A Summary of
Duke University's Successful Energy Management Program

Introduction

June 2004 marked the completion of the eighth successful year of FMD's Energy Management Program. The program began with the approval of a $3.5 Million loan by the Duke University Board of Trustees in September 1996. To date, the program has saved over $4.7 Million in directly metered utilities (*Exhibit 1*).

The University's facilities are an eclectic mix of building styles and construction, including research facilities, libraries, offices, auditoriums, dormitories, classrooms, dining halls, a central steam-heating plant, self contained high voltage system, miles of roads and sidewalks, individual building chillers for air conditioning, thousands of lighting fixtures and exit lights. There is also a marine research facility located 180 miles east of Durham on the North Carolina coast. The current replacement value exceeds $1.5 billion for the physical plant consisting of over 163 buildings averaging 44 years in age. Approximately 70% of the buildings are more than 75 years old.

Initially, FMD's Energy Management Program targeted lighting and water consumption, starting with a survey of all buildings for replacement of inefficient exit signs, fluorescent light fixtures, and installation of automatic lighting control sensors. In rest rooms, the lavatories, urinals, and commodes were retrofitted with water saving devices. This approach allowed us to tackle "low-hanging fruit" and to capture large, rapid savings with which to repay the loan and provide funds for additional projects. As these projects reached completion, FMD's Energy Team addressed building more efficient mechanical systems such as air conditioning, cooling towers, chillers, heating equipment, pumps, air handling units, windows, and fans. The simple payback for this initial work was 3.6 years.

Utility Cost Increases

In FY1994-95, the University's utility budget was $9 million, a figure reflecting a continuing trend of escalating utility consumption and costs. Consumption has been driven both by increased intensity of usage (greater student consumption, more campus

research activities and longer daily hours of operation, and an ever-expanding use of computers), and by a dramatic increase in building square footage as a result of new construction. *Exhibit 2* shows that gross square footage has increased by 25% in this period, and the end is not yet in sight. *Exhibit 3* charts changes in the University's electrical and water consumption as square footage increased.

Concern regarding increasing utility consumption led FMD to consider a comprehensive, campus-wide energy management program. FMD contracted with an outside energy service consultant to explore options for accomplishing the work and to select specific projects to pursue. Ultimately, the Department decided to perform energy retrofit work using in-house resources and project management, and local contractors.

First Energy Management Efforts

During the 1980's and early 1990's, only a few energy management projects were completed on campus. Following earlier interior design standards, most buildings on the University's campus were over- illuminated. Early energy management technology choices were limited due to poor experiences with available technology such as electronic ballasts that failed at high rates. Subsequently, in some buildings, many lighting fixtures were simply disconnected to reduce energy. During this time frame the University tried to save energy by extensive use of the 34-watt "Economy" fluorescent lamp, but the lamp created a dismal lighting environment. Although energy consumption was reduced, it resulted in lighting that was below acceptable levels. When current energy management projects began, FMD was confronted with the challenging goal of reducing energy while improving the quality of lighting in campus buildings.

Campus-Wide Approach

Initially, FMD hired a consultant to conduct an audit of lighting and water retrofits for saving energy in campus buildings. The study report specified many single source items and had a package implementation price estimate of $6.7 million, with potential annual saving of $945,000. Over $824,000 of the consultant's package price was mark-up, monitoring, project management, insurance, and similar costs. As a result, FMD decided to implement the recommendations in-house.

Approval and Funding

In September 1996, FMD presented its proposed campus building energy management project to the Board of Trustees and requested a loan of $3.5 million. The loan would be repaid from savings in water, electricity and steam over an estimated period of 8 years. The loan was approved, and by December 1996 work had begun.

Strategy

Initially FMD focused on projects that were relatively easy to implement (lighting and restroom water retrofits) and that produced immediate savings. These measures were straightforward, did not require engineering design, and the energy saving retrofit technology was mature and available at competitive prices. FMD controlled or performed the work using in-house project management of contractors and Duke craftsmen.

In addition to energy conservation, FMD wanted to improve the quality of life for its customers. All work was carefully scheduled ahead of time to minimize interference with normal activities. Project managers coordinated carefully with customers and dealt promptly with questions or concerns. The initial projects fell into the general categories of steam trap maintenance, building restroom retrofits, and lighting improvements. As success began to build, we added HVAC repair and replacement, and more advanced water conservation measures.

Once these energy management projects were underway, we initiated a variety of other initiatives. For example, all new construction projects, renovation projects and maintenance projects were required to undergo an energy management review to identify energy savings for lighting, water, and equipment.

The Baseline

All campus buildings are metered to measure consumption of electricity, water, and steam condensate. FMD established FY 1995-96 as the baseline from which to measure the savings realized in subsequent years because that was the last year before the campus energy projects were begun. Savings estimates are based on comparison of consumption against the FY1995-96 baseline consumption year.

Energy Initiative

The latter half of FY1996-97 was the first period in which energy savings accrued, and the total saved in that partial year was $225,500. In FY1997-98, savings totaled $745,151. This amount exceeded the initial annual projection and allowed FMD to accelerate the loan repayment schedule. Furthermore, major components of the water project were not implemented until later in the project, thus delaying their impact on savings. In FY1998-99 combined energy and water savings grew to $1,006,041 million and in subsequent years have averaged well over $900,000 per year. The program's success is clear and it has received extensive national recognition. In 1999 the U. S. Department of Energy's, Rebuild America Program presented its "Outstanding Energy Partner" Award to Duke University, its' first ever to a university. Later that year the U.S. Environmental Protection Agency inducted Duke into the EPA Energy Star Building Honor Society. In 2000, APPA awarded FMD the Award for Excellence. Because of continued campus efforts to conserve energy, DOE awarded its Energy Champion Award to the University in 2002.

Steam/Mechanical

Leaking steam traps waste large amounts of water, along with the energy needed to superheat the water to steam. FMD established a steam trap maintenance program for immediate repair of inoperative steam traps. High-pressure traps are checked twice a year, and low and medium pressure traps are checked once a year. In addition, we adjusted mechanical systems to re-balance air flows to meet actual space requirements, resulting in a net reduction of energy required for air conditioning and heat. FMD added a heat recovery cycle to reduce electrical and steam consumption for reheat in buildings that require large amounts of outside air for ventilation. In addition, using its own funds, FMD made many renovations, system upfits, and repairs in the Central Steam Plant that were focused on saving energy. On average, the University now saves 30 million pounds of steam per year due to various steam and heating conservation measures.

Water

FMD used some of the 1996 loan to fund a number of water saving projects. We installed low flow (1.0 gpm) aerators on lavatories, and low flow flush valves (1.6 gpm) on urinals and commodes throughout the campus, saving not only water, but also the energy used to heat the hot water in the lavatories. Condensation from cooling coils is now collected and used as makeup water for cooling tower systems. In science and research buildings, lab equipment with single pass water for cooling have been replaced by closed loop systems, in which water is circulated through the lab equipment and then to a cooling tower to remove heat. The water is then re-circulated. Since the inception of the program, FMD has helped the University save an average of 60 million gallons per year.

Lighting

The lighting project was the most extensive, affecting over 104 buildings on campus. In the vast majority of retrofits, FMD replaced T12 lamps and standard magnetic ballasts with T8 Triphosphor lamps, electronic ballasts, and cleaned the fixture lens and reflective surfaces. The Department also replaced mercury vapor lamps with metal halide, replaced incandescent exit signs with LED, and placed motion sensors on lighting systems in classrooms, conference rooms, restrooms, and public areas of buildings.

HVAC

Faced with aging and inefficient chillers in several buildings in and near LSRC, FMD installed one large central chiller in the existing mechanical room in LSRC and extended chilled water lines to the other buildings. The chilled water loop was expensive and not justifiable on the basis of energy savings alone. But the energy savings due to replacing old, inefficient chillers and pumping systems were significant, and maintenance costs have been sharply reduced, while reliability has been increased. Other energy saving strategies included installing variable speed drives on air distribution fans, replacing chilled water distribution pumps, adding variable air volume fans to air distribution systems, and heat recovery systems.

Exhibit 2 illustrates the results of FMD's energy management efforts. In the eight years since the baseline period of FY 1995/1996, the gross square footage maintained by FMD has increased by 30%. Despite that increase and the more energy-intensive use of the buildings, the combined cost of electricity and steam increased by only 17%. The cost of water increased by only 1%. The net cost of energy, per gross square foot dropped by 10%. In the eight years from BOT approval of the loan, cumulative energy and water savings in the baseline buildings has exceeded $6.5 Million (*Exhibit 1*), with a continuing annual savings in the range $800,000 to $1 Million.

Central Chilled Water

FMD's energy conservation program is not limited to the efforts proposed to the Board of Trustees in 1996. In the past, each new campus building had its own self-contained cooling system, and dedicated chiller. The new Towerview Central Plant produces chilled water at a central location at a higher level of efficiency. Central chiller plants provide opportunities to strengthen energy infrastructure and increase energy efficiency, reduce air pollution, combat global warming, enhance energy security and decrease emissions of ozone-destroying CFC refrigerants.

The Towerview Central Chilled Water plant that was completed in 2001 is beginning to have major payback for the University as the distribution system is expanded and more buildings are brought on line. Major existing buildings, including Physics, Gross Chemistry, Bryan Center, and Biological Science have been now connected to the Plant. The connection of these four buildings alone enabled the removal of seven aging chillers and their attendant issues of low efficiency, declining reliability, increased maintenance and chlorofluorocarbon (CFC) emissions. *Exhibit 4* shows the up front one time savings gained by avoiding replacement of the old chillers amounted to $3,977,000, and the annual estimated energy savings was $166,000.

As new and existing buildings are brought on line, the capacity of the Towerview plant is being increased in 2,000 Ton increments. Currently, the plant can produce 8,000 Tons of cooling for University and Housing buildings, and at full capacity, will produce 10,000 Tons. FMD plans call for increasing use of central chiller plants for new buildings and also for existing buildings wherever possible.

Conclusion

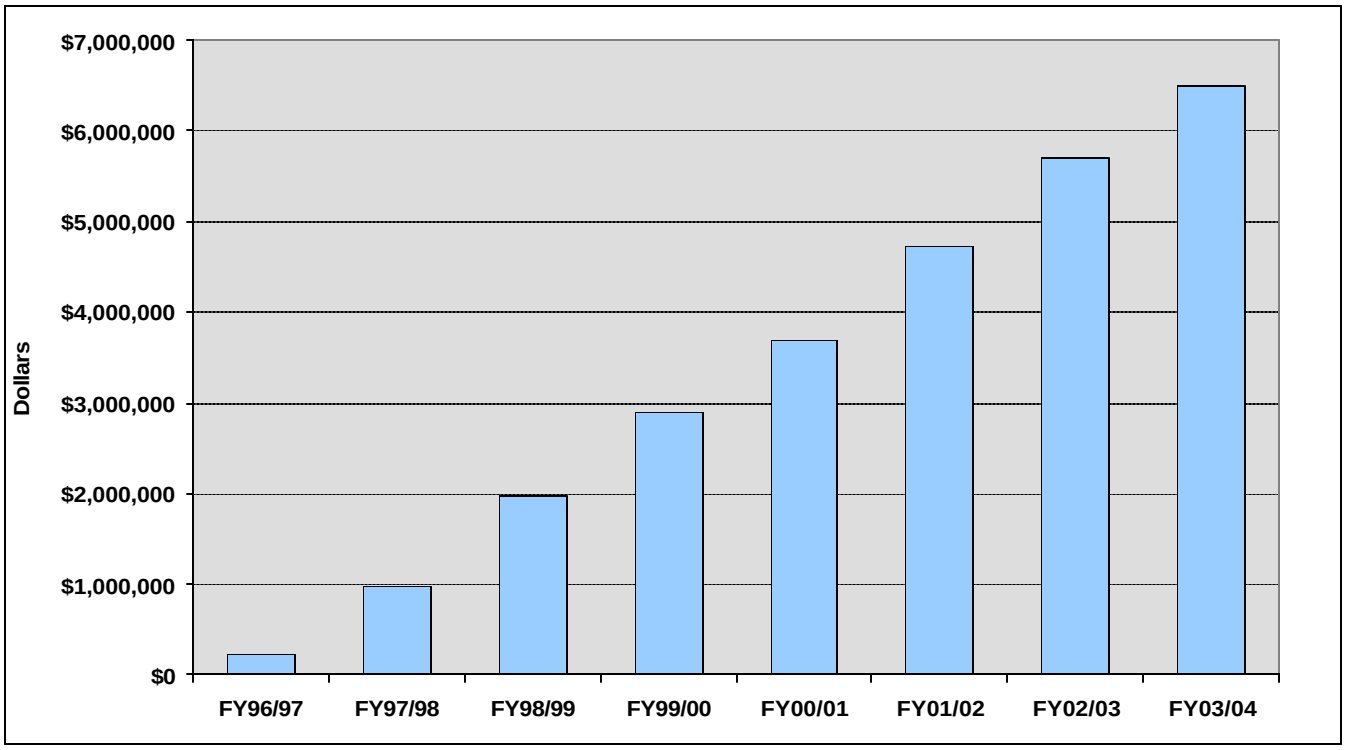
Exhibit 4 includes all projects completed by FMD's Energy Management Program, plus some of the benefits of the new Central Chiller Plant. Total program costs to date are $7,898,084 including partial costs of connection to central chilled water plant. The rate of annual saving is currently $2,262,870. The simple payback period, counting only the annual savings, is 3.5 years and the Return on Investment (ROI) is 29%. A separate column lists Deferred Chiller Savings. This $3.9 Million Cost Avoidance accrued in buildings where connection to the chilled water loop took the place of building chiller replacement.

In summary, the decision of the Board of Trustees in 1996 to invest $3.5 Million in an Energy Management Program has enabled FMD to save the University over $4.7 Million to date. The energy and water savings derived from FMD's program will continue to accrue year after year. In future phases of the program, FMD will continue to look for even more significant opportunities to save money and to lead the University toward more energy efficient practices.

Exhibit 1

FMD Energy Management Program

Cumulative Dollar Savings



	Annual	Cumulative
FY96/97	$225,500	$225,500
FY97/98	$745,151	$970,651
FY98/99	$1,006,041	$1,976,692
FY99/00	$922,440	$2,899,132
FY00/01	$800,460	$3,699,592
FY01/02	$1,036,618	$4,736,210
FY02/03	$966,303	$5,702,513
FY03/04	$800,200	$6,502,713

Exhibit 2

Comparison of Actual Costs and Energy Consumption In FMD Administered Buildings

FY95/96 Compared to FY03/04

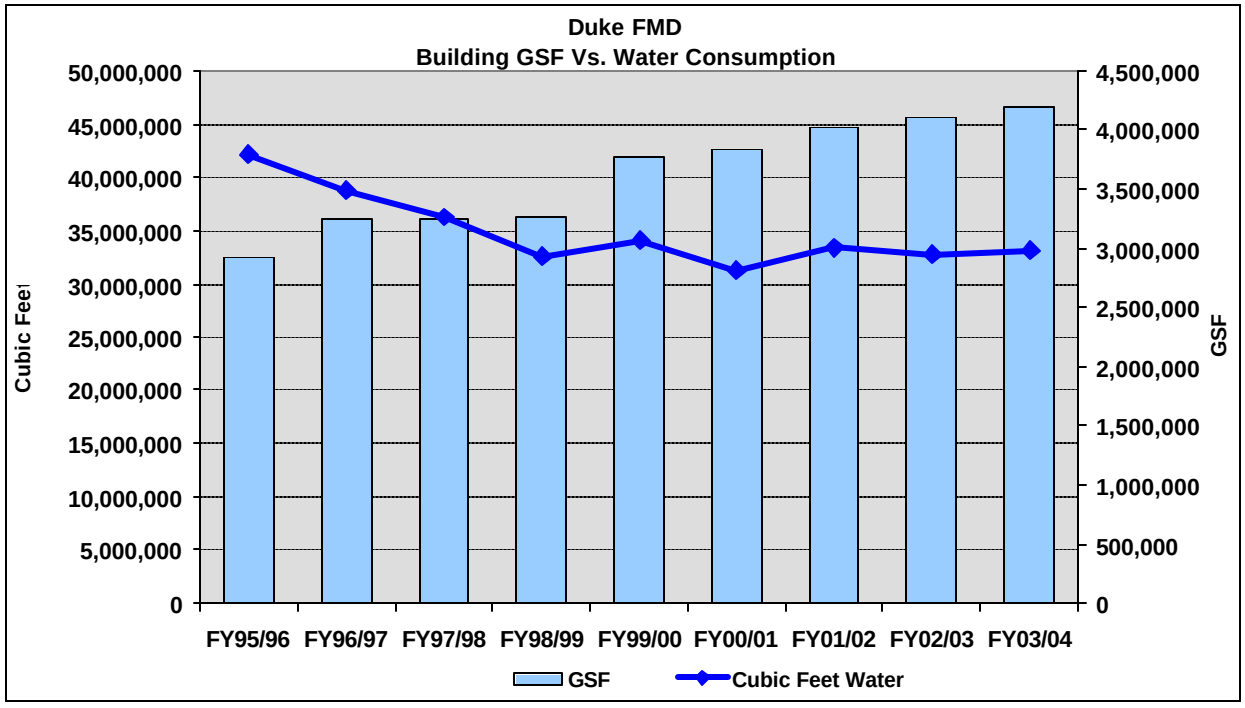
Year	FY95/96	FY03/04	% Delta
GSF	**3,224,502**	**4,200,000**	**30%**
Electricity $	$5,318,852	$5,757,178	8%
Water $	$686,250	$694,543	1%
Steam $	$2,083,851	$2,910,483	40%
Energy $	$7,402,703	$8,667,661	17%
Lbs Steam	388,492,557	502,399,041	29%
BTU	376,837,780,336	487,327,069,871	
KBTU	376,837,780	487,327,070	
MBTU	376,838	487,327	
KWH Elec	103,996,976	145,623,328	40%
BTU	354,837,682,112	496,866,795,136	
KBTU	354,837,682	496,866,795	
MBTU	354,838	496,867	
BTU (Tot)	731,675,462,448	984,193,865,007	35%
KBTU	731,675,462	984,193,865	
MBTU	731,675	984,194	
BTU/GSF	226,911	234,332	3%
Energy $/GSF	$2.30	$2.06	-10%

Summary:

1. FY95/96 is designated Base Year because this was the last year before FMD's campus wide energy management program began.
2. Since the Base Year, energy costs, consumption, and FMD administered area have generally increased.
3. Since the Base Year, energy consumption per square foot and energy cost per square foot have fallen.

Exhibit 3

Growth of Electricity and Water Costs
As FMD Administered Area Increased



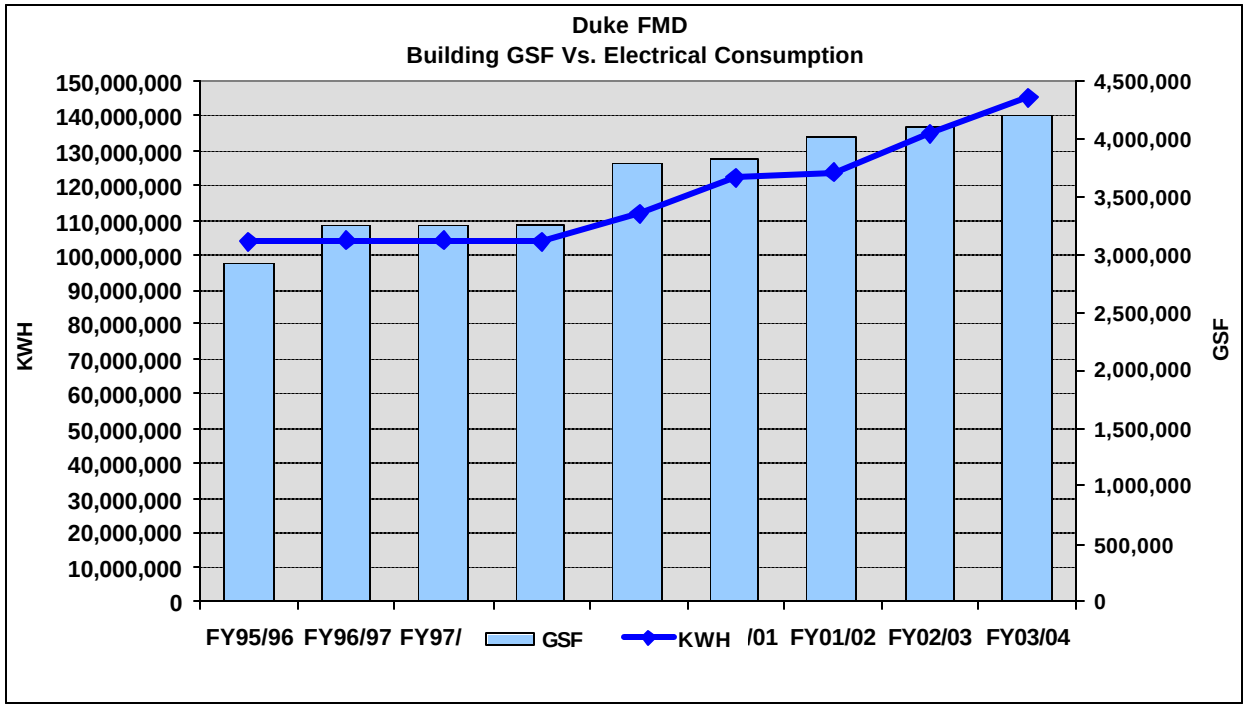


Exhibit 4

FMD Energy Management Projects Completed 1994-2002 (1)

Efficiency Measure	Detail	First Cost	Deferred Chiller Savings	Estimated Annual Savings	Simple Payback (Years)
FY94/95 Savings & Cost Avoidance					
Premium Efficiency Motors	Operate more efficiently than normal motors. Used on fans and pumps in HVAC applications.	$182,339		$43,414	4.2
Compact Fluorescent Lamps	Energy efficient replacement for incandescent lamps. Consume less energy and have longer life.	$83,622		$25,340	3.3
Fluorescent Retrofits	Replace standard fluorescent ballasts with more efficient electronic ballasts and replace 40W lamps with 32W lamps.	$85,377		$27,541	3.1
LED Exit Signs	Consume much less energy than incandescent signs and last many times longer.	$58,464		$12,180	4.8
Motion Sensors	Save energy by automatically turning off lights during unoccupied periods.	$2,565		$1,166	2.2
Steam Traps	Trap maintenance pilot program.	$12,472		$10,393	1.2
Steam Plant Tipping Fees	Landfill charges to dump ash eliminated by recycling to cement manufacturing facility.	$0		$58,000	
HVAC Controls	Replacement of pneumatic controls by DDC enabled more efficient operation of buildings.	$59,400		$11,000	5.4
Natural Gas Line	Installation enabled use of natural gas as fuel for steam production when gas cost was below other fuels.	$0		$79,000	
Electric Rate Adjustment	President's Home placed on different electrical rate schedule enabling electrical cost savings.	$300		$3,000	0.1
FY95/96 Savings & Cost Avoidance					
Steam Plant Energy Programs	Numerous equipment upgrades and changes in practices resulting in energy and maintenance savings.	$1,646,800		$358,000	4.6
Natural Gas Spot Pricing	Use of gas at steam plant when cost justified.	$34,000		$68,000	0.5
Chiller Rebates	Demand side rebates offered by Duke Power to encourage purchase of energy efficient chillers.	$0	$107,000		
Water Measures	Water cooled air compressors replaced by air cooled.	$88,000		$16,000	5.5
Compact Fluorescents	Energy efficient replacement for incandescent lamps. Consume less energy and have longer life.	$39,600		$12,000	3.3
Fluorescent Retrofits	Replace standard fluorescent ballasts with more efficient electronic ballasts and replace 40W lamps with 32W lamps.	$108,500		$35,000	3.1
LED Exit Signs	Consume much less energy than incandescent signs and last many times longer.	$177,600		$37,000	4.8
Sensors/Timers	Save energy by automatically turning off lights during unoccupied periods.	$32,200		$14,000	2.3
Steam Traps	Regular maintenance program checking for leaking and blowing traps expanded to all steam traps.	$936,000		$208,000	4.5
FY95/96 $3.5 Million Energy Initiative					
Campus Lighting Project	Campuswide retrofit of fluorescent fixtures, incandescents, mercury vapor lamps with energy efficient electronic ballasts and T8 lamps, motion sensors, compact fluorescents, and metal halide.	$1,922,944		$463,005	4.2
Campus Water Project	Retrofit of academic building restrooms with low flow flush valves on commodes and urinals and flow reduction aerators on lavatories.	$103,394		$127,171	1.0
FY95/96 $3.5 Million Energy Initiative Phase II					
LSRC Reverse Economizer	The large outdoor air component at LSRC is used to provide winter cooling at Physics without mechanical refrigeration.	$40,000		$15,520	2.6
LSRC Building Optimization	Adjust air flows to meet actual space requirements, in many cases, less than indicated at building design.	$25,000		$30,000	3.6
LSRC Condensate Reclaim	Capture condensed moisture from air conditioning coils and pipe to cooling tower for use as makeup.	$26,000		$20,000	1.3
Physics 3 MEV Chiller	Remove failed reciprocating chiller and connect to Central Chilled Water Loop.	$20,000		$10,000	2.0
Gross 1st Floor VAV	Install Variable Air Volume controls on first floor AHU	$45,000		$13,700	3.3
Perkins VSDs	Install Variable Speed Drives on four AHUs in new part of Perkins Library.	$40,000		$9,500	4.2
Perkins Filters	Replace old carbon filters with new style filter contributing much lower pressure drop and requiring less fan power.	$56,000		$40,000	1.4

FMD Energy Management Projects Completed 1994-2002 (2)

Efficiency Measure	Detail	First Cost	Deferred Chiller Savings	Estimated Annual Savings	Simple Payback (Years)
LSRC Fume Hood Micro-switches	Install indicators for open fume hood sash so that sashes can later be closed by maintenance personnel, reducing amount of air exhausted out fume hood.	$10,600		$30,756	0.3
Perkins CHW Loop to New Divinity	CHW lines run from Perkins chillers to take advantage of higher efficiency chillers. New Divinity chillers remain for backup.	$78,000		$17,000	4.5
Set VSD Max Speed	Set a maximum speed on all variable speed drives below actual maximum fan speed to reduce energy consumption.	$7,000		$1,200	5.8
Gross Condensate and Heat Reclaim	Reclaim condensate from cooling coils, and redirect thermal energy from incoming air to reheat coil.	$65,000		$15,000	4.3
Physics Instrument Cooling	Connect all lab instruments to closed loop cooling and discontinue use of single pass city water.	$204,000		$51,000	4.0
Perkins Cooling Tower VSDs	Install Variable Speed Drives on cooling tower fan motors to match fan speed to cooling load.	$42,000		$8,571	4.9
Bio Sci CHW Pump VSD	Install Variable Speed Drives on pump motors to match pump speed to cooling requirements.	$10,750		$1,827	5.9
Gross Vacuum Water Recovery	Recycle treated water from vacuum pumps and send to cooling tower makeup instead of waste down drain.	$4,000		$4,652	0.9
Gross Instrument Cooling	Connect all lab instruments to closed loop cooling and discontinue use of single pass city water.	$158,400		$36,180	4.4
Bio Sci AHU 2.3 VSD	Install Variable Speed Drives on AHU fan motors to match fan speed to cooling load.	$5,498		$819	6.7
Bio Sci AHU 0.10 VSD	Install Variable Speed Drives on AHU fan motors to match fan speed to cooling load.	$8,580		$2,231	3.9
Bryan Center AHU VSDs	Install Variable Speed Drives on AHU fan motors to match fan speed to cooling load.	$26,196		$3,255	8.0
Perkins VAV	Replace/upgrade original Variable Air Volume system which contains numerous malfunctioning boxes and air valves.	$250,000		$35,000	7.1
WC Union Cond. Water Conserv. 03.2001	Remove single pass cooling of refrigeration compressors and replace with recirculating cooling tower.	$105,000		$36,876	2.8
LSRC Power Factor Correction	Install capacitor bank to correct electrical power factor.	$55,370		$7,130	7.8
7725 TAB VAV Boxes 03.2001	Test and balance VAV boxes to reduce larger than necessary air flow to classrooms and library.	$6,300		$2,000	3.2
7725 VSDs 03.2002	Install Variable Speed Drives on AHU fan motors to match fan speed to cooling load.	$11,000		$1,976	5.6
FMD Energy Initiative 2001-2002					
LSRC CFM Reduction 03.2002	Reduce Outside air and exhaust in lab areas where supply exceeds requirements.	$3,700		$45,000	0.1
Gross Rev. Economizer 03.2002	Modify valve and program control to circulate water through chilled water coils and deliver to central CHW loop	$3,200		$7,594	0.4
Gross CHW DeltaT Program 03.2002	Replace/modify CHW coil valves and controls to achieve greater temp difference between entering and leaving water	$24,000		$4,019	6.0
7776 Chiller Cond. Tube Cleaning 03.2002 (Pilot Program)	Install automatic condenser tube cleaning cycle to reduce fouling buildup and lower chiller energy consumption.	$41,213		$17,468	2.4
East Union Ice Machine 03.2002	Install drain line from ice machine in kitchen to collect and recycle condenser coolant water	$4,200		$1,395	3.0
LSRC CFM Reduction 06.2002	Reduce Outside air and exhaust in office areas where supply exceeds requirements.	$3,500		$18,000	0.2
CHW Loop Connections & Deferred Chiller Replacement					
Physics Building	Remove chillers at end of life cycle and instead of replacing chillers, connect building to central chilled water loop.	$200,000	$750,000	$22,000	
Gross Chemistry	Remove chillers at end of life cycle and instead of replacing chillers, connect building to central chilled water loop.	$330,000	$1,800,000	$106,165	
Bryan Center	Remove chillers at end of life cycle and instead of replacing chillers, connect building to central chilled water loop.	$185,000	$480,000	$10,747	
Biological Science	Remove chillers at end of life cycle and instead of replacing chillers, connect building to central chilled water loop.	$230,000	$840,000	$27,079	
	Totals	**$7,898,084**	**$3,977,000**	**$2,262,870**	**3.5**