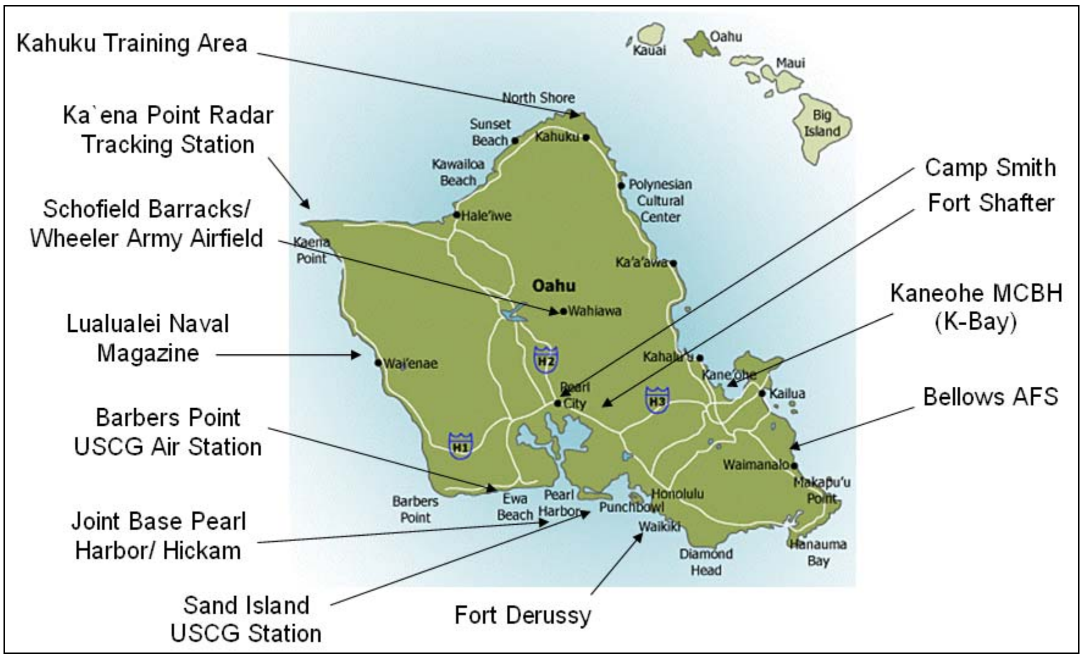

Figure 1: Military Installations on O`ahu, Hawai`i

Joint Base Pearl Harbor-Hickam (JBPHH) is in the process of combining two historic bases into a single joint installation to support both Air Force and Navy missions, along with the tenant commands, and all the service members and their families. By capitalizing on best practices of both services, they will continue to enhance the warfighting readiness, maximize delivery of installation support services throughout the joint base, and capture identified efficiencies.

Introduction

This report contains the results of the comprehensive building energy efficiency assessment conducted at Pearl Harbor, Hawaii, by Pacific Northwest National Laboratory (PNNL). The scope of this activity was based on using the Facility Energy Decision System (FEDS) process to identify cost-effective energy- and cost-reduction projects. Six buildings were selected for detailed energy audits of sufficient scope to comply with Energy Independence and Security Act (EISA), section 432 requirements for energy and water evaluations at covered facilities. The results of the FEDS assessment will be used by the installation to develop an implementation plan for the energy conservation measures identified, and outline how Pearl Harbor will meet the goals of Executive Order 13423 by FY 2015.

Purpose

The purpose of this report is to present the findings resulting from the site visit performed January 19-29, 2010, and subsequent modeling and analysis. The objective of the site visit was to collect the necessary data to conduct building assessments using the FEDS model, resulting in a list of cost-effective, energy- and cost-reduction projects for Pearl Harbor.

Site Visits and Teams

The formal kickoff of the site assessment at Pearl Harbor was held on the morning of January 19, 2010. The PNNL team presented an overview of the FEDS assessment process, the data requirements, and schedule for the Pearl Harbor work. Participating in this meeting were:

1. Jared Strebel – Resource Efficiency/Energy Manager, NAVFAC Hawaii
2. Randy Grant – JBPHH Energy Manager
3. Jill Sims – Project Manager/Technical Lead, SENTECH Hawaii
4. Roger Dunn– Resource Efficiency Manager, JBPHH
5. Doug Dixon – PNNL
6. Daryl Brown – PNNL
7. Bill Chvála – PNNL
8. Marcus De La Rosa – PNNL

Description of Facilities

The scope of the FEDS assessment performed at Pearl Harbor was limited to six buildings selected by Pearl Harbor personnel. Table 1 identifies the six buildings audited at Pearl Harbor and their individual and collective floor space.

Table 1. Buildings Audited

Facility Functions	Proxy Facility No.	Building Floor space (sq. ft.)
Data Center	87	53,724
Storage and Offices	167	450,000
Maintenance Shops and Offices	440	68,232
Storage, Offices, and Data Center	475	288,000
Navy Exchange	631	285,515
Maintenance Shops and Offices	1670	141,354
Total		**1,286,825**

Analytical Approach

The general approach was to develop a FEDS model of the buildings audited at Pearl Harbor, calibrate that model to actual FY 2009 energy use with FY 2009 weather data, and then utilize the model to predict energy consumption and identify cost-effective retrofits under typical meteorological year (TMY) weather conditions.

Buildings

Six buildings were selected by Pearl Harbor personnel for the FEDS assessments. Building characteristics were developed from a combination of inferencing relationships within the FEDS model (driven by building type, size, climate, and vintage), walk-through audits of selected buildings at Pearl Harbor, and additional building data collected while visiting the Base.

Energy Prices

Hickam Air Force Base, Pearl Harbor, and Camp Smith (hereinafter, Hickam, Pearl, and Smith) are all served by Hawaiian Electric Company (HECO) under Schedule PP, Large Power Primary Voltage Service. Minor differences in the marginal electricity costs for the three organizations stem from differences in their power factors and the use of Rider M, Off-Peak and Curtailable Services, by Pearl.

The root marginal demand charge for Schedule PP is $11.85/kW. Energy charges are billed per a declining block structure that is a function of the peak demand. This effectively results in an additional $2.78/kW demand charge because an increase in demand shifts more energy into higher-priced blocks. The first 200 kWh/kW are billed at $0.121534/kWh, and the second 200 kWh/kW are billed at $0.113702/kWh. All kWh in excess of 400 kWh/kW are billed at $0.110668/kWh. The demand profiles at Hickam, Pearl, and Smith all result in the marginal kWh being billed at the rate for the third block.

Several adjustments are applied that affect the marginal electricity cost. The total bill is decreased by 0.1% for each 1% that power factors are above 85% (and vice-versa if the power factor is below 85%). “Interim” increases in the rates established in 2007 and 2009 add 2.82% to the total bill. Finally, the combination of public benefit funds, energy cost, and integrated resource planning surcharges add a little more than $0.03 to the cost of each kWh.

The billing demand for each month is the higher of the actual peak demand for that month or the average of peak demand for that month and the peak demand for the previous 11 months. This structure cannot be directly modeled in FEDS, but was found to be equivalent to a 92% annual demand ratchet, which can be modeled in FEDS.

Pearl utilizes Rider M to reduce its demand charge by agreeing to reduce its load from 5-9 PM, Monday through Friday. This rider reduces its billing demand by 75% of the difference between its overall peak demand and its peak demand during the 5-9 PM period. For Pearl, the Rider M billing demand averaged 96% of its actual peak demand during 2009. This is equivalent to using the actual peak demand as the billing demand and reducing the demand charge by 4%, which was the modeling approach used for FEDS.

The resulting marginal electricity costs are summarized in Table 2.

Table 2. Marginal Electricity Rates for Pearl Harbor

Rate Component	Pearl
Demand Charge, $/kW	14.24
Energy Charge, $/kWh	0.1426
Effective Demand Ratchet, %	N/A

Model Calibration

Building energy use was simulated with FEDS to predict the total site energy consumption for FY 2009 using FY 2009 weather data. Uncertain elements of the modeling assumptions were adjusted until the model's energy consumption prediction matched "reasonably well" with actual energy consumption for FY 2009. Specific model calibration results are shown in Table 3.[2]

Table 3. FEDS Calibration Results

Building Number	Fuel Type	Error (%)
87	Electricity	0.3
167	Electricity	0.5
440	Electricity	0.0
475	Electricity	0.8
631	Electricity	2.2
1670	Electricity	-1.0

[2] For example, an error of +0.5% means that the model predicts energy consumption 0.5% higher than reported consumption.

Description of Opportunities Identified

The number of conceivable energy conservation measures, fuel-switching opportunities, and renewable-energy projects at federal sites is very large. The FEDS model is used to cost-effectively identify energy saving opportunities. FEDS is a software tool that provides a comprehensive method to quickly and objectively identify energy improvements that offer maximum life-cycle cost savings. FEDS determines the optimum set of cost-effective retrofits from a current database of hundreds of proven technologies. These include retrofits for heating, cooling, lighting, motors, building envelope, and hot water systems. Interactive effects are also evaluated as part of the optimization process so that energy savings are not double counted or undercounted. The results are based on life-cycle cost economics consistent with 10 CFR 436.

FEDS identifies the package of retrofits that individually and collectively minimize the life-cycle cost of building energy services, resulting in projects where the net present value (NPV) of the investment is greater than or equal to zero and the savings-to-investment ratio (SIR) is greater than or equal to one. Results are developed for government (appropriated) and alternative (e.g., ESPC and Utility Energy Service Contracting [UESC]) financing assumptions.

In general, the discount rate is higher and the economic evaluation life is shorter for alternative financing compared to government financing. The economic life for the latter is set at 25 years with the discount rate adjusted each year in response to market conditions. The currently prescribed government discount rate is 3.0% in real terms, i.e., in excess of general inflation. Alternative financing assumptions are not prescribed, but set by negotiation between the ESCO and the federal organization. An economic evaluation life of 10 years and a real discount rate of 10% are used to represent alternative financing conditions in this assessment, based on a collection of prior site experiences in the Army.

Table 4a summarizes the FEDS results by retrofit category (e.g., cooling) and type (e.g., chillers) using appropriated funding as the source of capital for the projects. Table 4b summarizes the FEDS results by retrofit category using alternative financing as the source of capital for the projects. The complete list of cost-effective energy- and cost-reduction projects resulting from the FEDS modeling and analysis are presented Appendices B-1 (appropriated funds) and B-2 (alternative financing).[3]

[3] It should be noted that in addition to this report, the Pearl Harbor energy manager will also receive a CD-ROM, which includes all the FEDS input data and output project files. The input data files reflect information collected during the site visits and additional assumptions required to perform the FEDS modeling and assessment. The output project files contain significantly more detailed information to support the list of cost-effective energy projects identified in Appendices B-1 and B-2.

Table 4a. Summary of All Cost-Effective Projects Identified from the FEDS Assessment for Pearl Harbor Using Appropriated Sources of Capital (by Retrofit Category and Type)

Retrofit Category	Retrofit Type	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR	Simple Payback (yr)
Envelope	Roof/Attic Insulation	2,158	76,742	413,561	894,072	3.2	5.4
	Subtotal	**2,158**	**76,742**	**413,561**	**894,072**	**3.2**	**5.4**
Cooling	Water-Cooled Chillers	3,893	197,942	1,254,765	1,023,281	1.8	6.3
	Subtotal	**3,893**	**197,942**	**1,254,765**	**1,023,281**	**1.8**	**6.3**
Hot Water	Heat Pump Water Heaters	416	20,020	24,921	74,494	4.0	1.2
	Tank and Pipe Insulation	31	1,531	1,875	7,060	4.8	1.2
	Subtotal	**447**	**21,551**	**26,796**	**81,554**	**4.0**	**1.2**
Lights	Compact Fluorescents (CFLs)	182	12,285	1,448	205,235	143	0.1
	Electroluminescent Exit Signs	14	2,977	17,352	34,006	3.0	5.8
	T-8s, other Fluorescents	6,917	346,827	1,660,551	4,139,621	3.5	4.8
	High Pressure Sodium Lamps	93	5,086	49,901	34,858	1.7	9.8
	Subtotal	**7,206**	**367,175**	**1,729,252**	**4,413,720**	**3.6**	**4.7**
Total		**13,704**	**663,410**	**3,424,374**	**6,412,627**	**2.9**	**5.2**

From Table 4a, the total cost-effective energy savings is estimated at 13,704 MMBtu/year representing $663,410/year savings with an overall savings to investment ratio (SIR) of 2.9.

The greatest energy saving potential was found in lighting measures (7,206 MMBtu/year), followed by cooling (3,893 MMBtu/year). The largest estimated dollar savings was also found in lighting ($367,175/year), again followed by cooling ($197,942/year). Hot water measures (4.0) followed by lighting (3.6) showed the greatest SIR.

Table 4b. Summary of All Cost-Effective Projects Identified from the FEDS Assessment for Pearl Harbor Using Alternative Financing Sources of Capital (by Retrofit Category and Type)

Retrofit Category	Retrofit Type	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR	Simple Payback (yr)
Envelope	Roof/Attic Insulation	1,719	84,592	202,462	400,639	3.0	2.4
	Subtotal	**1,719**	**84,592**	**202,462**	**400,639**	**3.0**	**2.4**
Cooling	Packaged A/C Units	32	6,132	35,326	2,352	1.1	5.7
	Water-Cooled Chillers	879	30,223	120,226	122,026	2.0	4.0
	Subtotal	**911**	**36,355**	**155,552**	**124,378**	**1.8**	**4.3**
Hot Water	Heat Pump Water Heaters	402	11,548	21,454	91,264	5.3	1.9
	Tank and Pipe Insulation	27	895	943	7,037	8.5	1.1
	Subtotal	**429**	**12,443**	**22,397**	**98,301**	**5.4**	**1.8**
Lights	Compact Fluorescents (CFLs)	451	16,240	4,485	173,664	39.7	0.3
	Electroluminescent Exit Signs	13	2,549	14,667	846	1.1	5.8
	T-8s, other Fluorescents	6,721	221,981	1,563,792	519,556	1.3	7.0
	High Pressure Sodium Lamps	21	769	5,129	855	1.2	6.7
	Subtotal	**7,206**	**241,539**	**1,588,073**	**694,921**	**1.4**	**6.6**
Total		**9,446**	**374,929**	**1,735,131**	**1,218,460**	**1.7**	**3.4**

From Table 4b, the total cost-effective energy savings is estimated at 9,446 MMBtu/year representing $374,929/year savings with an overall savings to investment ratio (SIR) of 1.7.

The greatest energy saving potential was found in lighting measures (7,206 MMBtu/year), followed by envelope measures - insulation (1,719 MMBtu/year). The largest estimated dollar savings was also found in lighting ($241,539/year), again followed by envelope measures ($84,592/year). Hot water (5.4) followed by envelope measures (3.0) showed the greatest SIR.

As would be expected, the total number of cost-effective retrofits is fewer (and installed cost/ capital investment is less) under alternative financing sources of capital, and thus, the energy and dollar savings are likewise less. The total number of cost-effective retrofits using appropriated sources of capital is 72 and the total number of cost-effective retrofits using alternative financing sources of capital is 38. Using appropriated funding will save 4,258 MMBtu/year and $288,481/year more than alternative financing. Utilizing alternative financing reduces the simple payback from 5.2 to 3.4 years because many projects with longer paybacks are eliminated under the alternative financing scenario.

The complete list of cost-effective energy- and cost-reduction projects is given Appendix B-1 for appropriated funding and in Appendix B-2 for alternative financing.[4]

[4] The Pearl Harbor energy manager will also receive a CD, which includes all the FEDS input data and output project files. The input data files reflect information collected during the site visits and additional assumptions required to perform the FEDS modeling and assessment.

Conversion to Water-Cooled Chillers

Water-cooled condensing of cooling equipment refrigerant results in a significant improvement in efficiency compared to air-cooled condensing chillers. This advantage stems from two factors. Condenser water from an evaporative cooling tower is generally cooler than ambient air (except when the relative humidity is very high), and water is a more effective heat transfer fluid than air. The two factors work together to lower the refrigerant condensing temperature, which improves both theoretical and actual refrigeration cycle efficiency. Combining cooling loads met by multiple smaller cooling units into fewer central units allows additional efficiency gains by using centrifugal compressors, a more efficient technology than alternative compressor types commonly used in smaller cooling equipment. These advantages do come at a price, however. Condensing refrigerant with water requires additional costs associated with a cooling tower, condenser water pumps and piping, and a shell to enclose the water as it passes by the condenser tubing. The condenser pump also represents an additional power consuming device that an air-cooled unit does not have. Finally, the distribution of centrally chilled water incurs pumping and piping costs and pumping energy not required by distributed direct expansion coolers (e.g., window air conditioner [AC] and packaged rooftop AC).

For the reasons noted above, water-cooled chillers offer significant performance advantages over air-cooled equipment that must be weighed against their additional capital costs. During the last few decades, space cooling has become much more common in Hawaiian military facilities because internal heating loads (e.g., personal computers and other office equipment) have increased, building designs have become less suitable for natural ventilation, and occupants expect a more comfortable working environment. The FEDS model generated retrofit recommendations replacing air-cooled chillers with water-cooled chillers <u>at the building level</u>. The following paragraphs discuss the impact of combining these energy conservation measures (ECMs) into a centralized chilled-water plant. More details of the assessment of water-cooled chillers at Hickam AFB, Pearl Harbor, and Camp Smith are provided in Appendix D.

Building 631, the Navy Exchange (NEX) and Commissary, is currently served by a collection of packaged rooftop direct expansion (DX) AC units. The proposed retrofit would replace the existing DX units with a new chilled water coil (in the existing air-handler units [AHU]), two water-cooled chillers, a cooling tower, condenser water pumps and piping, and chilled water pumps and piping. The new chiller plant was assumed to be sited on the ground on the southeast side of the building, next to the Commissary.

The peak and annual building cooling loads were estimated with the FEDS model, and the performance of the existing packaged DX units was estimated from the vintage of the existing equipment. From this information, the annual kWh and peak kW electrical loads were calculated and then combined with Pearl Harbor's electricity rates to calculate the current annual electricity costs. The existing system performance and electricity cost figures are presented in Table 5.

Table 5. Pearl Building 631 Existing System Performance and Electricity Cost

Building	Peak Load, Tons	Annual Load, Ton-hours	Annual Capacity Factor	Existing Air Cooled kW/ton	Existing Annual Electricity kWh	Existing Peak Electricity kW	Existing Annual Electricity Cost
Navy Exchange (NEX)	275.1	918,580	0.38	1.2859	1,181,180	354	
NEX Food Court	125.0	342,737	0.31	1.2859	440,717	161	
Commissary	194.4	716,633	0.42	1.2859	921,501	250	
Totals	594.5	1,977,950	0.38	1.2859	2,543,446	764	$493,300

In this size range, the water-cooled chillers were assumed to use a centrifugal compressor rated at 0.51 kW/ton. In addition, the chilled water pumps, condenser water pumps, and cooling tower fan would be expected to consume 0.18 kW/ton, for a total cooling plant performance of 0.69 kW/ton. The annual electricity bill for the water-cooled system was calculated to be $264,700 based on these assumptions, resulting in an annual savings of $228,600 and a peak electric load reduction of 354 kW.

A new 600-ton water-cooled chiller plant (chillers, cooling tower, pumps, plant piping, electrical, controls, and structure) was estimated to cost $656,000. Chilled water piping running to and from the ground to every rooftop air-handling unit was estimated to cost $225,000. The cost of the new chilled water coils was estimated to be $180,000. These figures include all direct construction costs, but do not include any allowance for design or SIOH costs. Based on the direct cost, the payback period is 4 years. With an additional 16% for design and SIOH, the payback period rises to 4.5 years.

Recommendations for More In-Depth Assessments

The FEDS model can provide an unbiased assessment of literally hundreds of energy conservation projects; unfortunately, it is not all-inclusive. While the scope of this project is limited to energy-saving projects included in the FEDS model, the energy-saving opportunities identified below were recognized during the site visit and may be worth additional consideration by the site energy staff. It is recommended that the site pursue additional assessments of these potential projects.

Cool Roofs. FEDS does not evaluate the potential savings for cool roof projects.

Building Controls. Recommendations for building controls cannot be easily inferred by the FEDS model engine. A detailed building assessment focused on all heating, ventilation, and air conditioning (HVAC) equipment is required to develop project proposals.

Programmable Thermostats. The FEDS model does not consider programmable thermostats in the energy analysis. Programmable thermostats are considered a conservation measure rather than an equipment replacement or building improvement. Programmable thermostats could be a useful conservation measure in smaller commercial buildings or any building that is unoccupied during part of the day.

Implementation Options

Pearl Harbor has a number of options for implementing the ECMs identified in this assessment. As shown in Table 6, implementing the building level ECMs using appropriated funds would require an investment of about $3.4M and save 13,704 MMBtu/year or $663,410/year with an overall savings to investment ratio (SIR) of 2.9. Implementing the ECMs with alternative financing (ESPC or UESC) would save 9,446 MMBtu/year or $374,929/year with an overall savings to investment ratio (SIR) of 1.7 and an investment cost of $1.7M. However, the investment cost under alternative financing does not include the financing charges over the life of the project.

The recommended option for implementing the building level ECMs would be to pursue appropriated funds, either through the ECIP program or sustainment, renovation, and modernization (SRM) at the base level. This would result in the greatest energy and cost savings to the Navy (see Table 6). The ECIP program within the Navy/Marines may not be an option for these building energy efficiency ECMs, because the focus of the current program is on renewable energy projects. If appropriated funds are not available, then alternative financing would provide the means to get most of the projects implemented without requiring a high up front investment from the Navy.

Table 6. Comparison of Funding Sources

Funding Source	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Estimated Financing Costs ($)[5]	Total Cost ($)	SIR
Appropriated funding	13,704	663,410	3,424,374	0	3,424,374	2.9
Alternative financing	9,446	374,929	1,735,131	1,248,313	2,983,444	1.7

Public Benefit funds may be available for some of these ECMs through Hawaii Energy. Hawaii Energy operates the new and expanded Hawaii Energy Efficiency Programs under contract to the Hawaii Public Utilities Commission (HPUC) and paid for by electric utility ratepayer fees.

[5] Assumes alternative financing at an annual interest rate of 6% for 20 years.

Emissions Reduction

Implementing all the cost-effective building retrofits using appropriated funds will result in a 18% reduction in greenhouse gas emissions. These reductions are summarized in table 7 and included for each building in appendix C.

Table 7. Reduction in Greenhouse Gas Emissions

Greenhouse Gas	Building 167	Building 475	Building 631	Building 1670	Building 87	Building 440	Totals
Sulfur Oxides (lb)							
existing	48,430	54,380	52,842	17,429	49,228	11,276	233,585
post-retrofit	43,439	44,784	38,915	14,164	41,169	8,553	191,024
difference	(4,991)	(9,596)	(13,927)	(3,265)	(8,059)	(2,723)	(42,561)
% change	10.31	17.65	26.36	18.73	16.37	24.15	18.22
Nitrogen Oxides (lb)							
existing	23,142	25,986	25,268	8,328	23,524	5,388	111,636
post-retrofit	20,758	21,400	18,596	6,768	19,673	4,087	91,282
difference	(2,384)	(4,586)	(6,672)	(1,560)	(3,851)	(1,301)	(20,354)
% change	10.30	17.65	26.40	18.73	16.37	24.15	18.23
Carbon Monoxide (lb)							
existing	39,805	44,696	43,473	14,325	40,461	9,268	192,028
post-retrofit	35,703	36,808	31,985	11,642	33,837	7,030	157,005
difference	(4,102)	(7,888)	(11,488)	(2,683)	(6,624)	(2,238)	(35,023)
% change	10.31	17.65	26.43	18.73	16.37	24.15	18.24
Carbon Dioxide (tons)							
existing	4,902	5,505	5,353	1,764	4,983	1,141	23,648
post-retrofit	4,396	4,533	3,938	1,434	4,167	866	19,334
difference	(506)	(972)	(1,415)	(330)	(816)	(275)	(4,314)
% change	10.32	17.66	26.43	18.71	16.38	24.10	18.24
Particulate Matter (lb)							
existing	958	1,076	1,046	344	974	223	4,621
post-retrofit	859	886	769	281	814	169	3,778
difference	(99)	(190)	(277)	(63)	(160)	(54)	(843)
% change	10.33	17.66	26.48	18.31	16.43	24.22	18.24
Hydrocarbons (lb)							
existing	16,475	18,499	4,409	5,929	16,746	3,836	65,894
post-retrofit	14,776	15,234	4,065	4,818	14,004	2,909	55,806
difference	(1,699)	(3,265)	(344)	(1,111)	(2,742)	(927)	(10,088)
% change	10.31	17.65	7.80	18.74	16.37	24.17	15.31

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Appendix A

FEDS Data Collection Form

Appendix A
FEDS Data Collection Form

The following form is used to collect FEDS input data during building audits. Note that not all data types indicated on this form are applicable to all buildings. Nor is all the information indicated on this form always available. Where necessary, the FEDS model infers the values for missing data based on other known building characteristics.

FEDS Building Information for ___________________________

Building Number / Description / Size:						
	Description	**% of building**	**# of floors**	**Occupancy Schedule:**	**Start**	**End**
Use Area 1				**Weekday:**		
Use Area 2				*(military time)* **Saturday:**		
Use Area 3				**Sunday:**		
Aspect ratio (N:E):				# Occupants: (occupied); (unoccupied)		
Zones: Single (1) Perimeter w/ halls (4) Central w/ perimeter (5)				**Unoccupied Months:**		

ENVELOPE

Roof type: BUILT-UP METAL PANEL SHINGLES/SHAKES	**Floor type:** SLAB ON GRADE CRAWL SPACE
- if built-up, deck type: WOOD CONCRETE METAL	- insulation? type / thickness / R-value:
- insulation? type / thickness / R-value:	- ground floor carpet (crawlspace only)? YES NO
- floor-floor height:	
- floor-ceiling height:	**Windows - #panes:** 1 2 3
- suspended ceiling? YES NO	**- frame type:** WOOD/VINYL METAL THERMAL BREAK METAL
Wall: WOOD SIDING MASONRY/WOOD MASONRY CURTAIN MET PANEL	- TINTING SHADING FILM
- insulation? type / thickness / R-value:	**- % of wall area that is glass:**

LIGHTING

Technology Type	**Fixture Description (size, #lamps, wattage, reflectors,** ballasts, application, etc.)*	**Use Area or % of building served**	**Fixture density or count**	**Mounting Method**	Utilization
Exit Signs					
		Exterior		--	
		Exterior		--	
		Exterior		--	

INC = incandescent CFL = compact fluorescent FL = fluorescent MV = mercury vapor MH = metal halide HPS = high pressure sodium
LPS = low pressure sodium EX = exit sign *2-tube T12=2T12; 4-tube T12=4T12; 2-tube T8=2T8; 2-tube T5=2T5; 4-tube Biax=4BIAX

SERVICE HOT WATER

Portion of building set served (whole buildings) (sq. ft, %, # of buildings, or USE AREA)	**System 1:**	**System 2:**	**System 3:**
Fuel type			
System type	DISTRIBUTED LOOP	DISTRIBUTED LOOP	DISTRIBUTED LOOP
Equipment vintage			
Tank capacity (gallons, #tanks**)**			
Heating capacity (loop only)			
Thermostat set point, °F			
Tank insulation – thickness/R-value			
Efficiency			
Loop length (perimeter or stacked service)			
#Faucets / aerators installed (%)			
#Showers / low-flow showerheads installed (%)			
Note presence of: bottom boards, near tank pipe insul., tank wrap, heat traps, electronic pilots			

Auditor: _____________________________________ **Date:** __________________ **Sheet** ________ **of** ________

HVAC

Portion of set NOT heated (ft², %, # of bldgs, use area):	HEATING		
Portion of building set served (whole buildings) (sq. ft, percent, number of buildings, or USE AREA)	**Type 1:**	**Type 2:**	**Type 3:**
Fuel type			
Equipment type: 0=Elec. resistance baseboard 1=Forced air furnace 2=Air-source HP 3=Ground-coupled HP 4=Radiator/central steam/hw 5=Fan coils/central steam/hw/electricity 6=AHU/central steam/hw 7=Radiator/boiler 8=Fan coils/boiler 9=AHU/boiler 10=Radiant/central steam/hw 11=Radiant/single bldg boiler 12=Infrared			
Output capacity (total per building)			
Number of pieces of equipment			
Efficiency (%)			
Equipment vintage (approximate if necessary – new/old)			
Thermostat set point(s), °F			
Portion of set NOT cooled (ft², %, # of bldgs, use area):	**COOLING**		
Portion of building set served (whole buildings) (sq. ft, percent, number of buildings, or USE AREA)	**Type 1:**	**Type 2:**	**Type 3:**
Fuel type			
Equipment type: 0 = Evap. cooler 1 = Window/wall units 2 = Air source heat pump 3 = Ground-coupled heat pump 4 = Package or split DX 5 = Fan coils/central chilled water 6 = AHU/central chilled water 7 = Fan coils/absorption chiller 8 = AHU/absorption chiller 9 = Fan coils/conventional chiller 10 = AHU/conventional chiller			
Output capacity (total per building)			
Number of units			
Manufacturer & model #			
Equipment vintage (approximate if necessary – new/old)			
Thermostat set point(s), °F			
	VENTILATION		
Ventilation control mode: 0=cycle 1=constant 2=constant occupied hours/cycle unoccupied hours 3=constant occupied hours/off unoccupied hours 4=no mechanical ventilation			
Ventilation supply air (cfm)			
Outdoor air (NONE, 100%, OTHER?)			
Infiltration (note cracks, open windows, CFM or ACH)			
Desiccant dehumidification (and heat source)?			

MISC. EQUIPMENT

Refrigeration, food prep, or other - note if irregular. Atypical equipment: description including type, fuel, capacity, utilization.

MOTORS

	Type 1:	**Type 2:**	**Type 3:**	**Type 4:**
Horsepower				
# Motors of this type				
Utilization				
Other nameplate data				

NOTES/DRAWINGS

Appendix B

Comprehensive List of Cost-Effective Projects Identified from the FEDS Assessment Using Appropriated/Alternative Financed Sources of Capital

Appendix B-1
Comprehensive List of Cost-Effective Projects Identified from the FEDS Assessment Using Appropriated Sources of Capital

Table B-1 identifies the 72 cost-effective energy- and cost-reducing retrofit projects identified from the FEDS modeling and analysis based on the assumption that the projects will be funded using appropriated sources of capital funds. Key energy and economic results are presented for each cost-effective retrofit measure. The projects are grouped by building category. More detail, supporting each line-item project recommendation, is contained in the FEDS input and output files, which are delivered to the site energy manager on a CD in conjunction with this report.

Table B-1 Comprehensive List of Cost-Effective Projects Using Appropriated Sources of Capital

FEDS Category		Technology Change	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
87	Data Center Hanger	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	-	63	373	726	2.9
	Data Center Hanger	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	-	43	248	485	3.0
	Data Center Hanger	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	56	3,332	30,830	24,759	1.8
	Data Center Hanger	Replace existing 2x4 3-tube T8 lighting with 2X4 3-tube advanced (super) T8 25W with reflector	149	7,757	20,702	108,889	6.3
	Data Center Hanger	Replace existing electric water heater with heat pump water heater	5	279	428	811	6.1
	Data Center Hanger	Replace existing electric water heater with heat pump water heater	3	129	428	290	2.8
	Data Center Hanger	Suspended Ceiling: Increase Insulation by R-11	236	10,357	39,520	132,810	4.4
	Data Center Hanger	Replace existing air-cooled chiller with water-cooled reciprocating electric chiller (very high efficiency) and cooling tower	780	34,689	103,186	253,913	4.7
	Data Center Hanger	Replace existing air-cooled chiller with water-cooled reciprocating electric chiller (very high efficiency) and cooling tower	584	40,805	341,513	159,622	1.7
	TOTAL		1,813	97,454	537,228	682,305	2.3
167	storage	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	153	932	1,710	2.8
	storage	Replace existing 1x8 2-tube T12 lighting with 1X8 2-tube T8 with reflector	314	22,383	160,316	215,419	2.3
	storage	Replace existing 1x8 2-tube T8 lighting with 2X4 3-tube advanced (super) T8 lighting	70	5,301	54,113	35,092	1.6
	storage	Service hot water: wrap tank with insulation, insulate pipe near tank, install aerators, lower tank temperature	3	142	166	658	11.9

FEDS Category		Technology Change	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
	Admin/control room	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	2	224	1,258	2,589	3.1
	Admin/control room	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	-	26	140	273	3.0
	Admin/control room	Replace existing 2x4 4-tube T8 lighting with 2X4 3-tube advanced (super) T8 25W with reflector	392	14,946	50,912	198,730	4.9
	Admin/control room	Replace existing 2x4 4-tube T8 lighting with 2X4 3-tube advanced (super) T8 25W with reflector	43	1,712	5,990	22,599	4.8
	Admin/control room	Replace existing 1x8 2-tube T8 lighting with 2X4 3-tube advanced (super) T8 lighting	553	23,186	149,392	239,384	2.6
	Admin/control room	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	297	9,254	29,289	124,986	5.3
	Admin/control room	Replace existing 2x4 3-tube T8 lighting with 2X4 3-tube advanced (super) T8 25W with reflector	340	12,398	67,702	138,990	3.1
	Admin/control room	Replace existing electric water heater with heat pump water heater and install aerators	48	2,890	3,466	12,719	7.7
	Admin/control room	Suspended Ceiling: Increase Insulation by R-19	1,171	22,551	147,235	227,995	2.5
	Admin/control room	Service hot water: Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	1	58	128	248	6.3
	TOTAL		3,235	115,224	671,039	1,221,392	2.8
440	East Wing	Replace 3-lamp T-8s with 2-lamp super T-8s	46	2553	13267	31182	3.4
	East Wing	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	107	640	1219	2.9
	East Wing	Add 4 inches fiberglass insulation to interior surface of metal roof	129	7310	26665	100630	4.8
	Cooled Center	Replace 3-lamp T-8s with 2-lamp super T-8s	86	4692	24301	57397	3.4
	Cooled Center Admin	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	54	320	610	2.9
	Cooled Center Shops	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	54	320	610	2.9
	Cooled Center	Add 4 inches fiberglass insulation to interior surface of metal	460	27245	97683	376746	4.9

FEDS Category		Technology Change	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
		roof					
	A Wing	Replace air-cooled chiller with water-cooled chiller and cooling tower	87	7907	81877	2333	1.4
	A Wing Admin	Replace 32W T-8s with 25W super T-8s	48	2567	21131	23574	2.1
	A Wing Admin	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	161	960	1829	2.9
	A Wing Shops	Replace 32W T-8s with 25W super T-8s	39	2170	14707	23076	2.6
	A Wing Shops	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	161	960	1829	2.9
	A Wing	Increase insulation by R-19 above suspended ceiling	101	5121	42186	46988	2.1
	Uncooled A Wing	Replace 4-lamp 32W T-8s with 3-lamp 30W super T-8s	10	564	3978	5840	2.5
	Uncooled A Wing	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	52	320	578	2.8
	Uncooled Center	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	52	320	578	2.8
	TOTAL		1009	60770	329635	675019	3.0
475	Admin/data center	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	246	1,398	2,843	3.0
	Admin/data center	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	-	82	466	947	3.0
	Admin/data center	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	866	40,857	164,429	514,673	4.1
	Admin/data center	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	226	12,212	54,810	149,172	3.7
	Admin/data center	Replace existing electric water heater with heat pump water heater	14	789	6,426	480	1.1
	Admin/data center	Replace existing electric water heater with heat pump water heater	6	313	1,285	885	2.3
	Admin/data	Replace existing air-cooled chiller with water-cooled	1,881	83,890	545,818	443,733	2.1

FEDS Category		Technology Change	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
	center	reciprocating electric chiller (very high efficiency) and cooling tower					
	storage	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	309	1,864	3,463	2.9
	storage	Replace existing 2x4 3-tube T8 lighting with 2X4 2-tube advanced (super) T8 32W with reflector	574	35,800	126,334	473,136	4.7
	storage	Replace 400W metal halide lighting with 310W high pressure sodium	21	815	4,422	9,011	3.0
	TOTAL		3,590	175,313	907,252	1,598,343	2.8
631	NEX	Replace 75W Incandescent light with 18W CFL	182	12,285	1,448	205,235	142.7
	NEX	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	2	483	2,795	5,523	3.0
	NEX	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	1,989	105,041	475,490	1,278,087	3.7
	NEX	Replace existing electric water heater with heat pump water heater	275	14,340	10,318	56,699	12.9
	Food Court	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	169	932	1,983	3.1
	Food Court	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	305	14,514	52,295	189,094	4.6
	Food Court	Replace existing propane water heater with heat pump water heater	13	256	514	522	4.6
	Food Court	Replace existing propane water heater with heat pump water heater	13	256	514	522	4.6
	Food Court	Replace existing propane water heater with heat pump water heater	13	256	514	522	4.6
	Food Court	Replace existing propane water heater with heat pump water heater	13	256	514	522	4.6
	Food Court	Replace existing propane water heater with heat pump water heater	13	256	514	522	4.6
	Food Court	Suspended Ceiling: Increase Insulation by R-19	61	4,158	60,272	8,903	1.1
	TOTAL		2,880	152,270	606,120	1,748,134	3.9

FEDS Category		Technology Change	Energy Savings (MMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
1670	1-story admin	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	108	621	1,257	3.0
	1-story admin	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	37	2,086	22,198	12,593	1.6
	1-story admin	Replace existing air-cooled chiller with water-cooled reciprocating electric chiller (very high efficiency) and cooling tower	88	4,829	45,111	14,811	1.5
	2-story shops	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	2	328	1,864	3,793	3.0
	2-story shops	Replace existing 2x4 2-tube T8 lighting with 2X4 2-tube advanced (super) T8 25W with reflector	435	20,938	103,038	245,123	3.4
	2-story shops	Replace 250W metal halide lighting with 2x3 6-tube biaxial lighting with reflector	42	2,564	15,327	27,826	2.8
	2-story shops	Replace existing air-cooled chiller with water-cooled reciprocating chiller (very high efficiency) and cooling tower	473	25,822	137,260	148,869	2.6
	2-story shops	Service hot water: rap Tank with Insulation, Insulate Pipe Near Tank, Low flow shower heads, Aerators, Lower Tank Temperature	27	1,331	1,581	6,154	11.7
	1 story high bay	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	-	102	621	1,161	2.9
	1 story high bay	Replace 400W metal halide lighting with 310W high pressure sodium	72	4,271	45,479	25,847	1.6
	TOTAL		1,177	62,379	373,100	487,434	2.3

Appendix B-2
Comprehensive List of Cost-Effective Projects Identified from the FEDS Assessment Using Alternative Financing Sources of Capital

Table B-2 identifies the 38 cost-effective energy- and cost-reducing retrofit projects identified from the FEDS modeling and analysis based on the assumption that they will be funded using alternative financing source of capital funds. Alternative financing includes UESC and ESPC, as well as any other third party financing. Key energy and economic results are presented for each cost-effective retrofit measure. The projects are grouped by building category.

Table B-2 Comprehensive List of Cost-Effective Projects Using Alternative Financing Sources of Capital

FEDS Category		Technology Change	Energy Savings (MMMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
87	Data Center	Replace air-cooled chillers with water-cooled reciprocating electric chiller (very high efficiency) and cooling tower	879	30,223	120,226	122,026	2.0
		Replace electric water heater with heat pump water heater	5	98	497	1,100	3.2
		Replace electric water heater with heat pump water heater	3	101	497	243	1.5
		Replace existing 2x4 3-tube T8 with 2X4 3-tube advanced (super) 25W T8 with reflector	154	5,717	24,014	20,875	1.9
		Suspended Ceiling: Increase Insulation by R-11	1,066	44,547	45,843	311,198	7.8
	TOTAL		2,107	80,686	191,077	455,442	3.4
167	Admin/control room	Replace existing 1x8 2-tube T8 with 2X4 3-tube advanced (super) T8	549	11,854	173,294	2,304	1.0
		Replace existing 2x4 2-tube T8 with 2X4 2-tube advanced (super) 25W T8 with reflector	294	7,202	33,975	18,079	1.5
		Replace existing 2x4 3-tube T8 with 2X4 3-tube advanced (super) 25W T8 with reflector	337	7,282	78,535	16,259	1.2
		Replace existing 2x4 4-tube T8 lighting with 2X4 3-tube advanced (super) T8 with reflector	389	8,410	59,058	43,739	1.7
		Replace existing 2x4 4-tube T8 lighting with 2X4 3-tube advanced (super) T8 with reflector	43	948	6,948	4,880	1.7
		Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	2	44	1,459	16	1.0
		Replace propane water heater with heat pump water heater plus misc. measures	48	1,127	4,020	12,552	4.1
		Service hot water: Install faucet aerators, lower tank temperature	1	33	19	231	13.4
	storage	Service hot water: Install faucet aerators, lower tank temperature	2	57	63	667	11.5
	TOTAL		1,665	36,957	357,371	98,727	1.3
440	East Wing	Replace 3-lamp T-8s with 2-lamp super T-8s	47	2,606	13,267	2,746	1.2
	East Wing	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	122	640	108	1.2
	East Wing	Add 4 inches fiberglass insulation to interior surface of metal roof	130	7,815	26,665	21,356	1.8

FEDS Category		Technology Change	Energy Savings (MMMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
	Cooled Center	Replace existing packaged DX AC with higher efficiency unit	32	6,132	35,326	2,352	1.1
	Cooled Center Admin	Replace 3-lamp T-8s with 2-lamp super T-8s	84	4704	24301	4602	1.2
	Cooled Center Admin	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	61	320	53	1.2
	Cooled Center Shops	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	61	320	53	1.2
	Cooled Center	Add 4 inches fiberglass insulation to interior surface of metal roof	426	26825	97683	67147	1.7
	Cooled A Wing	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	185	960	179	1.2
	Cooled A Wing	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	185	960	179	1.2
	Cooled A Wing	Increase insulation by R-11 above suspended ceiling	97	5405	32271	938	1
	Uncooled A Wing	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	57	320	33	1.1
	Uncooled Center	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	0	57	320	33	1.1
	TOTAL		819	54,215	233,353	99,779	1.4
475	Admin/data center	Replace electric water heater with heat pump water heater	6	168	1,491	307	1.2
		Replace existing 2x4 2-tube T8 with 2X4 2-tube advanced (super) 25W T8 with reflector	896	33,264	190,738	68,844	1.4
		Replace existing 2x4 2-tube T8 with 2X4 2-tube advanced (super) 25W T8 with reflector	233	8,347	63,579	7,066	1.1
		Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	49	1,621	12	1.0
		Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	<1	16	540	4	1.0
	storage	Replace existing 2x4 3-tube T8 lighting with 2X4 2-tube advanced (super) T8 with reflector	574	17,040	146,548	88,160	1.6
		Replace existing 400W MH lighting with 310W HPS lighting	21	769	5,129	855	1.2
	TOTAL		1,731	59,653	409,646	165,248	1.4
631	NEX Food Court	Replace existing 2x4 2-tube T8 with 2X4 2-tube advanced (super) 25W T8	305	11,403	60,662	30,816	1.5

FEDS Category		Technology Change	Energy Savings (MMMBtu/yr)	1st Year Savings ($/yr)	Installed Cost ($)	Net Present Value ($)	SIR
		with reflector					
		Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	36	1,081	35	1.0
		Replace propane water heater with heat pump water heater	13	290	596	1,349	3.3
		Replace propane water heater with heat pump water heater	13	290	596	1,349	3.3
		Replace propane water heater with heat pump water heater	13	290	596	1,349	3.3
		Replace propane water heater with heat pump water heater	13	290	596	1,349	3.3
		Replace propane water heater with heat pump water heater	13	290	596	1,349	3.3
	NEX	Replace existing 2x4 2-tube T8 with 2X4 2-tube advanced (super) 25W T8 with reflector	2,286	83,491	551,569	152,826	1.3
		Replace existing 40W INC spot with 11W CFL	241	8,946	2,805	95,741	35.1
		Replace existing 75W INC with 18W CFL	210	7,294	1,680	77,923	47.4
		Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	3	100	3,243	58	1.0
		Replace propane water heater with heat pump water heater plus misc. measures	275	8,604	11,969	70,317	6.9
	TOTAL		3,386	121,324	635,989	434,461	1.7
1670	1 story Admin	Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	1	23	721	18	1.0
	2-story	Replace existing 250W MH lighting with 6-tube biaxial lighting with reflector	47	1,873	17,779	874	1.0
		Replace existing 2x4 2-tube T8 with 2X4 2-tube advanced (super) 25W T8 with reflector	483	17,840	119,525	57,486	1.5
		Replace LED exit signs with ELECTROLUMINESCENT PANEL RETRO KIT	2	70	2,162	65	1.0
		Service hot water: Iinstall LFSHs, Aerators, Lower Tank Temperature	24	805	861	6,139	8.1
	TOTAL		557	20,611	141,048	64,582	1.5

Appendix C

Building Details

Appendix C
Energy Conservation Measures for Pearl Harbor Buildings

The following sections describe in detail the cost-effective retrofit projects for the six buildings visited by PNNL. Energy consumption by fuel type and building energy system are presented along with the direct and indirect (e.g., at the utility power plant for electricity consumption) emissions impacts. The figures presented are for the case of appropriated funding.

Building 87 Data Center

Building 87 is a 53,724 ft^2 data center built inside an historic hanger on Ford Island at Pearl Harbor Naval Base. The building is a wood frame construction connected to existing concrete walls inside the hanger. The ceiling of the data center is connected to the metal structure of the original hanger leaving a very tall open space above the data center ceiling and the existing hanger roof.

The building has a large server room (approximately 8,600 ft^2), in addition to general office space. The building also has a 24/7 control and dispatch room, which was inaccessible during the auditing team's visit. The hanger doors on the southwest end opens to a 6,000 ft^2 high bay space that is the full height of the existing hanger. This space is not conditioned.

Cooling is provided by a 60-ton air-cooled chiller providing chilled water to air-handling units in the building. The server space, electrical room, and uninterruptible power supply (UPS) room are cooled with 11 Liebert air-cooled chillers. These were installed in 2001 and provide approximately 250 tons of cooling. Because of the sensitive computer systems, climate control is continuous and operates within a narrow band.

The largest single load in the building is the computers in the data center. The data center is served by 2, 750-kVA UPS systems. During the site visit, these were showing loads between 155 – 166 kVA and 179 – 187 kVA, respectively.

The predominant lighting type (approximately 75%) is 2-tube F32T8 lighting installed in 2x4 fixtures in the suspended ceiling. Hallways and admin spaces have 2x2 fixtures with 2-tube F32T8U U-type lamps. The open high-bay space has eight 400-watt metal halide fixtures.

The building has one 10-gallon electric hot water heater in the kitchen area.

Energy Consumption by Fuel Type

The actual metered energy consumption for FY2009 was 5,454,720 kWh. The modeled energy consumption for a typical year was 5,445,574 kWh before retrofits and 4,554,094 kWh after proposed retrofits are implemented. The energy use intensity goes from 619.5 MMBtu/Ksf to 518.1 MMBtu/Ksf after retrofits.

Annual Energy Use by Building Set and Fuel Type

Building Set ... 87 (Data Center)
Data Center Hanger

Fuel	Energy	Energy Intensity (user units/1000ft2)	Energy Intensity (MMBtu/1000ft2)	Dollars (2009)*
Electricity (kWh)				
existing	5,445,574	181,519.1	619.5	930,039
post-retrofit	4,554,094	151,803.1	518.1	773,290
difference	-891,480	-29,716.0	-101.4	-156,748
% change	-16	-16	-16	-17
Total (MMBtu)				
existing	18,586	619.5	619.5	930,039
post-retrofit	15,543	518.1	518.1	773,290
difference	-3,043	-101.4	-101.4	-156,748
% change	-16	-16	-16	-17

* Dollar values for electricity include both energy and demand components.

Energy Consumption by End Uses

During a typical year, the computer loads are the largest energy user with over 2,960 MWh/ year, followed by cooling with 1,624 MWh/year.

Annual Energy Use by Building Set, Fuel Type, and End Use
Building Set ... 87 (Data Center)
Data Center Hanger

Fuel	Heating	Cooling	Vent	Lights	Motors and Misc Equip	Hot Water *
Electricity (kWh)						
existing	0	1,624,274	659,145	199,426	2,960,248	2,481
post-retrofit	0	785,607	659,145	148,759	2,960,248	335
difference	0	-838,667	0	-50,667	0	-2,146
% change	0	-52	0	-25	0	-86
Total (MMBtu)						
existing	0	5,544	2,250	681	10,103	8
post-retrofit	0	2,681	2,250	508	10,103	1
difference	0	-2,862	0	-173	0	-7
% change	0	-52	0	-25	0	-86
Total (MMBtu/1000ft2)						
existing	0	185	75	23	337	0
post-retrofit	0	89	75	17	337	0
difference	0	-95	0	-6	0	0
% change	0	-52	0	-25	0	-86

* Energy consumption values for both distributed and central SHW are reported for Hot Water annual energy use.

Emission Reduction

The emission reductions from implementing the proposed retrofits are as follows:

```
        Annual Emissions by Building Set and Pollutant Type
                  Building Set... 87 (Data Center)
                       Data Center Hanger

Sulfur Oxides (lb)
 existing                          49,228
 post-retrofit                     41,169
 difference                        -8,059
 % change                             -16

Nitrogen Oxides (lb)
 existing                          23,524
 post-retrofit                     19,673
 difference                        -3,851
 % change                             -16

Carbon Monoxide (lb)
 existing                          40,461
 post-retrofit                     33,837
 difference                        -6,624
 % change                             -16

Carbon Dioxide (tons)
 existing                           4,983
 post-retrofit                      4,167
 difference                          -816
 % change                             -16

Particulate Matter (lb)
 existing                             974
 post-retrofit                        814
 difference                          -159
 % change                             -16

Hydrocarbons (lb)
 existing                          16,746
 post-retrofit                     14,004
 difference                        -2,741
 % change                             -16
```

Additional Considerations

This assessment was limited to developing the model and producing the typical retrofits that are built into the FEDS model. As part of the current PACOM ARRA funding, Lawrence Berkeley National Laboratory will be studying other efficiency measures in the data center.

Photos

Because of security concerns, building photos were not permitted during the audit. Publicly available satellite images show the exterior of Building 87.

Photo courtesy Microsoft Corporation BING.COM maps.

Figure C1. Building 87 Satellite Image

Building 167 Engineering Warehouse

Building 167 is a 450,000 ft^2 mixed-use building. Large areas of unconditioned storage space occupy the lower three floors. Unconditioned warehouse space accounts for 193,500 ft^2 of space and 43% of the building total. Administrative spaces occupy the top two floors and parts of floors 1 through 3. Administrative space accounts for 256,500 ft^2 of space and 57% of the total building. The upper floors also have small laboratory, electronics and testing spaces. The first floor also houses a control/situation room and computer lab.

The building is primarily cooled by the chilled water plant located directly across the street from 167. This plant has three 800-ton water-cooled chillers installed in 1999. In addition to the central chiller plant, supplemental cooling is provided by multiple air-cooled chillers and package units.

Building 167 has mix of lighting vintages and types because the building use has changed and equipment has been replaced on an ad hoc basis. The storage areas of the building have predominantly older T12 lighting. Approximately 75% of the lighting is 8-foot, 2-tube T12 fluorescent, while the remainder is 8-foot, 2-tube T8 fluorescent. The administrative space and small labs are predominantly T8 fluorescent in the form of 8-foot 2-tube T8 (20%), 2x4 2-tube T8 (2%), 2x4 3-tube T8 (19%), 2x4 4-tube T8 (2%), 4-foot 2-tube T8 (35%), and 2x2 2-tube U-shaped T8 (2%).

The building has a range of use types including unconditioned storage, standard office, small labs, and a small control center. The control room has a small computer center with dedicated air-conditioning system and UPS.

Energy Consumption by Fuel Type

The actual metered energy consumption for FY2009 was 5,530,000 kWh. The modeled electrical consumption for a typical year (not including central plant energy) was 4,341,739 kWh before retrofits and 3,883,019 kWh after proposed retrofits are implemented. The energy use intensity goes from 72.9 MMBtu/Ksf to 65.7 MMBtu/Ksf after retrofits.

Annual Energy Use by Building Set and Fuel Type
Building Set ... 167
Warehouse (Admin)

Fuel	Energy	Intensity (user units/1000ft2)	Intensity (MMBtu/1000ft2)	Dollars (2009)*
Electricity (kWh)				
existing	4,341,739	9,648	32.9	741,517
post-retrofit	3,883,019	8,629	29.4	659,341
difference	-458,720	(1,019)	(3.5)	(82,176)
% change	10.6	10.6	10.6	11.1
Central Chilled Water				
existing	1,498,293	3,330	40.0	173,444
post-retrofit	1,360,479	3,023	36.3	157,490
difference	-137,814	(306)	-3.7	(15,954)
% change	9.2	9.2	9.2	9.2
Total (MMBtu)				
existing	32,798	72.9	72.9	914,961
post-retrofit	29,579	65.7	65.7	816,831
difference	-3,219	(7.2)	(7.2)	(98,130)
% change	9.8	9.8	9.8	10.7

Energy Consumption by End Uses

Cooling is the largest energy consumer in the facility with 19,908 MMBtu/year, while motors and other miscellaneous loads are estimated to consume 5,993 MMBtu/year.

Annual Energy Use by Building Set, Fuel Type, and End Use
Building Set ... 167

Fuel	Heating	Cooling	Vent	Lights	Motors and Misc Equip	Hot Water *
Electricity (kWh)						
existing	0	564,661	574,082	1,429,066	1,755,819	18,111
post-retrofit	0	511,737	517,053	1,095,565	1,755,819	2,845
difference	0	(52,924)	(57,029)	(333,501)	-	(15,266)
% change	0.0	9.4	9.9	23.3	0.0	84.3
Central Chilled Water						
existing	0	1,498,293	-	-	-	-
post-retrofit	0	1,360,479	-	-	-	-
difference	0	(137,814)	-	-	-	-
% change	0.0	9.2	0.0	0.0	0.0	0.0
Total (MMBtu)						
existing	0	19,908	1,959	4,877	5,993	62
post-retrofit	0	18,073	1,765	3,739	5,993	10
difference	0	(1,835)	(194)	(1,138)	-	(52)
% change	0.0	9.2	9.9	23.3	0.0	83.9
Total (MMBtu/1000ft2)						
existing	0	78	8	20	25	-
post-retrofit	0	70	7	15	25	-
difference	0	(8)	(1)	(5)	-	-
% change	0.0	10.3	12.5	25.0	0.0	0.0

* Energy consumption values for both distributed and central SH W are reported f or Hot Water annual energy use.

Emission Reduction

The emission reductions from implemented the proposed retrofits are as follows:

```
       Annual Emissions by Building Set and Pollutant Type
       Building Set... 167 (storage)

Sulfur Oxides (lb)
existing                   48,430
post-retrofit              43,439
difference                 -4,991
% change                   10.3

Nitrogen Oxides (lb)
existing                   23,142
post-retrofit              20,758
difference                 -2,384
% change                   10.3

Carbon Monoxide (lb)
existing                   39,805
post-retrofit              35,703
difference                 -4,102
% change                   10.3

Carbon Dioxide (tons)
existing                   4,902
post-retrofit              4,396
difference                 -506
% change                   10.3

Particulate Matter (lb)
existing                   958
post-retrofit              859
difference                 -99
% change                   10.3

Hydrocarbons (lb)
existing                   16,475
post-retrofit              14,776
difference                 -1,699
% change                   10.3
```

Additional Considerations

The storage areas should be evaluated for zone-based occupancy sensors to control existing lighting. Specific implementation of controls and zoning are not automatically included in the FEDS energy model.

Photos

Because of security concerns, building photos were not permitted during the audit. Publicly available satellite images show the exterior of Building 167.

Photo courtesy Microsoft Corporation BING.COM maps.

Figure C2. Building 167 Satellite Imagery

Building 440

Building 440 (including 440A) is a 68,000 ft^2 mixed-use building with administrative space and both conditioned and unconditioned shops. The building is comprised of three sections built in different eras. The original structure sits roughly in the middle and consists of a mixture of shop and office space. An east wing was added later that contains a supply area and lunchroom. The most recent addition (440A) also consists of a mixture of shops and offices. This portion of the building has several high-bay rooms. About 20% of 440A and 10% of the original structure are not cooled. The east wing is entirely cooled.

Space cooling is provided by a combination of air-cooled chillers and direct expansion (DX) equipment. Two 60-ton Trane chillers serve the 440A addition. Three 5.83 ton Filtrine chillers provide direct cooling of test equipment in 440A. Two more 5.83-ton Filtrine chillers cool equipment in the original structure. The shop that is served by the two Filtrine chillers is also served by a 40-ton DX unit (no access to roof, so manufacturer is unknown). The northern half of the original building and the east wing are served by three 20-ton Trane DX units and several single-room DX units. Finally, the south end of the main building is served by a 40-ton Trane chiller.

Building lighting consists of a wide array of fixture types, sizes, and number of lamps per fixture, but it appears to be entirely T-8 fluorescent. There are about two dozen incandescent can lamps in the conference room, but that technology is required to allow dimming when needed. Exit signs are LED type.

Energy Consumption by Fuel Type

The actual metered energy consumption for FY2009 was 1,335,680 kWh. The modeled energy consumption for a typical year was 1,247,303 kWh before retrofits and 946,089 kWh after proposed retrofits are implemented. The energy use intensity goes from 62.4 MMBtu/ksf to 47.3 MMBtu/ksf after retrofits.

Annual Energy Use by Building Set and Fuel Type
Building Set ... 440

Fuel	Energy (kWh)	Intensity (kWh/1000ft2)	Intensity (MMBtu/1000ft2)	Dollars (2010)
Electricity				
existing	1,247,303	18,280	62.4	243,675
post-retrofit	946,089	13,866	47.3	182,426
difference	-301,214	-4,415	-15.1	-61,250
% change	-24	-24	-24	-25

Fuel	(MMBtu)
Electricity	
existing	4,257
post-retrofit	3,229
difference	-1,028
% change	-24

Energy Consumption by End Uses

Cooling is estimated to consume 1,601 MMBtu/year, while motors and equipment are the second largest use at 1,260 MMBtu/year. Ventilation and lighting energy use are approximately the same and combine to consume 1,375 MMBtu/year.

Annual Energy Use by Building Set, Fuel Type, and End Use
Building Set ... 440

Fuel	Heating	Cooling	Vent	Lights	Motors and Misc Equip	Hot Water
Electricity (kWh)						
existing	0	469,080	223,140	179,584	369,171	6,328
post-retrofit	0	251,151	192,403	127,036	369,171	6,328
difference	0	(217,930)	(30,737)	(52,548)	-	-
% change	0	-46	-14	-29	-	-
Electricity (MMBtu)						
existing	0	1,601	762	613	1,260	22
post-retrofit	0	857	657	434	1,260	22
difference	0	(744)	(105)	(179)	-	-
% change	0	-46	-14	-29	-	-
Electricity(MMBtu/1000ft2)						
existing	0	23.5	11.2	9.0	18.5	0.3
post-retrofit	0	12.6	9.6	6.4	18.5	0.3
difference	0	(10.9)	(1.6)	(2.6)	-	-
% change	0.0	-46	-14	-29	-	-

Emission Reduction

Current and prospective indirect (at the utility power plant) emissions from implementing the proposed retrofits are as follows:

Annual Emissions by Building Set and Pollutant Type
Building Set... 440

Sulfur Oxides (lb)	
existing	11,276
post-retrofit	8,553
difference	-2,723
% change	-24
Nitrogen Oxides (lb)	
existing	5,388
post-retrofit	4,087
difference	-1,301
% change	-24
Carbon Monoxide (lb)	
existing	9,268
post-retrofit	7,030
difference	-2,238
% change	-24
Carbon Dioxide (tons)	
existing	1,141
post-retrofit	866
difference	-276
% change	-24
Particulate Matter (lb)	
existing	223
post-retrofit	169
difference	-54
% change	-24
Hydrocarbons (lb)	
existing	3,836
post-retrofit	2,909
difference	-926
% change	-24

Additional Considerations

Combining and replacing the existing three air-cooled chillers (not counting the Filtrine equipment coolers) with a pair of water-cooled chillers would save energy, but should be evaluated for cost-effectiveness.

Photos

Because of security concerns, building photos were not permitted during the audit. Publicly available satellite images show the exterior of Building 440.

Photo courtesy Microsoft Corporation BING.COM Maps.

Figure C3. Building 440 Satellite Imagery

Building 475

Building 475 is a 288,000 ft^2 mixed-use building with administrative space, unconditioned warehouse space, and a data center. Unconditioned storage is the predominant use type in the building representing 190,400 ft^2 and roughly 66% of the floor area. Unconditioned storage is found on floors 4, 5, and 6; the south receiving dock on the first floor; and a small, unused area on the 3rd floor. Approximately, 82,400 ft^2 (29% of the total area) is dedicated to administrative space, including all of the 2nd floor and parts of floors 1 and 3. Finally, a 15,200 ft^2 data center is located on the 3rd floor.

Space cooling is provided by ten air-cooled chillers with a 200-ton total capacity located on the roof. Only the administrative spaces and the data center are currently cooled by air-handling units in the zone.

Lighting in the administrative spaces is provided by 2x4 2-tube T8 where suspended ceiling exists or 4-foot 2-tube T8 direct/indirect lighting over cubicals in open spaces. Storage areas have 4-foot 2-tube T8 surface mounted lighting. The receiving dock on the first floor has a few metal halide lights.

Energy Consumption by Fuel Type

The actual metered energy consumption for FY2009 was 5,984,000 kWh. The modeled energy consumption for a typical year was 6,015,439 kWh before retrofits and 4,953,940 kWh after proposed retrofits are implemented. The energy use intensity goes from 71.3 MMBtu/Ksf to 58.7 MMBtu/Ksf after retrofits.

Annual Energy Use by Building Set and Fuel Type
Building Set ... 475

Fuel	Energy	Intensity (user units/1000ft2)	Intensity (MMBtu/1000ft2)	Dollars (2009)*
Electricity (kWh)				
existing	6,015,439	20,887	71.3	1,027,365
post-retrofit	4,953,940	17,201	58.7	841,185
difference	-1,061,499	(3,686)	(12.6)	(186,180)
% change	17.6	17.6	17.6	18.1
Total (MMBtu)				
existing	20,525	71.3	71.3	1,027,365
post-retrofit	16,903	58.7	58.7	841,185
difference	-3,622	(12.6)	(12.6)	(186,180)
% change	17.6	17.6	17.6	18.1

Energy Consumption by End Uses

The motors and other miscellaneous loads are the largest consumers, using an estimated 7,385 MMBtu/year. Cooling is the second largest consumer with over 6,449 MMBtu/year. Lighting energy use was quite high in the facility with over 4,140 MMBtu/year, primarily the result of shift work and HID lighting.

Annual Energy Use by Building Set, Fuel Type, and End Use
Building Set ... 475

Fuel	Heating	Cooling	Vent	Lights	Motors and Misc Equip	Hot Water *
Electricity (kWh)						
existing	0	1,889,372	742,680	1,212,886	2,163,695	6,807
post-retrofit	0	1,341,999	633,718	813,608	2,163,695	919
difference	0	(547,373)	(108,962)	(399,278)	-	(5,888)
% change	0.0	29.0	14.7	32.9	0.0	86.5
Central Chilled Water						
existing	0	-	-	-	-	-
post-retrofit	0	-	-	-	-	-
difference	0	-	-	-	-	-
% change	0.0	0.0	0.0	0.0	0.0	0.0
Total (MMBtu)						
existing	0	6,449	2,535	4,140	7,385	23
post-retrofit	0	4,581	2,163	2,777	7,385	3
difference	0	(1,868)	(372)	(1,363)	-	(20)
% change	0.0	29.0	14.7	32.9	0.0	87.0
Total (MMBtu/1000ft2)						
existing	0	22.4	8.8	14.4	25.6	0.1
post-retrofit	0	15.9	7.5	9.6	25.6	0.0
difference	0	(6)	(1)	(5)	-	(0)
% change	0.0	29.0	14.7	32.9	0.0	87.0

* Energy consumption values for both distributed and central SHW are reported for Hot Water annual energy use.

Emission Reduction

The emission reductions from implementing the proposed retrofits are as follows:

```
Annual Emissions by Building Set and Pollutant Type
Building Set... 475

Sulfur Oxides (lb)
existing                   54,380
post-retrofit              44,784
difference                 -9,596
% change                   17.6

Nitrogen Oxides (lb)
existing                   25,986
post-retrofit              21,400
difference                 -4,586
% change                   17.6

Carbon Monoxide (lb)
existing                   44,696
post-retrofit              36,808
difference                 -7,888
% change                   17.6

Carbon Dioxide (tons)
existing                   5,505
post-retrofit              4,533
difference                 -972
% change                   17.7

Particulate Matter (lb)
existing                   1,076
post-retrofit              886
difference                 -190
% change                   17.7

Hydrocarbons (lb)
existing                   18,499
post-retrofit              15,234
difference                 -3,265
% change                   17.6
```

Additional Considerations

The storage areas should be evaluated for zone-based occupancy sensors to control existing lighting. Specific implementation of controls and zoning are not automatically included in the FEDS energy model.

Photos

Because of security concerns, building photos were not permitted during the audit. Publicly available satellite images show the exterior of Building 475.


Photo courtesy Microsoft Corporation BING.COM Maps.

Figure C4. Building 475 Satellite Imagery

Building 631 Naval Exchange (NEX)

Building 631, the Naval Exchange building, was built in 2002 and covers 285,515 ft^2. It is the largest Exchange in the military. It is actually more similar to a small shopping mall than just a retail store. It is attached to the Commissary by a common wall (not covered in this assessment), and includes a large, 2-story atrium and attached food court.

Cooling is provided by 24 roof-top units with a total cooling capacity of 659 tons.

Lighting in the store is provided predominantly by 2x4 2-tube T8 fixures. Additional display or specialty lighting is present in many areas such as 2-lamp CFL recessed fixtures, R20 INC track lighting, and biaxial fluorescent wall washing fixtures.

Service hot water is provided by electric hot water heaters in the store restrooms and propane water heaters in the food service area.

Energy Consumption by Fuel Type

The actual metered energy consumption (Exchange only) for FY2009 was 5,331,120 kWh, making it one of the largest energy consumers on base. The modeled energy consumption for a typical year was 5,843,265 kWh before retrofits and 4,304,693 kWh after proposed retrofits are implemented. The energy use intensity goes from 69.8 MMBtu/Ksf to 51.4 MMBtu/Ksf after retrofits.

Annual Energy Use by Building Set and Fuel Type
Building Set ... 631

Fuel	Energy	Intensity (user units/1000ft2)	Intensity (MMBtu/1000ft2)	Dollars (2009)*
Electricity (kWh)				
existing	5,843,265	20,466	69.8	997,960
post-retrofit	4,304,693	15,077	51.4	730,942
difference	-1,538,572	(5,389)	(18.4)	(267,018)
% change	26.3	26.3	26.3	26.8
Other Fuels (MMBtu)				
existing	75	0.3	0.3	1,684
post-retrofit	0	-	0.0	0
difference	-75	(0.3)	-0.3	(1,684)
% change	100	100	100	100
Total (MMBtu)				
existing	19,937	69.8	69.8	245,508
post-retrofit	14,688	51.4	51.4	224,434
difference	-5,250	(18.4)	(18.4)	(21,074)
% change	26.3	26.3	26.3	8.6

Energy Consumption by End Uses

Because the NEX is primarily retail and has long hours, lighting is the largest end-use with 2,098,352 MMBtu/year, while cooling is the second largest consumer, using over 1,889,549 kWh/year.

Annual Energy Use by Building Set, Fuel Type, and End Use
Building Set ... 631

Fuel	Heating	Cooling	Vent	Lights	Motors and Misc Equip	Hot Water *
Electricity (kWh)						
existing	0	1,889,549	530,504	2,098,352	1,232,050	92,812
post-retrofit	0	1,069,912	506,058	1,482,366	1,232,050	14,309
difference	0	(819,637)	(24,446)	(615,986)	-	(78,503)
% change	0.0	43.4	4.6	29.4	0.0	84.6
Other Fuels (MMBtu)						
existing	0	-	-	-	-	75
post-retrofit	0	-	-	-	-	-
difference	0	0	0	0	0	-75
% change	0.0	0.0	0.0	0.0	0.0	100.0
Central Chilled Water						
existing	0	-	-	-	-	-
post-retrofit	0	-	-	-	-	-
difference	0	0	0	0	0	0
% change	0.0	0.0	0.0	0.0	0.0	0.0
Total (MMBtu)						
existing	0	4,793	1,315	6,364	2,282	317
post-retrofit	0	2,147	1,237	4,472	2,282	41
difference	0	-2,646	-78	-1,892	0	-276
% change	0.0	55.2	5.9	29.7	0.0	87.1
Total (MMBtu/1000ft2)						
existing	0	16.8	4.6	22.3	8.0	1.1
post-retrofit	0	7.5	4.3	15.7	8.0	0.1
difference	0	-9	0	-7	0	-1
% change	0.0	55.2	5.9	29.7	0.0	87.1

* Energy consumption values for both distributed and central SHW are reported for Hot Water annual energy use.

Emission Reduction

The emission reductions from implementing the proposed retrofits are as follows:

Annual Emissions by Building Set and Pollutant Type
Building Set... 631

Sulfur Oxides (lb)	
existing	52,842
post-retrofit	38,915
difference	-13,927
% change	26.4
Nitrogen Oxides (lb)	
existing	25,268
post-retrofit	18,596
difference	-6,672
% change	26.4
Carbon Monoxide (lb)	
existing	43,473
post-retrofit	31,985
difference	-11,488
% change	26.4
Carbon Dioxide (tons)	
existing	5,353
post-retrofit	3,938
difference	-1,415
% change	26.4
Particulate Matter (lb)	
existing	1,046
post-retrofit	769
difference	-277
% change	26.5
Hydrocarbons (lb)	
existing	4,409
post-retrofit	4,065
difference	-344
% change	7.8

Additional Considerations

None.

Photos

The following photo’s show current building condition.

Photo courtesy Microsoft Corporation BING.COM

Figure C5. Building 631 Satellite Imagery

Figure C6. Miscellaneous Photos of NEX

Building 1670

Building 1670 is a 141,354 ft^2 mixed use building consisting of administrative space, high bay space, shops, and a large sewing area. Small administrative areas are dispersed throughout the building, although the west one story addition is dedicated to administrative functions. The large high bay is unconditioned, although small portable/trailers are used as office space, cooled by window units. A number of other shops are housed in the building including rigging shops, small machine shops, and a sand blasting shop. Because of the activity in the building and nearby work, a large shower facility is located on the second floor of the two story section. Finally, the east end of the building is a two-story addition that houses the sewing functions on the top floor.

Cooling on the one-story administrative addition is provided by a roof-mounted air-cooled package unit. The high bay spaces are uncooled, except for office areas, which are cooled by window units as noted. The two-story section has two roof-mounted air-cooled chillers.

The one-story administrative addition is lit entirely with 2x4 2-tube and 2x2 U-tube F32T8 lights in the suspended ceiling. The high bay shop area has 60 skylights and the sewing shop has 20 skylights, which provide light to the space. The skylights are of poor quality with no dispersion of light, which creates strong light areas and shadows on the work space below. When people move around the space below, their eyes have to constantly adjust to the shadows and beams of light. Approximately 72, 400-watt metal halide pendent lights provide light to the high bay, although there was ample natural light at the time of the visit. The 2-story section has 36, 250-watt metal halide pendent lights in the sewing space. Miscellaneous T8 fluorescent lighting is scattered throughout.

Hot water for the shower area is provided by an electric water heater with two, 300 gallon tanks. With over 32 shower heads, the model estimates that over 400 gallons of hot water is used each day.

Energy Consumption by Fuel Type

The actual metered energy consumption for FY2009 was 1,870,080 kWh. The modeled energy consumption for a typical year was 1,927,940 kWh before retrofits and 1,566,848 kWh after proposed retrofits are implemented. The energy use intensity goes from 46.5 MMBtu/Ksf to 37.8 MMBtu/Ksf after retrofits.

Annual Energy Use by Building Set and Fuel Type
Building Set ... 1670

Fuel	Energy	Intensity (user units/1000ft2)	Intensity (MMBtu/1000ft2)	Dollars (2009)*
Electricity (kWh)				
existing	1,927,940	13,639	46.5	329,268
post-retrofit	1,566,848	11,085	37.8	266,052
difference	-361,092	(2,555)	(8.7)	(63,216)
% change	18.7	18.7	18.7	19.2
Total (MMBtu)				
existing	6,580	47	46.5	329,268
post-retrofit	5,348	38	37.8	266,052
difference	-1,232	(9)	(8.7)	(63,216)
% change	18.7	18.7	18.7	19.2

Energy Consumption by End Uses

The motors and other miscellaneous loads are estimated to consume 693,189 kWh/year, while cooling is the second largest consumer with over 580,164 kWh/year. Lighting energy use was quite high in the facility with over 500,506 kWh/year, primarily the result of shift work and HID lighting.

Annual Energy Use by Building Set, Fuel Type, and End Use
Building Set ... 1670

Fuel	Heating	Cooling	Vent	Lights	Motors and Misc Equip	Hot Water *
Electricity (kWh)						
existing	-	567,052	145,162	500,506	693,189	22,032
post-retrofit	-	351,225	136,175	372,010	693,189	14,252
difference	0	(215,827)	(8,987)	(128,496)	-	(7,780)
% change	0.0	38.1	6.2	25.7	0.0	35.3
Total (MMBtu)						
existing	-	1,935	495	1,708	2,365	76
post-retrofit	-	1,198	465	1,270	2,365	49
difference	0	-737	-30	-438	0	-27
% change	0.0	38.1	6.1	25.6	0.0	35.5
Total (MMBtu/1000ft2)						
existing	0	13.7	3.5	12.1	16.7	0.5
post-retrofit	0	8.5	3.3	9.0	16.7	0.3
difference	0	-5	0	-3	0	0
% change	0.0	38.1	6.1	25.6	0.0	35.5

* Energy consumption values for both distributed and central SHW are reported for Hot Water annual energy use.

Emission Reduction

The emission reductions from implementing the proposed retrofits are as follows:

Annual Emissions by Building Set and Pollutant Type
Building Set... 1670

Sulfur Oxides (lb)	
existing	17,429
post-retrofit	14,164
difference	-3,265
% change	18.7
Nitrogen Oxides (lb)	
existing	8,328
post-retrofit	6,768
difference	-1,560
% change	18.7
Carbon Monoxide (lb)	
existing	14,325
post-retrofit	11,642
difference	-2,683
% change	18.7
Carbon Dioxide (tons)	
existing	1,764
post-retrofit	1,434
difference	-330
% change	18.7
Particulate Matter (lb)	
existing	344
post-retrofit	281
difference	-63
% change	18.3
Hydrocarbons (lb)	
existing	5,929
post-retrofit	4,818
difference	-1,111
% change	18.7

Additional Considerations

None.

Photos

Because of security concerns, building photos were not permitted during the audit. Publicly available satellite images show the exterior of Building 1670.

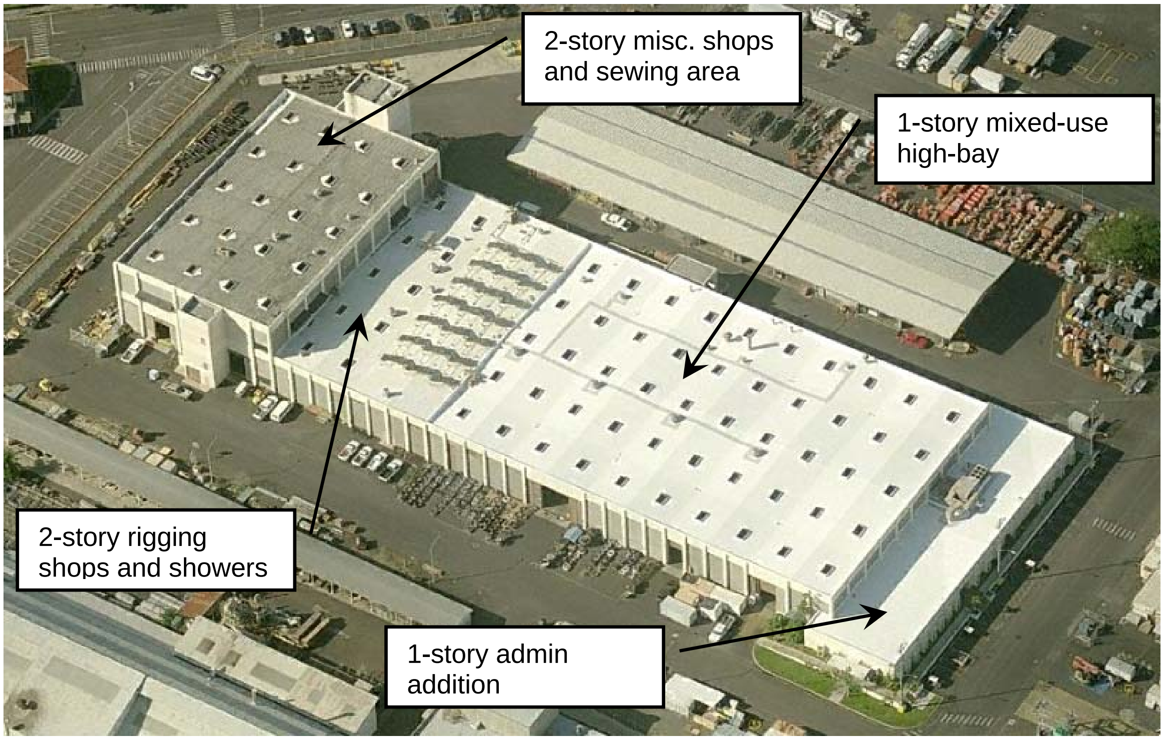

Photo courtesy Microsoft Corporation BING.COM Maps.

Figure C7. Building 1670 Satellite Imagery

Appendix D

Conversion to Water-Cooled Chillers for Building Space Cooling

Appendix D: Conversion to Water-Cooled Chillers for Building Space Cooling

Water-cooled condensing of cooling equipment refrigerant results in a significant improvement in efficiency compared to air-cooled condensing. This advantage stems from two factors. Condenser water from an evaporative cooling tower is generally cooler than ambient air (except when the relative humidity is very high), and water is a more effective heat transfer fluid than air. The two factors work together to lower the refrigerant condensing temperature, hence improving both theoretical and actual refrigeration cycle efficiency. Combining cooling loads met by multiple smaller cooling units into fewer central units allows additional efficiency gains by using centrifugal compressors, a more efficient technology than alternative compressor types commonly used in smaller cooling equipment. These advantages do come at a price, however. Condensing refrigerant with water requires additional costs associated with a cooling tower, condenser water pumps and piping, and a shell to enclose the water as it passes by the condenser tubing. The condenser pump also represents an additional power consuming device that an air-cooled unit does not have. Finally, the distribution of centrally chilled water incurs pumping and piping costs and pumping energy not required by distributed direct expansion coolers (e.g., window AC and packaged rooftop AC).

For the reasons noted above, water-cooled chillers offer significant performance advantages over air-cooled equipment that must be weighed against their additional capital costs. During the last few decades, space cooling has become much more common in Hawaiian military facilities because internal heating loads (e.g., personal computers and other office equipment) have increased, building designs have become less suitable for natural ventilation, and occupants expect a more comfortable working environment. The paragraphs that follow document the expected costs and energy savings associated with example conversions to water-cooled chillers at Hickam, Pearl, and Smith. Many other similar conversions are possible at these three facilities, but additional analysis was not possible with the assessment resources available. The installations are encouraged to consider additional opportunities for using water-cooled chillers where the economics are justified.

Hickam AFB

Buildings 2130, 2131, and 2133 are currently served by a small central cooling plant comprised of two air-cooled chillers. The proposed retrofit would replace the existing air-cooled chillers with two water-cooled chillers, a cooling tower, and condenser water pumps and piping. The existing chilled water pumps and piping would not change and the electrical service to the central plant should be adequate for the retrofit.

The peak and annual building cooling loads were estimated with the FEDS model, and the performance of the existing chillers was estimated from manufacturer's specifications for the two units. From this information, the annual kWh and peak kW electrical loads were calculated and then combined with Hickam's electricity rates to calculate the current annual electricity costs. The existing system performance and electricity cost figures are presented in Table D1.

Although the FEDS model estimates a peak of only 61 tons for the three buildings, two 40-ton water cooled chillers were assumed for the retrofit to match the existing nameplate capacity of the two air-cooled chillers. In this size range, the water-cooled chillers were assumed to use a rotary screw compressor rated at 0.73 kW/ton. In addition, the condenser water pump and cooling tower fan would be expected to consume 0.12 kW/ton for a total cooling plant performance of 0.85 kW/ton. The annual electricity bill for the water-cooled system was calculated to be $35,360 based on these assumptions, resulting in an annual savings of about $15,000 and a peak electric load reduction of 22 kW.

Table D1. Hickam Buildings 2130, 2131, 2133 Existing System Performance and Electricity Cost

Building	Peak Load, Tons	Annual Load, Ton-hours	Annual Capacity Factor	Existing Air Cooled kW/ton	Existing Annual Electricity kWh	Existing Peak Electricity kW	Existing Annual Electricity Cost
2130	18.1	73,335	0.46	1.204	88,296	21.8	
2131	10.3	40,647	0.45	1.204	48,939	12.4	
2133	32.7	100,092	0.35	1.204	120,511	39.3	
Totals	**61.0**	**214,074**	**0.40**	**1.204**	**257,745**	**73.5**	**$50,087**

The two new 40-ton water-cooled chillers were estimated to cost $88,200 and the cooling tower, condenser pump, and piping an additional $26,100. These figures include all direct construction costs, but do not include any allowance for design or SIOH costs. Based on the direct cost, the payback period is 8 years. With an additional 16% for design and SIOH, the payback period rises to 9 years.

Pearl Harbor

Building 631, the Navy Exchange and Commissary, is currently served by a collection of packaged rooftop direct expansion (DX) AC units. The proposed retrofit would replace the existing DX units with a new chilled water coil (in the existing air-handler units [AHU]), two water-cooled chillers, a cooling tower, condenser water pumps and piping, and chilled water pumps and piping. The new chiller plant was assumed to be sited on the southeast side of the building, next to the Commissary.

The peak and annual building cooling loads were estimated with the FEDS model and the performance of the existing packaged DX units was estimated from the vintage of the existing equipment. From this information, the annual kWh and peak kW electrical loads were calculated and then combined with Pearl Harbor's electricity rates to calculate the current annual electricity costs. The existing system performance and electricity cost figures are presented in Table D2.

Table D2. Pearl Building 631 Existing System Performance and Electricity Cost

Building	Peak Load, Tons	Annual Load, Ton-hours	Annual Capacity Factor	Existing Air Cooled kW/ton	Existing Annual Electricity kWh	Existing Peak Electricity kW	Existing Annual Electricity Cost
Navy Exchange (NEX)	275.1	918,580	0.38	1.2859	1,181,180	354	
NEX Food Court	125.0	342,737	0.31	1.2859	440,717	161	
Commissary	194.4	716,633	0.42	1.2859	921,501	250	
Totals	594.5	1,977,950	0.38	1.2859	2,543,446	764	$493,300

In this size range, the water-cooled chillers were assumed to use a centrifugal compressor rated at 0.51 kW/ton. In addition, the chilled water pumps, condenser water pumps, and cooling tower fan would be expected to consume 0.18 kW/ton for a total cooling plant performance of 0.69 kW/ton. The annual electricity bill for the water-cooled system was calculated to be $264,700 based on these assumptions, resulting in an annual savings of $228,600 and a peak electric load reduction of 354 kW.

A new 600-ton water-cooled chiller plant (chillers, cooling tower, pumps, plant piping, electrical, controls, and structure) was estimated to cost $656,000. Chilled water piping running to and from the ground to every rooftop air-handling unit was estimated to cost $225,000. The cost of the new chilled water coils was estimated to be $180,000. These figures include all direct construction costs, but do not include any allowance for design or SIOH costs. Based on the direct cost, the payback period is 4 years. With an additional 16% for design and SIOH, the payback period rises to 4.5 years.

Camp Smith

Buildings 401, 402, 403, and 404 are currently served by window DX AC units. The proposed retrofit would replace the window units with room fan coil units, external chilled water supply and return piping and a central water-cooled chiller plant serving all four buildings. The same plant would also serve Building 20. Because the building already has air-cooled chillers, it also has chilled water piping within the building, but will need chilled water supply and return piping to and from the new central plant. The new chiller plant was assumed to be sited on the West side of Bailey Road, opposite Building 401.

The peak and annual building cooling loads were estimated with the FEDS model, and the performance of the existing window DX AC units and air-cooled chillers were estimated from manufacturer's specifications for the two types of units. From this information, the annual kWh and peak kW electrical loads were calculated and then combined with Smith's electricity rates to calculate the current annual electricity costs. The existing system performance and electricity cost figures are presented in Table D3.

Table D3. Smith Buildings 401-404, and Building 20 Existing System Performance and Electricity Cost

Building	Peak Load, Tons	Annual Load, Ton-hours	Annual Capacity Factor	Existing Air Cooled kW/ton	Existing Annual Electricity kWh	Existing Peak Electricity kW	Existing Annual Electricity Cost
401	65.7	147,804	0.26	1.16	171,515	76.2	
402	65.7	147,804	0.26	1.16	171,515	76.2	
403	65.7	147,804	0.26	1.16	171,515	76.2	
404	65.7	147,804	0.26	1.16	171,515	76.2	
20	142.8	419,327	0.34	1.44	603,203	205.3	
Totals	405.5	1,010,544	0.28	1.26	1,289,263	510	$275,500

In this size range, the water-cooled chillers were assumed to use a centrifugal compressor rated at 0.57 kW/ton. In addition, the chilled water pumps, condenser water pumps, and cooling tower fan would be expected to consume 0.18 kW/ton for a total cooling plant performance of 0.75 kW/ton. The annual electricity bill for the water-cooled system was calculated to be $164,200 based on these assumptions, resulting in an annual savings of $111,300 and a peak electric load reduction of 206 kW.

A new 400-ton water-cooled chiller plant (chillers, cooling tower, pumps, plant piping, electrical, controls, and structure) was estimated to cost $520,000. Chilled water piping that would be mounted on the exterior of Buildings 401-404 was estimated to cost $85,000. Chilled water piping running to and from the new central plant to Buildings 401-404 and 20 was estimated to cost $189,000. The cost of the new chilled water coils for Buildings 401-404 was estimated to be $75,000. These figures include all direct construction costs, but do not include any allowance for design or SIOH costs. Based on the direct cost, the payback period is 8 years. With an additional 16% for design and SIOH, the payback period rises to 9 years.

Before implementing this project, Camp Smith should consider other possible means of serving these five buildings with water-cooled chillers. An expansion of the chilled water plant serving Building 700 may offer some economies over the new plant proposed here, but the chilled water distribution piping would be longer. Integration with a new chilled water plant serving the eventual replacement of the Old Hospital Complex would probably be ideal if the complex is going to be replaced relatively soon.

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