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ENERGY CONSERVATION OPPORTUNITIES IN MAHANANDA DAIRY UNIT OF MRSDMM INDIA BY ENERGY AUDIT

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Abstract
The purpose behind the energy optimization in MRSDMM (Mahanand Rajya Sahakari Dudh Mahasangh Maryadit), Mumbai, is to control the energy consumption for getting the overall maximum efficiency. This case study primarily consists the energy audit of major energy consumers including horizontal fire tube boiler and other utilities like softener pump, PHE (Plate Heat Exchanger) etc. The design data have been taken from MRSDMM, Mumbai, India. The aim of this case study is to obtain the energy conservation of boiler and to suggest them to how to reduce the energy conservation and increase the efficiency of the plant without making any changes to daily routine process. The overall savings of ₹ 141.63 Lacs is estimated consisting of ₹ 107 Lacs, ₹ 4.35 Lacs and ₹ 30.28 Lacs by energy performance improvement of boiler, softener pump and PHE chiller respectively.

Keywords: Energy audit, energy conservation, Mahanand Dairy, MRSDMM

I. Introduction
MRSDMM is an Apex Federation of District / Taluka milk unions established to implement the Operation Flood program in the state of Maharashtra. The main objectives of MRSDMM are to procure milk from the member milk unions at remunerative rates and distribute the same to the consumers at reasonable rates.
MRSDMM is thus working as a vital link between the milk producers and consumers and working for the economic development and upliftment of the farmers in the rural areas.
MRSDMM was established on 09th June, 1967. At present MRSDMM have 85 member unions (25 District and 60 Taluka) with more than 24000 primary milk societies & 25 lakh milk producers which includes appx. 27000 women members. The Present turnover for the financial year 2015-16 is 49315.96 lakh. We have plants at Goregaon, Vashi, Pune, Latur, Nagpur, Chalisgaon and Vaibhavwadi. The capacity of Mahanand Dairy was expanded up to 6 LLPD during the year 1997-98. “Mahanand Dairy” Mumbai Unit of MRSDMM mainly carries out the processing (pasteurization, clarification and homogenization), packing, cold storage and distribution of cow milk and Toned Milk in Mumbai Market. Some small quantities of milk products such as Shrikhand and Paneer were also manufactured till 2001 ± 2002. From the year 2002 ± 2003 onwards some new value-added milk products such as curd, lassi, flavored milk, ghee, etc. are added in manufacturing range and quite a sizeable quantity of these products is manufactured and marketed.
An energy audit is an inspection survey and an analysis of energy flows for energy conservation in a building. It may include a process or system to reduce the amount of energy input into the system without negatively affecting the output. In commercial and industrial real estate, an energy audit is the first step in identifying opportunities to reduce energy expenses.
The object of study to carry out energy audit of Mumbai Unit of Mahanand Dairy to examine the energy conservation opportunities, while maintaining or improving human comfort, health and safety are of primary concern. Beyond simply identifying the sources of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost-effective opportunities for energy savings.

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II. Energy Audit Methodology

As per the Indian Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption" [1].

The whole process of energy audit in Mahanand Dairy performed, is shown below with the help of a flowchart in figure 1.

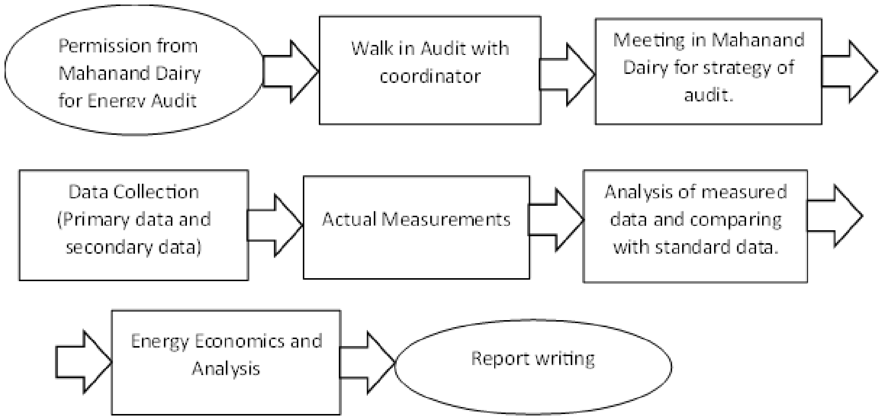

Figure 1: Progression of sensors

Following instruments were used in the energy audit of Mahanand Dairy, for data collection by actual measurements.

i. Tri-vector Power meters with 1 clamp-on type CT.
ii. Digital temperature indicator for liquids.
iii. Thermal imager.
iv. Flue gas analyzer.
v. Ultrasonic flow meter.
vi. Digital thickness gauge.
vii. Digital pressure gauge.
viii. Heat gun.
ix. Lux meter.
x. Measuring tape.

The energy audit in Mahanand Dairy is focused mainly on a. Electricity bill analysis b. Plate heat exchanger c. Softener pump d. boiler

The details of data collection and analysis are explained in further sections.

III. Electricity Bill analysis

The electricity bill data of Mahanand Dairy of 12 months from June 2022 to May 2023 was collected. The maximum demand (MD), total energy consumption, power factor (PF) incentives and unit rate was noted down [3].

Table 1: Electricity Bill Analysis

Month and Year	MD Recorded	Billing Demand	Total energy consumption	PF	PF incentive	Unit rate
	kVA	kVA	kWh	%		₹/kWh
Jan-23	1222	1600	492660	99.2	372972	11.2
Feb-23	1320	1600	477360	99.8	367119	11.37
Mar-23	1398	1600	543820	99.7	412034	11.2

Apr-23	1418	1600	566980	99.5	420392	10.97
May-23	1500	1600	611560	99.4	318631	11
Jun-22	1514	1600	586940	99.6	433794	10.94
Jul-22	1448	1600	550840	99.8	414747	11.14
Aug-22	1442	1600	550860	98.9	288973	11.08
Sep-22	1418	1600	534520	98.5	137460	11.12
Oct-22	1406	1600	567700	99.8	195176	10.53
Nov-22	1408	1600	521900	99.2	190586	11.54
Dec-22	1342	1600	505960	99.99	180886	10.57

As the dairy is receiving attractive amount of incentive by maintaining the appropriate power factor, the energy saving potential does not exist from Table 1.

IV. Boiler Analysis

A horizontal fire tube boiler is used in MRSDMM to convert the water into steam, which is required for process heating purpose as shown in the figure 2.

The first pass of the water will be through the partly corrugated furnace and the cylindrical combustion chamber. The second pass starts when the water converts into steam and flow from the furnace into small bore smoke tubes located over the furnace. At the end of the pass and near the central smoke box, the flow divides into two parts. The third pass of the steam is through the smoke tubes located outside the main arrangement and which opens at the exit on the rear of the boiler.

Figure 1: Fire tube boiler at MRSDMM

There are two methods to calculate the efficiency of the boiler.

a) Direct method

b) Indirect method

The efficiency of MRSDMM boiler is calculated using indirect method, so as also to find the different types of losses in the boiler.

4.1 Performance analysis of boiler [2]

The boiler is furnace oil fired. The ultimate analysis of the furnace oil is shown in the Table 2.

Table 2: Ultimate Analysis of Furnace Oil

Carbon	84
Hydrogen	12
Nitrogen	0.5
Oxygen	8.1
Sulphur	1.5
Moisture	0.5
GCV of fuel	10000

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Fuel firing rate	2650kg/hr
Surface temperature of boiler	80°C
Surface area of boiler	151.5m²
Humidity	0.03kg/kg of dry air
Wind speed	3.5m/s

The efficiency of boiler is calculated by easily by measuring all the losses occurring in the boilers is called as indirect method of efficiency according to IS 8753: Indian Standard for Boiler Efficiency Testing.
Table 3 shows the measured parameters and associated calculations.
Table 3: Efficiency Calculation

Fuel gas temperature	230°C
Ambient temperature	30°C
CO_2 % in flue gas by volume	10.8
O_2 % in flue gas by volume	7.4
Theoretical air required	{(11.6*C)+[34.8*(H_2-O_2/8)]+(4.35*S)}/100 kg/kg of fuel
	{(11.6*84)+[34.8*(12-1.5/8)]+(4.35*1.5)}/100
	13.639 kg/kg of fuel
Excess air supplied (EA)	(O_2%/21-O_2%)*100
	(8.1/21-8.1)*100
	62.79%
Actual mass of air supplied/kg of fuel (AAS)	[(1+EA)/100]*theoretical air
	[(1+62.79/100]*13.92
	8.69 kg/kg of fuel
Mass of dry fuel gas	mass of (CO_2+SO_2+N_2+O_2) in fuel gas + N_2 in air we are supplying
	[(0.84*44)/12] + [(0.015*64)/32] + {[(22.62-13.92)*23]/100} + [(22.62*77)/100]
	8.67 kg/kg of fuel
% Heat loss in dry flue gases	{[m*Cp*(Tf-Ta)]/GCV of fuel}*100
	{[8.67*0.24*(230-30)]/10000}*100
L_1	4.164%
Heat loss due to evaporation of water due to H_2 in fuel (%)	{{9*H_2*[584 + Cp*(Tf-Ta)]}/GCV of fuel}*100
	{{9*0.12*[584 + 0.43*(230-30)]}/10000}*100
L_2	7.236%
% Heat loss due to moisture in fuel	{m*[584+Cp(Tf-Ta)]/GCV of fuel}*100
	{0.005*[584+0.43(230-30)]/10000}*100
L_3	0.0335%
% Heat loss due to moisture in air	{[AAS*humidity factor*Cp*(Tf-Ta)]/GCV of fuel}*100
	{[8.67*0.025*0.43*(230-30)]/10000}*100
L_4	0.186%
Radiation and convection loss Where n = 1.25	$0.548*[(Ts/55.55)^4-(Ta/55.55)^4]+1.957*(Ts-Ta)^n$*sq.rt of [(196.85*Vm+68.9)/68.9]
	$0.548*[(353/55.55)^4-(303/55.55)^4]+1.957*(353-303)^n$*sq.rt of [(196.85*3.8+68.9)/68.9]

	1303 W/m²
	1120.58 kcal/m²
Total radiation and convection loss per hour	1120.58*151.5
	169767.87 kcal
% Radiation and convection loss	[169767.87/(10000*2650)]*100
L_5	0.64 %
Boiler efficiency by indirect method	100-(L_1+L_2+L_3+L_4+L_5)
	100-(4.164+7.236+0.0335+0.186+0.64)
	87.75 %

4.2 Fuel Substitution Analysis [2]

In Energy is an important input in the production. There are two ways to reduce energy dependency; energy conservation and substitution. Fuel substitution has taken place in all the major sectors of the Indian economy. It refers to substituting existing fossil fuel with more efficient and less cost/less polluting fuel such as natural gas, biogas and locally available agro-residues.

The natural gas (PNG) has following advantages over Furnace oil, as follows:-

A. The expenses on Natural Gas are considerably low as compared to that of Furnace oil, thereby saving the operational cost.
B. The operations are very clean as compared to the Furnace oil, because there are chances of spillage of Furnace oil through the pipelines, valves etc., making the place very dirty. This can be avoided with the use of PNG.
C. Due to the use of PNG, less pollutant flue gases are exhausted in the environment, compared to that of Furnace oil, helping to protect the Green Earth. This is helpful not only delivering the social responsibilities, but to achieve the targets required for ISO 14000 (Environmental Management System) also.
D. Due to the use of PNG, less carbon will be deposited in the tubes of boilers, as compared to that of Furnace oil, thereby reducing the maintenance cost and increasing the thermal efficiency of the boile₹ The risk of breakdowns of the system is also reduced.
E. As the Natural Gas is supplied through pipeline continuously, no need to build the inventory, as in the case of Furnace oil, thereby reducing the inventory cost, space for inventory etc.
F. No need to use the fuel pump, thereby reducing the electricity and maintenance costs.

In view of the above benefits, the need of shifting the boiler from furnace oil to PNG is strongly recommended.

Table 4 shows the comparison of PNG and furnace oil.

Table 4: Furnace oil and Natural Gas Comparison

S N	Description	Unit	Value
A	Gross Calorific Value of Furnace oil	Kcal / Kg.	10090
B	Net Calorific Value of PNG	Kcal / SCM	8500
C	Quantity of PNG equivalent to 1 lit. of Furnace oil (A / B)	SCM	1.187
D	Rate of Furnace oil (Incl. Transportation)	₹ / Lit.	32
E	Rate of PNG	₹ / SCM	35
F	Rate of PNG for quantity equivalent to 1 lit. of F.O. (C X E)	₹	41.54
G	Saving per lit. of F.O. if replaced by equivalent qty. of PNG (D - F)	₹	9.54

4.3 Analysis of Boiler Investment and Savings [4]

In order to consider fuel substitution from furnace oil to PNG, the cost estimation considering boiler house modification is given in the Table 5.

Table 5: Economic Analysis of Boiler Performance

SN	Description	Investment (₹ Lacs)
1	New PNG connection from M/S. Mahanagar Gas Limited up to MRS	16
2	Civil Works for the above	1
3	Downstream pipeline from MRS to Boiler house	8
4	Modifications in Boiler house	
	a. for 2 burners of 4 TPH retrofit	70
	b. Condensing economizer for 4 TPH feed water 4000 Lit./Hr.	18
	c. Dearator for 8 TPH steam generation with local supply	12
	d. for 1 burner of 2.8 TPH retrofit	30
	e. Condensing economizer for 2.8 TPH feed water 2000 Lit./Hr.	16
	TOTAL ₹ IN LACS	**171**

MRSDMM is consuming 4000 liters per day for boiler, tetra fino and product block as shown in the Table 6. The associated saving is also shown.

Table 6: Consumption of FO and PNG

S N	Description	FO Consumption	Fuel Substitution Savings	Operational days per year	Annual Savings
		Liters/day	**₹**	**No.**	**₹**
1	Regular dairy operations	2000	9.54	365	6964200
2	For Tetra Fino	1000	9.54	200	1908000
3	For Product Block	1000	9.54	200	1908000
	TOTAL	**4000**	9.54		**10780200**

The tentative saving from this project is ₹ 107.8 Lacs per year. Total investment of the project is ₹ 171 Lacs. The payback period is approximately 19.17 months.

V. Softener Pump

Softener pump is used to remove the scales, dirt, calcium and magnesium. Hard water is formed due to increased proportion of calcium and magnesium. In MRSDMM, local authority water is received in the plant for process. The water received is hard water which cannot be directly used for process or in any other equipment. The water received flows through a softening process, so that it can be used in the plant. In MRSDMM, water is used in process department for chilling of milk and also in boiler for steam generation. It is necessary to use an efficient pump for softening process. Figure 3 shows softener pump used at MRSDMM.

Figure 2: Softener Pump at MRSDMM

5.1Performance Analysis of Softener Pump [3]

The design data of pump was collected from the manufacturer's manual and the actual data was measured at the field as shown in the Table 7.

Table 7: Performance Analysis of Pump

The design data of the pump:	
Capacity of pump (Q)	= 64m³/hr = 0.0177m³/s
Power	= 15kW
Head	= 59.8m
Efficiency of pump	= 77.6%
Mechanical efficiency index (MEI)	= 70%
Actual data:	
Flow/discharge	= 22.15m³/hr = 0.006152m³/s
Velocity	= 0.84m/s
Suction pressure = Hs	= -3m
Discharge pressure = Hd	= 42m
Power required	= 10.4kW
Total head = H = Hd-Hs	= 42-(-3) = 45m
Efficiency of pump	= [(Q*ρ*g*H)/(kW*MEI*1000)]
	= [(0.006152*1000*9.81*45)/(10.4*0.7*1000)
	= 0.373 = 37.3%
Actual power required	= [(Q*ρ*g*H)/(ηp*MEI*1000)]
	= [(0.006152*1000*9.81*45)/(0.776*0.7*1000)
	= 4.99kW
Savings	= power required-actual power required
	= 10.4 - 4.99
	= 5.40kW
Pump works for 20 hrs a day	= 5.40*20 = 108kW-hrs
Unit rate	= 11.21/kW
Savings in Rs	= 108*11.21*30*12
	=4,35,844 ₹/annum

As, the efficiency of the pump is very low, either to be checked the pump internally or the pump is to be replaced by pump fitted with variable frequency drive.

VI. Plate heat exchanger (PHE) Chiller Unit

A plate heat exchanger is an equipment in which two fluids are present to exchange the heat from hot fluid to cold fluid. Figure 4 shows the PHE used at MRSDMM. The basic working of PHE is that there several plates present, and on one side of the plate there is a hot fluid and on the other side is cold fluid. Both the fluids enter from one side of the plate. Even though both fluids enter from one side, they don't get mixed with each other because the arrangement is made so. In MRSDMM the two fluids are ammonia and water. Ammonia is the refrigerant, the hot water which comes from the process department needs to be cooled. Water gives its heat to ammonia and get cooled, and again can be used for process.

Figure 3: Plate Heat Exchanger at MRSDMM

6.1 PHE Chiller Performance Analysis

The measurements and analysis of chiller unit of PHE is given in the Table 8.

Table 8: PHE Chiller Performance Analysis

Design specifications	
Make	Evapco (Shanghai) refrigeration equipment co. ltd
Model	CAIC-304
Refrigerant	Ammonia (NH_3)
Design pressure	2.07 MPa
Storage capacity of NH_3 compressor	1000kg
Plate type material	= SS-316
Water inlet temp. of condenser	= 32°C
Water outlet temp. of condenser	= 36°C
Ammonia condensing temperature	= 40°C
Heat rejection capacity	= 138TR
Water flow though condenser	= 18m³/hr
ρ = density	= 999.78kg/m³
T_2 (water inlet temperature)	= 4.2°C
T_1 (water outlet temperature)	= 1.9°C
Q = discharge	= 18 m³/hr = 0.005 m³/s
Ideal RE	= (Q*ρ)*Cp*(water inlet temperature-water outlet temperature)
	= (0.005*999.78)*4.19*(4.2-1.9)
Refrigeration effect	= 48.174 kW
	= 48.174/3.517
	= 4.93 tonnes
Power required for pump	= 1.1kW
Specific power consumption	= 1.1/48.174
	= 0.0228kW/TR
Actual discharge	= 0.0018 m³/s
Actual RE	= (Q*ρ)*Cp*(water inlet temperature-water outlet temperature)
	= (0.0018*999.78)*4.19*(4.2-1.9)
	= 17.342 kW
Saving	= (Ideal RE - Actual RE)*no.of working hours*no.of working days*unit rate
	= (48.174 – 17.342)*24*365*11.21
	= 3027690 ₹

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6.2 Energy Conservation Opportunities in PHE Chiller

As the TR capacity is too low it can be increased by getting design inlet and outlet conditions. The further suggestions include maintenance of air filter, oil filter, oil pump, condenser cleaning etc.

VII. Discussion

Boiler is a utility used for the generation of steam. Generation of steam using less amount of energy is very important aspect in the industry with a perspective to decrease the expenses in purchasing the Furnace Oil (FO). In order to reduce the expense, the boiler running on FO should be replaced with Piped Natural Gas (PNG). By installing this, MRSDMM may save ₹107 lacs per year. The soft water plant pump efficiency is very low and by installing a new one will save much amount of energy as well as money. The annual saving is ₹ 4.35 Lacs by the efficiency improvement. The PHE chiller unit used needs to be maintained in continuous interval of time and the gaskets used should be changed, so as to minimise the leakage, so as to operate the chiller at the design parameters The annual savings of ₹ 30.28 Lacs is expected by performance improvement of PHE chiller unit. The overall savings is estimated to be ₹ 141.63 Lacs per year as shown in Table 9.

Table 9: Overall Savings at the Plant

Parameters	Unit	Boiler	Softener Pump	PHE Chiller
Investment	₹ (Lacs)	171	2	12.5
Savings	₹ (Lacs)	107	4.35	30.28
Payback period	Months	19	6	5

The annual savings is also represented by bar chart as shown in the figure 5.

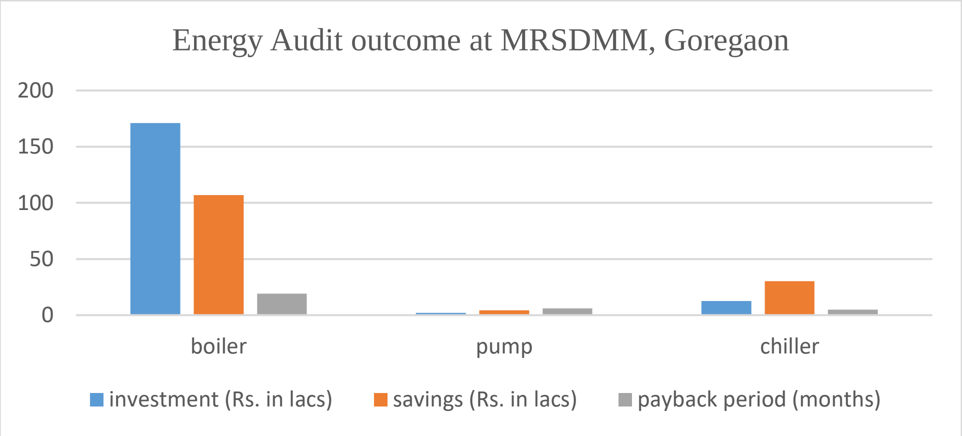

Figure 4: Bar Chart Representation of Energy Saving at MRSDMM

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