ENERGY MANAGEMENT CONSULTATION AND TRAINING PROJECT

HINDUJA HOSPITAL SURVEY

RESOURCE MANAGEMENT ASSOCIATES OF MADISON INC.

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HINDUJA HOSPITAL - BOMBAY

HH-1 Executive Summary

The Hinduja Hospital is located in Bombay. The facility has 295 patient rooms and is utilized at 100% of its capacity at all times. It has a staff of 1,400 employees. Hinduja is a private hospital which serves any of the general public able to afford its fees. (See *Figure HH-1*.)

This report looks at the facility's existing energy consumption patterns, provides a description of the building's energy-using systems and previous facility energy conservation activities, and presents recommendations based on calculations provided in this report. (See Appendix HH-A.)

The hospital's energy sources are electricity, light diesel oil (LDO), high-speed diesel (HSD), and liquefied petroleum gas (LPG). Of these, electricity is the most important as it represents 90% of the hospital's energy cost. This is followed by LDO at 9% and HSD and LPG, each at 0.5%.

Together, the survey team and facility staff identified ten Energy Conservation Opportunities (ECOs). After analysis of the opportunities, seven are recommended for implementation.

The total energy cost savings of the recommended measures is Rs.3,990,000 (US$ 128,700). This equals 17% of the facility's current energy budget. The Rs. 12,500,00 (US$ 403,00) implementation investment would be payed back in 3.1 years. If all measures were implemented, the total savings would be reduced slightly because of interactions between the ECOs. *Table HH-1* summarizes the recommended opportunities.

The survey team recommends that the facility management hire local engineering consultant(s) to help in the design and implementation of those ECOs not familiar to the facility's technical staff.

Table HH-1
Summary of Estimated Savings from Implementation of Recommended ECOs

Description of Recommended ECO	**Implementation Cost (Rupees)**	**Anticipated Annual Savings (Rupees)**	**Investment Payback (years)**	**Light Diesel Oil Annual Savings (liters)**	**Electricity Annual Savings (kWh)**
ECO # 1 Variable Speed chilled Water (CW)	2,351,753	528,683	4.4	-	144,055
ECO # 2 Direct-Fired Absorption Chillers	NOT RECOMMENDED				
ECO # 3 High-Efficiency Centrifugal Chillers	6,045,000	1,651,766	3.7	-	450,072
ECO # 4 Cooling Tower Plant Controller	465,000	183,682	2.5	-	50,050
ECO # 5 Steam Production Efficiency Improvement	1,345,927	633,750	2.0	97,500	-
ECO # 6 Provide a Facility Energy Engineer	144,000	235,566	0.6	3,166	58,000
ECO # 7 Water Consumption Reduction	PROVIDED FOR REFERENCE				
ECO # 8 Solar Preheating for Domestic Hot Water	1,575,927	377,208	4.2	137,181	-
ECO # 9 High-Efficiency Motors for Air-Handling Units	571,795	378,928	1.5	-	103,250
ECO #10 Steam Distribution/Condensate Return	PROVIDED FOR REFERENCE				
TOTALS	**12,498,895**	**3,989,583**	**(avg) 3.1**	**237,847**	**805,427**

HH-2 Description of Facility

The Hinduja Hospital is a privately owned hospital with 295 beds. It offers a full range of medical treatment and is always full to capacity.

The hospital is a 16-story, 17,350-square meter facility located on the shore of the Arabian Sea. It is a masonry structure with aluminum-framed windows. (See *Figure HH-1*.)

The facility has a very capable engineering and maintenance department that maintains the hospital and plans building modifications.

HH-3 Facility Energy Use

The major sources of energy consumption are electricity, LDO, and LPG. Electricity is provided by a local utility, whereas LDO and LPG are purchased and stored in tanks. See *Table HH-2* for rates and annual consumptions.

The supply of LDO and LPG is quite reliable. In addition, LDO and LPG rates are comparatively more stable than electricity rates.

Of the fuel sources, electricity has a 90% share of the hospital's total energy costs. The major consumers of electricity are air conditioning, lighting, fans, pumps, refrigeration, and medical equipment.

Figure HH-1
Hinduja Hospital

Table HH-2
Hinduja Hospital Total Energy Consumption

Description	Electricity	High-Speed Diesel (HSD)	Light Diesel Oil (FO)	Liquefied Petroleum Gas (LPG)
High Heating Value				
kcal/kg		9,500	10,700	11,642
Btu/lb		17,106	19,267	20,963
Btu/liter		35,000	36,454	23,481
Average Density				
kg/liter		0.93	0.86	0.51
Annual Consumption				
kWh/year	5,800,000			
liters/year		14,400	316,650	
kg/year				18,500
MMBtu/year		505	11,562	855
Average Cost per Unit				
In Local Currency,				
per kWh	3.67			
per liter		6.50	6.50	
per kg				6.42
In $US				
per kWh	0.12			
in $US/MMBtu	34.69	5.98	5.74	4.48
Annual Expenses				
In Rupees	21,286,000	93,600	2,058,225	118,770
In $US	686,645	3,019	66,394	3,831
In % of Fuel Costs	90.4	.4	8.7	.5
Total Annual Energy Expenses				
In Rupees	23,556,595			
In $US	759,890			

Exchange Rate: 1 $US = 31 Rs.

HH-4 Description of Existing Energy-Using Systems

Air Conditioning

The peak building air conditioning load is 600 tons. Air conditioning is provided by a chilled water (CW) system consisting of three chillers and pumps. A schematic of the system is shown in *Figure HH-2*. The pumps and chillers are configured in what is known as a parallel arrangement. The pumps are connected to the chillers via a common pipe, also known as a common header, which allows any one pump to be used with any given chiller. The hospital mechanical staff operates the chiller(s) and pump(s) combination necessary to meet the space cooling loads. These chillers and pumps are brought on or off line manually to maintain a constant CW supply temperature. Typically, this ranges between 6°C (42.8° F) and 9°C (48.2°F), depending on the season and air conditioning load.

The system design consists of chilled water coils (CWC) located in air-handling units (AHUs).

The control strategy consists of three-way, two-position bypass automatic control valves at each of the AHU cooling coils, located on floors one through six, and two-way valves on floors seven through sixteen. On a call for cooling from the thermostat, the three-way valve is opened to allow full flow of chilled water through the cooling coil. In the case of the three-way valves, once the temperature set point is satisfied, the control valve is opened to the full bypass position. The The hospital staff informed us that they have encountered problems with almost all their control valves, causing them to disconnect them from any automatic control functions.

The air control on the CW system consists of automatic air vents located in the return piping at the roof terrace level. The expansion make-up tank consists of an open tank located on the roof terrace and connected to the CW return pipe at this level. The open tank provides a surface for air, particularly oxygen, to enter the CW system.

Entrained oxygen has two major undesirable consequences: (1) it reacts with the steel pipe and leads to corrosion of the pipe and (2) being a poor conductor of heat, it lowers the heat transfer, and thus efficiency, at the coils. It is recommended that a compression tank and a centrifugal air separator be installed in the system.

Heat is rejected by multiple cooling towers piped in parallel. Similarly, the cooling tower pumps are also arranged in parallel (see *Figure HH-3*). The pumps and tower fans are brought on manually as the load increases. The load is monitored using the refrigerant head pressure in the chiller and the condenser water supply temperature. The operator is able to determine whether to bring on additional cooling towers and pumps or to turn them off.

Figure HH-2
Schematic of Hinduja Hospital's Existing Chilled Water System

Figure HH-3
Schematic of Existing Cooling Tower Plant

Both the CW and condenser water are treated for hardness. This is good for the system as it minimizes scaling in the piping and, more importantly, in the coils and the tube surfaces of the chiller. There is, however, no treatment being done to control biological growth and corrosion. Both are important as they affect the longevity as well as efficient operation of the system. Algae formation in the cooling tower sumps was reported as being a problem. A water treatment schedule is recommended, as it will reduce maintenance while improving system endurance and performance.

Air Handling Systems
The AHUs are single-zone, packaged units, each containing permanent filters made from fibrous material, a four- or six-row cooling coil, and a centrifugal supply fan. The supply air is ducted, while return air utilizes return air plenum formed by the space above the false ceilings (see *Figure HH-4*). The AHUs run twenty-four hours a day.

Supply air is introduced into the spaces through grilles that located in the ceiling. (See Appendix HH-B, photo 4.) The return path is a ceiling plenum, and openings in the ceiling along the room perimeter allow the return air to enter the plenum from the conditioned space. Outside air is ducted into the return air plenum from louver opening in the outside wall near the AHU.

Exhaust Systems
The building exhaust system consists of central exhaust fans with distributed exhaust ductwork. Air-balancing dampers were not used, so the grilles farthest from the exhaust fans were starved of air. Typically, these fans run continuously.

Steam Production
Steam is produced to make domestic hot water, heat for drying laundry, for sterilization, and for cooking. The boiler room has five 300 kg/hr water tube boilers. The boilers are of the vertical type which utilize LDO. Four boilers are run, while one serves as a backup. The boilers are ten years old and were produced by Vapor-Therm. The are all model 300, type 300-SN4. (See Appendix B, photos 1 and 2.)

Large amounts of soot are produced in the boilers. At the end of each day, the boiler operator cleans the combustion chamber and the outsides of the water/steam tubes. The staff has attempted to regulate the combustion air supply to reduce the sooting problem. So far, simple adjustments of air supply have not solved the problem. Each day, the boilers are adjusted to minimize smoking from the exhaust stack.

Fuel is supplied to the burner by a fuel pump for each boiler. A separate water pump for each boiler supplies it with 70 °C (158 °F) make-up water. Make-up water is softened prior to feeding it into the condensate return tank. Every three months, the water side of the boiler tubes is acid washed to remove scale.

Figure HH-4
Schematic of Typical Air-Handling Unit (AHU) Serving a Public Area

The boilers are rated to produce 300 kg of saturated steam at 15 kg/cm^2 (213 psig). The hospital produces steam at 5 kg/cm^2 (70 psig).

Lighting

The hospital is lit primarily by four-foot fluorescent tubes. Approximately two and one-half years ago, the hospital began converting all the ballasts in these fixture from magnetic core and coil types to electronic types. The expected savings were 30% of total lamp and ballast watts. The new ballasts, made by CEMA, appear to be working well.

The fluorescent lamps currently in use are 1-1/2" in diameter, coated with standard phosphors. They have a life span ranging from 2,000 to 8,760 hours.

The electronic ballasts retrofitted in the hospital seem to have good reliability. A controlled monitoring of energy use should be done comparing the magnetic versus the electronic ballasts to ensure that proper savings and light output are being obtained.

Longevity of fluorescent tubes is typically 20,000 hours. The lamp manufacturer should be contacted to determine expected life of its product and the potential causes for the short life which is being experienced with the product. Electronic ballasts with no ground wires, loose-fitting tubes, and improperly matched ballasts and tubes are a few of the problems which may explain the short life of the existing tubes.

Electrical Generators

The hospital has 1,030 kVA of diesel engine-driven generation. HSD is used to fuel the generators. The generators are made by MTV of Germany.

Since Bombay has a fairly reliable electrical supply, the hospital sees power outages only once every six months. A typical outage lasts two to three hours.

To keep the backup generators in good working order, they are run one time each week. Records indicate that it takes about one liter of fuel to produce each kWh. Because of their short operating periods, the generators are not a good opportunity for energy conservation.

Kitchens

The kitchen produces food for patients as well as the hospital staff. It uses LPG, steam, hot water, and electricity to refrigerate supplies, cook the food, and clean the dishes.

No specific opportunities were identified for the kitchen. Like all end-uses of energy, the kitchen is a good place to identify creative ways to minimize energy consumption. Since the kitchen is a specialized process area, the staff operating the equipment need to be involved in the development of energy conservation projects.

Domestic Water Heating
Domestic water heating includes the hot water for patients' rooms, kitchens, laundry, and maintenance. Hot water is produced by a "calorifier". The calorifier is a large tank which has a steam coil inside of it. As hot water is used, cold make-up water is supplied to the tank. The steam coil is operated to keep the water inside the tank at a constant 55°C (131°F).

An energy-saving opportunity exists in the production of hot water. Given the large amount of solar energy available in India, city water could be preheated, using solar panels, prior to entering the calorifier. Final heating in the calorifier will ensure a constant hot water temperature regardless of sunlight availability.

HH-5 Energy Conservation History

The hospital's engineering and maintenance department is very energy conscious. Minimizing costs is the largest motivating factor. This is especially true in the case of electricity, which is the largest component of the facility's energy budget. While other fuel prices have remained stable, electricity rates continue to increase.

Previous audits have presented many opportunities which the hospital has pursued and implemented The following is a list of previously implemented ECOs that were identified during this survey:

- Energy consumption is recorded and tracked (See Appendix HH-B, photo 3.)
- Electronic ballasts have been installed in all four-foot fluorescent fixtures. The manufacturer supplying the ballasts claimed a 30% reduction in ballast and lamp electricity consumption.
- Submeters have been placed on key electricity-using areas to monitor consumption and respond to changes which may indicate excessive use.
- Two energy audits were previously completed in the facility. Measures recommended were examined and implemented where appropriate.
- An outside firm is routinely brought in to maximize the boilers' efficiencies in their current condition.
- A chiller plant prioritization schedule has been established to maximize plant efficiency under a given load.
- Facility power factor correction was implemented to reduce kVA charges.
- Steam traps were recently replaced, and the entire steam-trapping process was reviewed and

modified as needed.

- 15-watt bed lights were retrofitted to use a 5-watt compact fluorescent lamp.

During the EMCAT LPD survey, a number of additional energy cost-saving measures were identified. Section HH-6 discusses these opportunities, and Section HH-7 provides the survey team's recommendations of which opportunities to implement. Calculations are presented in Appendix HH-A of this report.

HH-6 Summary of ECOs

The following is a summary of the potential ECOs that were identified and studied. The complete calculations are given in Appendix HH-A.

The ECOs presented in this report are based on information received during the survey. Cost estimates are based on United States pricing at the time of the survey. From this, estimates were calculated and are presented in Appendix HH-A.

Assumptions were made in a conservative direction. If the facility wishes to recalculate the savings based on modified conditions, Appendix HH-A will guide their calculations.

ECO-1: Variable Speed Chilled Water (CW) Distribution

The existing chilled water system is controlled manually by operating a combination of chillers and pumps to meet space cooling load requirements. Comfort and energy efficiency can be improved by converting to a primary/secondary system with variable speed distribution and automatic controls.

With a primary/secondary configuration, chilled water generation and distribution functions are separated. The chillers are located in the primary loop and generate the CW. A distribution pump located in the secondary loop conveys the CW to the air handling and fan coil units that provide cooling to the various spaces.

The primary/secondary loops have separate pumps. This allows the secondary pump speed, and thus flow, to be varied to match the cooling load without affecting operation of the chillers which require a constant flow at all loads. Since there is a significant amount of time each year when the cooling load is below design maximum and the CW flow requirements are correspondingly reduced, a variable speed drive allows the pump to operate at slower speeds. This reduces pump brake horsepower requirements and thus the energy consumed by the pump.

Annual Energy Cost Savings: Rs. 528,683 (US$ 17,054)
Annual Electricity Saved: 144,055 kWh

Implementation Costs:	Rs. 2,351,753 (US$ 75,863)
Simple Payback:	4.4 years

(See Appendix HH-A, ECO #1 for detailed descriptions and calculations involved with this ECO.)

ECO - 2: Direct-Fired Absorption Chiller(s)

The existing electric chillers Could be replaced with two 300-ton, two-stage, direct-fired absorption chillers that use LDO as their fuel.

These units could be installed after removal of the existing electric chillers with some modifications to the existing cooling tower and chilled water piping inside the chiller plant room. LDO supply piping and combustion intakes would need to be provided. Also, the products of combustion would need to be removed via a chimney venting system.

The economic feasibility of absorption cooling depends on the cost savings realized by replacing electricity with an alternative energy source. Higher electricity rates as compared to LDO will favor absorption cooling. Using the present utility rates for both electricity and LDO, the approximate monthly run time and the Coefficient of Performance (COP) of the existing chillers and the absorption units, an economic analysis was conducted to calculate the simple payback.

Annual Energy Cost Savings:	Rs. 2,013,225 (US$ 64,942)
Annual Electricity Saved:	2,397,828 kWh
Increased LDO Use:	1,045,920 liters (38,128 MMBtu)
Implementation Costs:	Rs. 12,555,000 (US$ 405,000)
Simple Payback:	6.2 years

(See Appendix HH-A, ECO #2 for detailed descriptions and calculations involved with this ECO.)

ECO - 3: High-Efficiency Centrifugal Chillers

The existing electric chillers are approximately twelve years old. The efficiency of these chillers is lower than that of chillers available today. Also, the existing chillers use R-11, which is an ozone-depleting refrigerant. This refrigerant has been banned under the Montreal Protocol and will be phased out of production by the end of 1995. Only recycled R-11 will be available thereafter. It is anticipated that the price of recycled R-11 is likely to go up significantly. Therefore, operating R-11 machines in the future will be more expensive, especially if the refrigerant has to be replaced regularly to overcome losses due to leaks or maintenance repair.

This ECO looks at replacing two of the existing chillers with two 300-ton, high-efficiency centrifugal chillers that have a lower kW/Ton rating and use non-CFC refrigerants (e.g., HCFC-

123 or HFC-134a). These units can be installed after removal of the existing electric chillers with relatively few modifications to the existing cooling tower and chilled water piping inside the chiller plant room.

Annual Energy Cost Savings: Rs. 1,651,766 (US$ 53,282)
Annual Electricity Saved: 450,072 kWh
Implementation Costs: Rs. 6,045,000 (US$195,000)
Simple Payback: 3.7 years

(See Appendix HH-A, ECO #3 for detailed descriptions and calculations involved with this ECO.)

ECO - 4: Cooling Tower Plant Controller

At the present time, the cooling tower fans and pumps are brought on manually to maintain a constant condenser supply temperature. With a cooling tower plant controller, the condenser supply water temperature set point could be reset to a lower value during cooler months. This would result in energy savings from more efficient chiller operation. In addition, starting and stopping of the fans and pumps can be controlled to match the system load more closely. This would eliminate excessive fan and pump run time.

Annual Energy Cost Savings: Rs. 183,682 (US$ 5,924)
Annual Electricity Saved: 50,050 kWh
Implementation Costs: Rs. 465,000 (US$ 15,000)
Simple Payback: 2.5 years

(See Appendix HH-A, ECO #4 for detailed descriptions and calculations involved with this ECO.)

ECO - 5: Steam Production Efficiency Improvement

The hospital uses steam to produce domestic hot water to cook, to dry clothes in the laundry, and to sterilize medical equipment. The steam is produced by five small, vertical, “tea kettle” type steam boilers. Each boiler is rated to produce 300 kilograms (660 pounds) of steam per hour at 150 psig. The boilers can be fueled on either FO or LDO. Presently, LDO is the fuel used. (See Appendix HH-B, photos 1 and 2.)

Combustion analysis performed during the survey showed high amounts of excess oxygen, carbon monoxide, and combustibles. The boiler flue gases also contained large amounts of soot. The amount of soot was large enough to cause combustion analyzer failure after only a short period of monitoring. All observations indicated that the fuel was not being burned completely.

A previous Hinduja Hospital energy audit estimated boiler efficiency at 55%. Boilers of this type should be achieving an 80% fuel utilization efficiency.

This ECO evaluates the potential energy cost savings realized if the boilers were replaced with 80%-efficient vertical boilers of similar physical size.

Annual Energy Cost Savings:	Rs. 633,750 (US$ 20,500)
Annual Light Diesel Oil Saved:	97,500 liters
Implementation Costs:	Rs. 1,295,180 (US$ 41,780)
Simple Payback:	2.0 years

(See Appendix HH-A, ECO #5 for detailed descriptions and calculations involved with this ECO.)

ECO - 6: Provide a Facility Energy Engineer

A common obstacle to energy conservation is finding staff time in the daily duties to interact with facility energy users in order to identify and implement energy conservation opportunities. If a technical staff member's duties are shared between both facility operations and energy conservation, he typically must put energy conservation as a second priority. Since it is rare for facility staff to be caught up with their work, the energy conservation opportunities are usually delayed. Given the large expenditures on energy, a dedicated energy engineer will easily pay for his salary through the reduction and avoidance of energy costs.

The energy engineer would be responsible for identifying, prioritizing, designing, implementing, and tracking results of energy conservation opportunities. He would also be responsible for finding funding for the energy conservation opportunities. Sources of funding not only include in-house financing, but also such arrangements as shared savings with energy service companies.

The entire facility staff is an excellent resource for locating energy conservation opportunities. This resource is not usually used. With a facility energy manager, there is a continuous source of energy awareness, training, and a point of contact to submit conservation ideas. An energy manager solicits input from the entire facility staff. Contests and rewards motivate employees to seek creative ways to save energy without negatively affecting operation quality.

An energy engineer is a profit center. He will not only pay for his salary, but he will also generate revenue for the facility by reducing overhead costs. By reducing or preventing the increase of energy consumption by only one percent, the energy engineer will pay for his salary, and generate a profit of Rs. 90,630 (US$ 2,924) per year.

(See Appendix HH-A, ECO #6 for detailed description and calculations involved with this ECO)

ECO -7: Water Consumption Reduction

Water consumption relates to energy conservation in two ways: First, it requires electrical pumps to pressurize the water and move it around the building. Second, hot water is generated by heating it with steam. Regardless of whether the water is hot or cold any instance where water is used in excess, or is leaked, is an opportunity for energy conservation.

This ECO identifies two measures which will reduce water usage. The first is to install flow controlling shower and faucet heads. Typically, the flow of water for shower and faucet use is in excess of what is necessary. Shower and faucet heads have been developed which control the pattern and flow of water so that the user is satisfied and the consumption is reduced by 50%. The second measure is to conduct a routine review of plumbing fixtures such as sink faucets, toilets, and water valves to locate leakage. The repair is typically inexpensive and simple.

Appendix HH-A, ECO #7 provides tables to help quantify the energy and water savings that can be realized by implementing the measures discussed above.

ECO - 8: Solar Preheating for Domestic Hot Water

Hospitals require a large amount of domestic hot water. This water enters the facility at 20°C (68°F) and is heated to 55°C (130°F). This opportunity is to install solar panels to preheat the domestic water from 20°C to 32°C. The remaining heat will be added in the calorifier. This allows one-third of the energy to be provided for by the sun. Regardless of the amount of preheating which is done, the water will be heated to the final temperature in the calorifier.

Annual Energy Cost Savings:	Rs. 377,208 (US$ 12,168)
Annual Light Diesel Oil Saved:	137,181 liters
Implementation Costs:	Rs. 1,575,420 (US$ 50,820)
Simple Payback:	4.2 years

(See Appendix HH-A, ECO #8 for detailed descriptions and calculations involved with this ECO.)

ECO - 9: High-Efficiency Motors for Air-Handling Units

The air-handling units for public spaces are operated by small motors, typically 10 horsepower in size. Although small, they have a large amount of run hours. This opportunity involves the retrofit of 35 existing motors with high-efficiency motors. The difference in efficiency will be approximately 6%. In addition. high-efficiency motors run cooler and last longer than standard-efficiency motors. This will also reduce air conditioning and maintenance costs.

Annual Energy Cost Savings:	Rs. 378,928 (US$ 12,223)
Annual Electricity Saved:	103,250 kWh
Implementation Costs:	Rs. 571,795 (US$ 18,445)
Simple Payback:	1.5 years

(See Appendix HH-A, ECO #9 for detailed description and calculations involved with this ECO.)

ECO - 10: Steam Distribution/Condensate Return Efficiency
The steam distribution system in general was in very good shape and well insulated. This ECO is to routinely inspect the steam distribution system to identify and repair steam and condensate leaks in valves and piping. This ECO is provided because most facilities perceive that the lost condensate and steam has little value. The tables presented in Appendix HH-A, ECO #10, show that small leaks of steam and condensate add up to real energy losses. They are intended for future reference.

HH-7 Recommendations

Of the ECOs summarized in the previous section, the following are recommended for implementation. Payback was used as the main selection criterium. In some cases, the ECOs were alternatives for the same opportunity, and so the one with the lower payback was selected. The ECO involving solar water heaters was recommended even though it has a slightly higher payback. This is because there are tax incentives available that would make the payback period shorter than was calculated here.

ECO #1 Variable Speed Chilled Water (CW) Distribution
ECO #3 High-Efficiency Centrifugal Chillers
ECO #4 Cooling Tower Plant Controller
ECO #5 Steam Production Efficiency Improvement
ECO #6 Provide a Dedicated Facility Energy Engineer
ECO #8 Solar Preheating for Domestic Hot Water
ECO #9 High-Efficiency Motors for Air-Handling Units

ECOs #2, is not being recommended for implementation. ECOs #7 and #10 are provided for future reference.

APPENDIX HH-A
ECO Calculations

ECO # 1

VARIABLE SPEED CHILLED WATER (CW) DISTRIBUTION

Description of ECO

Under this ECO, the existing CW system would be modified into a primary/secondary configuration. This will separate the CW generation from the distribution. The primary loop will consist of the chillers where the CW will be generated, and the secondary loop will be the distribution circuit consisting of CW coils in air-handling units, through which CW will be conveyed to the load. A typical primary/secondary arrangement is shown in *Fig. HH-1*. The bypass piping between the primary and secondary allows the pumping systems in these loops is to be decoupled and the speed of the secondary distribution pump is to be varied to match the cooling load. A transducer located downstream at the furthest loop is set to maintain minimum pressure head differential required to meet the peak load requirements at that point. The transducer provides a signal to the variable speed drive control to vary the speed of the secondary pump to maintain the pressure head differential. This results in a reduction in the brake horsepower requirements of the secondary pump at part load conditions.

In order to have a variable volume system, the CW coils must be controlled using two-way valves. The existing system consists of a mixture of three-way, two-position control valves and two-way valves. We were informed that most of these were inoperable, so new two-way valves will be required at these locations.

Two-way valves vary the system flow of CW in proportion to the cooling load. As the cooling load in the building drops, the two-way valves close, causing the secondary pump to produce higher pressure. The differential pressure sensor, located at the point in the circuit farthest from the pump, will sense this rising pressure and send a signal to the Variable Speed Drive (VSD) to slow the pump and eliminate generation of excessive pressure. This reduction in speed will cause the secondary CW flow rate to go down in proportion to the speed. As this occurs, the primary loop flow rate will be greater than in the secondary loop. The difference will bypass to the chiller return water where it will mix with the CW return from the system. The result is a reduction in the chiller return water temperature.

A temperature sensor located in the chiller supply main header piping will unload the chillers to maintain the CW supply temperature set point. Chiller sequencing will be accomplished via a flow sensor located in the secondary loop and a chiller plant controller. As the load decreases, the secondary pump will be slowed to decrease the flow. The flow sensor will provide an input signal to the chiller plant controller. When this signal indicates flow below a set point, a chiller will be disabled, and similarly, as the load increases, an additional chiller will be enabled. Once a chiller is enabled, its own controller will load and unload the chiller to maintain a set CW supply temperature. The primary CW pumps would be interlocked with their respective chiller to run only when that chiller is enabled.

Energy Savings And Economics of Implementing ECO

The existing CW system is controlled manually. Chillers and pumps are brought on-line as needed to maintain a relatively constant CW supply temperature. The annual energy consumption of the existing CW system was estimated based on the number of hours a month the CW pumps ran. This information, along with the pumps horsepower, utility electrical rates, and cooling load distribution, was obtained and used to estimate the total annual electrical energy used for chilled water pumping in the facility. This data is presented in *Table 1.1.*

The energy savings were calculated by subtracting the energy consumption of the new pumping arrangement from the estimated energy consumption of the existing pumping system (see *Tables 1.1* and *1.2*):

Annual Energy Savings: 374,472 - 230,417 = 144,055 kWh

Annual Cost Savings: Rs. 1,374,312 - Rs. 845,629 = Rs. 528,683 (US$ 17,054)

Implementation Costs (*Table 1.3*) Rs. 2,351,753 (US$ 75,863)

Simple Payback: Rs. 2,351,753/Rs. 528,683 = 4.4 years

Figure 1.1
Typical Variable Speed Pump System Using Two-Way Valve Control and Reversed Return Piping

ECO #2

DIRECT-FIRED ABSORPTION CHILLER(S)

Description of ECO

This ECO considers the possibility of replacing the three existing electric chillers with two 300-ton Lithium Bromide absorption chillers that use Light Diesel Oil (LDO) as fuel. The units studied are two-stage units chosen because of their higher Coefficient of Performance (COP) compared to the single-stage units. Higher COP units use less fuel and so compete better with electric chillers.

These units can be installed after removal of the existing electric chillers and with some modifications to the existing cooling tower and chilled water piping inside the chiller plant room. Fuel supply piping and combustion air intakes would be required, along with a chimney exhaust system.

Energy Savings And Economics of Implementing ECO

The economic feasibility of absorption cooling is dependent upon the cost of the alternative fuel sources. In this case, the two fuels are LDO and electricity. The utility rates for both electricity and LDO and the approximate monthly run time and COP of the existing chillers were obtained from the hotel's mechanical staff (see *Table 2.1*).

The energy-use estimates of the existing system and the direct-fired absorption chillers are given in *Tables 2.1* and *2.2*. The system COP used for the existing electric chillers includes the energy for the auxiliary equipment such as cooling tower fans and pumps. This auxiliary load will also exist for the absorption units and is taken into account in *Table 2.2.*

Annual Energy Savings:

Electric 2,566,178 - 168,350 = 2,397,828 kWh

Light Diesel Oil - 38,128 MMBtu[1] (-1,045,920 liters)

Annual Cost Savings: Rs. 9,417,873 - Rs. 7,404,648 = Rs. 2,013,225 (US$ 64,942)

Implementation Costs (*Table 2.3*): Rs. 12,555,000 (US$ 405,000)

Simple Payback: Rs. 12,555,000/ Rs. 2,013,225 = 6.2 years

[1] The negative sign indicates an increase in energy use due to fuel switching

ECO #3

HIGH-EFFICIENCY CENTRIFUGAL CHILLERS

Description of ECO

There are three existing 300-ton centrifugal chillers. The efficiency of these chillers is lower than that of chillers available today. Also, the existing chillers use R-11 which is a CFC refrigerant and will no longer be produced after 1995. The replacement costs for these refrigerants are expected to rise significantly, making the operation of these machines potentially very expensive if refrigerant were to leak out and need replacement.

This ECO looks at replacing two of the existing chillers with two 300-ton, high-efficiency centrifugal chillers that have a lower kW/Ton rating. One of the existing units will remain as a standby. These units can be installed after removal of the existing electric chillers and with some modifications to the existing cooling tower and chilled water piping inside the chiller plant room.

Energy Savings And Economics of Implementing ECO

The approximate monthly run time and kW/Ton of the existing chillers, along with the electric utility rates, were obtained from the operating staff.

The energy-use estimates of the existing system and the high-efficiency centrifugal chillers is given in *Table 3.1*. The kW/Ton used for the existing electric chillers does not include the energy for the auxiliary equipment, such as cooling tower fans and pumps. Although we are looking at the differences in the two systems, the auxiliary loads are the same in each case.

Annual Energy Savings: 450,072 kWh

Annual Cost Savings: Rs. 1,651,766 (US$ 53,282)

Implementation Cost (*Table 3.2*): Rs. 6,045,000 (US$195,000)

Simple Payback: Rs. 6,045,000/ Rs. 1,651,766 = 3.7 years

ECO #4

COOLING TOWER PLANT CONTROLLER

Description of ECO

At the present time, the cooling tower fans and pumps are brought on manually to meet the system load. The cooling towers are operated to maintain a condenser supply temperature of 30°C (86°F). With a cooling tower plant controller, starting and stopping of these fans and pumps could be controlled to match the system load more precisely than is achievable under the current mode of operation. Also, during milder, cooler weather, the condenser supply water temperature set point could be reset to a lower value resulting in more efficient chiller operation.

Energy Savings And Economics of Implementing ECO

It is estimated that for every 1°F the condenser water temperature is lowered, the efficiency of the chiller increases by one percent. This information, along with existing condenser supply temperatures, fan, and pump horsepower, and approximate hours of operation were used to estimate the potential energy savings. The savings accrue during the milder temperature months and are presented in *Table 4.1*:

Annual Energy Savings: 50,050 kWh

Annual Cost Savings: Rs. 183,682 (US$ 5,924)

Implementation Cost (*Table 4.2*): Rs. 465,000 (US$ 15,000)

Simple Payback: Rs. 465,000/ Rs. 183,682 = 2.5 years

ECO # 5

STEAM PRODUCTION EFFICIENCY IMPROVEMENT

Description of ECO

The hospital uses steam to produce domestic hot water, to cook, to dry clothes in the laundry, and to sterilize medical equipment.

The steam is produced by five small vertical type steam boilers. Each boiler is rated to produce 300 kilograms (660 pounds) of steam per hour at 150 psig. The boilers can be fueled on either furnace oil (FO) or light diesel oil (LDO). Presently, LDO is the fuel used.

Combustion analysis performed during the survey showed high amounts of excess oxygen, carbon monoxide, and combustibles. The boiler flue gases also contained large amounts of soot. The amount of soot was large enough to cause combustion analyzer failure after only a short period of monitoring. All of the observations indicated that the fuel was not being burned completely.

Given that excess air was present in the flue gases (without leaks into the stack), the following conditions are believed to be causing incomplete combustion. The most probable condition is incomplete mixing of air and fuel. This may be caused by wear or clogging of the burner tip which results in a poor spray pattern. Both wear and clogging may be caused by insufficient fuel filtration. Another potential cause may be excessive or insufficient fuel pressure when the fuel is being atomized through the nozzle. If pressure is insufficient, the fuel may not spread out. This would hinder air from making contact with the fuel. If pressure is too excessive, the fuel may escape the combustion zone prior to reaching a sufficient temperature to burn. All existing conditions must be monitored and compared with the design parameters of the boilers.

The boiler manufacturer's representative would be the best reference for determining the current difficulties with the boilers. He would be able to compare the hospital's boilers to the design parameters as well as make comparisons with other boilers of the same model and age. This comparison would establish the expected optimum achievable performance of the boilers. The cost of implementing recommendations from the manufacturer's representative can then be compared to the cost of purchasing new boilers to replace the existing equipment.

As reported by the hospital technical staff, new boiler options would be limited to small boilers which could be carried into the existing boiler room given its existing door opening clearance. Because of the relatively small amount of heat exchange area on small boilers, their efficiency will maximize at about 80% efficiency as measured by the higher heating value of the fuel.

Existing boilers are assumed to be operating with stack and skin losses totaling 45%. This means that only 55% of the fuel's energy is converted to steam in the boiler.

The following is an analysis which compares the benefits of replacing existing boilers with new ones.

Energy Savings And Economics of Implementing ECO

Existing Fuel Efficiency	55% (From previous Hinduja Hospital energy audit report)
New Boiler Efficiency	80% (From vendor information)

Present Fuel Consumption	26,000 liters LDO/month
Fuel Use with New Boiler	26,000 liters LDO/month x 55%/80% = 17,875 liters/month

Annual Fuel Savings with New Boiler
(26,000 liters - 17,875 liters) x 12 months/year
= 97,500 liters LDO/year

Annual Fuel Cost Savings 97,500 liters/year x Rs. 6.5 = Rs. 633,750 (US$ 20,500)

Investment to Purchase and Ship Five Boilers
Rs. 1,345,927 (US$ 43,417)

Simple Payback Based on Energy Savings
Rs. 1,345,927/Rs. 633,750 = 2.1 years

Energy Savings 97,500 liters/year x 36,454 Btu/liter = 3,554 MMBtu/year

ECO # 6

PROVIDE A DEDICATED FACILITY ENERGY ENGINEER

Description of ECO

This ECO is to provide a separate engineer within the technical department to identify, implement, and track progress of energy saving measures.

This engineer would identify new energy conservation opportunities by physical inspections of the hospital as well as receiving input from other hospital staff. As opportunities are identified, they would be pursued to determine their potential. A priority list of projects would then be established, and funding sought through in-house and outside sources.

To estimate the value of hiring a dedicated energy engineer, an assumption of 1% energy cost savings is used. This savings is attributed to the additional awareness and prompt implementation of energy conservation projects. Each year the 1% savings is maintained, the reduction in energy costs will pay for the salary of the energy engineer.

Energy Savings and Economics of Implementing ECO

ASSUMPTION:
Annual maintained energy savings of 1% because of the work of the energy engineer

Annual Fuel Cost Savings:	Rs 235,566 (US$ 7,599)
Implementation Costs: (annual salaries)	Rs. 144,000 (US$ 4,645)
Annual Profit From Hiring an Energy Engineer:	Rs. 91,566 (US$ 2,954)

The following page is the analysis which quantifies the ECO's cost savings and suggested qualifications for an energy engineer.

Qualifications of Dedicated Energy engineer
Following are qualifications suggested for this position. It is stressed that this energy engineer should be utilized only for energy conservation activities.

Energy Engineer
- 5 to 10 years of experience
- 3 years (minimum) of energy conservation experience
- mechanical or electrical engineering degree
- Knowledge of both mechanical and electrical systems
- Able to interact with all facility staff
- Able to create computer spreadsheets
- Understands financial payback calculations

ECO # 7

WATER CONSUMPTION REDUCTION

Description of ECO

This opportunity implements measures which reduce water consumption in the facility. This saves energy in two ways. The first savings is that of heated water, and the second is a savings of pump energy required to pressurize and move the water to its end use. Additional financial benefits are seen by reduction of water costs.

Reduction can come from two opportunities. The first is to install water aerators in faucets and shower heads. This will make the water flow “feel” the same to the end user, but will reduce the actual consumption by about 50%. This is accomplished by mixing air in with the water stream. This is not the same as just inserting a flow restrictor in the faucet or shower. Flow restrictors save water, but reduce occupant comfort. The second conservation opportunity is to routinely inspect water piping and water using devices for unwanted leakage. Leakage is common in toilets, faucets, and shut-off valves. Although these leaks may be relatively small, they add up to large water and energy loss.

SHOWER AND FAUCET AERATORS

Shower and faucet aerators will cut consumption of both hot and cold water. They reduce the water used in the shower and in the sink by about 50% while leaving the user with the same comfort as before. This also provides the benefit of reducing the demand on the water supply system during peak usage periods.

WATER LEAKS

Water leaks in toilets, faucets, showers, and other valves add up to a large loss because they are continuous. Housekeeping staff is an excellent resource to identify many of these leaks. With prompt repair, significant water consumption can be saved. Although the energy savings from fixing leaks is modest, the repair costs are typically minimal.

The following page presents methods used to estimate the value of leaking water.

LEAKING FAUCETS

one drop per second	= 192 gallons per month
90 drops per minute	= 310 gallons per month
120 drops per minute	= 429 gallons per month
3 inch stream prior to breaking into drops	= 1095 gallons per month
6 inch stream prior to breaking into drops	= 2190 gallons per month
9 inch stream prior to breaking into drops	= 3290 gallons per month

leaking toilet = 10 gallons per hour average

ECO #8

SOLAR PREHEATING FOR DOMESTIC HOT WATER

Description of ECO

This opportunity would preheat domestic hot water with solar panels. Presently, the water which is heated for domestic hot water begins at 20°C (68°F). Using steam, it is then heated to approximately 55°C (131°F). This measure saves energy by preheating the 20°C water to approximately 32°C (90°F) using solar panels mounted on the roof of the building. This would allow one-third of the energy used to heat hot water to be provided by the sun.

The fresh water supply will first circulate through the solar panels, and then it will enter the calorifier. If the weather is not favorable for solar heating on a given day, the water will still be heated to desired final temperature in the calorifier. For nighttime hot water usage beyond the stored amount, the calorifier would make up the shortfall.

Energy Savings and Economics of Implementing ECO

Annual Fuel Saved: 137,181 liters of LDO (2,120 MMBtu)

Annual Energy Cost Savings: Rs. 377,208 (US$ 12,168)

Implementation Costs: Rs. 1,575,420 (US$ 50,820)

Simple Payback: 4.2 years

The following page presents the method used to calculate this ECO's savings.

ECO # 9

HIGH-EFFICIENCY MOTORS FOR AIR-HANDLING UNITS

Description of ECO

This ECO would replace 35 existing, air-handling unit motors with high-efficiency motors. The savings from improved energy efficiency will pay to abandon the remaining motor life.

Motors lose energy in several ways. The largest areas include the following items:

- Copper losses that result naturally from current passing through the copper-wire windings

  Premium efficiency motors use larger diameter copper wire to decrease these losses. This adds 35% to 40% more copper in a high-efficiency motor.

- Magnetic core loss

  To accommodate the larger wire, the steel lamination that support the windings need larger wire slots. This requires more laminations to be put in each motor. Most standard-efficiency motors use low-carbon steel laminations. Premium-efficiency motors have high-grade silicon steel laminations which cut core losses in half. Special annealing and plating of rotor and stator components, plus use of high-purity aluminum rotor bars also reduce core losses.

- Friction loss

  Higher-grade bearings reduce friction loss.

- Windage Loss

  Windage losses in fan-cooled motors are reduced by the energy efficient motor's smaller, more efficient fan design.

- Other

  Overall, generally tighter tolerances and more stringent manufacturing process control are applied to minimize losses from unplanned conducting paths and stray load phenomena.

  Because of the reduced operating temperature of high-efficiency motors, their insulation and bearings last longer than standard-efficiency motors.

Energy Savings and Economics of Implementing ECO

Annual Energy Saved = 103,250 kWh / year

Annual Energy Cost Savings = Rs. 378,928
= US$ 12,223

Implementation Cost Estimate = Rs. 571,795
= US$ 18,445

Implementation Payback = 1.51 years

The following page provides the analysis made to estimate this ECO's energy-savings potential.

ECO # 10

STEAM DISTRIBUTION / CONDENSATE RETURN EFFICIENCY

Description of ECO

The distribution of steam and the return of its condensate present opportunities for energy conservation. This ECO involves the implementation of a routine steam distribution and condensate return survey to identify and eliminate heat loss sources. Common areas to increase efficiency include the following:

- Find and repair leaks in steam piping and valves
- Find and repair leaks in condensate piping and valves
- Find and repair leaking steam traps
- Return all steam condensate possible to the boiler
- Monitor amount of condensate returned to the boiler and its temperature
- Find and repair damaged or missing steam piping insulation
- Find and repair damaged or missing condensate piping insulation
- Eliminate unused steam lines which contribute to loss but no longer distribute steam
- Reduce pressure in steam lines where possible

Energy Savings and Economics of Implementing ECO

A specific estimate of savings is not being quantified for this measure. Instead, the following pages contain charts which quantify the value of locating and repairing steam and condensate losses.

An example of savings is to repair a valve steam leak 1/16" in diameter. Assuming the system is at 50 psi, the annual loss in energy cost is Rs. 16,461 (US$ 531). Because of steam's high energy content, it is important to identify and repair steam leaks immediately.

A second example of savings is to repair a condensate loss with the equivalent area of 25 square millimeters. This may be a valve which requires repacking. In a year's time, the loss would be Rs. 1,402 (US$ 45.22). One leak in itself does not create a significant energy loss, although most facilities have numerous leaks of this type. When the value of each leak is added together, the total loss becomes significant. Metering boiler feed water and blow-down water is a good way to identify the magnitude of condensate losses.

APPENDIX HH-B
Photographs

Appendix HH-B Photos

Photo 1 - Hinduja Hospital: Boiler Operator Demonstrating Five Vertical Type Water-tube Boilers

Photo 2 - Hinduja Hospital: New Tube Coil for Vertical Water-Tube Boilers

Photo 3 - Hinduja Hospital: Energy Management Graphs Displayed in Engineering Manager's Office

Photo 4 - Hinduja Hospital: Hospital Engineer and Survey Team Member Measuring AC Grille Discharge Temperature

APPENDIX HH-C
Contacts

Appendix HH-C General Facility Information

Name of Facility:	P.D. Hinduja National Hospital
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