ENERGY Audit Report

K.R. MANGALAM UNIVERSITY
THE COMPLETE WORLD OF EDUCATION

K.R. Mangalam University

Sohna Road, Gurugram,
Haryana 122103

Audit Date – 03 and 04 February, 2020

Audit Conducted by:

M/S Samarth Consultants,
212, Bhera Enclave, Paschim Vihar,
New Delhi, Delhi, 110087.

Registrar
K.R. Mangalam University
Sohna Road, Gurugram, (Haryana)

For SAMARTH MANAGEMENT PRIVATE LIMITED
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CERTIFICATE OF EXCELLENCE

THIS IS CERTIFY THAT **K. R. MANGALAM UNIVERSITY** HAS SUCCESSFULLY

COMPLETED THE **ENERGY** AUDIT PROGRAM

CONDUCTED ON **03-04 FEBRUARY 2020**

For SAMARTH MANAGEMENT PRIVATE LIMITED

Samarth Suri

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CERTIFICATE NO. **SMPL/2020/C-0011** DATE OF ISSUE **14-02-2020** AUTHORISED SIGNATORY

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New Delhi - 110087

Acknowledgement

Samarth Consultants is thankful to K.R. Mangalam University for providing us the opportunity to conduct an Energy Audit of their esteemed University. We are grateful to the Management, officers, and staff of K.R. Mangalam University for showing keen interest in the study and for the help and co-operation extended to Samarth Consultants team during the study.

We do hope that you will find the recommendations given in this report useful in helping you save energy. While we have made every attempt to adhere to high quality standards, in both data collection and analysis, as well as in presentation through the report, we would welcome any suggestions from your side as to how we can improve further.

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List of Abbreviations

SEC - Specific Energy Consumption

List of Units

°C	**-**	**Degree Celsius**
CFM	**-**	**Cubic Feet per Minute**
CMH	**-**	**Cubic Meter per Hour**
LPM	**-**	**Liters Per Minute**
Kg/cm^2	**-**	**Kilogram per centimeter square**
kW	**-**	**Kilo watt**
kWh	**-**	**Kilowatt hour**
KOE	**-**	**Kg of Oil equivalent**
m^3/hr	**-**	**Meter cube per hour**
Nm^3/hr	**-**	**Normal Meter cube per hour**
MW	**-**	**Mega Watt**
MWh	**-**	**Mega Watthour**

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1. Introduction

The working details of assignment are as follows:

Project	**Energy Audit**
Client	**K.R. Mangalam University**
Industry	**Educational University**
Contact	**Registrar and Dr. Vineet Dahiya (8800697002) (9811911970)**
Site	**K.R. Mangalam University Sohna Road, Gurugram, Haryana 122103**
Consultant	**Samarth Consultants**
Duration	03-02-2020 to 04-02-2020
Project Scope	Energy audit in the utility and process to assess the energy losses in the system.
Report	This document gives recommendations, details of findings and the way forward
Consultants involved	Mr. Atul Suri (Audit Manager) (EA-0388) (Certified Energy Auditor- BEE) Mrs. Seema Suri (EA-0048) (Certified Energy Auditor- BEE) Mr. Sunil Yadav (Engineer) Mr. Sanjeev Sharma (Engineer)
Notes	- The critical points are marked in red - The assumptions are marked in blue - The suggestions / alternatives in the audit report are based on the present operating conditions of equipment/systems and to the best of our knowledge. - Investment figures are estimated values and recommended to obtain cost from vendor

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1.1 Summary of Energy Conservation Measures

Table 1. **Summary of Energy Conservation Measures**

S. No	Energy Conservation Measure	Annual Savings Electricity		Investment	Payback
		kWh	Rs. Lakhs	Rs. Lakhs	Month
	Payback Period				
1	It is recommended to reduce contract demand to 1200KVA from 2000 KVA as maximum demand is not more than 1000 KVA	-	10.0	Nil	0
2	Improvement in Power Factor by installation of Capacitor Bank	55330	5.27	1.0	1
	Total	**55330**	**15.27**	**1.0**	**1 Month**

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2. Approach and Methodology

2.1. Approach

A team of 4 engineers were involved in carrying out the study, the general scope of which was as follows:

- Identify areas of opportunity for energy saving and recommend an action plan to bring down total energy cost.
- Conduct energy performance evaluation and process optimization study
- Conduct efficiency test of equipment and make recommendations for replacement (if required) by more efficient equipment with projected benefits.
- Suggest improved operation & maintenance practices.
- Provide details of investment for all the proposals for improvement
- Evaluate benefits that accrue through investment and payback period.
- Analyse various energy conservation measures and to prioritize based on the maximum energy saving & investment i.e. short, medium, and long term.

Prioritization	Payback Period
Short Term Project	Less than 6 months
Medium Term Project	Between 6 to 12 months
Long Term Project	More than 12 months

- Discuss with the plant personnel, the individual Energy Saving Projects (ESPs) for agreement for implementation.

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2.2. Methodology

- The general methodology followed is captured in the following figure –

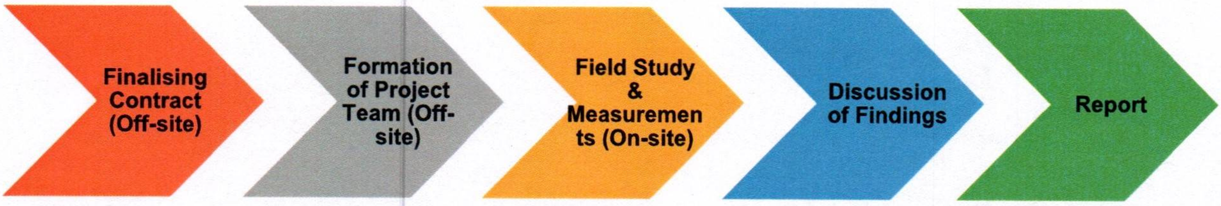

Figure 1. Methodology

The study was conducted in 3 stages:

- **Stage 1**: Walk through audit to understand process energy drivers, measurability and formulation of audit plan
- **Stage 2**: Detailed Energy audit
- **Stage 3**: Off-site work for data analysis and report preparation

2.3. Instruments Used for Energy Audit

The following portable instruments were used for data measurement:

- 3 – phase Power Analyzer
- Single phase Power Analyzer
- Ultrasonic Water Flow Meter
- Anemometer
- Hygrometer
- Sling Hygrometer
- Digital Thermometer
- Infrared Thermometer
- Pressure gauge
- Thermal Imager
- Flue Gas Analyzer
- Lux Meter

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3. University description and energy sources

About University

K.R. Mangalam University is the fastest-growing higher education University in Gurugram, India. Since its inception in 2013, the University has been striving to fulfil its prime objective of transforming young lives through ground-breaking pedagogy, global collaborations, and world-class infrastructure.

As we have stepped into the innovative world, we have gained exposure to unlimited learning and employment opportunities beyond the social and geographical boundaries. K.R. Mangalam University being a progressive learning platform is a host to knowledge-seekers from across the globe. KRMU has signed an MOU with University of Portsmouth (London), Middlesex University (London), Roehampton University (London), Jiangxi Administration Institute, Jinggangshan University, Cardiff Metropolitan University, University of Houston Department of Mathematics and University of Houston Department of Physics and many more under which many articulations are being designed for advanced learning programmes.

KR Mangalam University aspires to become an internationally recognized institution of higher learning through excellence in interdisciplinary education, research and innovation, preparing socially responsible life-long learners contributing to nation building.

- Foster employability and entrepreneurship through futuristic curriculum and progressive pedagogy with cutting-edge technology
- Install notion of lifelong learning through stimulating research, Outcomes-based education and innovative thinking
- Integrate global needs and expectations through collaborative programs with premier universities, research centres, industries and professional bodies
- Enhance leadership qualities among the youth having understanding of ethical values and environmental realities

4. Energy Sources and Cost

Electricity, Solar & fuel (Diesel) are major energy sources of the University.

- Electricity is supplied from DHBVN (Dakshin Haryana Bijli Vitran Nigam)
- The Diesel as a thermal energy source is used mainly in DG Sets of 1X625 KVA, 1X380 KVA and 1X250 KVA

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- The University has a solar power generating system of 310 KW on the rooftop of the academic building A, B, C blocks, DG room and the hostel building. The solar system is wheeled to the grid.

The energy cost from various sources of energy is given below:

Table 2. **Energy cost component of energy sources**

Source of energy	Unit	Cost
Electricity (Grid)	INR /kWh	9.53
Diesel	INR/Liter.	65.09

5. Observation and analysis

5.1. Electricity supply and Network

Electricity & fuel (Diesel) are major energy sources of the University. Electricity is supplied from DHBVN (Dakshin Haryana Bijli Vitran Nigam)

Total Consumption of Electricity from Grid in the period of Jan 19 to Dec 19 was

Total KWH: 16,64,720

Electricity Charges: Rs. 1,58,73,896

The Diesel as a thermal energy source is used mainly in DG Sets of 1X625 KVA, 1X380 KVA and 1X250 KVA

Total Consumption of Diesel in the period of Jan 19 to Dec 19 was:

- Total Diesel in Ltr. 18,173
- Cost of Diesel @ Rs.65.09/Ltr = Rs. 1182881/-

The University has a solar power generating system of 310 KW on the rooftop of the academic building A, B, C blocks, DG room and the hostel building. The solar system is wheeled to the grid.

- Total Solar Generated Electricity Generated by University: 1665800
- Total Exported Solar Generated Unit by University: 47540
- Total Unit Consumed by University from Solar Plant: 16,18,260

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Table 3. **Total Cost of Energy Consumed by University in Year Jan 19 to Dec 19**

Electricity (INR)	Diesel (INR)	Total Cost of Energy	% of electricity	% of Diesel
15873896	1182881	17056777	93.07	6.93

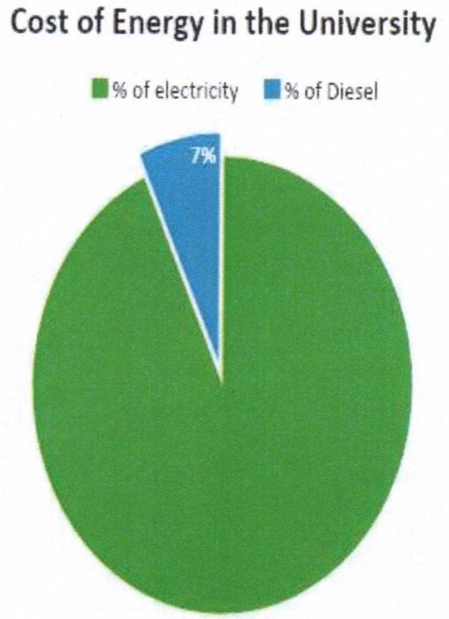

Figure 2. Share of Energy Consumption (Graph)

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Table 4. **Distribution of Energy Types in the University in the Last 12 Months**

ELECTRICITY	DIESEL	IN TJ		TOTAL	% OF ELECTRICITY	% OF DIESEL
1640720	18173	5.906592	0.621	6.527592	90.48654	9.513462

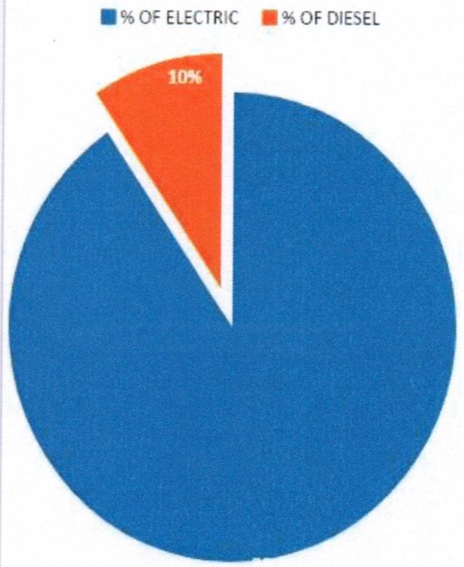

Figure 3. Share of Energy Cost (Graph)

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6. Analysis of Electricity Bills: Jan 19 to Dec 19

K.R. Mangalam University has only one electrical connection with a total contract demand of 2000 KVA. Power Supply is received from DHBVN (Dakshin Haryana Bijli Vitran Nigam). Monthly Electricity Billing has been studied for a period of one year. All parameters have been studied & tabulated in Table 5.

Table 5. **Month wise electrical energy consumption (12 Months data)**

Billing Month	Sanctioned Load, Kw/CD	Units Consumed, kWh	Units Consumed, kVAH	Export Solar Generated	Net Billed Units	Average P.F.	MDI	Surcharge	Fixed Charge (Rs)	Rebate	Sundry Charges	Energy Charge (Rs.)	Panel Demand charge (Rs.)/ Fuel Surcharge Adjustment	Electricity Duty (Rs.)	Total Bill, Rs.
Jan-19	2000	32600	32720	11340	21380	1.00	148	8633	320000	0	102452	144315	8791.2	2376	577934
Feb-19	2000	34180	34280	9260	25020	1.00	190	7475	320000	0	0	168885	9479	2562	500926
Mar-19	2000	39660	40760	11860	28900	0.97	886	7884	320000	0	0	195075	10493	2836	528404
Apr-19	2000	194820	206360	560	205800	0.94	1118	34718	320000	0	0	1389150	71905.8	19434	1800490
May-19	2000	271180	300660	300	300360	0.90	1266	67628	320000	0	247935	2027430	100240	27092	2722697
Jun-	2000	16724	17324	540	1727	0.97	106	21714	320	100	0	1165	62849	16716	1465

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19		0	0		00		6		000	000		725		290
Jul-19	2000	153420	157820	620	157200	0.97	1052	21567	320000	0	0	1061100	56676	15318	1453094
Aug-19	2000	256520	263580	160	263420	0.97	1216.4	32374	320000	34675	0	1778085	94875	25642	2183927
Sep-19	2000	249700	258000	120	257880	0.97	1258	32296	320000	0	0	1740690	92366	24964	2178020
Oct-19	2000	124480	127960	2920	125040	0.97	954	18142	320000	0	0	844020	45458	12286	1221764
Nov-19	2000	46100	46120	4560	41560	1.00	306	9250	320000	0	0	280530	16161	4368	621059
Dec-19	2000	46700	46760	5300	41460	1.00	176	9239	320000	0	0	279855	16087.6	4348	620291
Sum/ Avg.		**1616600**	**1688260**	**47540**	**1640720**	**0.957**	**1266**			`					**15873896**

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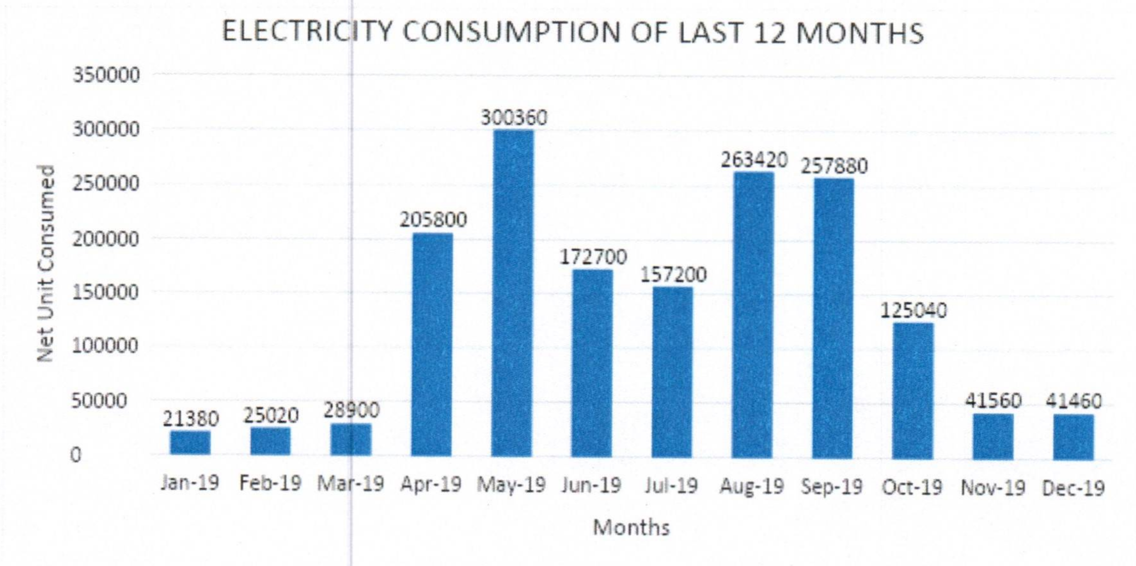

Figure 4. Electrical Energy Consumption

- It can be seen from figure 1, that electricity consumption in the month of May 19' is the highest.

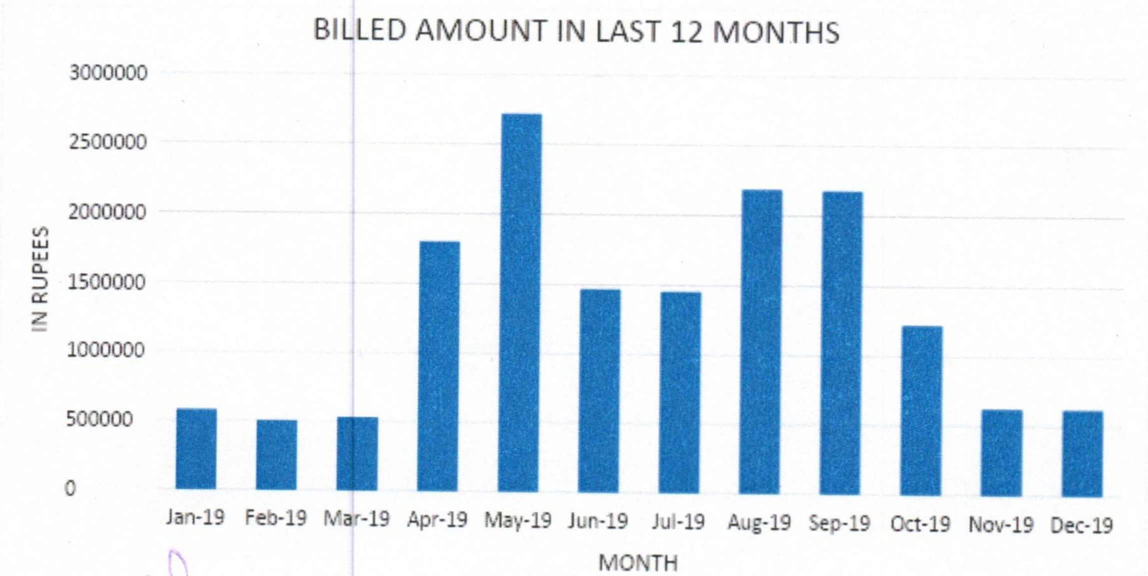

Figure 5. Billed Amount in 2020

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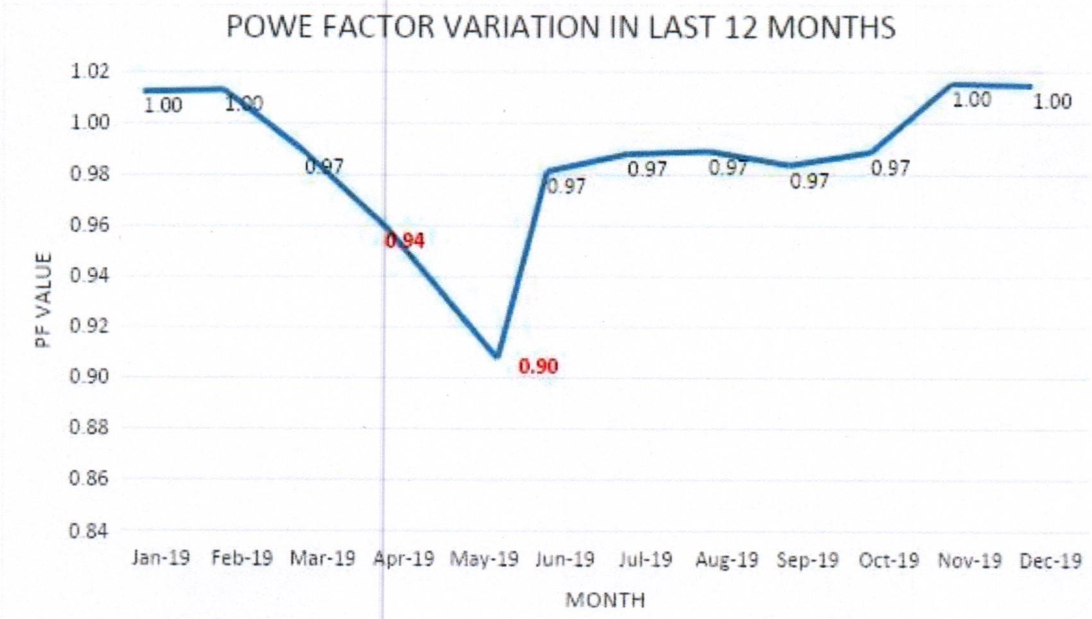

Figure 6. Power Factor Variation

- It can be seen from figure 3, that Recorded Highest Power Factor is 1.00 in Nov 2019 and Lowest is 0.90 in May 2019. Average Power Factor is 0.957 in the last 12 months.
- In April and May 2019 Power factor was reduced to 0.94 and 0.90. It is recommended to have a regular check on the Power Factor to maintain it.
- It is recommended to install Automatic Power Factor Correction Panel to achieve 0.99 Power Factor.
- **Cost saving possibility in this period (January 2019-December 2019) is approximately Rs. 5,00,000/- if KRMU could maintain 0.99 power factor.**

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7. Solar Power System

The University has a solar power generating system of 310 KW on the rooftop of the academic building A, B, C blocks, DG room and the hostel building. The solar system is wheeled to the grid.

Data for Solar Panels						
Sr. No	**Building**	**No. of Panels**	**Total no. of solar panels**	**Capacity**	**Total capacity**	**Rebate rate**
1	A	157	984	310 Kw/day	41850 units/month	0.25
2	B	375				
3	C	204				
4	DG	120				
5	Hostel	128				

Table 6. **Month-wise Solar Generated Units**

Sr. No.	Billing Month	Solar Generated KWH
1	Jan-19	32460
2	Feb-19	34080
3	Mar-19	39960
4	Apr-19	201220
5	May-19	292960
6	Jun-19	171400
7	Jul-19	156260
8	Aug-19	263420
9	Sep-19	255680
10	Oct-19	125600
11	Nov-19	46000
12	Dec-19	46760
Sum/Avg.		**1665800**

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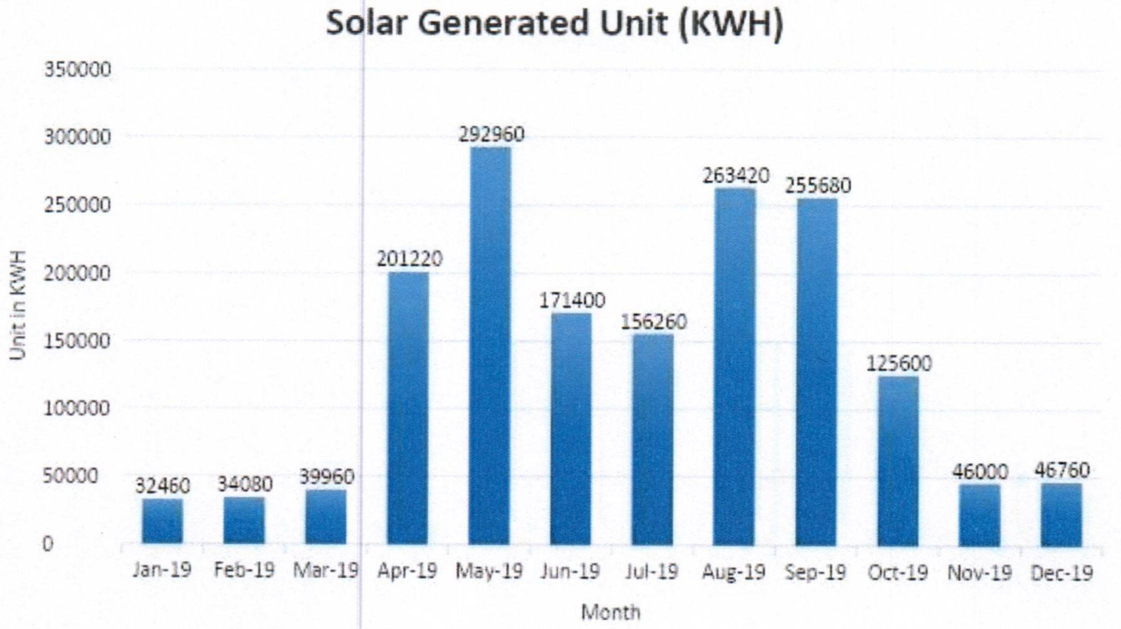

Figure 7. Solar Generated Unit (KWH)

Note – Total Capacity of Solar is 41750 units per month from the Bills. It is observed that solar generation is exceeding the limit 9 times in the last 12 months which is not possible.
Meter needs to be checked by the official person from the Electricity Department.

Table 7. **Average Sunshine data of Gurugram**

Month	Temperature	Average Sunshine (Hours)
January	13.5	8.3
February	17	9.4
March	22.8	10.6
April	29.4	11.5
May	33.1	12.1
June	33.4	11.8
July	30.2	9.6
August	29	9.1
September	28.2	9.4
October	25.8	10.1
November	20.8	9.6
December	15.5	8.9

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8. Transformer

K. R. Mangalam University draws power from DHBVN (Dakshin Haryana Bijli Vitran Nigam) at 11 KV. Subsequently, the voltage is stepped down by one (1) transformer of 2000 kVA from 11 kV to 0.433 kV. Transformer rated specifications are shown below.

Transformer Rated Details

Table 8. **TR Rated Details**

Sr. No.	Particulars	TR # 1
1	Make	NA
2	KVA	2000
3	Volts at HV/LV	11000/415
4	Phases	3
5	Frequency	50

Transformer Load Survey (TR 2000 kVA)

During the site visit, 24-hour log of Transformer (2000 kVA) (3th & 4th Feb. 2020) was made to record the load profile of Transformer, which includes the variations in the voltage, current, power factor, kW, kVA, Vthd, Ithd etc. Details of the load profile are provided in the below table and figure.

Table 9. **TR-1 2000 kVA Load Measurement Data**

Main Incomer LT Side		Transformer (2000 kVA)
Particulars	**Phase**	**Average Measured Values**
Voltage (Volts) (L-L)	Phase "R"	415
	Phase "Y"	417
	Phase "B"	413
Current (Amps)	Phase "R"	897
	Phase "Y"	495
	Phase "B"	548
	Neutral	15
Load (KW)	Phase "R"	208.05

Main Incomer LT Side		Transformer (2000 kVA)
Particulars	**Phase**	**Average Measured Values**
	Phase "Y"	113.22
	Phase "B"	125.45
	Total	**446.71**
Apparent Power (KVA)	Phase "R"	214.93
	Phase "Y"	119.18
	Phase "B"	130.67
	Total	**464.78**
Power Factor (P.F.)	Phase "R"	**0.968**
	Phase "Y"	**0.95**
	Phase "B"	**0.96**
Voltage THD %	Phase "R"	3.1
	Phase "Y"	3.2
	Phase "B"	3.1
Current THD %	Phase "R"	7.8
	Phase "Y"	6.9
	Phase "B"	8.8

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9. Observations Based on Recordings

- The measurement taken at the transformers includes data logging for every 5 seconds for 24 hours and during the logging period it was found that the average Voltage (L-L) for the transformer **is 415V**, which is satisfactory. No changes are required.
- The average P.F. is **0.95,** which is on the lower side. This can be increased up to 0.99 by adding or replacing de-rated capacitors with the new capacitors.

Effects Of High and Low Voltage

- Wide Voltage fluctuation is a common phenomenon all over the country. Generally, the voltage is very low during the daytime and high during night hours. Therefore, Industrial Units running round the clock, face the problem of both Low and High Input Voltage. Also, voltage fluctuation is a seasonal phenomenon and increases in the summer season. Moreover, on holidays, peak hours, rainy days and when the agricultural load is switched off, the voltage rises sharply in the feeder lines. There are few consumers of electricity, during such days, leading to comparatively lower voltage drop in the feeder lines; as a result consumers suffer from high voltage which is more dangerous.
- Most electrical equipment is designed for 230 volts (single-phase) or 410 volts (3-phase) and operates with optimum efficiency at its rated voltage. 50% of industrial load consists of motors. Due to continuously varying voltage and especially during peaks, electric motors draw considerably high current at high voltage **which increases energy consumption**, increases MDI and reduces power factor etc. These excessive power losses of motors generated at higher voltage results in premature failure of electrical equipment.
- Similar is the case with single-phase equipment such as bulbs and tubes, when voltage increases above 230 volts. For example, at 270 volts, the power consumption of 60 W bulb increase by almost 40% and the life of the bulb

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reduces from normal 1000 Hours to mere 100 Hours only (as per analysis report of ISI marked bulb manufacturers)

Transformer Loading and Efficiency

The efficiency of the transformers not only depends on the design but also, on the effective operating load. The variable losses depend on the effective operating load on the transformer. The maximum efficiency of the transformer occurs at a condition when the constant loss is equal to variable loss. For distribution transformers, the core loss is 15 to 20% of full load copper loss. Hence, the maximum efficiency of the distribution transformers occurs at a loading between 40 – 60%. For power transformers, the core loss is 25 to 30% of full load copper loss. Hence, the maximum efficiency of the power transformers occurs at a loading between 40 – 60%.

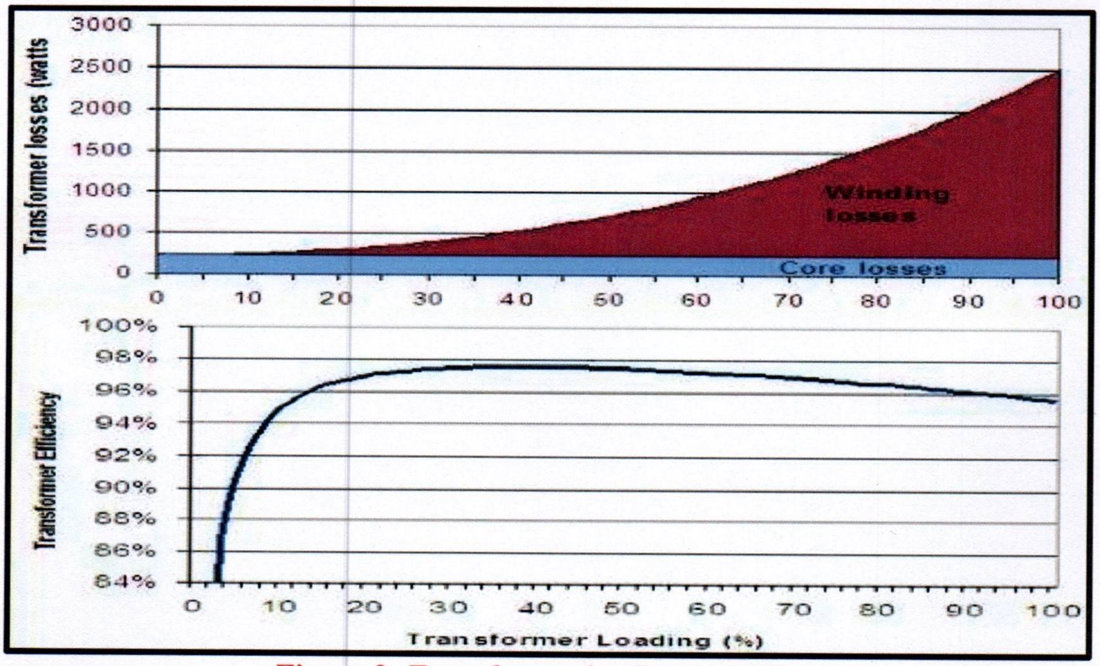

Figure 8. Transformer loading Vs Efficiency

All the electrical parameters required evaluating percentage loading & losses of Transformers were recorded for old building transformer.

No load and full load losses of the transformer are obtained from standards to calculate the transformer losses as follows.

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Note: Total loss = No load loss + Full load loss*(% Loading ^{2})

The efficiency of the transformers not only depends on the design but also, on the effective operating load. The variable losses depend on the effective operating load on the transformer.

Table 10. **Transformer loading**

Description	Transformer Capacity	Power factor	Maximum Apparent power	Average Apparent Power	Max Loading	Average Loading
	kVA	PF	kVA	kVA	%	%
TR1	2000	0.97	653.6	464.78	32.6%	23.23%

Transformer load is maximum at 32.6% noted during power quality analysis. There is no possibility of overloading. Though Maximum demand noted in the electricity bills of Jan. 2019 to Dec. 2019 is 1266. MDI has crossed 1200 KVA in three months only. Sanctioned load of the University is 2000 KVA. University is paying Rs 160 /KVA fixed charges every month. It is advisable to reduce contract demand and save on fixed charges.

University can save approximately Rs. 1,00,000/- per month and Rs 10,00,000/- yearly without any investment even if it has to pay a penalty for a few months.

10. Total Consumption

The University has facilities of HVAC, Lighting system, Fans, Lifts and Fire Fighting System in the Block A, Block B, Block C and Hostel of the University.

Table 11. **Distribution of Load in the University**

Load (KW) Distribution in the University						
Facility Operated	Block				Total	%age
	Block - A	Block - B	Block - C	HOSTEL		
AC	38	39.2	39.5	19.8	136.5	26.45
LIGHTING	12.48	9.32	10.84	13.02	45.66	8.85

FAN	52	52	51	12	167	32.35
LIFT AND FIRE SYSTEM	0	0	147	0	147	28.48
COMPUTER & LAPTOP	6	6	8	0	20	3.87
Total	108.48	106.52	256.34	44.82	516.16	100.00
%age	21.02	20.64	49.66	8.68		

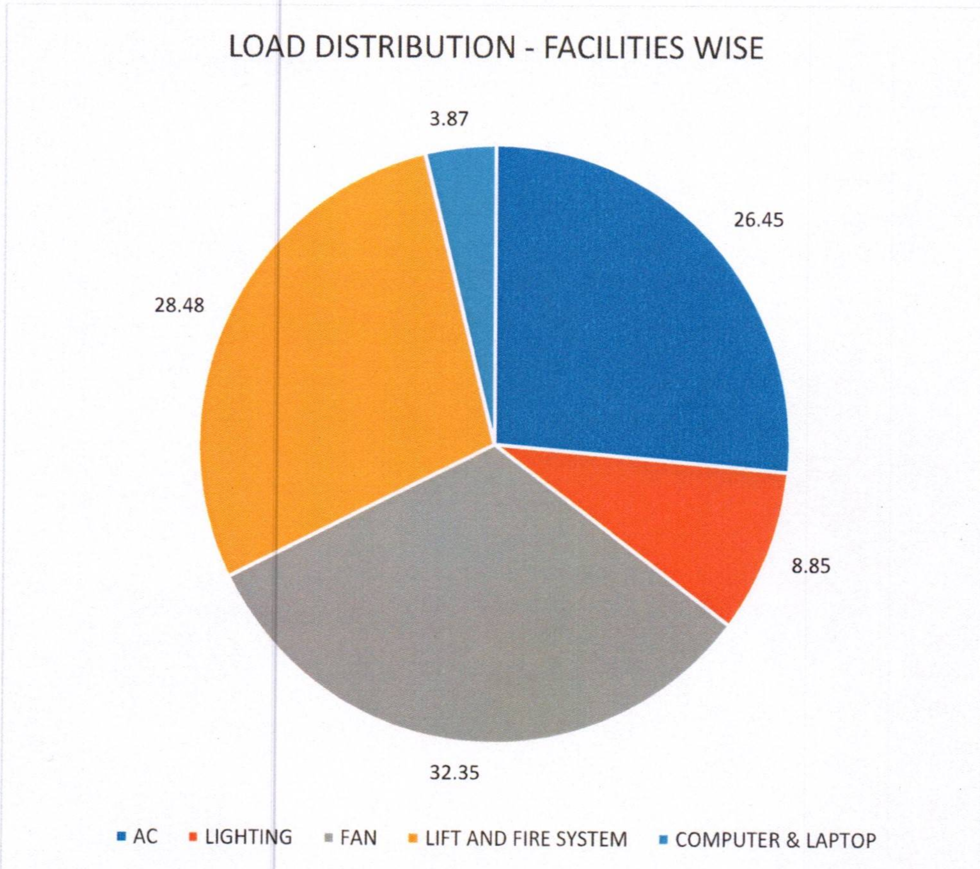

Figure 9. Load Distribution – Facilities-wise

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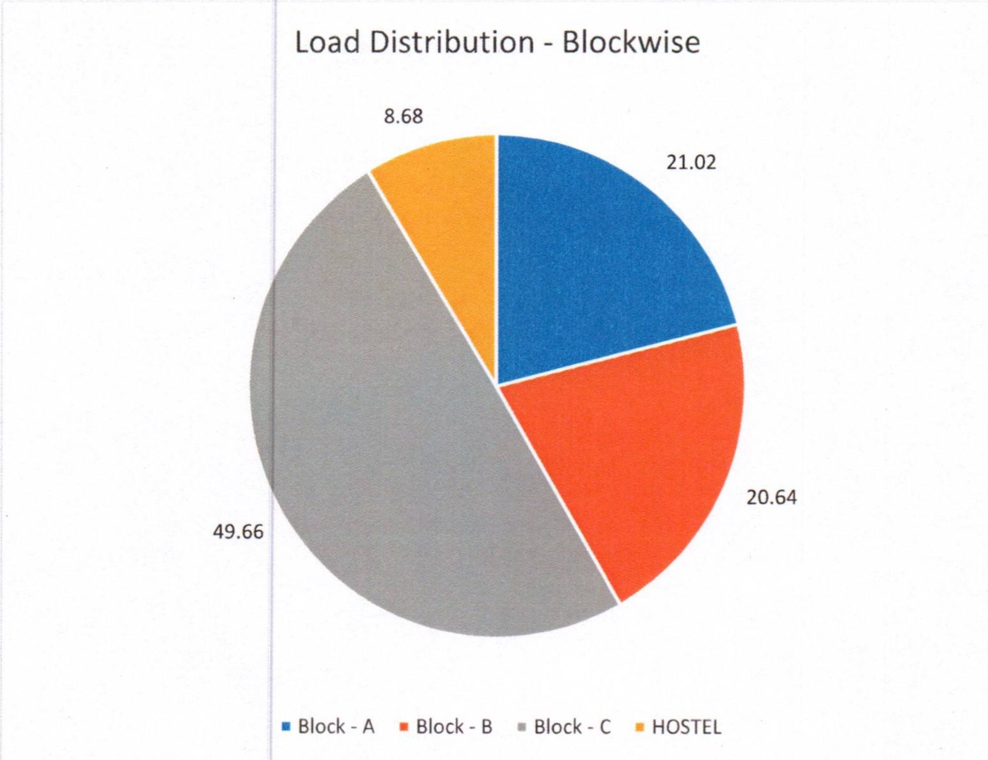

Figure 10. Load Distribution – Block-wise

- **Observation:** Block C consumption is approx. 50% of the total consumption.

11. HVAC System:

KRMU has installed 5 Air cooled Chillers on the terrace for fulfilling the requirement of Air conditioning of the space.

2 Nos 300 TR Hitachi
2 Nos. 150 TR Blue Star
1 No. 150 TR Hitachi

The Audit team was not able to evaluate the performance of the Chillers due to winter.

12. Water Pumps

KRMU has supply from Municipal water to meet the requirement for usage in University, Hostel and Washrooms. All the pumps are running as per the requirement.

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Primary and Secondary pumps were not in use at the time of audit due to winters. Hence the Audit team was not able to evaluate the performance of the pumps.

13. Lighting system

The University has already implemented energy efficient measures in lighting areas at different places. All conventional lamps are replaced by LED Lamps.

Table 12. **LED Consumption in the University**

Blocks	LED Consumption (KWH)	%age
A - Block	5.21	11.65
B - Block	1.83	4.09
C - Block	12.83	28.70
Hostel	13.90	31.09
Outer Area	10.94	24.47
Total Consumption (KWH)	44.71	

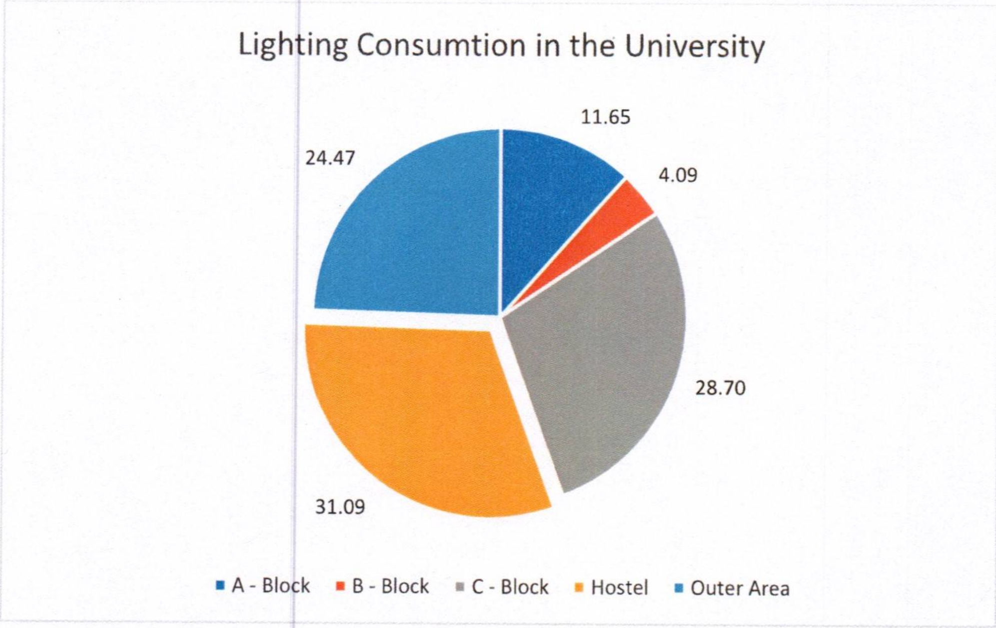

Figure 11. Lighting Consumption in the University

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Observation:

- It is recommended to install occupancy sensors ex. restroom, offices, lobby, staircases, panel room etc.
- University has opted for the latest LED technology for lighting.
- Lux was found satisfactory in many palaces but in some places, it differed with standard. It can be maintained as per university requirement.

Recommended value of illumination given as per National Building Code of India, 2005 clause 4.1.3, 4.1.3.2, 4.3.2 and 4.3.2.1

Table 13. **Details of measured lux in University**

S.NO.	LOCATION NAME	MIN LUX	MAX LUX	Recommendation
1	Ground Floor – A-Block	121	126	100-200
2	Basement – C-Block	103	115	100-200
3	DG Room - Terrace	250	340	200-400
4	Classrooms – C-block	310	450	300
5	Lecture rooms (including Demonstration areas)	310	450	300
6	Reading rooms	250	450	300-500
7	Laboratories	650	780	500-750
8	Corridors	150	170	150
9	Libraries	210	295	300
10	Moot court	245	450	300-500
11	Stage area	125	325	300
12	Canteen	80	120	100
13	Staff Room	155	185	150

14. Computers and Other Power Devices

University is using approximately 370 nos. of computer and other power electronic devices.

An average desktop computer uses between 60 and 300 watts. It is very difficult to know exactly how much computers use on average because there are so many different hardware configurations. We estimate that an average modern desktop PC will use approximately 100 watts of power per day approximately 4-6 hrs. working per day.

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Total consumption of electricity for 370 computers per day = 38.5 KWH= 770 KWH per month

Considering 250 days of working power consumption = 250 X 38.5 = 9625 KWH

Which is a substantial consumption.

To save energy, turn off the computer when it is not being used or enable power saving features such as hibernate, standby or sleep mode. Power saving modes will allow you to turn on a computer quickly when you need to use it. Sleep mode typically uses only 1-5 watts of power and can be set to turn on automatically after a set time of inactivity.

15. DG Performance

- Three DG installed of ratings – 625, 380 and 250 KVA
- DGs were running for power cuts. No major power cuts were observed
- Total diesel consumed = 18173 Litres.

16. General Tips for Energy Conservation in Different Utilities

Electricity

- Schedule your operations to maintain a high load factor
- Minimize maximum demand by tripping loads through a demand controller.
- Use standby electric generation equipment for on-peak high load periods.
- Correct power factor to at least 0.99 under rated load conditions.
- Set transformer taps to optimum settings.
- Shut off unnecessary computers, printers, and copiers at night.

Motors

- Proper size to the load for optimum efficiency.
- (High efficiency motors offer of 4 - 5% higher efficiency than standard motors)
- Check alignment.

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- Provide proper ventilation
- For every 10°C increase in motor operating temperature over recommended peak, the motor life is estimated to be halved.
- Check for under-voltage and over-voltage conditions.
- Balance the three-phase power supply.
- An Imbalanced voltage can reduce 3 - 5% in motor input power.
- Demand efficiency restoration after motor rewinding.

Drives

- Use variable-speed drives for large variable loads.
- Use high-efficiency gear sets.
- Use precision alignment.
- Check belt tension regularly.
- Eliminate variable-pitch pulleys.
- Use flat belts as alternatives to v-belts.
- Use synthetic lubricants for large gearboxes.
- Eliminate eddy current couplings.
- Shut them off when not needed.

Fans

- Use smooth, well-rounded air inlet cones for fan air intakes.
- Avoid poor flow distribution at the fan inlet.
- Minimize fan inlet and outlet obstructions.
- Clean screens, filters, and fan blades regularly.
- Use aerofoil-shaped fan blades.
- Minimize fan speed.
- Use low-slip or flat belts.
- Check belt tension regularly.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable fan loads.

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- Use energy-efficient motors for continuous or near-continuous operation
- Eliminate leaks in ductwork.
- Minimize bends in ductwork
- Turn fans off when not needed.

Blowers

- Use smooth, well-rounded air inlet ducts or cones for air intakes.
- Minimize blower inlet and outlet obstructions.
- Clean screens and filters regularly.
- Minimize blower speed.
- Use low-slip or no-slip belts.
- Check belt tension regularly.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable blower loads.
- Use energy-efficient motors for continuous or near-continuous operation.
- Eliminate ductwork leaks.
- Turn blowers off when they are not needed.

Pumps

- Operate pumping near best efficiency point.
- Modify pumping to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequenced control of smaller units.
- Stop running both pumps -- add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature differentials to reduce pumping rates.
- Repair seals and packing to minimize water waste.
- Balance the system to minimize flows and reduce pump power requirements.

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- Use siphon effect to advantage: don't waste pumping head with a free-fall (gravity) return.

Chillers

- Increase the chilled water temperature set point if possible.
- Use the lowest temperature condenser water available that the chiller can handle.
- Reducing condensing temperature by 5.5°C, results in a 20 - 25% decrease in compressor power consumption.
- Increase the evaporator temperature
- 5.5°C increase in evaporator temperature reduces compressor power consumption by 20 - 25%.
- Clean heat exchangers when fouled.
- 1 mm scale build-up on condenser tubes can increase energy consumption by 40%.
- Optimize condenser water flow rate and refrigerated water flow rate.
- Use water-cooled rather than air-cooled chiller condensers.
- Use energy-efficient motors for continuous or near-continuous operation.
- Specify appropriate fouling factors for condensers.
- Do not overcharge oil.
- Install a control system to coordinate multiple chillers.
- Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple chillers.
- Run the chillers with the lowest operating costs to serve base load.
- Avoid oversizing -- match the connected load.
- Isolate off-line chillers and cooling towers.
- Establish a chiller efficiency-maintenance program. Start with an energy audit and follow-up, then make a chiller efficiency-maintenance program a part of your continuous energy management program.

HVAC (Heating / Ventilation / Air Conditioning)

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- Tune up the HVAC control system.
- Consider installing a Plant 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 Plant thermal lag to minimize HVAC equipment operating time.
- In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials.
- In summer during unoccupied periods, allow temperatures to rise as high 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 kitchens, cleaning rooms, combustion equipment, etc. to avoid excessive exhausting of conditioned air.
- Use evaporative cooling in dry climates.
- Clean HVAC unit coils periodically and comb mashed fins.
- Upgrade filter banks to reduce pressure drop and thus lower fan power requirements.
- Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate.

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- Check pneumatic controls air compressors for proper operation, cycling, and maintenance.
- Isolate air conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains.
- Install ceiling fans to minimize thermal stratification in high-bay areas.
- Relocate air diffusers to optimum heights in areas with high ceilings.
- Consider reducing ceiling heights.
- Eliminate obstructions in front of radiators, baseboard heaters, etc.
- Check reflectors on infrared heaters for cleanliness and proper beam direction.
- Use professionally-designed industrial ventilation hoods for dust and vapor control.
- Use local infrared heat for personnel rather than heating the entire area.
- Use spot cooling and heating (e.g. -- use ceiling fans for personnel rather than cooling the entire area).

Lighting

- Reduce excessive illumination levels to standard levels using switching, de-lamping, etc. (Know the electrical effects before doing de-lamping.)
- Aggressively control lighting with clock timers, delay timers, photocells, and/or occupancy sensors.
- Install efficient alternatives to incandescent lighting, mercury vapor lighting, etc. Efficiency (lumens/watt) of various technologies range from best to worst approximately as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, mercury vapor, incandescent.
- Select ballasts and lamps carefully with high power factor and long-term efficiency in mind.
- Upgrade obsolete fluorescent systems to Compact fluorescents and electronic
- Change exit signs from incandescent to LED.

DG sets

- Optimize loading
- Use waste heat to generate steam/hot water /power an absorption chiller or preheat process or utility feeds.
- Use jacket and head cooling water for process needs.
- Clean air filters regularly.
- Insulate exhaust pipes to reduce DG set room temperatures.
- Use cheaper heavy fuel oil for capacities more than 1MW

Plants

- Seal exterior cracks/openings/gaps with caulk, gasketing, weather stripping, etc.
- Consider new thermal doors, thermal windows, roofing insulation, etc.
- Install windbreaks near exterior doors.
- Replace single-pane glass with insulating glass.
- Consider covering some window and skylight areas with insulated wall panels inside the Plant.
- If visibility is not required but light is required, consider replacing exterior windows with insulated glass block.
- Consider tinted glass, reflective glass, coatings, awnings, overhangs, draperies, blinds, and shades for sunlit exterior windows.
- Use landscaping to advantage.
- Add vestibules or revolving doors to primary exterior personnel doors.
- Consider automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
- Use intermediate doors in stairways and vertical passages to minimize Plant stack effect.
- Use dock seals at shipping and receiving doors.
- Bring cleaning personnel in during the working day or as soon after as possible to minimize lighting and HVAC costs.

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Water & Wastewater

- Recycle water, particularly for uses with less-critical quality requirements.
- Recycle water, especially if sewer costs are based on water consumption.
- Balance closed systems to minimize flows and reduce pump power requirements.
- Eliminate once-through cooling with water.
- Use the least expensive type of water that will satisfy the requirement.
- Fix water leaks.
- Test for underground water leaks. (It's easy to do over a holiday shutdown.)
- Check water overflow pipes for proper operating level.
- Automate blowdown to minimize it.
- Provide proper tools for wash down -- especially self-closing nozzles.
- Install efficient irrigation.
- Reduce flows at water sampling stations.
- Eliminate continuous overflow at water tanks.
- Promptly repair leaking toilets and faucets.
- Use water restrictors on faucets, showers, etc.
- Use self-closing type faucets in restrooms.
- Use the lowest possible hot water temperature.
- 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 freeze protection valves rather than manual bleeding of lines.

Miscellaneous

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- Meter any unmetered utilities. Know what normal efficient use is. Track down causes of deviations.
- Shut down spare, idling, or unneeded equipment.
- Make sure that all of the utilities to redundant areas are turned off -- including utilities like compressed air and cooling water.
- Install automatic control to efficiently coordinate multiple air compressors, chillers, cooling tower cells, boilers, etc.
- Minimize use of flow bypasses and minimize bypass flow rates.
- Provide restriction orifices in purges (nitrogen, steam, etc.).
- Eliminate unnecessary flow measurement orifices.
- Consider alternatives to high-pressure drops across valves.
- Turn off winter heat tracing that is on in summer.

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