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**PRELIMINARY ASSESSMENT OF ENERGY
CONSERVATION OPPORTUNITIES AT THE
NASA GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND**

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Preface

The goal of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to facilitate energy-efficiency improvements at federal facilities. This is accomplished by a balanced program of technology development, facility assessment, and use of cost-sharing procurement mechanisms. Technology development focuses upon the tools, software, and procedures used to identify and evaluate energy-efficiency technologies and improvements. For facility assessment, FEMP provides metering equipment and trained analysts to federal agencies exhibiting a commitment to improve energy use efficiency. To assist in procurement of energy-efficiency measures, FEMP helps federal agencies devise and implement performance contracting and utility demand-side management strategies.

Pacific Northwest Laboratory (PNL)^(a) supports the FEMP mission of energy systems modernization. Under this charter, the Laboratory and its contractors work with federal facility energy managers to assess and implement energy-efficiency improvements at federal facilities nationwide.

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Executive Summary

An assessment of energy use and identification of energy-efficiency opportunities was undertaken in 27 major buildings representing 2,444,712 square feet (ft²) at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. Based on the most recent and accurate data available, the site paid \$6,276,530 for electricity and \$1,309,839 for fossil fuel in fiscal year (FY) 1991, for a total cost of \$7,586,369. Historic fuel consumption data are given in Table S.1 and shown in Figure S.1.

Table S.1. Total Energy Use and Costs for FY 1987-91

FY	Total Consumption		Total Cost
	MBtu	Btu/ft ²	\$K
1987	774,083	327,181	6,878
1988	752,342	319,207	6,329
1989	810,919	342,751	5,228
1990	836,745	342,267	5,607
1991	739,905	302,655	7,586

Figure S.1. Historical Energy Use at the Site (FY 1987-91)

Based on the data in Table S.1, the site has experienced mixed results in its efforts to reduce energy use. For example, from FY 1987 through FY 1991, the site saw a 7.5% decrease in energy use (Btu/ft²). However, this decrease in energy use was likely the result of a warmer than normal 1991–92 winter rather than through energy efficiency measures and activities. During this time period (FY 1987–91), consumption of electricity increased over 5% on a kWh/ft² basis (not shown in the table) despite the warm winter. And, comparing FY 1990 to FY 1987, the site experienced nearly a 5% increase in energy use (Btu/ft²). Though the energy use at the site has historically been gradually decreasing (Figure S.1), the highly variable energy use at the site will make it difficult for the site to reach the goals of the Executive Order¹ and the Comprehensive Energy Policy Act (EPAAct) of 1992² to reduce energy consumption from the FY 1985 level by 20% by FY 2000.

The scope of work for this assessment was limited and therefore our investigation concentrated on acquiring and reviewing historical energy-related data that directed us to more thoroughly investigate those energy systems where a significant cost-effective energy and/or cost savings would be most readily acquired. Therefore, we focused our assessment and quantified our recommendations for 1) lighting, 2) central plants (primarily the distribution systems), and 3) building ventilation. Other (qualitative) recommendations are given and are based on our observations, engineering judgment and experiences at over 30 other federal installations. We have also provided information and guidance on taking advantage of any applicable utility incentive programs that could be used to cost-share technology retrofits.

During the site surveys and assessment, building use, equipment, and lighting configurations were observed and numerous lighting level readings were taken in office areas, laboratories, common areas, and warehouse space. Discussions were also held with members of the facility engineering staff to obtain facility-related energy use characteristics and with a number of building occupants as to lighting adequacy and comfort. As part of the assessment, 15-minute load profiles for 24-hour periods for different weekdays and at different times of the year were obtained from the electric utility and examined. The profiles were consistent from month-to-month and revealed a significant base load ranging from about 15 to 17 MW compared with peak loads of 18 to 24 MW. Therefore, visits to the site were made during non-working hours to assess lighting (and other) conditions during these periods to better understand why non-working loads were so significant.

Based on the daytime and nighttime observations and site data collected, evaluated and analyzed, we found significant energy savings potential from installing retrofit technologies for lighting, building air-handling systems as well as from refurbishment of the central steam distribution system. These opportunities, summarized in Table S.2, should be incorporated into a comprehensive approach to site-wide energy efficiency program.

Table S.2. Recommended Cost-Effective Energy Conservation Opportunities

Measure	Estimated Yearly Savings		
	kWh	MBtu	\$
Efficient Fluorescent Fixtures	2,996,100	-	196,060
Light-Emitting Diode Exit Signs	580,000	-	22,180
Repair Distribution System	-	1.51	61,000
Ventilation Fan Control	1,258,000		57,900
Total	4,834,100	1.51	337,140

In this approach, we recommend systematically treating the site from the top down (as a whole) and determine the most life-cycle-cost-effective retrofit technology based on a fuel-blind technology-neutral analysis. That is, determine the most *cost-effective* way to deliver services (e.g., lights, heat, cool, hot water, etc.) to the site and site facilities.

We also recommend that retrofit technologies and projects be implemented in a sensible order. For example, all building shell and interior lighting retrofits should be identified and undertaken prior to implementing an HVAC system retrofit or control system, or prior to the scheduled replacement/refurbishment of the Central Heating Plant (CHP), Central Refrigeration Plant (CRP) and distribution systems. With this approach, the building loads (cooling and/or heating) are minimized first and the heating/cooling systems are then properly sized and designed to meet the new (reduced) loads. At the same time, the feasibility and applicability of other energy and/or demand-management measures such as thermal energy storage or onsite generation for peak shaving can be more accurately evaluated.

Specific recommendations based on this preliminary assessment for energy efficiency are given in detail in the report (with backup calculations) and are summarized as follows:

- **Lighting** - We estimated the number of fixtures in the buildings and the energy and cost savings for a lighting retrofit of the 2x4 four-tube fixtures, 1x4 two-tube hallway fixtures and exit lights in approximately 576,000 ft² of office and 1,000,000 ft² of laboratory and other space in 27 buildings. The analysis is based on an average fixture density of three 2x4 four-tube fixtures/120 ft² of office space, one 1x2 two-tube fixture per four office/laboratory/other fixtures, and one 40-watt incandescent exit light/1000 ft² of total space. The selected retrofits are based on 11 hours/day-5 day/week operation of office and laboratory lights and 24 hours/day-7 days/week operation of hallway and exit lights. The analysis is based on one-to-one fixture-for-fixture replacement with new fixtures that result in an average 20–25% reduction in footcandle levels

for all square footage (and still maintain federal standards) and are the most life-cycle-cost-effective technologies. The retrofits will also result in better lighting quality and distribution along with the significant energy savings. The retrofit results are given in Table S.3. The minimum electrical energy savings from a fixture-for-fixture replacement is over \$218,000/year with an installed cost for the technologies (including utility rebates) of \$922,500 (current dollars). The net present value of these retrofit measures is over \$3,576,000.^(a)

Table S.3. Lighting Retrofit Analysis Results

					Annual Savings			
Exist. Fixture - Watts		Number	Retrofit ^(a) - Watts		NPV ^(b) \$	kWh	\$	Inst. Cost
2x4-4 Tube	190	13,133	DL2 + REF	79	2,013,700	2,968,100	136,530	645,350
1x4-2 Tube	75	3,283	DL1 + REF + ELC	34	982,400	1,294,150	59,530	208,000
Exit Lights	40	1,576	LED	5	580,000	482,300	22,180	69,150
Totals					3,576,100	4,744,550	218,240	922,500

(a) DL2 + REF = delamp 2 tubes and add reflector.

DL1 + REF + ELC = delamp 1 tube add reflector and replace ballast with an electronic ballast.

LED = light-emitting diode-type fixture.

(b) Net Present Value.

There are also other cost-effective opportunities (not quantified in this assessment) for lighting controls particularly in those buildings with glass-walled hallways, glass-walled entrances, and outdoor building lights that were found to be on when the daylighting fully overwhelmed their lighting contribution. The lighting in these areas can be controlled by use of photo-electric light sensors. In addition, high bay areas and machine shop areas were found to be fully lit when the work areas were empty of personnel. On a weekend and at night all hallway lights were found to be on in examined buildings. These also could be controlled through the use of sensors. An additional 10 - 15% in lighting energy savings can be obtained at the site through cost-effective controls, and utility rebates are available for lighting controls.

- **Central Plants** - The site staff have indicated that the heating system condensate return lines have significantly deteriorated resulting in loss of condensate return, and replacement/refurbishment is included in future upgrades at the site. In CY 1991, 18.847 million gallons of makeup water was required for the system. If we assume that 40% of the total makeup water for the boilers is lost due to deterioration of the

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- (a) Net present value is defined as the (net) life-cycle savings of the retrofit as compared to not implementing the retrofit. The savings include installed cost and the present value of annual energy, operations and maintenance and future replacement cost. A positive NPV indicates that the retrofit is cost-effective to implement.

condensate return lines, the CY 1991 line loss equals approximately $18.887 \times 0.4 = 7.55$ million gallons of water. The associated heat loss is equivalent to 52,500 therms (@75% delivery efficiency), or over \$23,000 of boiler fuel (natural gas) per year at current natural gas cost.

- **Building HVAC** - From site-supplied fan motor size data, discussion with site staff and off-hours site survey, we determined that ventilation fan motors in at least 21 of the 27 building examined operate 24 hours a day, 365 days a year. Though no data were acquired on motor duty cycle, we estimate that building fan motors with a total of ~770 hp operate 24 hours/day. If one-half of these fans can be turned off for 12 hours/day, the estimated savings are: $770 \text{ hp} \times 0.5 \times 12 \text{ hr/day} \times 365 \text{ day/year} \times 0.746 \text{ kWh/hp} \times \$0.046/\text{kWh} = \$57,900/\text{year}$ (1,258,000 kWh/year).

It has been shown in similar facilities at other federal sites to be cost-effective to replace motors (on failure) with high-efficiency motors, particularly those motors used for high-duty cycle applications. This includes drives for high-duty-cycle fans and pumps. This also include the motors in the CHP and CRP. In addition, there are utility rebates available for high-efficiency motors.

Also, where feasible, we recommend 1) two-speed fan operation, 2) replacing inlet-vane with variable speed drive (VSD) control of variable air volume (VAV) flow rate, and 3) modifying outside air control and installing low-leak dampers to provide zero outside air during unoccupied periods. As part of the planned site-wide control system upgrade, we recommend it include improving control and balance to minimize heating/cooling exchanger loads, fine-tuning for optimal start/stop control, adjustment of the HVAC systems (where possible) in buildings to increase the volume of outside air in cooler weather for cooling, and curtailment of the use of air-circulating fans in clean rooms that are not in use.

With a lighting retrofit, there will be a net energy and cost savings from reduced cooling load (not quantified).

Currently, temperature set points in buildings are established at cooling/heating use location. Each radiator has a valve that permits using either hot water or chilled water depending on outside temperature. There are no provisions for valving off radiators during periods when neither heating nor cooling is required and therefore we recommend that this capability be installed, even though the secondary water pumps are turned off.

- **Structural and Thermal** - Buildings with marginal insulation should be cost-effectively retrofitted with insulation and upgraded with energy-efficient glazing as they are renovated—taking into consideration the available utility incentives. It is generally not cost-

effective to retrofit unless it is part of a planned major renovation project. In addition, insulation should be added to bare metal-skinned wall sections such as those in Building 16W.

- **Electrical Generation and Distribution System** - The GSFC has scheduled replacement of its diesel electric generators and these units should be considered for use in cogeneration and/or general peak shaving in addition to their use to support mission-critical activities. This requires a thorough engineering analysis and was not quantified in this assessment.

A comprehensive transformer (and distribution system) assessment was not undertaken. However, based on experiences at other NASA sites, the mission-critical nature of the activities likely require that all the transformers remain energized. Therefore, there is no recommendation for immediately modifying the transformer and associated distribution system to reduce losses. However, as transformers are replaced, we recommend they be replaced with high-efficiency amorphous-core transformers. This strategy is cost-effective and can save 10–15% in transmission and distribution system losses. This strategy may also qualify for utility incentives under "site-specific measures" part of the utility rebate program.

Discussions were also held with staff of the Potomac Electric Power Company (PEPCO) to better understand its demand-side management (DSM) and other incentive programs that would be applicable to the site. PEPCO offers extensive rebate programs for electric technologies that are available to government agencies served by PEPCO, and recently the GSFC has taken advantage of many of the rebate offerings. Current technologies with rebates include:

- high-efficiency lighting
- high-performance building envelopes
- high-efficiency packaged air conditioners and heat pumps
- high-efficiency chillers
- high-efficiency motors
- HVAC system controls
- high-efficiency water heating
- high-efficiency refrigeration
- site-specific (custom program) measures

- thermal energy storage
- new construction incentives.

We recommend that the site go beyond just accepting rebates and form a "partnership" with PEPCO to develop a "custom" program that includes a comprehensive package including the utility providing up-front financing for technologies, cost sharing in the form of incentives and technology installation contracting.

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1.0 Introduction

The National Aeronautics and Space Administration is encouraging energy efficiency in its buildings and facilities as part of an overall strategy to meet the requirements of the Executive Order on Energy Efficiency¹ and the Comprehensive Energy Policy Act of 1992.² Under NASA-Defense Purchase Request Number S-79013-E, NASA requested technical assistance from the Pacific Northwest Laboratory to conduct a site visit, examine selected buildings and facilities, and suggest appropriate and economically acceptable energy efficiency measures and future actions at NASA's Goddard Space Flight Center. PNL was also tasked to investigate the current and future demand-side management (DSM) programs offered by the servicing electric utility that would be applicable for the site.

The information for this assessment was collected during site visits to the Goddard Space Flight Center during September and October, 1992, by Lawrence Hoffman, of L. Hoffman and Associates, subcontractor to PNL. The assessment addresses energy supply and cost, estimated energy distribution and use, and cost-effective options to reduce energy consumption at the center. Applicable utility DSM programs are also identified.

A recommended strategy is identified to undertake a more comprehensive long-term energy reduction program at the site. A model approach is also given for the site to develop a partnership with the serving electric utility to implement a "custom" site-wide DSM program incorporating the several incentives offered by the utility to governmental agencies.³

2.0 Facility Description

The Goddard Space Flight Center, Greenbelt Facility, is located in Greenbelt, Maryland, a suburb of Washington, D.C. It was established in 1959, and during the last three decades the Center has developed (in-house) more than 40 space satellites; managed the development of more than 160 satellites for NASA; launched over 175 payload-carrying Delta rockets; flown scientific payloads on over 2,500 sounding rockets and 550 balloons; and provided tracking, communications, and data handling for NASA.

The GSFC owns 1,121 acres of land and controls 150 acres of land through permit agreements, for a total control of 1,271 acres. A portion of the GSFC covering 529 acres is located east of the Soil Conservation Service Road and north of Greenbelt Road. This portion of the GSFC contains the "energy-significant" campus area. There are 27 energy-significant buildings on the campus as well as a number of smaller structures and office-trailers. These 27 buildings are covered by this assessment and contain a total of 2,444,712 gross square feet. The buildings examined are listed in Table 2.1, and a square footage of building use is given in Table 2.2. Appendix A contains a map of the campus area with building identification. Appendix B provides additional details on the examined buildings.

At the time of this effort, GSFC employed 7,868 personnel. Staff is composed of 3,708 NASA full-time employees, 30 NASA part-time employees, and 4,130 supporting personnel through contractors. Contractor-provided support includes 1,633 scientists and engineers as well as technical, professional, administrative, and clerical support.

Table 2.1. Description of Major Buildings Examined

Building Number	Building Type
1	Space Projects Building - Cafeteria, GEWA Store, Personnel and Travel
2	Research Projects Laboratory, Gas Laboratory
3	Central Flight Control and Range Installation Building
4	Plant Operations Building
5	Instrument Construction and Development Laboratory
6	Spaces Sciences Laboratory
7	Payload Testing Facility
8	Administration Building
10	Environmental Testing Laboratory
11	Applied Sciences Laboratory
12	Tracking & Telemetry Laboratory
13	Network Control Center Facility
14	Spacecraft Operations Facility
15	High Capacity Centrifuge Facility
16	Logistics and Supply Facility - Shipping and Receiving
16W	Logistic and Supply Facility - Mail Room
17	Administrative Support Building, Safety Office, Bid Room, and Facilities Engineering Division
18	Administration Support Building - Information Technology Center
19	Technical Support Building
20	Technical Support Building
21	Meteorological Systems Development Laboratory, Cafeteria, Library, and Credit Union
22	Space and Terrestrial Applications Facility
23	Data Interpretation Laboratory
24	Central Heating and Refrigeration Plant
26	NASA Space Science Data Center
28	Technical Processing Facility
29	Spacecraft Systems Development and Integration Facility

Table 2.2. Square Footage and Uses of Major Buildings Examined

Building Number	Office	Laboratory	Special	Other Areas	Gross
1	16,481	0	27,909	30,510	74,900
2	27,012	12,758	31,885	9,945	81,600
3	21,765	300	47,350	44,585	114,000
4	7,110	0	28,438	1,652	37,200
5	27,761	10,166	75,134	18,039	131,100
6	42,908	1,090	14,058	47,744	105,800
7	22,571	485	82,052	52,092	157,200
8	40,637	0	23,737	55,626	120,000
10	750	0	39,900	11,050	51,700
11	35,230	8,955	22,155	60,060	126,400
12	49,935	755	9,760	45,650	106,100
13	0	0	33,316	16,484	49,800
14	8,590	0	52,270	87,567	148,427
15	9,713	0	30,405	4,130	44,248
16	17,365	0	1,205	14,622	33,192
16W	34,595	670	136,750	22,570	194,585
17	22,835	0	4,741	11,124	38,700
18	15,638	0	10,537	9,125	35,300
19	7,563	5,651	3,635	3,851	20,700
20	5,479	4,483	5,853	4,885	20,700
21	29,077	4,951	57,240	63,732	155,000
22	49,233	5,980	41,755	59,332	156,300
23	44,775	5,552	64,869	69,704	184,900
24	0	0	24,775	3,025	27,800
26	12,125	0	16,394	25,281	53,800
28	23,757	605	37,659	34,439	96,460
29	3,455	0	53,790	21,555	78,800
Totals	576,360	62,401	977,572	828,379	2,444,712

Note: Buildings 25 and 27 are not on the main campus.

3.0 Energy Use and Cost

3.1 Energy Supply

Energy for the main campus of the GSFC is supplied by electricity, natural gas, and fuel oil. Electricity is furnished at 34.5 kV, by the Potomac Electric Power Company (PEPCO). Emergency backup power for critical loads is provided by four 500-kW diesel generators on-site operating at 4.16 kV. The diesel generators are currently only used to supply power to critical loads in the Building 3-13-14 complex during space flight missions. Natural gas is supplied by the Washington Gas Light Company. Fuel oil is supplied by commercial bulk suppliers.

PEPCO power is supplied through two feeders to the facility's substation located near Building 24. The 34.5-kV feed is transformed to 13.8 kV and 4.16 kV for distribution to load centers on the facility. A load center located in each building transforms the voltage to utilization voltages of 480/277 volts and 208/120 volts. The electric power consumed by the main campus of GSFC can be divided into two primary categories: 1) the motors-drive power for chillers, for oil/gas-fired boilers, for building air-handling systems, and for research loads, and 2) the lights, office equipment and other plug loads.

The main campus of GSFC has a Central Heating Plant (CHP) and a Central Refrigeration Plant (CRP), both located in Building 24. There are also distributed electric-driven chillers serving several buildings to provide cooling to specific loads (e.g., a main-frame computer installation).

The CHP supplies steam for heating, humidification, and process uses throughout the facility. The plant contains five boilers, three rated at 33,000 pounds of steam per hour, one rated at 35,000 pounds of steam per hour and one rated at 24,000 pounds of steam per hour, for an overall total of 158,000 pounds of steam per hour. These units can be fired with either natural gas or fuel oil (No. 2 or No. 6). Currently, the boilers are fired with natural gas with No. 2 fuel oil as a backup.

The steam is distributed through an underground distribution system serving the buildings examined and returned via a condensate return line. Steam is supplied to the distribution system at approximately 100 psia. The steam pressure is subsequently reduced in stage(s) prior to final use.

The CRP consist of six electric motor-driven centrifugal chillers. There is one 3,000-ton unit, two 1,500-ton units and three 2,000-ton units, for a total capacity of 12,000 tons of refrigeration. In addition, 1,500 tons of free cooling capacity in the form of plate-

type heat exchangers, for use in cold weather, is in place. Chilled water is supplied to the buildings by a system of underground chilled water supply and return piping.

3.2 Energy Use

The historical energy use (and cost) data for the site were incomplete for all the fuels and were only available in summary form for FY 1987 through FY 1990. Tables 3.1 and 3.2 summarize the energy use (and costs) at the site for FY 1987 through FY and CY 1991. Table 3.3 gives the electrical energy use (kWh and MW) by month for CY 1991. Figure 3.1 shows the historical energy use trend at the site for FY 1987 through FY 1991.

Table 3.1. Energy Use and Costs by Fuel for FY 1987–91

FY	Electric		Gas		Oil	
	MWh	Cost (\$K)	1000 ft ³	Cost (\$K)	Gallons	Cost (\$K)
1987	124,050	5,818	310,631	956	213,000	104
1988	119,370	5,243	290,003	882	324,000	204
1989	128,799	4,055	301,800	992	425,495	181
1990	130,487	4,251	310,398	1,104	433,945	252
1991	134,561	6,276	245,162	1,167	195,687	143

Table 3.2. Total Energy Use and Costs for FY 1987–91

FY	Total Consumption		Total Cost
	MBTu ^(a)	Btu/Ft ^{2(b)}	\$K
1987	774,083	327,181	6,878
1988	752,342	319,207	6,329
1989	810,919	342,751	5,228
1990	836,745	342,267	5,607
1991	739,905	302,655	7,586

(a) Based on 3413 Btu/kWh, 1033 Btu/ft³ natural gas, 140,000 Btu/gallon oil.

(b) Based on 2,365,912 ft² in FY 1987–89 and 2,444,712 ft² in FY 1990–1991.

Table 3.3. Electricity Use and Cost^(a)

<u>CY 1990</u>	<u>MWh</u>				<u>Maximum</u>	<u>Cost</u>
	<u>On-Peak</u>	<u>Int-Peak</u>	<u>Off-Peak</u>	<u>Total</u>	<u>Demand (MW)</u>	<u>(\$1,000)</u>
October	2,887.8	2,635.8	5,458.2	10,981.7	22.54	427.32
November	2,782.4	2,574.3	6,056.7	11,413.5	19.81	411.18
December	2,592.2	2,471.4	5,341.8	10,405.3	17.58	375.52
<u>CY 1991^(b)</u>						
January	2,434.9	2,324.0	5,334.1	10,093.0	18.36	366.98
February	2,429.2	2,664.7	4,590.4	9,284.2	19.24	350.95
March	2,100.5	1,976.2	3,566.3	7,643.0	14.64	287.57
April	2,009.5	1,846.4	3,816.6	7,672.5	15.18	287.23
May	2,376.9	2,184.9	4,322.8	8,875.6	16.91	541.19
June	2,396.4	2,192.5	4,464.8	9,053.6	17.29	563.56
July	3,418.6	3,206.5	6,827.4	13,452.5	23.39	748.83
August	3,382.8	3,124.4	6,173.5	12,680.8	23.77	752.55
September	3,046.9	3,112.5	5,640.8	11,800.2	23.89	729.24
October	2,718.3	2,759.0	5,273.3	10,750.5	21.01	431.35
November	2,593.3	2,636.1	6,210.1	11,439.5	21.83	437.79
December	2,709.3	2,583.2	6,261.1	11,553.6	19.87	424.14
FY 1991 Totals				134,561.3		6,276.53
Blended Cost = \$0.047/kWh						
CY 1991 Totals				135,504.4		6,355.80
Blended Cost = \$0.046/kWh						

(a) Total campus fuel use based on the best available data supplied by the site.

(b) PEPCO's metering equipment malfunctioned from March 1991 through June 1991 and therefore the values are estimates based on reconstructed data.

Figure 3.1. Historical Energy Use at the Site (FY 1987–1991)

3.3 Energy Costs and Rates

The site paid \$6,276,530 for electricity and \$1,309,839 for fossil fuel in FY 1991, for a total cost of \$7,586,369. The average (blended) rate the site paid for electricity in FY 1991 was \$0.047/kWh. The average cost for fossil fuel in FY 1991 was \$5.10/MBtu, and for all fuel was \$8.88/MBtu.

3.3.1 Electrical Energy Rates

PEPCO provides electricity to the site under its "Time Metered General Service Schedule GT" rate with a "Curtable Service Rider CS." The rate schedule is shown on the next page. A copy of the PEPCO GSFC applicable tariff is provided in Appendix C.

Rate Element	June 1 – October 31	November 1 - May 31
Customer Charge	\$273.80	\$273.80
Energy Charge (¢/kWh) ^(a)		
On-Peak Period	3.069	2.241
Intermediate Period	2.425	1.704
Off-Peak Period	0.905	0.479
On-Peak Demand Charge	\$9.70/kW	-
Maximum Demand Charge	\$4.00/kW	\$4.00/kW
Fuel Rate (adjustment)	Variable/kWh	Variable/kWh
Curtailment Demand Credit	3.55%/kW curtailed	-
Curtailment Demand Penalty	2 x kW credit x kW over maximum allowed	
Discount for Service ≥ 66kV	10%	10%
Environmental Surcharge	0.012¢/kWh	0.012¢/kWh

- (a) On-Peak Period: 12:00 noon - 8:00 pm
Intermediate Peak Period: 8:00 pm - 12:00 midnight
Off-Peak Period: 12:00 midnight - 8:00 am, Saturdays, Sundays and
Holidays

Peak demand is the maximum 30-minute demand recorded during the billing month.

3.3.2 Natural Gas and Fuel Oil Rates

The rates for natural gas and fuel oil are both based entirely on the amounts delivered to the GSFC. The current (CY 1992) cost of natural gas delivered to the site is \$0.405/therm. The site paid \$0.344/therm in FY 1990 and \$0.461/therm in FY 1991. The current cost for fuel oil delivered to the site ranges between 64 cents and 70 cents per gallon, depending upon the sulfur content. The site paid an average of \$0.58/gallon in FY 1990 and \$0.73/gallon in FY 1991 for No. 2 and No. 6 fuel oil (combined).

4.0 Utility Program Offerings

The Potomac Electric Power Company has extensive incentive programs for commercial, governmental, and multifamily residential customers. Information and literature (dated June 1992) on three programs most applicable to the GSFC were provided by PEPCO during a September 23, 1992, meeting at PEPCO offices. The three *Powerwatchers Programs* are: 1) New Building Design, 2) Custom Rebate, and 3) Thermal Energy Storage. The overall rebate program is extensive and covers new construction as well as modification of existing facilities and energy systems. The rebates could significantly increase the attractiveness and cost-effectiveness of a comprehensive upgrade/retrofit of existing facilities and systems as well as the economics of new construction.

4.1 New Building Design Program

Under the New Building Design Program, PEPCO will pay 50% of the cost of an energy reduction study for new building construction, up to a maximum of \$5,000/building. This would be payable even if energy-efficient technologies are not implemented. The energy reduction incentives are based on the maximum demand (kW) reduction and varies between \$350 and \$750 per kilowatt. Under this program, the incentives are designed to cover the incremental costs between "standard practice" technologies and "energy efficient technologies." PEPCO provides information to allow the customer to determine the incentive amount based on the increase in efficiency above established "baseline parameters." The incentives apply to the following qualified technologies:

- High-Efficiency Lighting Systems
- High-Performance Building Envelopes
- High-Efficiency Packaged Air Conditioners and Heat Pumps
- High-Efficiency Chillers
- High-Efficiency Motors
- HVAC Controls
- High-Efficiency Water Heaters and Refrigeration.

4.2 Custom Rebate Program

The Custom Rebate Program covers existing commercial, governmental, and multi-family buildings and provides incentives for customers to replace current technologies with energy-efficient technologies. If a desired technology is not covered under PEPCO published options, the customer can propose a "custom program" to reduce load (kW) and may qualify for incentives. The technologies currently listed under the program are given in Table 4.1.

4.3 Thermal Energy Storage Program

The Thermal Energy Storage Program is available to new or existing facilities. The objective of the program is to reduce peak energy use. Only thermal energy storage systems installed in conjunction with electrically driven cooling equipment qualify.

Qualifying applications under the program include ice, chilled water, and eutectic salt storage systems. The systems must meet all or a portion of a building's cooling needs during PEPCO's summer peak billing period. PEPCO will pay for 50% of the cost of a feasibility study up to \$5,000 and will pay \$350/kW of cooling load deferred during the peak summer demand period.

Table 4.1. PEPCO's Custom Rebate Program Incentives

Technology	Rebate
High-Efficiency Lighting	
Fixtures	\$19-70/fixture
Lamps	\$0.75-27/lamp
Ballasts	\$10-29/ballast
Exit Signs	\$10-110/conversion or retrofit
Reflectors	\$25/reflector
Lighting Controls	
Daylighting	\$0.12/watt controlled
Occupancy Sensor	\$65-135/sensor

Table 4.1. (contd)

Technology	Rebate
High-Performance Building Envelope	
Roof Insulation	\$0.11-0.96/ft ²
Low-E Glass	\$3.25/ft ²
Reflective Glass	\$3.25-3.55/ft ²
Reflective Film	\$1.00/ft ²
High-Efficiency Packaged Air Conditioners & Heat Pumps	
Air-Cooled	\$45/ton/1.0 EER above min.
Water-Cooled	\$40/ton/1.0 EER above min.
Packaged Terminal	\$50/ton/1.0 EER above min.
High-Efficiency Chillers	
Air-Cooled	\$450/ton/1.0 kW/ton below max.
Water-Cooled	\$550/ton/1.0 kW/ton below max.
Variable-Speed	\$80-120/ton
High-Efficiency Motors	
1.0 and Greater hp	\$1.50-6.00/hp/1.0 eff above min.
HVAC Controls	
Variable-Speed Air-Handling	\$140/hp
Two-Speed Cooling Tower Fans	\$6.50/hp
Chilled Water Reset	\$5.00/ton
High-Efficiency Water Heating	
Heat Pump Water Heating	\$500-1000/unit
Point-of-Use Water Heating	\$50/unit
Insulation	\$0.30-0.60/unit gallon
High-Efficiency Refrigeration	
Oversized Condensers	\$104/hp

Table 4.1. (contd)

Technology	Rebate
External Heat Exchangers	\$300/unit
Remote Subcoolers	\$54/hp
Compressor Unloading	\$18/hp
High-Efficiency Fan Motors	\$13/linear foot of case
Anti-Condensate Heater Control	\$13/linear foot of case
Site-Specific Measures (Case-by-Case)	
Measures Not Listed Above	\$350/kW reduction

5.0 Findings

5.1 General

In performing this assessment, the interiors of 24 of the 27 major buildings on the GSFC campus were examined. We did not examine interiors of Buildings 3, 13 and 14 because these buildings are connected structures, have restricted access and are likely in the "mission variable" category and therefore exempt from the Executive Order. Even though building walkthroughs were not performed in these buildings, observations were made from all entrance doors and through windows around the buildings as to the nature of hall and office lighting.

There are also a number of NASA-owned and rented office trailers (~ 16) and smaller buildings on the main campus that were not included in the survey. These buildings are small and not significant energy consumers. Building 9, the Main Gatehouse, a small building with independent electric and gas metering, was also not covered by this assessment. The amount of energy consumed by this building, as indicated by its electric and gas bills, is very small.

During the building surveys, building use, equipment and lighting configurations were observed and numerous lighting level readings were taken in office areas, laboratories, common areas, and warehouse space (see Appendix D). Discussions were also held with members of the facility engineering staff to obtain facility-related energy use characteristics and with a number of building occupants to ascertain lighting adequacy and comfort.

Based on the data in Figure 3.1 and Table 3.2, the site has experienced mixed results in its efforts to reduce energy use. For example, from FY 1987 through FY 1991, the site saw a 7.5% decrease in energy use (Btu/ft²). However, this decrease in energy use is likely the result of a warmer than normal 1991-92 winter rather than through energy efficiency measures and activities. During this time period (FY 1987-91), consumption of electricity increased over 5% on a kWh/ft² basis (not shown in Table 3.2) despite the warm winter. And, comparing FY 1990 to FY 1987, the site experienced nearly a 5% increase in energy use (Btu/ft²) over this time period.

Also, as noted in Table 3.3, there is an observed gradual increase in electricity consumption from the winter of 1990-91 through the beginning of the winter of 1991-92. The largest increase occurs during the on- and intermediate-peak periods, with a commensurate increase in peak demand. This indicates both an increase in the number and use/duty cycle of electrical energy-consuming equipment. Though the energy use at the site has been gradually decreasing since FY 1987, the rate (and year-to-year

inconsistency) will make it difficult for the site to reach the goals of the Executive Order and the Comprehensive Energy Policy Act (EPA) of 1992 to reduce energy consumption from the FY 1985 level by 20% by FY 2000.

To better understand electrical consumption at the site, 15-minute demand profiles for 24-hour periods for different weekdays and at different times of the year were obtained from PEPCO and examined. The plots were found to be similar and consistent for most all of the time periods examined. We therefore chose representative plots for the time period of August 4, 1992, through August 12, 1992, to illustrate how the electric energy use decreases during off-hours at the site (nights and weekends; see Appendix C). Peak energy consumption during working hours ranges from 18 to 24 MW, while the baseline consumption during non-working and weekend hours ranges from 15 to 17 MW (a 20-30% reduction). Because of the significant energy baseline, visits were made to the site during non-working hours (weekend and on a weekday night) to assess lighting (and other) conditions during these periods to better understand why non-working loads were so significant. The field notes from this survey and other surveys during the data collection are given in Appendix D. The findings are summarized and discussed below.

5.2 Lighting

Like any facility of this vintage, size and complexity, there was a mix of lighting technologies found at the GSFC during the building walkthroughs. These include fluorescent, incandescent, mercury vapor, quartz and metal halide lamps that provide indoor and outdoor lighting. The indoor areas (offices, laboratories, computer rooms, common areas, etc.) typically contain 2x4 four-tube, and/or 1x4 two-tube fluorescent fixtures with 34-watt "energy mizer" lamps. There are some areas with one-tube and/or two-tube 8-foot fluorescent fixtures. In addition to the 8-foot fixtures, the high-bay areas are served in part by energy-efficient high intensity discharge (HID) and high pressure sodium (HPS) lamps with the remaining light provided by fluorescent fixtures. Night outdoor lighting is provided by a variety of HID and HPS lamps.

In the 1970s there was a concerted energy conservation effort at the site. Selected fluorescent fixtures were taken out of service by disconnecting the fixture ballast and the units were tagged by a piece of red tape attached to the fixture. Existing red-tagged fixtures were found in only a few of the buildings.

For over 10 years the GSFC has been using 34-watt "energy mizer" lamps. Even so, older energy-inefficient ballasts predominate. A member of the facility staff estimated that only 10% of the ballasts are of the newer, higher-efficiency (electronic or hybrid) category. Electronic ballast are used when replacing defective units, in fixture retrofits, and for new installations.

Information supplied by GSFC engineering personnel indicated that over the last several years a number of buildings have undergone some fixture replacement. The replacement amounted to 100% in two buildings and typically 10% in the other buildings. The buildings identified as receiving retrofits are Buildings 1, 2, 4, 5, 7, 8, 12, 24, and 26. However, it was indicated that in all cases the old 2-tube fluorescent fixtures were replaced by 4-tube fixtures with "high-efficiency" ballasts.

Extensive daylighting is used in the building designs. Window areas that receive direct sunlight are typically covered by a tinted plastic film. There are glass-walled hallways and entryways, some with glass extending to the second or a higher floor. Several glass-walled entryways contained fluorescent fixtures with photoelectric, sensor-controlled switches that prevent the fixtures from operating when the light levels are adequate. This was the exception rather than the normal condition. Typically the numerous glass wall entryways, stairways, and hallways had all lamps illuminated even when flooded with natural light. In fact, in most cases during daylight, in good weather, the indoor lights contributed little to the light levels.

In each building surveyed, light level readings were taken in entryways, hallways, and offices. The hallway illumination levels varied considerably between the examined buildings. In some buildings, in some hallways, the lighting level is reasonable though non-uniform. In some buildings, the hallway lighting levels are significantly above the Illuminating Engineering Society and federal-recommended 10-footcandle level for "non-working areas" and "corridors."

In the majority of the offices surveyed, the light levels were above the recommended 50 footcandle level at the working surface. This was the case even in rooms that contained inoperative red tagged fixture(s). In some offices, light levels in excess of 180 footcandles were measured at the work surface. There are many 120-square-foot offices illuminated by four 2x4 four-tube fixtures. This results in a 3 to 5.5 watts per square foot for area lighting, even for offices receiving substantial daylighting. By comparison, new energy efficiency lighting technology can deliver cost-effective high-quality lighting at the recommended footcandle levels at 1.5 to 2 watts per square foot.

The majority of comments received from staff regarding lighting was that the work areas were overilluminated. Some workers expressed a desire to remove some of the fluorescent tubes in some office fixtures. There were few comments about the lack of adequate illumination. Building 16W is primarily a warehouse with some office areas. The lighting level typically measured 50 footcandles in open areas and often less than 50 footcandles in some other areas near the shelving. Some building occupants claimed they need flashlights to read identifying labels on warehoused items.

In a number of machine shops, high bay areas, and other areas using industrial-type lighting (e.g., HID), there was little if any activity. Even so, the areas were fully illuminated. In one very large high bay there is lighting at three levels: HID lamps at the ceiling, fluorescent lamps on a lower grid, and fluorescent task/area lighting above desk and work areas around the periphery of the room. During in survey, in the entire area, only one worker at a desk in the periphery area (with area lighting) was observed.

Observations on a weekend and on a weekday evening showed that entrance and hall lights were on in most buildings. Also, an estimated 5 to 10% of the unoccupied office lights were on. On the weekend visit, even though the building was locked, a high-bay window showed that ceiling HID lamps were *all* illuminated.

5.3 Heating, Ventilating and Air Conditioning

The following findings regarding the site HVAC systems reflect information acquired from building walkthroughs as well as from historic site data collected during the site visits. Because of the limited scope of work, we chose to concentrate on those areas where there appeared to be substantial opportunity for efficiency improvement. Not all of the raw historic data supporting the findings are included in this report. Summarized data are presented where important.

5.3.1 Heating and Cooling

The central heating and cooling plant makeup water logs were examined and are summarized for CY 1991 in Table 5.1. In CY 1991, 18.847 million gallons of makeup water was needed. The site staff have indicated that the heating system condensate return lines have significantly deteriorated with significant loss of condensate return. The economic penalty associated with the makeup comes from: 1) the cost of the water, 2) the cost of treating the makeup water, 3) the increase system deterioration associated with a high level of makeup water, and 4) the heat lost in unreturned condensate.

Some of the makeup water is used to make up for the loss of steam used for steam humidification and by the cafeteria (process steam). If we assume that approximately 60% of the required makeup water is for these uses of steam, 40% of the total makeup water for the boilers is therefore *lost* in the distribution system due to deterioration of the condensate return lines.

In CY 1991, this line loss equaled approximately $18.847 \times 0.40 = 7.55$ million gallons of water. Based on a return condensate temperature of 170°F and a water supply temperature of 60°F, and saturated steam, the system loses 110 Btu per pound of lost

Table 5.1. Makeup Water for Boilers and Chillers for CY 1991

Month	Thousands of Gallons	
	Boilers	Chillers
January	1,717.97	63.35
February	1,555.09	81.01
March	1,811.37	93.31
April	1,530.61	69.78
May	1,459.63	138.27
June	1,558.97	107.50
July	1,419.78	109.24
August	1,312.73	99.74
September	1,363.68	88.17
October	1,475.85	80.90
November	1,665.40	166.07
December	1,975.86	119.44
Total	18,846.94	1,216.78

condensate (based on the steam tables). This equates to: 7.55 million gallons x 8.32 lb/gal x 110 Btu/lb = 7,000 million [M]Btu loss. Assuming an overall steam system delivery efficiency of 75% for the GSFC steam plant, the yearly water loss equates to 7,000 MBtu x 0.75 = 5,250 MBtu x 10^5 Btu/therm = 52,500 therms. The value of this heat loss is equivalent to over 52,500 therms x \$0.45/therm = \$23,625 of boiler fuel (natural gas) per year at current natural gas cost. The cost for the makeup water for this loss equates to ~ \$23,000/year at a water rate of \$3.00/1000 gallons.

5.3.2 Building Ventilation

All the buildings examined have significant air-handling systems. Buildings 1, 2, 4, 5, 6, 7, 8, 10, 11, 12, 15, 16W, 16, 17, 18, 19, 20, 21, 22, 23, 26, and 28 have multiple fan air-handling systems operating 24 hours a day. All the other examined buildings have air-handling systems that operate a significant portion of the day. The more recent installations (retrofit and new) employ variable air volume (VAV) systems that are somewhat more efficient than the older constant-volume (CV) systems. Heat recovery units (to capture some of the energy in the exhaust air by incoming air) are not employed in any of the buildings.

Hood ventilators were examined. The energy loss from air exhausted by the hoods is small compared to total building air exhausted. The only sizable area (room) exhaust ventilator observed was in the plating facility, where safety dictates the observed appropriate exhaust level of air.

The significant evening, weekends, and holidays electrical baseload noted above was suspected to be related to building ventilation and was therefore more thoroughly investigated. Since we observed that most building lights are off during non-working periods (see above), we surmised the CHP and CRP (with associated pumps, motors, etc.) and the building air-handling systems as the major contributors to the significant off-hours (base) load.

Though the individual buildings ventilation systems controls are locally set and the site staff can control the ventilation start and stop sequence, central monitoring or control is not employed. And with the locally-controlled systems it is suspected that misadjustment and tampering occurs even though the systems were properly set. There were some strong complaints in one building as to overly cold temperature in midsummer and that sweaters and jackets were kept in some offices. The cold temperature likely results from excess cooling required for humidity control.

Information acquired from the site staff during the site inspection document the air-handling systems fans that are not deactivated/turned off during non-working hours (see Appendix E). Without end-use metering and not knowing the velocity head, the static pressure, the fan outlet velocity, the fan efficiency, the drive motor efficiency, and the duty cycle for each fan, it is not possible to quantify the power draw by the individual building air-handling systems. However, the total fan power for the 21 of the 27 buildings with 24-hour air-handling system operations is ~770 hp. This equates to: $770 \text{ hp} \times 24 \text{ hr/day} \times 365 \text{ day/year} \times 0.746 \text{ kWh/hp} = 5,032,000 \text{ kWh/year}$.

5.4 Structural and Thermal

Most of the buildings examined have marginal or adequate insulation and were likely retrofitted and upgraded during the late 1970s. However, there is one metal-skinned supply building (Building 16W) that was found to be without adequate insulation. Insulation, in the form of insulating bats inside the metal skin, would reduce the heating and cooling needs.

6.0 Recommendations

There are considerable energy saving opportunities at the GSFC. And, of significance, PEPCO offers extensive rebate programs that apply to government agencies served by PEPCO. These incentives increase the attractiveness and cost-effectiveness of most of the recommended facility modifications to reduce energy consumption and costs.

There is significant energy savings potential from installing retrofit technologies for lighting and the building air-handling system as well as tuning and refurbishment of the central steam generating and supply system. The following is a recommended generic course of action followed by specific retrofit recommendations for the site.

6.1 FEMP Model Program for Facility Energy Efficiency

Our overall recommended general approach is to systematically treat the site from the top down (as a whole) and determine the most life-cycle-cost-effective retrofit technology based on a fuel-blind technology-neutral analysis. That is, determine the most *cost-effective* way to deliver services (e.g., lighting, heating, cooling, refrigeration, hot water, etc.) to the site and site facilities. A critical element of this approach is to form a partnership with PEPCO to develop a "custom" program that includes the utility providing up-front financing, cost sharing in the form of incentives and technology installation contracting.³ PNL experience with over 10 utilities serving federal sites has indicated that there needs to be significant site-utility understanding and collaboration in order to develop such a program to effectively implement energy-efficiency technologies. Appendix F gives a comprehensive explanation of this approach.

We also recommend that retrofit technologies be identified and implemented in a sensible order. For example, all building shell and interior lighting retrofits should be identified and undertaken prior to implementing an HVAC system retrofit or the undertaking of the final design of the expected replacement/refurbishment of the CHP, CRP and distribution systems currently scheduled for FY 1994-95. With this approach, the building loads (cooling and/or heating) are minimized and the heating/cooling system is (re)designed to meet the new loads. Once these steps are taken, the feasibility and applicability of other cost-saving, energy and demand-management measures such as thermal energy storage or on-site generation for peak shaving can be more accurately evaluated.

6.2 Lighting Retrofits

In general, lighting is the most cost-effective retrofit for a site to undertake, especially if the electric utility offers incentives, and should be the first retrofit measure implemented in a building or facility. Significant savings in this category are obtainable through 1) upgrading fixtures to cost-effective high-efficiency fixtures and at the same time bringing lighting levels to federal standards, 2) preventing the unwarranted use of luminaires (e.g., use when daylighting provides adequate illumination), 3) using task-oriented illumination where appropriate, and 4) reducing off-hour common area lighting (e.g., hallways).

Though a comprehensive fixture count was not conducted, we have conservatively estimated the number of fixtures and the energy and cost savings for a lighting retrofit of the 2x4 four-tube fixtures, 1x4 two-tube hallway fixtures and exit lights in approximately 576,000 ft² of office and 1,000,000 ft² of laboratory and other space (see Table 2.2). The analysis is based on an average fixture density of three 2x4 four-tube fixtures/120 ft² of office/lab square footage, one 1x2 two-tube hallway fixture per four office/lab fixtures and one 40-watt incandescent exit light per 1000 ft² of total square footage. The selected retrofits are based on 11 hours/day-5 day/week operation of office and laboratory lights and 24 hours/day-7 days/week operation of hallway and exit lights. The analysis is based on one-to-one, fixture-for-fixture replacement with new fixtures that result in an average 20-25% reduction in footcandle levels for all square footage and are the most life-cycle-cost-effective technologies. The retrofits will also result in better lighting quality and distribution.

Table 6.1 gives a summary of the analysis results using the FEMP-developed Lighting Technology Screening Matrix (LTSM)⁴ software analysis program (see Appendix G) and a

Table 6.1. Lighting Retrofit Analysis Results

Exist. Fixture	Watts	Number	Retrofit ^(a)	Watts	NPV ^(b) \$	Annual Savings		Inst. Cost
						kWh	\$	\$
2x4-4 Tube	190	13,133	DL2 + REF	79	2,013,700	2,968,100	136,530	645,350
1x4-2 Tube	75	3,283	DL1 + REF + ELC	34	982,400	1,294,150	59,530	208,000
Exit Lights	40	1,576	LED	5	580,000	482,300	22,180	69,150
Totals					3,576,100	4,744,550	218,240	922,500

(a) DL2 + REF = delamp 2 tubes and add reflector.

DL1 + REF + ELC = delamp 1 tube add reflector and replace ballast with an electronic ballast

LED = light-emitting diode-type fixture.

(b) Net Present Value.

blended electricity rate of \$0.0476/kWh. The installed cost of the retrofit includes the applicable PEPCO rebate and assumes local labor rates for installation. The NPV is based on life-cycle cost analysis using the current (FY 1993) federal discount rate of 4.0%.⁵

From Table 6.1, a minimum estimate of energy savings is over \$218,000/year, with an installed cost for the technology of \$922,500 (current dollars), including the utility rebates. The NPV of these retrofit measures is over \$3,576,000.

There are also other cost-effective opportunities (not quantified) for lighting controls particularly in those buildings with glass-walled hallways, glass-walled entrances, and outdoor building lights that were found to be on when the daylighting fully overwhelmed their lighting contribution. The lighting in these areas can be controlled by use of photoelectric light sensors. In addition, high bay areas and machine shop areas were found to be fully lit when the work areas were empty of personnel. On a weekend and at night all hallway lights were found to be on in examined buildings. These lights also should be controlled through the use of sensors--even after a retrofit. An additional 10-15% in lighting energy savings can be obtained at the site through cost-effective controls, and utility rebates are available for lighting controls.

6.3 Heating, Ventilating, and Air Conditioning

With a lighting retrofit, there will be energy and cost savings from reduced cooling load during the periods that the buildings are cooled. There will also be a need for slightly increased heating during the time the buildings are heated to make up for the reduction in heat loss from the higher-efficiency lighting equipment. The potential savings in refrigeration load and the increase in heating load depends upon the individual building cooling and heating requirements. However, based on the climate at the GSFC, the utility rate structure (i.e., significantly higher rates during the cooling season) and relatively low cost for delivered steam, there will be a net positive energy and energy cost savings for space conditioning from a relighting project. However, the savings have not been quantified and is beyond the scope of this study. The reduced cooling load should be evaluated and considered when upgrading the CRP and distribution system.

6.3.1 Central Plant and Distribution System

Based on the boiler makeup water analysis, the heating system condensate return lines are in need of repair and/or replacement (see Section 5.3.1). Energy (52,500 therms) and fuel cost (\$23,625) savings can be realized with remedial action. The site has recognized this problem and has scheduled several million dollars of chiller/central plant upgrades and

distribution system renovation for FY 1993–95. However, prior to the major refurbishment of the distribution systems scheduled in FY 1994 and 1995, we recommend that the engineering and economic analysis be reviewed to ascertain if replacing all or part of the central steam (and chilled water) system with distributed systems (for heating and cooling) is cost-effective. The analysis should consider the utility rebates (and potentially utility financing) for high-efficiency chillers, high-efficiency packaged air conditioners and heat pumps. The feasibility and economics of absorption and distributed gas engine-driven chillers should also be assessed. The analysis should also be based on building loads once all cost-effective thermal, lighting, and HVAC system retrofits are undertaken.

6.3.2 Building Ventilation Systems

Currently, temperature set points in buildings are established at cooling/heating use location. Each radiator has a valve that permits using either hot water or chilled water depending on outside temperature. There are no provisions for cutting-off radiators during periods when neither heating nor cooling is required and therefore we recommend that this capability be installed, even though the secondary water pumps are turned off. Cut-off capability could also provide an anticipator capability that permits temperature stabilization prior to pumping more hot or chilled water through a heat exchanger.

The air-handling system motors in the buildings consume a substantial amount of electric energy particularly since many systems operate 24 hours a day, 365 days a year (see Section 5.3.2). If one-half of these fan motors can be turned off for one-half of the day, this will result in a savings of: $770 \text{ hp} \times 0.5 \times 12 \text{ hr/day} \times 365 \text{ day/year} \times 0.746 \text{ kWh/hp} \times \$0.046/\text{kWh} = \$57,900/\text{year}$ (1,258,000 kWh/year). There will also be additional significant space conditioning (heating/cooling) savings from shutting off ventilation systems during off-hours. However, without additional data on volumetric air flow and fan efficiency, these savings cannot be quantified.

There are additional savings through replacing motors with high-efficiency motors. Though the potential additional savings for motor retrofits at GSFC has not been quantified in this assessment, we have demonstrated at other federal sites that it is cost-effective to replace motors *on failure* (ROF) with high-efficiency motors, particularly those motors used for high-duty-cycle applications and especially for those fan systems that must operate 24 hours/day to provide critical ventilation and cooling.^{6,7} Cost-effective ROF strategies include drives for high-duty-cycle fans and pumps, including motors used in the CHP and CRP. The utility offers rebates for high-efficiency motors (see Table 4.1).

Also, where feasible, we recommend: 1) two-speed fan operation, 2) replacing inlet-vane with variable speed drive (VSD) control of variable air volume (VAV) flow rate, 3) modifying outside air control and installing low-leak dampers in the CV systems to provide zero outside air in unoccupied periods, 4) improving control and balance to minimize

heating/cooling exchanger loads, and 5) implementing (or fine tuning) optimal start/stop control. In addition, we recommend that site staff adjust the HVAC systems (where possible) to increase the volume of outside air in cooler weather for cooling and curtail the use of air-circulating fans in clean rooms that are not in use.

The site has limited system monitoring/control capability and this includes air-handling system monitoring. The system does not however include the ability to measure temperatures in buildings or to control heat balances within the buildings. The site has planned for the modification and upgrade to the centralized utility control system in FY 1993-95. If a centralized control system is not installed it is recommended to install a monitoring/metering system to, at a minimum, monitor energy use and temperature in the major buildings. A monitoring system will provide the information necessary to optimize system performance. Based on a recent thorough survey and analysis of automated meter reading technologies, a system can be designed specifically to meet the needs of the GSFC.⁸

6.4 Structural and Thermal

Buildings with marginal insulation should be cost-effectively retrofitted with and upgraded with energy-efficient glazing as they are renovated. It is generally not cost-effective to retrofit unless it is part of a planned major renovation project. In addition, insulation should be added to bare metal-skinned wall sections such as those in Building 16W. This retrofit would be relatively easy and cost-effective since the inside of the bare metal-skinned wall sections are open and readily accessible. Once again, the utility offers incentives for building envelope insulation, and low emissivity and reflective glass and film.

6.5 Electrical Generation and Distribution System

The GSFC has scheduled replacement of its diesel electric generators and these units should be considered for use in cogeneration and/or general peak shaving in addition to their use to support mission-critical activities. This requires a thorough engineering analysis and was not quantified in this assessment.

A comprehensive transformer (and distribution system) assessment was not undertaken. However, based on experiences at other NASA sites, the mission-critical nature of the activities likely require that all the transformers remain energized. Therefore, there is no recommendation for immediately modifying the system to reduce transformer and associated distribution system losses. However, as transformers are replaced, we recommend they be replaced with high-efficiency amorphous-core transformers. Prior analyses at other federal sites have indicated this strategy is cost-effective and can save 10 to 15%

of the energy that is normally lost in the transmission and distribution system.^{6,7} This strategy may also qualify for utility incentives under the "site-specific measures" part of the PEPCO program (See Table 4.1).

6.6 Operations

The site staff should also review the operations and maintenance (O&M) practices for the CHP, CRP and building HVAC systems and modify if necessary to ensure that all systems are properly maintained. Though not quantified in this assessment, based on recent experience at other similar large federal facilities, a minimum savings of 20 to 30% in HVAC system energy use can be realized through a comprehensive O&M program. This includes resetting dampers and thermostats to their proper positions; changing filters; replacing worn belts, pulleys and bearings; repairing leaking ductwork and piping; cleaning fan coils; and repairing and calibrating flow, temperature and pressure-measuring instruments.

7.0 References

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Appendix A

Goddard Space Flight Center Site Map and Buildings List

A.1

Appendix B

Details of Site Buildings Assessed

Building 1: Space Projects Building - Cafeteria, GEWA Store, Personnel and Travel

Year Built: 1960

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors

Square Footage:

Gross	Office	Laboratory	Special
74,900	16,481	0	27,909

Building 2: Research Projects Laboratory - Gas Laboratory

Year Built: 1960

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
81,600	27,012	12,758	31,885

Building 3: Central Flight Control and Range Installation Building

Year Built: 1961

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse (contains building associated air conditioning unit)

Square Footage:

Gross	Office	Laboratory	Special
114,000	21,765	300	47,350

Building 4: Plant Operations Building

Year Built: 1961

Type of Construction: Permanent and Semi-Permanent - Steel and Masonry

Configuration: 1 Floor

Square Footage:

Gross	Office	Laboratory	Special
37,200	7,110	0	28,438

Building 5: Instrument Construction and Development Laboratory

Year Built: 1962

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors (contains 2 high-bays: 1) 35,780 ft², 25 ft high and 2) 3,420 ft², 51 ft high)

Square Footage

Gross	Office	Laboratory	Special
131,100	27,761	10,166	75,134

Building 6: Space Sciences Laboratory

Year Built: 1962

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
105,800	42,908	1,090	14,058

Building 7: Payload Testing Facility

Year Built: 1962

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors (contains high-bay, 13,475 ft², 29 ft high)

Square Footage:

Gross	Office	Laboratory	Special
157,200	22,571	485	82,052

Building 8: Administration Building

Year Built: 1963

Type of Construction: Permanent - Steel and Masonry

Configuration: 7 Floors (contains building associated air conditioning unit)

Square Footage:

Gross	Office	Laboratory	Special
120,000	40,637	0	23,737

Building 10: Experimental Testing Laboratory

Year Built: 1962

Type of Construction: Permanent - Steel

Configuration: 2 Floors and Mezzanine (contains high-bay, 19,500 ft², 74 ft high)

Square Footage:

Gross	Office	Laboratory	Special
51,700	750	0	39,990

Building 11: Applied Sciences Laboratory

Year Built: 1963

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse (contains high-bay, 6,230 ft², 17 ft)

Square Footage:

Gross	Office	Laboratory	Special
126,400	35,230	8,955	22,155

Building 12: Tracking and Telemetry Laboratory

Year Built: 1964

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
106,100	49,935	755	9,760

Building 13: Network Control Center Facility

Year Built: 1979

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors

Square Footage:

Gross	Office	Laboratory	Special
49,800	0	0	33,316

Building 14: Spacecraft Operations Facility

Year Built: 1964

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
148,427	8,590	0	52,270

Building 15: High Capacity Centrifuge Facility

Year Built: 1965

Type of Construction: Permanent - Steel and Masonry

Configuration: 2 Floors (contains high bay, 6,000 ft², 12.2 ft high)

Square Footage:

Gross	Office	Laboratory	Special
44,248	9,713	0	30,405

Building 16: Logistic and Supply Facility - Shipping and Receiving

Year Built: 1964

Type of Construction: Permanent - Steel and Masonry

Configuration: 4 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
33,192	17,365	0	1,205

Building 16W: Logistic and Supply Facility - Mail Room

Year Built: 1964

Type of Construction: Permanent-Steel

Configuration: 3 Floors

Square Footage:

Gross	Office	Laboratory	Special
194,585	34,595	670	136,759

Building 17: Administrative Support Building -Safety Office, Bid Room and Facilities

Engineering Division

Year Built: 1963

Type of Construction: Permanent - Steel and Masonry

Configuration: 2 Floors

Square Footage:

Gross	Office	Laboratory	Special
38,700	22,835	0	4,741

Building 18: Administrative Support Building -Information Technology Center

Year Built: 1963

Type of Construction: Permanent - Steel and Masonry

Configuration: 2 Floors

Square Footage:

Gross	Office	Laboratory	Special
35,300	15,638	0	10,537

Building 19: Technical Support Building

Year Built: 1963

Type of Construction: Permanent - Steel and Masonry

Configuration: 1 Floor and Mezzanine

Square Footage:

Gross	Office	Laboratory	Special
20,700	7,563	5,651	3,635

Building 20: Technical Support Building

Year Built: 1963

Type of Construction: Permanent - Steel and Masonry

Configuration: 1 Floor

Square Footage:

Gross	Office	Laboratory	Special
20,700	5,479	4,483	5,853

Building 21: Meteorological Systems Development Laboratory - Cafeteria, Library, and Credit Union

Year Built: 1965

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
155,000	29,077	4,951	57,240

Building 22: Space and Terrestrial Applications Facility

Year Built: 1967

Type of Construction: Permanent - Steel and Masonry

Configuration: 4 Floors and Penthouse (contains high-bay, 3,400 ft², 20 ft high)

Square Footage:

Gross	Office	Laboratory	Special
156,300	49,233	5,980	41,755

Building 23: Data Interpretation Laboratory

Year Built: 1966

Type of Construction: Permanent - Steel and Masonry

Configuration: 4 Floors

Square Footage:

Gross	Office	Laboratory	Special
184,900	44,775	5,552	64,869

Building 24: Central Heating and Refrigeration Plant

Year Built: 1961

Type of Construction: Permanent - Steel and Masonry

Configuration: 2 Floors

Square Footage:

Gross	Office	Laboratory	Special
27,800	0	0	24,775

Building 26: NASA Space Science Data Center

Year Built: 1967

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors

Square Footage:

Gross	Office	Laboratory	Special
53,800	12,125	0	16,394

Building 28: Technical Processing Facility

Year Built: 1979

Type of Construction: Permanent - Steel and Masonry

Configuration: 2 Floors

Square Footage:

Gross	Office	Laboratory	Special
96,460	23,757	605	37,659

Building 29: Spacecraft Systems Development and Integration Facility

Year Built: 1990

Type of Construction: Permanent - Steel and Masonry

Configuration: 3 Floors and Penthouse

Square Footage:

Gross	Office	Laboratory	Special
78,800	3,455	0	53,790

Notes: In this listing basements are counted as a floor; Buildings 25 and 27 are not on the main campus; and Building 30 is currently under construction.

Appendix C

Potomac Electric Power Company Rate Schedule and Load Plots

MD - GT

TIME METERED GENERAL SERVICE SCHEDULE "GT"

AVAILABILITY - Shall be applicable in the Maryland portion of the Company's service area to customers whose maximum thirty (30) minute demand equals or exceeds 1,000 KW during two (2) or more months within twelve (12) billing months. Once a customer's account is established it will remain in Schedule "GT" even if the party responsible for the account should change. Removal from Schedule "GT" is based solely on the criteria stated in the following paragraph.

Any customer presently on Schedule "GT" whose maximum thirty (30) minute demand is less than 900 KW for twelve (12) consecutive billing months, may at the customer's option elect to continue service on this schedule or elect to be served under any other available schedule.

This schedule will become active for eligible customers as soon as the three (3) month customer notification process is completed. New accounts may, however, elect to waive the customer notification process.

Available for low voltage electric service at sixty hertz.

Available for standby service when modified by Schedule "S".

Available for primary service when modified by Rider "GT-3A" or Rider "GT-3B".

Not available for temporary service or supplementary loads metered separately from lighting and other usage in the same occupancy.

Not available for railway propulsion service.

CHARACTER OF SERVICE -

SECONDARY SERVICE - The service supplied under this schedule normally will be alternating current, sixty hertz, either (i) single phase, three wire, 120/240 volts or 120/208 volts, or (ii) three phase, four wire, 120/208 volts or 265/460 volts.

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June 6, 1991

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MD - GT

CHARACTER OF SERVICE - (Continued)

PRIMARY AND HIGH VOLTAGE SERVICE - The service under this schedule when modified by Rider "GT-3A", normally will be alternating current, sixty hertz, three phase, three wire, at 13.2 KV or 33 KV, and when modified by Rider "GT-3B", will be 66 KV or above. Primary nominal service voltage levels will be specified by the Company on the basis of its available facilities and the magnitude of the load to be served.

MONTHLY RATE -

	Billing Months of <u>June - October</u> (Summer)		Billing Months of <u>November - May</u> (Winter)	
A. Customer Charge	\$ 273.80	per month	\$ 273.80	per month
B. Energy Charge				
On-Peak Period	3.069¢	per kwhr	2.241¢	per kwhr
Intermediate Period	2.425¢	per kwhr	1.704¢	per kwhr
Off-Peak Period	.905¢	per kwhr	.479¢	per kwhr
C. On-Peak Demand Charge	\$ 9.70	per kw	-	
D. Maximum Demand Charge	\$ 4.00	per kw	\$ 4.00	per kw
E. Minimum Charge - The Customer Charge				
F. Facilities Charge - The customer may elect to pay the fee for the facilities provided pursuant to Section 10--SERVICE CONNECTIONS of the Company's "General Terms and Conditions" through the application of a monthly charge of 2% of the amount which would otherwise be payable as a contribution-in-aid-of-construction under Subsection 10.e.3--Charges for Service Connections, Commercial - Industrial. The monthly charge will be recalculated each time additions or retirements to the facilities occur as the result of modifications, relocations, or alterations.				

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MD - GT

In the event that the facilities are removed before they have been in place for five (5) years, the customer shall agree to pay the cost of removal plus the original cost to which the facilities charge was applied, less depreciation and estimated salvage value. The customer initially making the monthly payment election, and all subsequent customers at the same location, shall pay this monthly charge until such time as the facilities are removed, or the current customer elects to terminate the charge, by the payment of an amount equal to the contribution in aid of construction which would be paid on the depreciated original cost of the installed facilities. In the event that the property is sold by the customer, the customer shall pay an amount equal to the contribution in aid of construction which would be paid on the depreciated original cost of the installed facilities or shall secure the written election of the new owner of the property to pay the fees provided for above.

RIDER "FR" - FUEL RATE - Charges for fuel cost and energy purchases, computed in accordance with the provisions of Fuel Rate - Rider "R", combined with monthly charges under the provisions of this schedule, constitute the total charge for the service which the Company furnishes.

RATING PERIODS -

Weekdays - (Excluding Holidays)

On-Peak Period	12:00 noon	to	8:00 p.m.
Intermediate Period	8:00 a.m.	to	12:00 noon
		and	
	8:00 p.m.	to	12:00 midnight
Off-Peak Period	12:00 midnight	to	8:00 a.m.

Saturdays, Sundays and Holidays

Off-Peak Period All Hours

Holidays

For the purpose of this tariff, holidays will be New Year's Day, Rev. Martin Luther King's Birthday, Presidents' Day, Memorial Day, Independence Day, Labor Day, Columbus Day, Veterans' Day, Thanksgiving Day and Christmas Day, as designated by the Federal Government.

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BILLING DEMANDS -

On-Peak (Summer Billing Months Only) - The billing demand shall be the maximum thirty (30) minute demand recorded during the on-peak period of the billing month.

Maximum (All Months) - The billing demand shall be the maximum thirty (30) minute demand recorded during the billing month.

RIDER "GT-1" - POWER FACTOR - This rider is applied to and is a part of Schedule "GT" if the customer is found to have a leading power factor or a lagging power factor of less than 85%. If power factor corrective equipment satisfactory to the Company has not been installed within ninety (90) days of notification by the Company, the demand charges will be multiplied by a factor of 1.111.

RIDER "GT-3A" - PRIMARY SERVICE - This rider is applied to and is a part of Schedule "GT" when the Company furnishes service directly from its electric system at voltages of 13.2 KV or above, the customer providing at the customer's own expense, all necessary transformers, converting apparatus, switches, disconnectors, regulators and protective equipment. In such case the service will be measured at the primary voltage and a discount of 5% will be allowed on parts (A) through (E) of the Monthly Rate.

RIDER "GT-3B" - HIGH VOLTAGE SERVICE - This rider is applied to and is a part of Schedule "GT" when the Company furnishes service directly from its electric system at voltages of 66 KV or above, the customer providing at the customer's expense, all necessary transformers, converting apparatus, switches, disconnectors, regulators and protective equipment. In such case the service will be measured at the high voltage and a discount of 10% will be allowed on parts (A) through (E) of the Monthly Rate.

RIDER "CS" - CURTAILABLE SERVICE - This rider is applied to and becomes a part of Schedule "GT" when a customer meets the criteria set forth in Curtailable Service - Rider "CS".

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RIDER "CLR" - COMMERCIAL LOAD REDUCTION SERVICE - This rider is applied to and becomes a part of Schedule "GT" when a customer meets the criteria set forth in Commercial Load Reduction Service - Rider "CLR".

RIDER "TS" - THERMAL ENERGY STORAGE SERVICE - This rider is applied to and is a part of Schedule "GT" where the customer's primary cooling energy requirements are supplied by an electrical thermal energy storage system. In this case, the Maximum Demand Rate is modified as follows:

Maximum Demand

The billing demand shall be the maximum thirty (30) minute demand recorded all weekday hours between 8 a.m. and 8 p.m., except those on holidays.

METER READING - Watt-hour meters will be read to the nearest multiple of the meter constant and bills rendered accordingly.

GENERAL TERMS AND CONDITIONS - This schedule is subject in all respects to the Company's "General Terms and Conditions for Furnishing Electric Service" and the Company's "Electric Service Rules and Regulations".

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CURTAILABLE SERVICE RIDER "CS"

CURTAILABLE SERVICE - This rider is applied to and is a part of Schedules M-GT" or "GT" when a customer selected by the Company for participation in this program agrees to establish a firm service level and to curtail load to that level upon the request of the Company in accordance with the following provisions:

1. The customer will establish a firm service level which provides for a minimum load curtailment of one hundred (100) kilowatts of load.
2. The Company will request load curtailments only during potential curtailment periods in the five (5) summer billing months of June through October. Potential curtailment periods include all weekday hours between noon and 8:00 p.m., except those on holidays. For the purposes of this rider holidays include: Memorial Day, Independence Day, Labor Day, and Columbus Day as designated by the Federal Government.
3. The customer will receive a potential curtailment warning from the Company not less than thirty (30) minutes prior to a load curtailment implementation request. Upon receipt by the customer of a load curtailment implementation request from the Company, the recorded demand of the customer must be reduced to a level at or below the customer's contractually agreed upon firm service level within five (5) minutes. The demands of the customer must be maintained at or below this firm service level until either:
 - (a) The customer is notified by the Company that the load curtailment period has ended, or
 - (b) The end of the potential curtailment period on the day of the request.

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4. Each requested load curtailment will have a maximum duration of six (6) hours.
5. Total number of load curtailment implementation requests during any calendar year will not exceed fifteen (15).
6. The Company is solely responsible for determining the need for load curtailment.
7. The customer will receive a credit in each summer billing month in which curtailment is requested. The amount of the credit will be \$8.60 for each kilowatt of curtailed load during the billing month for low voltage secondary service. For customers taking service at voltage levels of 13.2 KV or higher, the monthly credit per kilowatt of curtailed load will be reduced by 3.55%.
8. The customer's curtailed load in any billing month will equal the lesser of:
 - (a) The customer's maximum thirty (30) minute demand recorded in the billing month during an on-peak period less the customer's contractually agreed upon firm service level, or
 - (b) The customer's maximum thirty (30) minute demand recorded in the billing month during an on-peak period of potential curtailment less the maximum thirty (30) minute demand recorded during any period(s) of requested load curtailment in that month.
9. The firm service level may be adjusted on an annual basis, subject to approval by the Company.
10. The customer will be charged a penalty in any month in which the recorded load during a period of curtailment exceeds the customer's contractually agreed upon firm service level. This penalty will equal two (2) times the monthly credit per kilowatt of curtailed load (including appropriate adjustment for voltage level) multiplied by the number of kilowatts by which the customer's maximum demand during any period of curtailment in the billing month exceeds the contractually agreed upon firm service level.

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No penalties for non-performance will be assessed for new customers until each new customer has experienced six (6) curtailments. In addition, each customer will be allowed one (1) penalty-free period during each calendar year to be used at the customer's option.

11. The Company will install, own, and maintain special metering and communications equipment required for this service. The Company will be responsible for providing a suitable warning device and the customer will be responsible for installing the device at the customer's expense.
12. Credits and penalties computed for billing purposes under the provisions of this rider shall be exempt from the discounts provided for those customers served under Riders "GS-3A", "GS-3B", "M-GT-3A", "M-GT-3B", "GT-3A" and "GT-3B".
13. This Rider "CS" shall not apply to service interruptions resulting from system emergency operating conditions.
14. All contracts for service under this schedule shall be effective for one (1) calendar year, after which the contract continues in force until either party notifies the other of a desire to terminate the agreement.

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PLOT OF KILOWATT HOURS VERSUS TIME - 15 MINUTE INTERVALS

5000177005 8-204 NASA GODDARD SPACE FROM 920804 TO 920902

PLOT FOR DATE 920804

PLOT OF KILOWATT HOURS VERSUS TIME - 15 MINUTE INTERVALS
5000177005 8-20% NASA GODDARD SPACE FROM 920804 TO 920902 PLOT FOR DATE 920805

PLOT OF KILOWATT HOURS VERSUS TIME - 15 MINUTE INTERVALS
5000177005 8-204 NASA GODDARD SPACE FROM 920804 TO 920902 PLOT FOR DATE 920806

PLOT OF KILOWATT HOURS VERSUS TIME - 15 MINUTE INTERVALS

5000177005 8-204 NASA GODDARD SPACE FROM 920804 TO 920902

Plot for Date 920809

PLOT OF KILOWATT HOURS VERSUS TIME - 15 MINUTE INTERVALS
 5000177005 8-204 NASA GODDARD SPACE FROM 920804 TO 920902 PLOT FOR DATE 920810

5000177005 8-204 NASA GODDARD SPACE FROM 920804 TO 920902

7483.75	7733.48	7186.41	7034.74	6885.07	6735.40	6436.06	6286.39	6136.72	5987.05	5837.38	5687.71	5538.04	5388.37	5238.70	5089.03	4939.36	4789.69	4640.02	4490.35	4340.68	4191.01	4041.34	3891.67	3742.00	3592.33	3442.66	3292.99	3143.32	2993.65	2843.98	2694.31	2544.64	2394.97	2245.30	2095.63	1945.96	1796.29	1646.62	1496.95	1347.28	1197.61	1047.94	898.27	748.60	598.93	449.26	299.59	149.92	0.25
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[illegible]

PLOT OF KILOWATT HOURS VERSUS TIME - 15 MINUTE INTERVALS
 5000177005 8-204 NASA GODDARD SPACE FROM 920804 TO 920902 PLOT FOR DATE 920812

Potomac Electric Power Company
P.O. Box 2812 Washington, DC 20067-2812
Telephone (202) 833-7500

AMOUNT PAID

558

(Pepco's Taxpayer Identification No. 53-0127880)

TYPE OF BILL ACTUAL READING
SERVICE ADDRESS GREENBELT MD

TIME-OF-USE BILL

SUMMER RATES IN EFFECT

H
08

NASA GODDARD SPACE FLIGHT
CENTER #S592598D
C/O B HOLLIDAY (CODE 292)
UTILITIES BRANCH
GREENBELT MD 20771

AMOUNT DUE AFTER	DUE DATE
JUL 03 91 549309.99	JUL 03 91 541192.11
INCLUDES LATE PAYMENT CHARGE	AMOUNT DUE

Payment may be made
payable to pepco

PLEASE WRITE THE
ACCOUNT NO. ON
YOUR REMITTANCE

450001770050000000000549309990703910541192110005000177005

PLEASE DETACH HERE AND RETURN THIS PART WITH YOUR PAYMENT

ACCOUNT NO. 5000177005

TYPE OF BILL ACTUAL READING

SERVICE ADDRESS GREENBELT MD

SERVICE PERIOD MAY 06 TO JUN 03 91 30 DAYS

RATE CODE	METER NO. (LAST DIGIT)	MULTIPLIER	METER READING PREVIOUS	METER READING PRESENT	KWH USED (SEE DEMAND)	DESCRIPTION	AMOUNT
						PRIOR BILL AMOUNT	287233.11
						PYMTS THRU JUN 11	287233.11CR
						3ACURTAILMENT PENALTY KW	.00
						1ACURTAILMENT CREDIT KW	.00
	R112		095550000	98300000	2750000	KILOWATT HOUR METER	
	R111		097970000	4080000	6110000	KILOWATT HOUR METER	
CB					43228300	OFF-PK \$.0275/KWHR**	118688.48
BE					2184962	INT-PK \$.0427/KWHR**	93202.18
AS					2357878	ON-PK \$.0492/KWHR**	116527.62
					8875670	TOTAL KILOWATT HOURS	
					16905.6	MAXIMUM DEMAND	67622.40
					16905.6	ON-PEAK KILOWATT DEMAND	163984.32
						DISCOUNT	19832.89CR
						MD ENVIRONMENT SURCHG	1000.00
						NET CURRENT BILL	541192.11

ACTUAL DEMAND 16905.6
I authorize the use of this bill for payment of my account.
been rendered and service is being provided for me.
YOU MAY REQUEST A CHANGE IN YOUR BILL THIS MONTH. THIS IS DUE
S.D. TIME FACTORS.

** SUMMER RATES ARE IN EFFECT JUNE THROUGH OCTOBER.
** A GENERAL RATE INCREASE OF 1.1 PERCENT FOR COMMERCIAL
CUSTOMERS HAS BEEN IMPLEMENTED FOLLOWING FINAL REGULATORY
APPROVALS. ON AN INFLATION-ADJUSTED BASIS, AVERAGE ANNUAL
RATES WILL BE AT THEIR LOWEST IN 15 YEARS.

PERIOD	DAYS	ENERGY, KWH	PER DAY	CHANGE, %
JUN 90	32	12001737	375054.3	
JUN 91	30	8875670	295855.7	21.1-

SUMMER RATES IN EFFECT

MD ENVIRON SURCHG PER KWH .00012000
**INCL. FUEL RATE PER KWH .01840620

AMOUNT DUE AFTER	DUE DATE
JUL 03 91 549309.99	JUL 03 91 541192.11
INCLUDES LATE PAYMENT CHARGE	AMOUNT DUE

SEE REVERSE SIDE FOR IMPORTANT INFORMATION

* IF APPLICABLE

Appendix D

Building Walkthrough Notes

Appendix D

Building Walkthrough Notes

Twenty seven buildings were examined by walkthroughs noting energy use characteristics. Particular attention was directed at lighting. In each building, numerous foot candle readings were taken as well as observations of watts per square foot. Observed light levels are based on readings taken with a General Electric triple range model 214 light meter. The sensitivity of the light meter is closely matched to the sensitivity of the human eye. The meter is also cosine-corrected with meter response proportional to the cosine of the angle that the incident light makes with the perpendicular. Estimates of watts per square foot are based on lighting wattage in a given area divided by the area. Area determinations are based on known ceiling tile dimensions and through use of a Hugo Meyer optical distance measuring instrument. This instrument has an expanded scale below 30 feet.

In general, it was observed that there is substantial variabilities between buildings as well within a building. Within a building, there is often considerable variation from hallway to hallway, from wing to wing, from office to office, as well as significant variability between floors. The following is based on notes taken during walkthrough inspections and a sampling of lighting characteristics. In the following all references to lighting fixtures are for fixtures with 34 watt (energy saving) fluorescent tubes unless specifically stated otherwise.

Building 1: Space Projects Building - Cafeteria, GEWA Store, Personnel & Travel

This building has very light colored walls that contributes to the interior brightness. An entrance is well lit with a 4-tube fixture. There is considerable variance in hallway lighting. Typically, in the basement halls, 4-tube fixtures are employed with spacing of 4' to 12'. Light levels vary between 60 and 100 fc. First and second floor halls typically employ 2-tube fixtures with 8' spacing (60 fc). Office, 4 4-tube fixtures, 120 sf, 120 fc. Office, 4 4-tube fixtures, 192 sf, 100 fc. Office, 140 sf, 4 4-tube fixtures, 120 fc. Large office, no consistent lighting pattern, 4-tube fixtures, as high as 5.6 watts per sf.

Building 2: Research Projects Laboratory - Gas Laboratory

Hallways variable, e.g., one hallway with touching 4 tube fixtures (170 fc), one with 2 tube fixtures with 4' spacing (60 fc). Light levels varied between 70 fc in storage areas and over 100 fc in offices. In offices, lighting power density typically around 4 watts/sf. Within the last two years this building was completely relamped with almost all 2-tube fixtures replaced with 4-tube fixtures.

Building 3: Central Flight Control and Range Installation Building

Building 13: Network Control Center Facility

Building 14: Spacecraft Operations Facility

Buildings 3, 13, and 14 are connected structures with restricted access and are believed to fall into the mission exempt category. Observations of lighting in offices and hallways from the outside the buildings appear to indicate typical densities found in other buildings. Sensors on some glass wall entrance lights were observed. Four-tube hall lamps with 8' spacing were observed. Observed offices include: 6 2-tube fixtures and 4 4-tube fixtures for various office sizes estimated to be in the 120 to 196 sf range.

Building 4: Plant Operations Building

Illumination levels varied considerably throughout the building. In one 12' x 15' room, light level at desktop was 80 fc with eight 34 watt fluorescent tubes operating out of a total of twelve tubes, with window blinds down the level was 70 fc. Other offices were as high as 110 fc. In main hallway the level had peaks of over 100 fc. In the shop area hallway, the light level was considerably lower.

Building 5: Instrument Construction and Development Laboratory

Hallways, 4-tube fixtures with 12' spacing (130 fc peaks), 4-tube fixtures with 8' spacing, 2-tube fixtures inline. Overly bright common areas. Area in front of elevator (130 fc peak). Measured office lighting density 2.9 watts per sf. One room had a switching arrangement in which either 2 or 4 bulbs in a given fixture could be turned on. High bay areas use HID and Power Grove fluorescent lamps, were extremely well lit with little if any activities.

Building 6: Space Sciences Laboratory

Hall lamps varied with 12', 16' and 20' spacings with illumination levels over 100 fc. Measured office light levels varied from 70 to 90 fc. With red tagged lamps off, many offices had lighting power densities of from 2 to 3 watts/sf.

Building 7: Payload Testing Facility

Halls, 2-tube lamps, 4 ft apart with many lamps off. Office, 180 sf, 8 2-tube fixtures, 3 red tagged and off, 60 fc. Office, 168 sf, 6 2-tube fixtures, 50 fc. Office, 200 sf, 5 4-tube fixtures. Several sampled offices, lighting density 3.4 watts/sf (all fixtures on). A number of red tagged de-energized fixtures in some rooms with reduced lighting levels (no complaints). High bay very well lit and no activities, estimated power density greater than 8 watts per sf. Offices, and industrial type activities.

Building 8: Administration Building

Hall and common area ceiling fixtures varied, some 2' x 2' square fixtures with 2 U-shaped fluorescent tubes (30 fc). Hall, 4-tube fixtures with 16' spacing. Dim hall with bullet ceiling lamps. Some hallway 4-tube fixtures have 2 tubes de-energized (50 fc) (3rd floor). Large work area, 4-tube fixture per 64 sf (80 fc). Some offices 4 2-tube fixtures per 225 sf (significant daylighting). Some offices with 6 2-tube fixtures have 2 lamps off. One office has 4 4-tube lamps with windows unshaded (150 fc). This building seems to generally have lower lighting levels than most examined. Maybe the administration, located in this building, is trying to set a good example.

Building 10: Experimental Testing Laboratory

This building supposedly has the largest clean room in the world. The building houses unique facilities. Did not observe any normal office space. Industrial type area and activities.

Building 11: Applied Sciences Laboratory

Hall, 4-tube fixture with 12' spacing (100 fc). Hall, 2-tube fixture, 4' spacing (30 fc). Office, 2 4-tube fixtures, 150 sf, daylighting (150 fc). Office, 150 sf, 6 2-tube fixtures, 2 fixtures red tagged, 2.5 watts/sf, 80 fc). Many offices have 2 of 6 fixtures red tagged (i.e., de-energized). Office, 150 sf, 2.5 watts/sf (100 fc). Room under renovation, 375 sf, 10 4-tube fixtures, 4 watts/sf (150 fc). Office, all lights off, blinds half way up, 40 fc in middle of room, no direct sunlight. Office, 10 2-tube fixtures, 250 sf, minimum window effect, 3 watts/sf, 70 fc. Some offices, all lights on, 120 fc. Glass wall entrance way, photo sensor controlled switches, lights off.

Building 12: Tracking and Telemetry Laboratory

One side entrance, floor to ceiling glass wall (2 stories), area flooded with daylighting, all inside entrance way lights on (200 fc). Another side entrance has sensor controlled switches and the inside entrance lights were off. Hall, 4-tube fixture with 16' spacing.

Hall with 4-tube fixtures with 8' spacing between fixtures (100 fc). Office, 140 sf, 4 4-tube fixtures with large tinted window, 180 fc (4.2 watts/sf). This was typical of an observed wing. One office, 196 sf with 4 4-tube fixtures (3 watts/sf). Office with a 4-tube fixture for every 32 sf (4.6 watts/sf). In general, measured office light levels varied between 70 and 196 fc. It is noted that many areas in the building changed function with time.

Building 15: High Capacity Centrifuge Facility

Hall, 4-tube fixtures, 10' spacing, some off. Hall, 2-tube fixtures, 8' spacing, many lamps off. Large modular work area, 4-tube fixture per 48 sf. Industrial type activities.

Building 16: Logistic and Supply Facility -Shipping and Receiving

Hall, sideways fixtures, 4-bulbs, 10 ft spacing, 80 fc. Hall, 4-tube, 16' spacing. Hall, sideways fixtures, 4-tube, 6' spacing. Office, 120 sf, 6 2-tube fixtures, 100 fc. Office, 4 4-tube lamps, 225 sf, 100 fc. Office, 3 4-bulbs lamps, 160 sf, 150 fc with window illumination. Office, 2 4-tube fixtures, 130 sf, 100 fc. Office, 6 2-tube fixtures, 140 sf, 3.2 watts/sf. Office, 150 sf, 3 4-tube fixtures, 100 fc. Conference room, 375 sf, 18 2-tube fixtures. Lamps in glass entrance were all on, 70 fc.

Building 16W: Logistic and Supply Facility - Mail Room

Three story metal skinned building without windows. First floor, very poor lighting. Only second floor office area is air conditioned. Office area contains modular office partitions, 4-bulbs per 64 sf. Second floor warehouse area, 2-tube fixtures with 8' power groove fluorescent bulbs. Third floor, some HID lamps and twin 4 ft fluorescent lamps.

Building 17: Administrative Support Building -Safety Office, Bid Room & Facilities Engineering Division

Hall, single tube fluorescent at ceiling/wall corner. Hall, 2-tube fluorescent fairly widely spaced. Office, 3 4-tube fixtures (150 fc). Office 2 4-lamp fixtures, 150 sf (110 fc). Office, 6 2-tube fluorescent, 150 sf (100 fc). Large office area, 3 4-tube lamps per 72 sf (80 fc). Large work area with partitions, 2-tube fixtures end-to-end with 4 to 5 feet between rows, uniform lighting (60 fc). In one area, significant use of task type lamps under shelves over work areas.

Building 18: Administrative Support Building - Information Technology Center

One hall, 2-tube fixtures with 8' spacing. A wide hall has 4-tube fixtures. Within the last year a laboratory had 2-tube fixtures replaced with 4-tube fixtures with 4-bank switching. When all lamps are on the lighting level is 150 fc. An office area has long rows of 2-tube fixtures with 4.5' between rows. The light level is uniform at 80 fc. Many offices have 4-lamp fixtures and are overly bright (130' fc over working area). The planning branch has 4-tube fixtures end-to-end with 4' between the rows (150 fc). Some entrance ways with glass outside walls had all fixtures on.

Building 19: Technical Support Building

Glass entrance had all lamps on when daylighting was more than adequate. Hall, 2-tube fixtures with 8' spacing (80 fc). Hall, 4-tube fixtures 8' spacing (130 fc). 150 sf offices with 4 4-tube fixtures (150 fc). Other offices, 4 4-lamp fixtures with 4' spacing between fixtures. Storerooms are very bright.

Building 20: Technical Support Building

Hallway, 2-lamp fixtures with 6' spacing (75 fc). Some hallways have 8' spacing. Large work area with 1 4-tube fixture for every 48 sf (130 fc). Office, 4 4-tube fixture, 150 sf, 150 fc. Some workers tilt computer screen down to lessen glare. Some workers with window offices work on computers with lights off.

Building 21: Meteorological Systems Development Laboratory - Cafeteria, Library, and Credit Union

There is great lighting variability within this building. In some areas the lighting density is conservative (1.5 watts/sf. In other areas the lighting levels are excessive. Some hall fixtures were spaced 16' ft apart with lighting level peaks of 130 fc. Large glass entrance ways had lighting levels of 150 fc with all lamps on. Sampling of offices varied from 70 to over 100 fc. One office measured 50 -70 fc with only 5 out of 12 lamps operating. one 180 sf office has twelve 34 watt lamps and daylighting. The light level was above 90 fc. Some laboratory areas measured as high as 150 fc. In one hallway, daylighting by itself provided 30 fc.

Building 22: Space and Terrestrial Applications Facility

Hall, 2-tube fluorescent with 6' spacing (60 fc). One hall with every other fixture out. Some storage areas overly bright (70 fc). Office 50 fc with fixtures de-energized. Some workers want only 2 out of 6 fixtures on even at night (i.e., over work area). Some offices with 4 4-tube fixtures, some with 6 2-tube fixtures for 150 sf. Some offices with

6 2-tube fixtures have 2 fixtures de-energized (red tagged). Some offices have all fixtures on. Fluorescent lamps are mainly aged with resulting lower outputs.

Building 23: Data Interpretation Laboratory

There is a large computer facility in this building. The computer area has a 2-tube fixture per 25 sf. This area has fluorescent dimmers. This building has a courtyard with inside glass walled hallways. Some halls have 2-tube fixtures with 6' spacing. There are some hallways with 4-tube fixtures with 16' spacing. There is a hallway with 4-tube sideways installed fixtures with 4' spacing. There are areas with 2-tube fixtures that are essentially end to end. Some office fixtures are red tagged with 2 out of 6 fixtures de-energized. In one office only 4 bulbs out of 12 were energized (no complaints). In one office an employee was working using only daylighting. In general, halls with glass walls facing the courtyard do not require illumination in sunny weather. Fixture covers appear to cause significant light loss. Measurements under apparently identical fixtures, one covered and one uncovered showed a 20% loss in fc level due to the cover. One 150 sf office utilized 4 4-tube lamps (70 fc) with blinds down. One 310 sf room had 8 4-tube fixtures (3.8 watts/sf). The room was overly bright.

Building 24: Central Heating and Refrigeration Plant

Building houses boilers and chillers - little office space.

Building 26: NASA Space Science Data Center

Lighting in building was recently redone. Hall, 2-tube fixtures with 4' spacing (80 fc). Office, 160 sf, 4 4-tube fixtures with 4 bulbs de-energized. Xerox room, 140 sf, 4 4-tube fixtures (170 sf). Some inside offices, 2 4-tube fixtures (90 fc). Coffee area 140 fc.

Building 28: Technical Processing Facility

Contains an atrium, no lamps, 120 fc. Some bullet lamps at inside wall ceiling, were on, did not contribute to light level in atrium. Hall, 4-tube fixtures sideways, 14' spacing, 80 fc. Office, 160 sf, 3 4-tube fixtures. Office, 120 sf, 2 4-tube fixtures. Center hall, bullet ceiling lights. Computer room, 4-bulbs per 64 sf. Inside office, 2 4-tube fixtures, 140 sf. Big complaint is that the building is too cold in the summer.

Building 29: Spacecraft Systems Development and Integration Facility

Entrance area, large incandescent lamps in bullet fixtures recessed in high ceiling. Hall, 4-tube fixtures, sideways, 18' spacing. Office (typical), 160 sf, 3 4-tube fixtures, 70 fc. Large industrial type work area with data processing activities.

Appendix E

Fan Motor Inventory on 24-Hour Operation

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN		SIZE (APPX TONS)	AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)					
1	ACS 002	9,500		23.75	North East Section of building - 1st floor cafeteria, GEWA store, security, travel	comfort offices	
1	ACS 003	9,290		23.225	South section of building - 1st and 2nd floors	offices	
1	ACS 004	32,600		81.5	North Center Section Basement	offices, computer and class rooms	
1	ACS 006				South West Section Basement	offices and computer room	
1	ACS 001	9,325		23.313	South Center Section Elec. Trans. Room	comfort	
1	ACS 008	24,200		60.5	North East Section Basement	offices and computer room	
2	ACS 001	36,640		91.6	North Center Section	labs	
2	ACS 009	12,700		31.75	South Center Section Rooms S1-S8	comfort offices	
2	ACS 010	6,800		17	South Center Section Rooms S9-S12	offices	
4	ACS 004	6,650		16.625	South Center Section	comfort/shops	
4	ACS 006	13,580		33.95	R. North Center Section	Grace's lab shops	
4	ACS 008	9,900		24.75	L. North Center Section	lab/shops	

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN (CFM)	SIZE		AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
			(APPX TONS)				
5	ACS 037	9,500	23.75		East Messine - NOT ON MAP		
5	ACS 006	1,940	4.85		South West Section - ground floor-(E19A and south section of E19; E14 and E14A)	plastic shop	
5	ACS 001	29,915	74.788		R. Center and South Center Section - Ground Floor; South Center Section - 2nd Floor	comfort and labs	
5	ACS 003	6,600	16.5		South West Corner of building - W6, W10 and W14	offices and labs	
5	ACS 004	1,100	2.75		South East Section of building - North Section of E19	plastic shop	
5	ACS 009	9,400	23.5		South East Section of building - E4, E5 and E5A	comfort	
5	ACS 011	9,650	24.125		North West Corner of building - W56, W50, W46 and W42		
5	ACS 012	9,650	24.125		South West Section of 1st and 2nd floors		
5	ACS 013	9,650	24.125		South West Center Section - ground floor; 2nd floor - W214A and 224A	computer room	
5	ACS 014	9,650	24.125		L. Center of North West Section of building		
5	ACS 024				NOT ON MAP		
5	ACS 036				NOT ON MAP	lab optics	

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN (CFM)	SIZE (APPX TONS)	AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
5	ACS 038			NOT ON MAP	lab optics	
5	ACS 015	9,650	24.125	West Center Section - W31, W29, W27, W21A, W63, W63A, W87A, W87	comfort and labs	
5	ACS 016	9,650	24.425	West Center Section - W21, W95, W95A, W93	comfort	
5	ACS 029	12,000	30	South Center Section - 3rd floor	offices and labs	
5	ACS 007	7,200	18	East Center Section - E36, E38A, and center section of E35	east highway	
5	ACS 008	9,400	23.5	East Center Section - E32, E26 and south section of E35		
5	ACS 010	10,670	26.675	1st and 2nd floor - E59, E47 and E51 area - North East	optics lab	
6	ACS 004	32,740	81.85	South West Section excluding S19A	comfort	
6	ACS 005	9,000	22.5	North Side and W19-W33	comfort	
6	ACS 001	10,274	25.685	East Side of building	comfort	
7	ACS 001	14,900	37.25	NOT ON MAP	clean room	
7	ACS 002	23,950	59.875	1st floor - West Center Section; 2nd floor West Center and East Center Sections	labs	
7	ACS 003	12,000	30	Center Section 2nd floor	comfort	
7	ACS 004	19,600	49	Rooms 024A, 024, 019, 019A, 019B, 017A, 017 & 018	computer room	

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN		AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)	SIZE (APPX TONS)			
7	ACS 005	28,700	71.75	1st floor - North West and North Center Sections; 2nd floor - North (except for North East Corner)	labs	
7	ACS 009	14,500	36.25	lower level of hibat 1st floor		
7	ACS 010	4,000	10	2nd floor - North East Center Section (B216)	Mezzanine	
7	ACS 012			NOT ON MAP	computer room	
7	ACS 006	33,500	83.75	South East Section - 19, 19A, 24, and 24A	labs	
8	ACS 001	10,160	25.4	North Side - 1st - 6th floors	northside comfort	
8	ACS 003	12,600	31.5	North and South Sections of Basement	photographic comfort	
8	ACS 004	18,700	46.75	Auditorium Area of Basement	graphics art	
8	ACS 006			NOT ON MAP	conf. rm. ex	
8	ACS 002	14,000	35	South Side - 1st - 6th floors	comfort	
10	ACS 001	20,000	50	East Half of Basement; North East Quarter and South East Corner of 1st floor	hibbay	
10	ACS 002	20,000	50	West Half of building	hibbay	
10	ACS 003	20,000	50	1st floor - South East Quarter; 2nd floor - North East Wuarter and Center and South Center Sections	hibbay	

SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN		AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)	SIZE (APPX TONS)			
11	ACS 004	31,990	79.975	South Section excluding E20A - E22 and the Mechanical Equipment Room in Basement	computer room	
11	ACS 005	9,000	22.5	East Section	labs	
11	ACS 006	2,700	6.75	South Section - E20A - E22 and Mech. Equip. Rm. (Basement)	ground floor labs	
11	ACS 018	16,000	40	South East Section - 1st and 2nd floor	highbay	
11	ACS 011			NOT ON MAP	labs	
12	ACS 004	32,870	82.175	North East and North Center Sections of building	computer room	
12	ACS 001	10,645	26.613	Ground floor - West Side; 1st and 3rd floors - West Side and North Center	comfort	
15	ACS 001	24,000	60	All of Building 15 except: Hydraulic Power Supply, Launch Phase Simulator 109 and control room - 1st floor	computer area	
16W	ACS 002	40,000	100	South East Corner	comfort	
16W	ACS 001	12,000	30	Center	warehouse	
16W	ACS 004	19,800	49.5	West Center - N115, N70, N70A-N70F; 2nd and 3rd floor - all except North West Corner	computer room	

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN	SIZE	AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)	(APPX TONS)			
16W	ACS 006	9,000	22.5	North East Section (in ceiling) S25, S25A, S39, S41A-S41C, S10, S45, S10, S353	comfort	
16W	ACS 007			Far North East Corner of building	comfort	
16	ACS 001	14,000	35	All Floors	comfort	
17	ACS 001	18,800	47	North Section	comfort	
17	ACS 002	25,100	62.75	Center and South Sections	comfort	
17	ACS 003			NOT ON MAP	cad room	
18	ACS 001	18,800	47	1st floor - North East Section; 2nd floor - South and Center	comfort	
18	ACS 003	1,305	3.263	STER S-E	comfort	
19	ACS 001	10,000	25	Center Sections	comfort	
19	ACS 002	11,000	27.5	North and South Sections	comfort	
19	ACS 003			NOT ON MAP	comfort	
20	ACS 001	18,800	47	North Center Section	labs	
20	ACS 002	25,000	62.5	West and South Sections	comfort	
20	ACS 003			NOT ON MAP	comfort	
21	ACS 001	27,550	68.875	North West Section	labs	
21	ACS 003	10,800	27	North West and South Sections excluding South East Section	comfort	
21	ACS 004	38,560	96.4	West Center Section	computer room	

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN		AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)	SIZE (APPX TONS)			
21	ACS 007	32,196	80.49	Ground floor - North East Section and South Section of R. North Center Section; 1st floor - North East Section and North West Section of South West Wing; 2nd floor - South West Wing	library	
21	ACS 002	26,050	65.125	Ground floor - North Section of R. North Center Section; 1st floor - R. North Center Section; 2nd floor - R. North Center and North East Sections	labs	
22	ACS 001	19,100	47.75	Ground floor - West and South Sides; 1st floor - West, South and North East Center Sections	comfort	
22	ACS 003	16,175	40.438	>	comfort	
22	ACS 004	16,975	42.438	North Half of West Center Section of 2nd floor	computer room	
22	ACS 005	18,550	46.375	2nd floor - East Center, South Half of West Center and East (147-153) Sections	labs and comfort	
22	ACS 006	21,750	54.375	North West and West Center Sections of 2nd floor	labs	
22	ACS 007	20,650	51.625	2nd floor - East Center Section	labs	

FAN SYSTEMS ON 24 HOUR OPERATION

BUILDING	FAN SYSTEM	FAN		AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)	SIZE (APPX TONS)			
22	ACS 009	14,200	35.5	Ground floor; 1st floor NW Section (178); 2nd floor - NW Center Section (Upper 178)	high bay	
22	ACS 010	18,900	47.25	Ground floor - NE & SE Sections except G70E&F; 1st floor NE Corner	colbalt area and computers	
22	ACS 008	27,150	67.875	3rd floor - Center Section and North Half	ABS and computers	
23	ACS 001	8,900	22.25	1st floor - C110 Area	computer room	
23	ACS 003	28,000	70	1st floor - C110 Area	computer room	
23	ACS 005	28,000	70	1st floor - C110 Area	computer room	
23	ACS 006	28,000	70	1st floor - C110 Area	computer room	
23	ACS 008	33,500	83.75	2nd floor - C110 Area	computer room	
23	ACS 010	3,140	7.85	2nd floor - C110 Area	computer room	
23	ACS 011	33,540	83.85	2nd floor/Mech. Eg. Rm.	computer room	
23	ACS 015	9,000	22.5	South West Center Section of 3rd floor	lab and computer room	
23	ACS 020	*3,000	*7.5	4th floor West Section	office,comp.rm	
23	ACS 021	13,400	33.5	4th floor West Section	office,comp rm	
23	ACS 023	13,400	33.5	4th floor Center Sec.	office,comp rm	
23	ACS 012			4th floor	offices computer room (Induction Units)	
23	ACS 022	9,000		4th floor	office,comp rm	

FAN SYSTEMS ON 24 HOUR OPERATI ON

BUILDING	FAN SYSTEM	FAN		SIZE (APPX TONS)	AREA SERVED	SPACE FUNCTION	JUSTIFICATION REASON
		(CFM)					
23	ACS 024	24,000	60	North Half of L. Center Section of building - E314-W323 and E304,E306 and N311	computer room		
23	ACS 016	11,350	28.375	1st - 4th floors North Side	office,comp rm induction unit		
23	ACS 017	15,300	38.25	3rd floor Center Sec (E330-W324)	photo E.R.T.S.		
23	ACS 025			4th floor Center Sect	office,comp rm		
23	ACS 026			4th floor West Section	office,comp rm		
23	ACS 027			4th floor West Section	office,comp rm		
26	ACS 001	4,080	10.2	Ground floor - North Section; 1st and 2nd floors North and South Sections	photographic		
26	ACS 003	4,020	10.05	West Section of Ground floor	tape storage		
26	ACS 004	41,115	102.79	Center Section of 1st floor	computer room		
28	ACS 003			South East Section of 1st, 2nd and 3rd floors	computer room under floor		
28	ACS 004			South West Section of 2nd floor	comfort, southwest offices		
28	ACS 006			South East Section of 2nd floor	computer room under floor		
28	ACS 007			Center and North Center Sections of 1st floor	comfort		
28	ACS 010			West Center (9, 10, 13) 2nd floor	computer room under floor		

[illegible]

Appendix F

FEMP Energy Efficiency Model Program

Appendix F

FEDERAL AGENCY ENERGY EFFICIENCY MODEL PROGRAM

in partnership with the
SERVICING UTILITY

Introduction

The Federal Energy Management Program of the U.S. Department of Energy [DOE-FEMP], through its lead laboratory, Pacific Northwest Laboratory [PNL], is supporting the design and implementation of a model program for federal customers in partnership with their servicing utility. This approach comprises identification and characterization of all cost-effective energy efficiency measures (or assets) on federal installations and subsequent "sale" of those efficiency assets to the servicing utility(s). The primary objectives of the model program are to:

- identify all electric and nonelectric life cycle cost-effective energy efficiency *projects* at one or more federal installations served by a common utility
- negotiate with the servicing utility to purchase the energy efficiency from its federal customers
- develop a schedule for each federal customer for project acquisition considering project *type, size, timing, capital requirements, and energy and dollar savings*
- design and implement a model demand-side management [DSM] approach which the utility could propose to its regulatory agency for application to all its federal customers.

Background

Projects in this model program are any actions which support the installation's mission and result in a reduction in energy costs and/or energy demand and usage. Examples of projects include energy end-use technology retrofits, onsite generation, cogeneration, O&M, innovative scheduling and operations, fuel switching, and rate structure analysis and renegotiation.

A facility-wide, fuel-neutral approach to identifying and acquiring energy projects yields the greatest savings and greatest return on taxpayer investments. FEMP and PNL have developed and successfully applied this approach. Experience at over 25 federal installations indicates that the typical federal installation could invest from one to two times the installation's annual energy bill in cost-effective projects. Benefits are significantly increased when combined with creatively designed utility programs.

The FEMP Model Program Approach

Major constraints faced by federal installations in identifying and acquiring life cycle cost-effective energy projects are: 1) installations have poor access to capital for modernization; 2) are required to follow procurement procedures that can take a year or more to implement; and 3) are not organized around a systematic approach to managing all aspects of their energy portfolio. The model program will address each of these constraints. PNL provides direct support to the installations to:

1. Understand and characterize all requirements for energy services. Energy services are those benefits provided by energy systems such as lighting, space heating, refrigeration, and process heat.
2. Understand and characterize the life cycle cost-effective energy efficiency opportunities. These opportunities are assets that can be sold to utilities in need of additional energy capacity, to the federal government as a means to reduce annual energy expenditures, and potentially to private

sector companies who will invest capital in return for a share of the energy cost savings.

3. Understand and characterize all potential sources of implementation funding for energy system modernization projects.
4. Understand, characterize and prioritize alternative energy projects.
5. Implement the selected projects.

The most promising approach for federal energy systems modernization is direct negotiation with the installation's electrical utility under a customized DSM program. The basic elements necessary for a DSM program to be successful in the federal sector are:

- The utility should target all cost-effective energy system modernization opportunities on the installation. Participation in the utility DSM program has a high transaction cost for the federal installation, and a relatively low transaction cost for the utility considering the size of large one-owner federal installations.
- The utility needs to *up-front finance 100%* of the site modernization activities.
- The utility needs to *fund a substantial portion* of the total cost of new technologies. The utility can afford to spend up to its long-run avoided cost to acquire capacity and energy efficiency.
- The utility needs to be able to *contract for the energy services company [ESCO]* for project implementation. Federal procurement rules make it difficult and time consuming for installations to hire their own contractors. An installation can however sole-source with its electric utility.

Experience

Innovative utilities currently working with FEMP and PNL to design and implement this prototype program for their federal customers include: Tacoma Public Utilities, Niagara Mohawk Power Corporation, Georgia Power Company, Savannah Electric and Power Company, Southern California Edison, Texas Utilities, Pacific Gas and Electric, Madison Gas and Electric, Baltimore Gas and Electric, San Diego Gas and Electric, and Florida Power and Light.

Appendix G

Lighting Technology Screening Matrix Summary

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Lighting Technology Screening Matrix Summary

The Lighting Technology Screening Matrix (LTSM) was developed in support of the Federal Relighting Initiative (FRI) to assist federal energy managers in their efforts to comply with mandated life-cycle costing for energy equipment investments. The LTSM is a DOS-based software tool that calculates the life-cycle cost of an existing lighting fixture and a large number of potential energy-efficient replacements, both for a one-to-one (fixture-for-fixture) replacement and on a lumen-equivalent (equal light output) basis.

The LTSM can be used to evaluate retrofits for many common configurations of fluorescent, incandescent, and exit lighting systems for any level (hours) of operation, blended electricity rate, discount rate, and utility rebate program.

The inputs to the LTSM include the following:

Discount Rate	Average Electrical Rate
State/Census Region	Analysis Period
End-Use Sector	Retrofit or New Project
Labor and Materials	Cost Multipliers (Override Defaults)
Fixture to Analyze	Minimum Lumen Ratio
Annual Operating Hours	Rebate Type

The outputs that the LTSM provides for the existing lighting system and each retrofit alternative are as follows:

Fixture name	Value of 1st year savings
Fixture code	Annualized ballast cost
Activity type	Annualized lamp cost
Lumen ratio	Annualized O&M cost
Watts	Annualized capital cost
Ballast life (yrs)	Annualized energy cost
Lamp life (yrs)	Annualized total cost
Installed cost	Life-cycle cost
Rebate value	Net present value
Annual kWh savings	Levelized energy cost

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