ENERGY AUDIT REPORT

September 2019

Prepared For ,
Krishna Institute of Medical Sciences
'Deemed to be University'

Malakapur, Pune-Banglore Highway, Tal.: Karad, Dist.: Satara Pin Code : 415 539, State : Maharashtra, India

Prepared By,

Green Scientific Development (I) Pvt. Ltd.

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1 CERTIFICATE

This Energy Audit Report is prepared & documented for Krishna Institute of Medical Sciences 'Deemed to be University', (KIMSDU) Karad, Maharashtra State on a best judgment basis by "Green Scientific Development (I) Pvt. Ltd (GSDIPL), Mumbai. The details contained in this report have been compiled in good faith based on the basis of information provided & shared by KIMSDU, Karad.

We further submit that the projections are the management's best estimates and no representation, warranty or undertaking, express or implied is made and no responsibility is accepted by Green Scientific Development (I) Pvt. Ltd and / or its affiliates and / or its Directors, employees / officers in this report or for any direct or consequential loss arising from any use of the information, statements or forecasts in the report.

Energy Auditor
(Certificate No. EA 4593)
Mr. Shripad Vishnu kale

(S.V. Kale)

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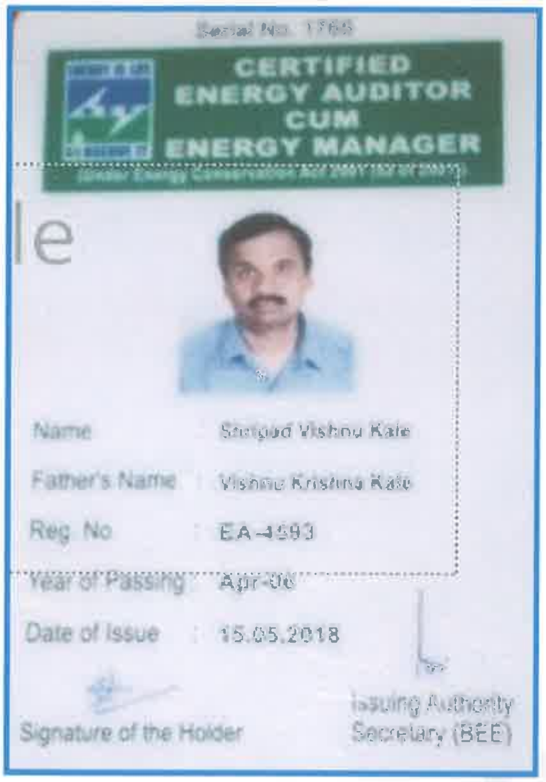
Director, GSDIPL
EMS ISO 14001 Lead Auditor
Mr. Kiran Mahadev Shinde

M/s. Green Scientific Development (I) Pvt. Ltd.
Scince 1998



Serial No. 1766

CERTIFIED ENERGY AUDITOR CUM ENERGY MANAGER

(Under Energy Conservation Act 2001 (52 of 2001))

Name	:	Shripad Vishnu Kale
Father's Name	:	Vishnu Krishna Kale
Reg. No	:	EA-4593
Year of Passing	:	Apr-06
Date of Issue	:	15.05.2018

Signature of the Holder

Issuing Authority
Secretary (BEE)

TÜV NORD

PR315: ISO 14001:2015 Lead Auditor
(Environmental Management Systems)
Training course

Certificate of Achievement

Mr Kiran M Shinde

has successfully completed the above mentioned course and examination

11th - 15th March 2019

MUMBAI, INDIA

CQI | IRCA
CERTIFIED COURSE

Regn. No.EM-6924

Certificate No.8827

National Productivity Council
(National Certifying Agency)

PROVISIONAL CERTIFICATE

This is to certify that Mr. / Mrs. / Ms. Bhalchandra Shridhar Bhurke

son / daughter of Mr. Shridhar

has passed the National Certification Examination for Energy Managers held in September - 2015 conducted on behalf of the Bureau of Energy Efficiency, Ministry of Power, Government of India and is qualified as Certified Energy Manager.

This certificate is valid till the issuance of an official certificate by the Bureau of Energy Efficiency.

Place : Chennai, India

Date : 10th February 2016

Controller of Examination

2 PREFACE

In the State Maharashtra and district Satara, KIMSDU is an important centre of medical education hub who offers undergraduate degree and diplomas for post-graduation in various branches of medical sciences. Krishna hospital is committed to provide standard treatments and quality care. Management is well aware and taking at most care & Responsibility for sustainable development of institutional all the activities.

With spiralling energy costs, KIMSDU appointed Green Scientific Development (I) Pvt Ltd with interest to trim down energy consumption and cost. The energy audit assignment is conducted for checking levels of energy aspects at the KIMSDU Facility, Karad.

The energy audit is aimed at recording and quantification of the energy consumption at location. Subsequently, it also tries to explore the possibilities of conserving energy through better practices and employment of latest technologies.

The report has classified the suggestions in to short, medium and long-term investment opportunities so that the management can take up the implementation according to investment and payback priorities.

3 ACKNOWLEDGEMENT

This Energy Audit is conducted hand in hand with the institutional staff assigned & involved in energy aspect by keeping common goal of accounting & contain energy usage without sacrificing the purpose of use of energy at its optimum requirement.

The institutional team had put there all possible interest, involvement & participated equally without which it would not be achieved satisfactorily.

We are thankful to the Top Management of Institute for appointing us to conduct energy audit. We further thanks for the contribution of the following dignitaries because of whom the study could progress smoothly to achieve its aim and objective;

-	Mr. (Dr.) M. V. Ghorpade	Registrar
-	Mr. Sataynaryan Mashalkar	Asstt. Registrar
-	Mr. Tushar Kadam	Administrative Officer
-	Mr. Yogesh Kulkarni	HOD Electrical

Last but not least, thanks to all those who contributed and putting continuous efforts for the success of energy saving, continual improvement & sustainable development during performance of all the institutional activities.

4 ABBREVIATIONS

Abbreviations	Full Form
Asstt.	Assistant
A	Ampere
AC	Alternating Current
AC's	Air Conditioner
Avg.	Average
^{0}C	Degree Centigrade
COP	Co-Efficient Of Performance
DC	Direct Current
Eff.	Efficiency
GSDIPL	Green Scientific Development (I) Pvt. Ltd.
HVAC	Heating Ventilation and Air Conditioning
HP	Horse Power
KIMSDU	Krishna Institute of Medical Sciences 'Deemed to be university'
KV	Kilo Volt
KvA	Kilo Volt Ampere
kW	Kilo Watts
Kwp	Kilo Watts Power
LPD	Liters Per Day
M or m	Meter
m/c	Machine
Min.	Minimum
mm	Millimeter
MSEDCL	Maharashtra State Electricity Distribution Company Ltd.
PRV	Pressure Reducing Valve
RH	Relative Humidity
Sec.	Second
SPV	Solar Photovoltaic
SWH	Solar Water Heater
THD	Total Harmonic Dispersion
V	Voltage
VFD	Variable Frequency Drive
VRV	variable refrigerant valve

5 EXECUTIVE SUMMARY

The major potential savings along with investment and payback period are given below.

Sr. No.	Energy Conservation Measures	Annual Savings		Investment (Rs. Lakhs)	Simple Payback Period (Months)
		Electricity (kWh)	Rs. Lakhs		
1	Arrestation of compressed air leakages in the system	6479	0.93	NIL	Instant
2	Cut-off pressure reduction instead of Pressure Reducing Valve	1204	0.17	NIL	Instant
3	Replacement of existing lighting system with LEDs (Considering around 50% of total replacement)	56340	8.12	30	12
4	Use of solar water heater for hot water generation	111714	16.1	10	12
5	Use of Heat Pump for Hot Water Generation	72242	10.41	25	29
6	Replacement of window / split AC with 5 star inverter type air conditioners	241210	34.78	70	25
7	Installation of solar hybrid VRF system for air conditioning	42647	6.15	15	29

Review of energy conservation activities done at site are summarised below:-

Approximately Saving in 2018-2019

Sr. No	Description	Saving / kWh
1	39 Watt LED Light, Qty - 21 From Sept 2015, Saving	13097
2	Solar System 10 Kwp from Oct 2015, Saving	13096
3	Energy Efficient 750 Kva trans, Install, May 2016 Saving	21900
4	Installation of APFC Panel, May 2016, Saving	276000
5	Hybrid solar System 35Out put Kw- Input 10Kw , Saving from Sept 2016	39087
6	International Hostel Led Lights, Total 7 Kw , 0.4 D. F x 6 Hours, May 2017 saving 80%	4435
7	VRV System 148 HP, May 2017, Saving 20% against regular AC [(Kw 110 x Df 0.4 x 300) x 20%]	13248
8	Inverter Ac installation Tr- saving 10% of regular AC 61 +17 AC (Year 105600unit consumption - saving 10%)	10560
9	Solar System 500 Kwp	720000

6 BASIC DETAILS

Name of institution	Krishna Institute of Medical Sciences 'Deemed to be University'
Location	Malakapur, Pune - Banglore Highway, Karad - 415 539, Maharashtra, India
Year of Establishment	1984
Activity	Medical Education
Facility	Medical College, Hospitals
Energy Scene	
Major Connected load	Air/Vacuum Compressors, Geyser, Ovens, AC Units, Lighting, Pumps, Computers, Medical & Other Office Equipment, etc.
Major Energy Sources	Electricity from the Grid
Energy Audit Date	**09 September 2019**

7 INTRODUCTION

7.1 Preamble

- Krishna Institute of Medical Sciences 'Deemed to be University' has a facility at Karad.
- The Campus is serviced by utilities like window & split AC's, lighting, electrical geysers, boilers, medical & office equipment like CT scan m/c's, MRI m/c's etc. as support services.
- With increasing energy costs, management approached GSDIPL for the energy audit of KIMSDU.
- GSDIPL submitted its proposal. This proposal was accepted by KIMSDU.
- This energy audit report for KIMSDU, Karad campus presents
    - The analysis of the data collected,
    - Field trials undertaken.
    - Observations, Recommendations & General Tips
- This energy audit report for is governed by the objectives, scope of work, and methodology discussed in ensuing paragraphs.

7.2 Objectives

- To undertake an energy audit so as to identify areas for energy saving
- To prioritize distinct areas identified for energy savings depending upon
    - Saving potential,
    - Skills,
    - Time frame for execution,
    - Investment cost,
    - Payback

7.3 Scope of Work

- To correlate monthly data of activity with energy consumption for annum.
- To study electrical energy metering, monitoring and control system existing at the institute and to recommend a suitable system for future monitoring.
- To study monthly power factor, maximum demand, working hours, load factor etc.

- Detailed Load management study for the reference period along with monthly electricity consumption and establish scope for Max Demand control through possible optimization of load factor.
- To undertake a detailed motor load study on major continuously operating motors equal to and above 10 HP with the help of a clamp on multi-meter to identify instantaneous motor parameters like kW, kVA, P.F., A, V, frequency etc.
- Based on above, to evaluate the possibility of replacing major motors with energy efficient motors.
- To study compressed air & nitrogen distribution system in the plant, in terms of compressor type, make, capacity, loading, motor type / size / loading etc. and to undertake output efficiency test for the operating compressors.
- To study existing requirements of chilled water/conditioned air provisions at present locations and to identify distinct possibilities of rationalization /savings.
- To study operation of chilled water/conditioned air with the help of operating records kept and spot measurements taken during the field study and identify COP for chilling compressors in usage and identify scope for optimization through improved operating/maintenance practices.
- To study existing maintenance practices for chilled water / air conditioning system and recommend areas for improvement in energy efficiency /savings.
- To identify, evaluate and prioritize energy saving opportunities into short, mid and long- term time spans depending upon investments, quantum of savings, skills and time required for implementation, etc.
- To recommend a time-bound action plan for implementation of accepted measures.
- To prepare draft energy audit report, present to management, undertake necessary modifications based on presentation meeting and submit the final report.

7.4 Methodology

Audit Team:

GSDIPL deputed team of experts for conducting the study and worked in close association with KIMSDU unit personnel.

Energy Auditor : Mr. Shripad Kale - BEE Certified Energy Auditor
Energy manager : Mr. Bhurke Bhalchandra - BEE Certified Energy Manger, ISO 45000LA
Client Rep. : Mr. Yogesh Kulkarni - HOD Electrical

Documentation :

- GSDIPL submitted an execution work plan along with checklist to the KIMSDU.
- KIMSDU provided relevant data support.
- KIMSDU nominated responsible person involved in energy aspect from Engg./Maintenance sections along with subordinator & senior managerial level for achieving aim and goal.

Field / Site Visit :

- Opening Meeting - GSDIPL undertook an “Orientation Meeting” with team.
- GSDIPL’s team conducted all necessary field trials admeasurements.
- GSDIPL provided all the instruments (List No 1) necessary for conducting the Field trials.
- Closing Meeting – On table Discussion conducted about field trial and its findings.

Report :

- Drafting of Report and its verification by management representative
- Final report submission to the management

List 1: List of the Instruments Used for Measurement

Instrument Name	Specification
Demand Analyzer	Suitable for electrical parameters like voltage, current, frequency, harmonics, active & reactive power, power factor etc.
Clamp-on Power Meter	0 - 1200 kW 0 - 600 Voltage, AC 0 - 800 Voltage, DC 0 - 2000 A, Current, AC / DC
Power Quality Analyzer	3 Ph. 4 Wire Recording Parameters: Voltage, Current, Frequency, Harmonics/ Inter harmonics up to 50th, THD of V, I and KW with K Factor, Transients Voltage, All Power Parameters, Inrush current, Flicker Recording, Graphical, Vectorial, Numeric representation, trending of data, monitoring of events, etc.
Lux Meter	0 - 50,000 lux level (Non-Contact Type)
Digital Thermal Anemometer	0 - 45 m/sec. 3%
Relative Humidity and Temperature Indicator	RH – 10% to 95% Temp. – 0 to 100 ^{0}C
Infrared Thermometers	40 ^{0}C to 500 ^{0}C
Portable Temperature Indicator	50 ^{0}C to 1200 ^{0}C
Stop Watch	Standard

8 ENERGY PERFORMANCE ASSESSMENT AND SAVINGS OPPORTUNITIES

8.1 Electricity Consumption

8.1.1 Electricity Consumption from Grid

A study was conducted to observe the variations in the electricity consumption for the past 4 years. The details of the same are given below.

Table 1. Electricity Consumption (2015-18)

Sr. No	Month	2015	2016	2017	2018
1	Jan	2,45,929	2,55,796	2,63,948	2,88,465
2	Feb	2,45,422	2,75,923	2,66,003	2,77,245
3	Mar	3,22,926	3,37,871	3,35,145	3,85,470
4	Apr	3,41,002	3,44,734	3,75,878	3,79,342
5	May	3,55,948	3,94,154	3,76,928	3,93,323
6	Jun	3,27,814	2,93,753	3,53,685	3,32,145
7	Jul	3,11,106	2,83,980	3,23,798	3,14,145
8	Aug	3,15,782	3,01,410	3,32,145	3,07,747
9	Sep	3,10,796	2,87,348	3,37,290	3,12,053
10	Oct	3,39,025	2,92,808	3,25,125	3,21,097
11	Nov	2,82,100	2,68,298	3,13,583	2,57,715
12	Dec	2,82,363	2,58,923	2,84,858	2,57,100
Total		**36,80,213**	**35,94,998**	**38,88,386**	**38,25,847**

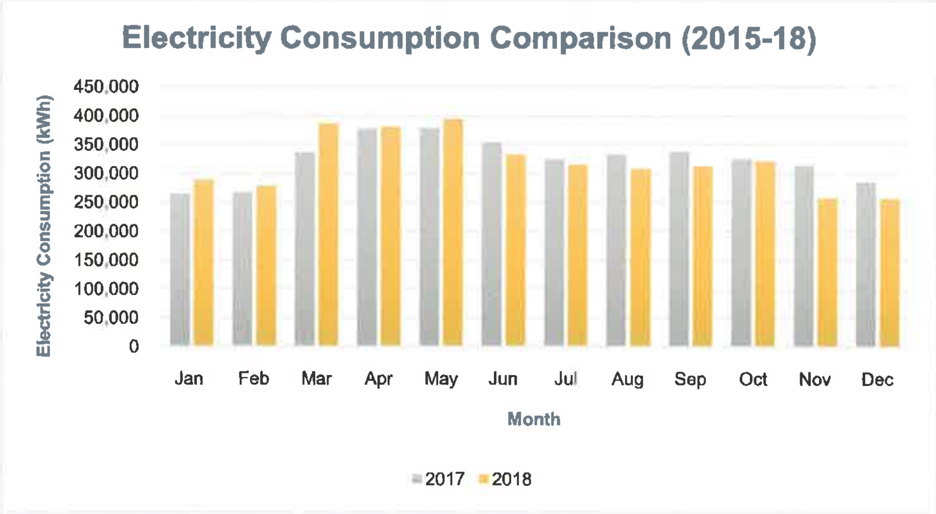


Figure 1. Electricity Consumption Comparison (2015-18)

From the above data, it can be seen that the minimum electricity consumption was in the year 2016 and maximum consumption was in the year 2017. Also, the annual electricity consumption did not change much in the year 2018 as compared to 2017. However, there is a variation in electricity consumption month-wise when compared between 2017 and 2018.

8.1.2 Electricity Generation using Solar PV system

Solar PV system of 500 kWp capacity was installed in the premise as a part of reduction in carbon emissions due to use of electricity. The details of the electricity generation month-wise from Solar Plant is given below.

Table 2. Solar PV Generation

Month	Solar PV Generation (kWh)
Apr-18	73,524
May-18	72,410
Jun-18	40,018
Jul-18	38,210
Aug-18	44,552
Sep-18	60,646
Oct-18	64,084
Nov-18	63,450
Dec-18	58,186
Total	515,080

Capacity Utilization Factor (CUF) of a Solar Plant is given by the ratio of actual amount of electricity generated to the maximum amount of electricity that can be generated.

CUF of the present system is 15.61%. As per MNRE report, the average CUF factor of a solar PV plant in India is between 15-19%.

8.1.3 Electricity Generation using DG sets

During power outage, as solar PV is also not available, DG sets were used as a backup option. The diesel consumption month-wise for the year of 2015 to 2018 is given below.

Table 3. Diesel Consumption – 2015-2018

Month	2015	2016	2017	2018
Jan	600	1600	1100	300
Feb	400	2200	700	700
Mar	600	1088	1400	600
Apr	800	3900	0	400
May	400	4200	3838	1500
Jun	800	800	7200	2300
Jul	300	700	1800	1300
Aug	1000	900	800	800
Sep	1400	1600	1300	1100
Oct	800	1200	1250	1500
Nov	400	1800	1300	1000
Dec	1200	1800	1400	800
Total	**8700**	**21788**	**22088**	**12300**

8.2 Regression Analysis

Heating and Cooling degree days (HDD/CDD) are used to indicate the effect of outside air temperature on building energy consumption during a specified time. They represent the number of degrees and the number of days that the outside air temperature at a specific location is lower/higher than a specified base temperature. Since the buildings are air-conditioned and no heating is involved, only CDD have been considered as independent variables.

The relationship between electricity consumption and cooling degree days is represented by the equation y = mx + c, alphabet 'y' represents energy consumption plotted on the y-axis and 'x' represents cooling degree days plotted on the x-axis. The slope of the line 'm' represents degree by which energy consumption varies corresponding to a rise of 'x' degree days. Constant 'C is known as base load, which is considered to occur as a constant load and is independent of the number of degree days or sales or footfall. R^2 is the coefficient of determination of the model & if its value is above 0.75, then the model is considered to correlate considerably with the independent variable.

Table 4. Cooling Degree Days – 2018

Month	Cooling Degree Days
January	31.8
Feb	56.7
Mar	118.8
Apr	179.9
May	207.5
Jun	83.5
Jul	19.3
Aug	13.8
Sep	47.9
Oct	86.9
Nov	63.0
Dec	28.4

Monthly data for cooling degree days (CDD @ 24°C) and electricity consumption for the year January 2018 – December 2018 is shown in Table above. The CDD with a base value of 24°C is selected because the majority of the cooling load is for human comfort condition

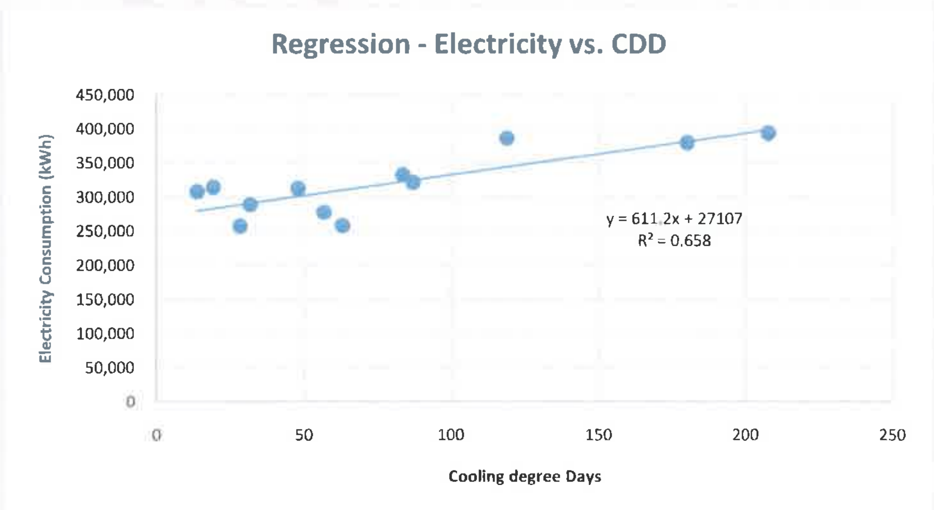


Figure 2. Regression – Electricity vs. CDD

The R^2 (coefficient of determination) value for the regression model is approximately 65.82%, this signifies that the weather (CDD) does not show any strong correlation with the electricity consumption of the facility.

It can be seen from the above figure that the electrical consumption does not comprise only of HVAC systems. However, it has been observed that the major connected load is HVAC systems comprising of approximately 1272 kW. So, there is a possibility of inefficiency in the HVAC systems which are indicated by the lower value of R^2.

8.3 Air/Vacuum Compressor

Air/Vacuum Compressor is one of the energy intensive equipment in the whole premise. It is known that only about 10% of the input energy to the compressor is converted to useful compressed air energy. Performance of the air/vacuum compressor is of great importance and a significant amount of energy savings can be achieved from it. In determination of air compressor performance, Free Air Delivery of the compressor is carried out. Presently, there are 2 air compressors present in KIMSDU Dental College & Clinic. During the weekdays, the larger capacity compressor is used for approximately 10 hours. The lower capacity compressor is used only on Saturday. Following is the data of the existing air compressors and air dryer in the college and clinic.

Table 5 (a). Air Compressor Details

Sr.	Parameters	Units	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6
1	Equipment no.	-	AC 01	AC 02	AC 03	AC 04	AC 05	AC 06
2	Make	-	Ingersoll Rand	Ingersoll Rand	Ingersoll Rand	Ingersoll Rand	KFC	Elgi
3	Type	-	Screw	Screw	Reciprocating	Reciprocating	Reciprocating	Reciprocating
4	Capacity	HP	40	10	10	7.5	1.0	5.0
5	Motor Power	kW	22	11	7.5	5.5	0.75	3.7
6	Total Current	A	43	23	11	8	0.5	5.2

Table 5 (b). Vacuum Compressor Details

Sr. No.	Location of Vacuum Compressor	Equipment No	Make	Type	Capacity (HP)	Motor Power (Kw)	Total Current (A)
1	Ward No 21 to 28	VC 01	Ingersoll Rand	Reciprocating	10	7.5	13
2	Ward No 21 to 28	VC 02	Ingersoll Rand	Reciprocating	10	7.5	13
3	CVTS	VC 03	Ingersoll Rand	Reciprocating	10	7.5	13
4	Ward No 10 & 11	VC 04	Ingersoll Rand	Reciprocating	10	7.5	13
5	Operation Theatre	VC 05	Ingersoll Rand	Reciprocating	05	3.7	8
6	OT	VC 06	Ingersoll Rand	Reciprocating	02	1.5	2.6
7	CASUALITY	VC 07	Ingersoll Rand	Reciprocating	02	1.5	2.6
8	ICU	VC 08	Ingersoll Rand	Reciprocating	02	1.5	2.6

Table 6. Air Dryer Details

Sr. No.	Parameters	Units	Air Dryer
1	Refrigerant	-	R22
2	Max. Temperature	°C	60
3	Max. Ambient Temperature	°C	50
4	Max. Inlet Pressure	barg	14

Another important part of the air/vacuum compressor and its system is the leakages present in the compressed air distribution and utilization system such as Pipeline, joints, end applications, etc. As we already know that 90% of the input energy to the compressor is wasted, leakages in the system will waste a significant amount of energy. A normal and healthy compressed air system consists of leakages of a quantity of maximum of 10% of the compressor rated quantity.

Energy Savings Recommendations:

1. **Energy Savings due to arrestation of compressed air leakages in the system**

During the audit, many air leakages were observed in the compressed air system. Assuming the diameter of the leak to be 1 mm at 7.5barg air pressure, the air leakage is approximately equal to 2.3cfm. Considering the specific energy consumption of the air compressor to be 0.18 kW/cfm. The power losses due to 10 leakages of 1 mm diameter is given below.

Table 7. Arrestation of compressed air leakages in the system

Sr. No.	Parameters	Units	Values
1	Diameter of leakage	mm	1
2	Pressure of Air	barg	7.5
3	Number of Leakages	nos.	5
4	Air flow through a single leak point*	cfm	2.3
5	Specific Energy Consumption of Air Compressor	kW/cfm	0.18
6	Total power losses due to leakages	kW	4.14
7	Daily Operating Hours	hours	10
8	Annual Working Days	days	313
9	Annual Energy Savings	kWh/year	6479
10	Electricity Tariff	Rs./kWh	14.42
11	Annual Cost Savings	Rs./year	93,427

https://www.tlv.com/global/TI/calculator/air-flow-rate-through-orifice.html

In actual, the quantity of the leakages will be more and the diameter of the leakage might be less or more. However, it is also recommended to conduct a detailed online compressed air leakage detection of the whole plant. This audit is conducted using Ultrasonic Leak Detector which detects ultrasonic sound released by small leakages which are unheard by a human.

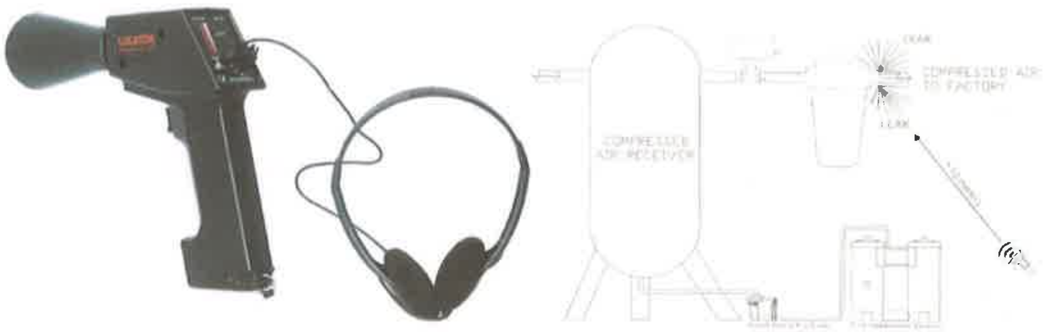


Figure 3. Ultrasonic Compressed Air Leakage Detection

2. **Cut-off pressure reduction instead of Pressure Reducing Valve**

Artificial demand of the compressors is the additional volume of air which is required because of end uses where air is not regulated, which is the result of supplying the air at a higher pressure than required for any application. Artificial demand increases the supply pressure which directly increases the power consumption of the air compressors.

Figure 4. Artificial Demand of Air Compressor

Presently, the cut-off pressure of the larger capacity air compressor is 7.8 kg/cm^2. The required air pressure is less than 6.5 kg/cm^2. Reduction of the cut-off pressure from 7.8 to 7 kg/cm^2 will give a significant amount of savings. Presently, the pressure reduction is done using a pressure reducing valve which is not a good energy efficiency practice. Savings due to the reduction of cut-off pressure of the compressor is given below.

Table 8. Cut-off pressure reduction instead of Pressure Reducing Valve

Sr. No.	Parameters	Units	Values
1	Cut-off Pressure	bar (g)	7.8
2	Proposed unloading pressure	bar (g)	7
3	Proposed loading pressure	bar (g)	6.5
4	Power consumption after reducing the cut-off pressure by 0.5 bar (g)	%	3
5	Power reduction due to reduction of cut-off pressure by 0.8 bar (g)	%	4.8
6	Present daily consumption**	kWh	192.14
7	Daily Operating Hours	hours	10
8	Annual Working Days	days	261
9	Annual Energy Savings	kWh/year	1204
10	Electricity Tariff	Rs./kWh	14.42
11	Annual Cost Savings	Rs./year	17,361

**As per Bureau of Energy Efficiency*

***Assuming 70% loading of the air compressor*

8.4 Lighting System (Indoor & Outdoor)

Lighting is the other important system present in the premise which is highly energy intensive. Fluorescent tubelights and CFL were observed commonly in the facility. The facility has already replaced these lights with energy efficient tubelights.

Energy Savings Recommendations:

- **Replacement of existing CFL and Fluorescent tubelights with LEDs**

However, there is still a 10% scope of replacement of the remaining CFL and tubelights with LEDs. Direct reduction in power consumption by 90 % is achieved with the replacement. This will also reduce the maximum demand of the whole plant by the same amount. As LEDs are semi-conductor devices, there is also a reduction in power factor improvement capacitor requirements in the facility.

Table 9. Total Replacement of existing lighting system with LEDs

Sr. No.	Parameters	Units	Values
1	Approximate power savings	kW	99
2	Daily Operating Hours	Hours	10
3	Annual Operating Days	days	313
4	Electricity Tariff	Rs./kWh	14.42
5	Annual Electricity Savings	kWh	307870
6	Annual Cost Savings	Rs./year	4468325
	10% Saving scope	Rs./Year	446832

8.5 Hot Water Generation

Hot water is required in the whole facility for different purposes like bathing, cooking and washing. Presently, there is no provision of central hot water system. Instead, different electric heaters are available. Hostels, VIP Rooms, Hospital building and canteen are the locations where hot water is required. The present hot water requirement based on the geyser capacity is given below.

Table 10. Hot water requirements

Geyser Capacity (litres)	Quantity	Total Capacity (litres)
6	53	318
10	29	290
15	7	105
25	4	100
35	7	245
50	71	3550
100	6	600
175	1	175
Total	**178**	**5383**

Based on the total geyser capacity, total hot water generation = 5383 litres. Considering an additional 30% usage of water giving a total of 7011 litres. Assuming this value of hot water required throughout the day.

Energy Savings Recommendations:

- **Use of Solar Evacuated Tube Water Heater with Hot Water Generation (At Laundry, CSSD & Hostel)**

Solar water heating will generate hot water free of cost with only a small power consumption of the feed water pump. Initial investment will be a little high. However, after the payback period is over, free hot water will be generated without any consumption of electricity. For generation of 7011 litres of hot water every day, following is the energy savings achieved using solar water heater.

Figure 5. Solar Evacuated Water Heater

Table 11. Solar Evacuated Tube Water Heater

Sr. No.	Parameters	Units	Values
1	Hot water required @ 55°C	litres/day	7011
2	Annual Solar Radiation Incident	kWh/m^2-year	1748.62
3	Annual Thermal Energy required for 7011 litres hot water	kWh/year	1,08,363.4
4	Thermal Efficiency of Solar Water Heater	%	65
5	Maximum Area of Solar Water Heater required	m^2	516.1
6	Annual Power Consumption of Geysers with 97% efficiency of geyser	kWh/year	1,11,714.8
7	Annual Cost savings with replacement	Rs./year	16,10,927

- **Use of Heat Pump for Hot Water Generation (At Laundry, CSSD & Hostel)**

Another alternative to the generation of hot water to solar water heater is a Heat Pump. Heat pump is similar to a refrigerator in construction. The only difference is that the hot side of the system is utilised in a heat pump to supply heat to a space, whereas the cold side of the system is utilised in a refrigerator to remove heat from a space. The electrical energy input to the heat pump is less than the thermal energy output because of its working cycle principle which is represented by COP. COP of a heat pump is the ratio of Thermal Energy supplied to the Electrical Energy Input. Therefore, for the same amount of heat supply, the energy input is lesser than electrical heater/geyser.

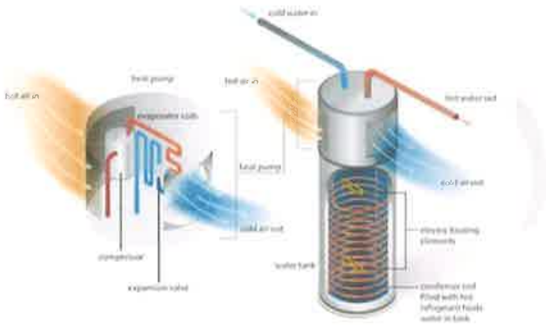


Figure 6. Heat Pump

A centralised heat pump system can be installed for meeting the hot water requirement of the whole facility or individual heat pump units can be installed for each building. The savings associated with the use of heat pump for hot water generation is given below.

Table 12. Heat Pump for Hot Water Generation

Sr. No.	Parameters	Units	Values
1	Hot water required @ 55°C	litres/day	7011
2	Annual Thermal Energy required for 7011 litres hot water	kWh/year	1,08,363.4
3	Annual Power Consumption of Geysers with 97% efficiency of geyser	kWh/year	1,11,714.8
4	COP of a Heat Pump	-	3
5	Annual Electrical Energy input of Heat Pump	kWh/year	36,121.1
6	Annual electrical energy savings	kWh/year	72,242.3
7	Electricity Tariff	Rs./kWh	14.42
8	Annual Cost Savings	Rs./year	10.41.733

A combined system consisting of Solar Evacuated Water Heater along with Heat Pump can be used in hybrid combination, thus optimising both renewable as well as energy efficient technology.

8.6 Air Conditioning System

Different buildings in the facility have split/window and duct-able air conditioning units. These air conditioners being smaller ratings have little scope unlike centralized chillers for applying means of energy saving like use of VFDs on AHUs and secondary pumps.

Present day VRF systems which are energy efficient find use only when the interiors are predesigned according to the VRF requirements.

Presently, VRV system of 148 HP is installed in the facility. However, medical college building and library area have split/window ACs. Also, some of the window/split ACs installed are with low BEE star rating.

Energy Savings Recommendations:

- **Replacement of existing split/window ACs with VRV system**

Replacement of existing split/window ACs with a VRV system of an equal size will give energy savings. The amount identified for the replacement of the AC is 240 HP which can be replaced with an equal amount of VRV system. The energy savings achieved with the same is given below.

Table 13. Replacement of Split/Window ACs with VRV system

Sr. No.	Parameters	Units	Values
1	Approximate power savings	kW	35.8
2	Daily Operating Hours	Hours	10
3	Annual Operating Days	days	313
4	Electricity Tariff	Rs./kWh	14.42
5	Annual Electricity Savings	kWh	1,12,054
6	Annual Cost Savings	Rs./year	16,15,818

- **Replacement of existing split/window ACs with 5-star inverter split ACs**

Existing split/window ACs can be replaced with 5-star inverter split ACs. Assuming presently all the split/window ACs are 3-star rated. The energy savings associated with the replacement of the same is given below.

Table 14. Replacement of Split/Window ACs with 5-star inverter split ACs

Sr. No.	Parameters	Units	Values
1	Existing 3-star split AC ISEER	-	3.55
2	5-star split inverter AC ISEER	-	4.75
3	Annual energy savings	%	33.8
4	Present split/window AC capacity	TR	228
		kW	228
5	Power savings	kW	77.06
6	Daily Operating Hours	Hours	10
7	Annual Operating Days	days	313
8	Electricity Tariff	Rs./kWh	14.42
9	Annual Electricity Savings	kWh	2,41,210
10	Annual Cost Savings	Rs./year	34,78,248

- **Solar Thermal VRF System Retrofit**

In solar hybrid air-conditioning system, refrigerant vapour from the compressor is further superheated through the solar energy. There is insulated container containing water, and this water is heated through solar energy. Refrigerant vapour in tubes will pass through this hot water chamber and therefore refrigerant vapour is superheated. Hot water inside the chamber can work for 8 h if the water is heated through solar panel for 4 to 5 h inside a well-insulated tank.

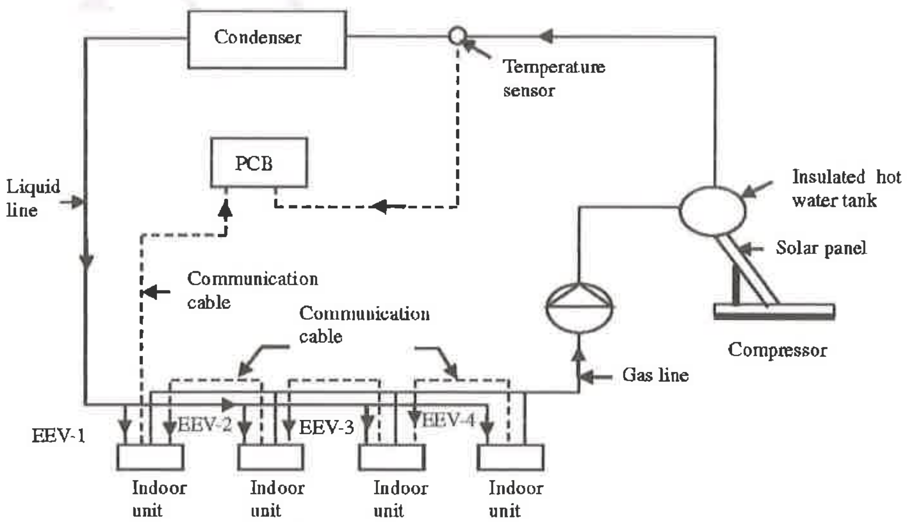


Figure 7. Schematic of Solar Thermal VRF Hybrid System*

**Source - Experimental analysis of a solar thermal hybrid VRF system for maximum energy economy based on Delhi (India) climate, S. Hasan, Mohd. E. Khan, Mohd. Parvez, Energy Sources, Part A, 05 Sept. 2019*

As per different experiments and studies, it was found that the savings for different compressor loadings is approximately 50%. However, these savings will change as per the availability of solar energy. Average monthly solar radiation for the site is given below.

Energy Savings Calculation:

Table 15. Energy Savings – Solar Thermal Hybrid VRF System

Month	Solar Radiation (kWh/m²/day)	% Solar Radiation variation	No. of Days	Consumption of VRF (kWh/month)*	Electricity Savings (kWh/day)*
January-18	4.95	0.73	30	3545	1239
February-18	5.83	0.86	31	7232	2979
March-18	6.44	0.95	31	13687	6220
April-18	6.80	1.00	28	19344	9282
May-18	6.80	1.00	31	23906	11475
June-18	3.95	0.58	31	9941	2773
July-18	2.85	0.42	30	2152	433
August-18	2.55	0.38	31	1590	286
Spetember-18	3.87	0.57	31	5702	1557
October-18	4.15	0.61	30	9689	2840
November-18	4.88	0.72	31	7500	2586
December-18	4.37	0.64	30	3166	977
Total				**1,07,454**	**42,647**

*These values are based on assumptions of Actual Cooling Degree Days

- Total Annual Electrical Energy Savings = 42,647 kWh
- Percentage Savings = 39.68 %
- Total Annual Electrical Cost Savings = Rs. 6,14,949/- (Rate- 14.42 Rs./KwH)
- Simple Payback Period = < 2 YEARS

8.7 Implementation Methodology

Following suggested implementation priority can be adopted.

Priority 1: Recommendations with No/Minor Investment

- Arrest compressed air leakages regularly.
- Improve air intake of compressor with improved ventilation
- Remove PRV and reduce compressor delivery end pressure – see performance on trial basis
- Modify hostel door with insertion type key locks for every room so that no appliances like geysers and lights, fans and AC units remain ON in absence of occupants.

Priority 2: Recommendations with Mid Term Investment

- Decide for implementation of replacement of existing AC with STAR rated AC units.
- Installation of LED type light fitting.
- Work out single DG set of 625 KVA instead of Running two inefficient DG set.
- Work out for reduction of Sanction Demand from MSEDCL.

Priority 3: Recommendations with Long Term Investment

- Installation of PV Solar system at roof top.
- Installation of Solar Water Heating (SWH) system.
- Installation of VRV system for AC.
- Installation of Solar Hybrid VRF System

8.8 Additional Energy Savings Recommendations

Good maintenance practices and some good working practices can reduce energy consumption. The details of the some of the practices are given below.

8.8.1 Electricity

- Optimize the tariff structure with utility supplier
- Schedule your operations to maintain a high load factor
- Minimize-Maximum demand by tripping loads through a demand controller
- Stagger star-up times for equipment with large starting currents to minimize load peaking.
- Use standby electric generation equipment for on-peak high load periods.
- Correct power factor to at least 0.95 under rated load conditions.

- Relocate transformers close to main loads.
- Use optimum setting for transformer taps.
- During no active load, disconnect primary power to transformers.
- Consider on-site DG generator.
- Keep dedicated meter for utility electric meter.
- Use Energy saver mode, Switch off computers & printers when not in use.

8.8.2 Motors

- Properly size to the load for optimum efficiency.
- Where ever possible, use energy efficient motors.
- Improve power factor by using synchronous motors.
- Keep regular check of alignment.
- Always carry rewinding carefully, and do restoration of demand efficiency. Incorrect rewinding results into reduction into the efficiency by 5 to 8%.
- Provide proper ventilation to the motor running areas.
- Regularly keep check point for low voltage and high voltage conditions.
- Keep check & balance all the 3 phase power supply.

8.8.3 Drives

- Use variable speed drives, for Large variable loads.
- High efficiency gear sets must be use.
- Do proper alignment with precision.
- Regularly maintain belt tension as required.
- Eliminate variable pitch pulleys.
- Use Flat belts which are better than v-belts.
- For Large gearboxes use Synthetic lubricants, which are better.
- Eliminate eddy current couplings.
- When not in use, Shut them off.

8.8.4 Fans

- For fan intakes use smooth, well-rounded air inlet cones. At the fan inlet, avoid poor flow distribution.
- Regularly clean screens, Filters & fan blades.
- Do not keep any obstructions at Fan Inlet and outlet.
- Aerofoil shape fan blades are more efficient.

- Use low slip/fan belts, maintain fan speed.
- Maintain belt tension regularly as required.
- Eliminate variable pitch pulleys.
- For large variable fan loads use variable speed drives.
- Where there is continuous operation, use energy-efficient motors.
- Minimise bend work and eliminate leaks in ductwork.
- When not in use, switch off fans.

8.8.5 Blowers

- For air Intakes, use cone & ducts for smooth & rounded air inlet.
- Remove obstructions from blower inlet and outlet points.
- Regularly, clean screens & filters. Replaced essentially.
- Maintain Blower speed.
- Keep belt tension as required, use standard OEM suggested belts with low-slip or no-slip.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable blower loads.
- Use energy-efficient motors for continuous operation.
- Turn blowers off when they are not in use

8.8.6 Pumps

- To minimize throttling modify pumping. Operate those near best efficiency point.
- Adapt to side load variation with variable speed drives or sequenced control of smaller units.
- Don't run spare pump with regular pump for pressure delivery. Add an auto start for an on line spare and if needed add a booster pump in the problem area.
- Booster pumps are great solution for small load as requiring higher pressures.
- To reduce pumping rates, increase fluid temperature differentials.
- Keep seals and packing in good condition, to minimize leakages / water waste.
- Balance the system, to minimize flows and reduce pump power requirements.
- Use siphon effect.

8.8.7 Air Compressors

- As per OEM recommendation, use synthetic lubricants. For positive displacement compressors maintain variable speed drive for variable load.
- Maintain lubricating oil temperatures not too high and not too low.
- Maintain oil filter regularly.
- For proper functioning inspect compressor intercoolers regularly.
- Re utilise water heat from a large compressor to power an absorption preheat process feeds.
- Develop and maintain efficiency calculation maintenance program.
- Do energy audit and take follow-up of same.
- Make an efficiency maintenance program as a part of your continuous assessment.

8.8.8 Compressed Air System

- Install a control system to co-ordinate multiple air compressors.
- For operating multiple air compressors with most efficient mode - Study part-load characteristic and cycling costs.
- Match the connected load -Avoid over sizing.
- Load up modulation-controlled air compressors. (They use almost as much power at partial load as at full load.)
- Turn off the back-up air compressor until it is needed.
- Reduce air compressor discharge pressure to the lowest acceptable setting.
- Use the highest reasonable dryer dew point settings.
- Turn off refrigerated and heated air dryers when the air compressors are off. Use a control system to minimize heatless desiccant dryer purging.
- Minimize purges, leaks, excessive pressure drops and condensation accumulation.
- Use drain controls instead of continuous air bleeds through the drains.
- Consider engine-driven or steam-driven air compression to reduce electrical demand charges.
- Replace standard V-belts with high-efficiency flat belts as the old V-belts wear out. Use a small air compressor when major production load is off.
- Take air compressor intake air from the coolest location.
- Use an air-cooled after cooler to heat building makeup air in winter, ensure foul for heat exchangers.
- Be sure that air / oil separators are not fouled.

- Clean regularly filters. Replace it regularly/when alarm. Across suction and discharge of filters Regularly monitor pressure drops.
- Use properly sized compressed air storage receiver.
- Minimize disposal costs by using lubricant that is fully demulsible.
- Find out alternatives to compressed air and use same where ever possible. Example; Blowers for cooling, Hydraulic in place of air cylinders, electric in place of air actuators & pneumatic controls.
- Use nozzles or venturi - type devices instead of blowing with open compressed air lines.
- Check for leaking drain valves on compressed air filter / regular sets. Certain rubber-type valves may leak continuously after they age and crack.
- Industry environments, control packaging lines with high-intensity photocell units instead of standard units with continuous air purging of lenses and reflectors.
- Do an energy audit and follow-up the findings.
- Establish efficiency & maintenance scheduled programs for compress Air. Make it a part of your continuous energy management program.

8.8.9 Chillers

- Set point check and maintain for chilled water temperature.
- Use the low temp. Condenser water available that the chiller can handle.
- Increase the evaporator temperature.
- When fouled, clean heat exchangers.
- Replace whenever essential old chillers/compressors with new higher-efficiency models.
- Use water-cooled in place air-cooled chiller condensers.
- Use energy-efficient motors for continuous operation.
- Specify for condenser – 'Fouling factors' clean or replace filters promptly upon alarm.
- Overcharging of oil is not correct.
- To co ordinate multiple chillers, install a control system.
- To determine most efficient mode for operating multiple chillers, perform the study part for knowing load characteristics & cost of cycle.
- Run the chillers to near base load for the lowest operating costs. Over sizing to match the connected load must be avoided.
- Off line chillers & cooling towers must be isolated.
- Do an energy audit and follow-up the findings.

- Establish a efficiency & maintenance scheduled programs for chillers. Make it a part of your continuous energy management program.

8.8.10 Heating, Ventilation and Air Conditioning

- Tune up the HVAC control system.
- Consider installing a building automation system (BAS) or energy management system (EMS) or restoring an out-of-service one.
- Balance the system to minimize flows and reduce blower / fan / pump power requirements.
- Eliminate or reduce reheat whenever possible.
- Use appropriate HVAC thermostat setback.
- Use morning pre-cooling in summer and pre-heating in winter (i.e. – before electrical peak hours).
- Use building thermal lag to minimize HVAC equipment operating time.
- In winter during unoccupied periods, allow temperature to fall as low as possible without damaging stored materials.
- Improve control and utilization of outside air.
- Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.
- Reduce HVAC system operating hours (e.g. – night, weekend). Optimize ventilation.
- Ventilate only when necessary. To allow some areas to be shut down when unoccupied, install dedicated HVAC systems on continuous loads (e.g. – computer rooms).
- Provide dedicated outside air supply to cleaning rooms, combustion equipment, etc. to avoid excessive exhausting of conditioned air.
- In dry climates, use evaporative cooling.
- During unoccupied periods, reduce humidification or dehumidification. Use atomization in place of steam for humidification. Clean HVAC unit coils periodically & Comb mashed fins.
- To reduce pressure drop, upgrade filter banks it lower fan power requirements. Monthly check HVAC filters and clean, change if appropriate.
- For proper operation cycle and maintenance check pneumatic controls air compressors.
- Use high-speed doors or clear PVC strip curtains to isolate air conditioned loading dock areas and cool storage areas.

- In high bay areas, install ceiling fans to minimize thermal stratification.
- In areas with high ceilings, relocate air diffusers to required heights. Possible, then reduce ceiling heights.
- Eliminate obstructions in front of radiators, baseboard heaters, etc.
- For dust and vapor control, use professionally designed ventilation hoods.
- Use spot cooling and heating
- Purchase only high-efficiency models for HVAC window units. Use time controller, for HVAC window units.
- Short cycle is the result of oversized units in poor humidity control, so don't oversize cooling unit.
- Install multi-fuelling capability and run with the cheapest fuel available at the time. Consider dedicated make-up air for exhaust hoods.
- Minimize HVAC fan speeds.
- In humid climates, consider desiccant drying of air to reduce cooling requirements.
- Seal leaky HVAC ductwork & around coils.
- Repair loose or damaged flexible connections including those under air handling units.
- Eliminate simultaneous heating and cooling during seasonal transition periods.
- Zone HVAC air and water systems to minimize energy use.
- Keep regular check on damper blades and linkages.
- Do an energy audit and follow-up the findings.
- Establish efficiency & maintenance scheduled programs for HVAC sytem. Make it a part of your continuous energy management program.

8.8.11 Refrigeration

- Use water-cooled condensers rather than air-cooled condensers. Challenge the need for refrigeration, particularly for old batch processes. Avoid over sizing – match the connected load.
- Consider gas-powered refrigeration equipment minimise electrical demand charges.
- Use “free cooling” to allow chiller shutdown in cold weather. Use refrigerated water loads in series if possible.
- Convert firewater or other tanks to thermal storage.
- Don’t assume that the old way is still the best – particularly for energy-intensive low temperature systems.
- Correct inappropriate brine or glycol concentration that adversely affects heat transfer and / or pumping energy. If it sweats, insulate it, but if it is corroding, replace it first.
- Make adjustments to minimise hot gas bypass operation. Inspect moisture / liquid indicators.
- Consider change of refrigerant type if it will improve efficiency. Check for correct refrigerant charge level.
- Inspect the purge for air and water leaks.
- Establish a refrigeration efficiency-maintenance program. Start with an energy audit and follow-up, and then make a refrigeration efficiency-maintenance program part of your continuous energy management program.

8.8.12 Cooling Towers

- Control cooling tower fans based on leaving water temperatures.
- Control to the optimum water temp. as determined from CT and chiller performance.
- Use two-speed or variable-speed drives for cooling tower fan control if the fans are few. Stage the cooling tower fans with on-off control if there are many.
- Turn off unnecessary cooling tower fans when loads are reduced.
- Cover hot water basins (to minimize algae growth that contributes to fouling). Balance flow to cooling tower hot water basins.
- Periodically clean plugged cooling tower water distribution nozzles. Install new nozzles to obtain a more-uniform water pattern.
- Replace splash bars with self-extinguishing PVC cellular-film fill.
- An old counter flow cooling towers, replace old spray-type nozzles with new square-spray ABS practically-non-clogging nozzles.

- Replace slat-type drift eliminators with high-efficiency, low-pressure-drop, self-extinguishing, and PVC cellular units.
- If possible, follow manufacturer's recommended clearances around cooling towers and relocate or modify structures, signs, fences, etc. that interfere with air intake or exhaust.
- Optimize cooling tower fan blade angle on a seasonal and / or load basis.
- Correct excessive and / or uneven fan blade tip clearance and poor fan balance. Use a velocity pressure recovery fan ring.
- Divert clean air-conditioned building exhaust to the cooling tower during hot weather. Re-line leaking cooling tower cold water basins.
- Check water overflow pipes for proper operating level. Optimize chemical use.
- Consider side stream water treatment.
- Restrict flows through large loads to design values. Shut off loads that are not in service.
- Take blow down water from the return water header. Optimize blow down water from the return water header. Automate blow down to minimize it.
- Send blow down to other uses (Remembers, the blow down does not have to be removed at the cooling tower. It can be removed anywhere in the piping system.) Implement a cooling tower winterization plan to minimize ice build-up.
- Install interlocks to prevent fan operation when there is no water flow.
- Do an energy audit and follow-up the findings.
- Establish a efficiency & maintenance scheduled programs for Cooling tower. Make it a part of your continuous energy management program.

8.8.13 Lighting

- Reduce excessive illumination levels to standard levels using switching; delamping, etc. (Know the electrical effects before doing delamping.)
- Aggressively control lighting with clock timers, delay timers, photocells, and / or occupancy sensors.
- Install efficient alternatives to incandescent lighting, mercury vapour lighting, etc. as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, and mercury vapour, incandescent.
- Consider high power factor and long-term efficiency for the selection of ballasts and lamps.
- Consider day lighting, skylights wherever possible.
- Consider painting the walls a lighter colour.
- Using less lighting fixtures, lower watts.
- Use task lighting and reduce background illumination.
- Cross verify regularly, exterior lighting system w r t festivals and events.
- Always provide LED signs and not incandescent.

8.8.14 Solar PV Plant

- Periodic cleaning of solar modules is necessary to get maximum possible output from the system.
- Cleaning must be done preferably with water or a wet cloth.
- Periodic checking of the inverter must be done for any degradation in its performance.
- Thermal checking of the module either yearly or half-yearly must be done for detection of any thermal hotspots in the panels and if possible replacement of the same.
- DC side periodic efficiency check of a solar module must be done and I-V characteristics must be determined for any loss in efficiency.
- Any failure in the solar module structures must be repaired as soon as possible, so as to avoid damage to the solar modules.

8.8.15 DG Sets

- Always use it optimistically for loading.
- Use waste heat for recovery.
- Use heat for jacket and head cooling water for process needs.
- Clean air filters regularly.
- Insulate exhaust pipes to reduce DG set room temperatures.
- Use good quality fuel oil as recommended.

8.8.16 Buildings

- Handle exterior with respect to green building norms.
- Thermal doors, thermal window, roofing insulation are better solution
- Use windbreakers near main doors, exterior doors.
- Install Insulating glasses
- Replace single pane glasses.
- Inside building, use insulated wall panels for covering window and skylight areas.
- Consider replacing exterior windows with insulated glass block, if visibility is not required. It will provide light.
- For sunlit exterior windows : tinted glass, reflective glass, coatings, awnings, overhangs, draperies, blinds and shades are solutions.
- Use landscaping to advantage.
- For primary doors add vestibules &/or revolving doors.
- At high-traffic passages consider automatic doors, air curtains, strip doors, etc.
- Self-closing doors uses is a good option.
- Address minimisation of building stack effect. Use intermediate doors in stairways and vertical passages.
- Use dock seals at shipping and receiving doors.

8.8.17 Waste & Waste Water

- Fix up water leaks.
- Promptly repair leaking toilets and faucets.
- Balance closed systems to minimize flows and reduce pump power requirements. Eliminate once-through cooling with water.
- Use the least expensive type of water source that will satisfy the requirement.
- Reduce flows at water sampling stations.
- Eliminate continuous overflow at water tanks.
- Recycle water, particularly for uses with less-critical quality requirements.
- Recycle water, especially if sewer costs are based on water consumption.
- Do not use a heating system hot water boiler to provide service hot water during the cooling season – install a smaller, more-efficient system for the cooling season service hot water.
- If water must be heated electrically, consider accumulation in a large insulated storage tank to minimize heating at on-peak electric rates.
- Use multiple, distributed, small water heaters to minimize thermal losses in large piping systems.
- Use the lowest possible hot water temperature.
- Install pre-treatment to reduce TOC and BOD surcharges.
- Consider leased and mobile water treatment systems, especially for deionised water.
- Seal sumps to prevent seepage inward from necessitating extra sump pump operation.
- Test for underground water leaks. (It's easy to do over a holiday shutdown.)
- Check water overflow pipes for proper operating level.
- Provide proper tools for wash down – especially self-closing nozzles.
- Verify the water meter readings.
- Use water restrictors on faucets, showers, etc. Use self-closing type faucets in restrooms.
- Install efficient irrigation.

8.8.18 Miscellaneous

- All the utilities must be meter and monitored for its optimum use.
- Efficiency must be regularly checked.
- Know the causes of deviations and take prompt action on same.
- Shut down spare equipments, idling or unneeded equipment.
- Make sure that all of the utilities to redundant areas are turned off and those are like compressed air, cooling water, etc.
- Install automatic control to efficiently co-ordinate multiple air compressors, chillers, cooling tower cells, boilers, etc.
- To reflect current loads and variations, renegotiate utilities contracts.
- To handle pick demand, consider nearby sources for buying utilities.
- Consider alternatives to high pressure drops across valves.
- Consider upgrades if your lease will continue for several more years.
- Adjust fluid temperature within acceptable limits to minimise undesirable heat transfer in long pipelines.
- Minimise use of flow bypasses and minimise bypass flow rates.
- Provide restriction orifices in purges (nitrogen, steam, etc.).
- Eliminate unnecessary flow measurement orifices.