International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 2, March 2015 |

Industrial Energy Audit for Manufacturing Industry

Laxmikant Radkar [1], Ganesh Tope [1], Nikhil Wadkhelkar [1], Sushant Rampure [1]

Department of Mechanical Engineering, NBNSSOE, Pune, Maharashtra, India[1]

ABSTRACT: Energy plays a central role in all organizations, especially those that are energy intensive. A detailed industrial energy audit is carried out to establish energy balances for Terminal Technologies (I) Pvt. Ltd., Pune. Energy consumption before installation of recommendations was 1,095,630 kWh/year for a period from February 2015 to January 2016. By implementing recommendations like VFDs, contract demand reduction and maximizing the power factor incentive, it is concluded that the total energy saving potential of 193,098 kWh per year is possible. Hence the total savingof Rs. 16.47 Lakhs per year is possible with initial investment of Rs. 5.67 Lakhs with overall payback period of 4-5 months.

KEYWORDS: Industrial energy audit, Energy consumption, Injection molding machines, Regression Analysis, VFD, Payback Period, BMS.

I. INTRODUCTION

Nothing is perfect, but perfection can be achieved with continuous efforts towards it. An energy audit does the same. It is defined as the verification, monitoring and analysis of energy use including submission of technical report containing recommendation for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption. It is an inspection, survey and analysis of energy flow for energy conservation in an industry to reduce the amount of input into the system without negatively affecting the output [1]. The main objectives of performing an audit are resource protection, climate protection, giving users permanent access to energy they need.

Industrial energy audit is performed for Terminal Technologies (I) Pvt. Ltd., Chakan, Pune, incorporated in 1994. Terminal Technologies (TT) is automotive and inter-connected components manufacturing industry having 109 companies as client. The purpose of an energy audit is to determine how energy is used in an existing facility and to reduce its use. Being manufacturing industry they are using primary energy source electricity continuously. Energy consumption of the company is 1,095,630 kWh/year for a period from February 2015 to January 2016 which costs around Rs. 8,929,397 per year. So objective is to reduce the energy consumption of the company to make them energy efficient.

II. METHODOLOGY

In order to carry an energy audit, Canadian Industry Program for Energy Conservation (CIPEC) manual suggested methodology known as Ten Step Methodology [2] which is :

1. Condition Survey
2. Establish Audit Mandate
3. Establish Audit Scope
4. Analyze Energy Consumption and Costs
5. Comparative Analysis
6. Profile Energy Use Pattern
7. Inventory Energy Use
8. Identify Energy Management Opportunities
9. Assess the Benefits
10. Macro Audit Report for Action

These are the standard ten steps given by manual. By following them it is possible to cover every minute detail of energy consumption and saving opportunities can be found out.

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 2, March 2015 |

Table (1): Schedule of energy audit

Sr. No.	Observations/ Inspection	Result
1	A complete walk through in the industry	Done
2	Discuss advantages of energy audit	Done
4	Inspect various sections for any energy wastage	Done
5	To identify instruments required for audit	See Table (2)
6	Prepare a list of major energy consuming machinery	See Table (3)
7	Calculate lighting and machine load	See Table (4)
8	Check any loose connection and leakage	None found

This is a check sheet of energy audit which gives the schedule of energy audit performed. Above table gives different primary steps involved in an audit. These steps help in identifying basics of an industrial audit.

Table (2): Schedule of energy audit

Sr.No.	Instruments Used
1	Digital Multimeter
2	Digital Tachometer
3	Measuring tape of 100 meter
4	Lux meter
5	Power factor meter
6	Energy meter

Above table identifies different tools required during the audit. These tools are required to calculate and measure different parameters required during an audit.

III. ENERGY SCENARIO OF THE COMPANY

Electricity is the prime source of energy in TT. The MSEDCL (MAHARASHTRA STATE Electricity Distribution Company Ltd.) power supply is coming to the plant with the help of 22kV feeders. The connected electrical load of plant is 750 kW and a contract demand is 641 kVA. Energy consumed is in the form of electricity. This electricity is mainly analyzed in kilo-watt-hour (kWh). The exiting tariff rate is Rs. 220/kVA for max demand and Rs.8.23/kWh for energy consumption.

List of major energy consuming machineries in company are tabulated in Table (4).

From the Table (4), it is observed that the M.D (actual) varies from a maximum value of 328 kVA in the month of Jun-15 to a minimum value of 150 kVA in the month of Feb-15 [3].

Table (3): Machines and Equipments in the Company

Sr. No.	Name of Machine/ Equipment	Quantity
1	Injection Molding Machines	16 Nos.
2	Stamping Machines	6 Nos.
3	Air Compressor	3 Nos.
4	Air conditioners	2 Nos.
5	Pumps	4 Nos.

Above table summarizes total machines and equipments available in the industry. These machines and equipments are used daily for production of terminal parts. By this way it becomes possible to set an audit mandate and scope within a facility.

IV. ANALYSIS

Analyzing historical energy consumption provides a basis for more in-depth analysis of energy performance. In particular, it provides the data needed for comparing performance.
Analysis is divided in two parts:

1. Comparative Analysis
2. Economic Analysis

IV.1 COMPARATIVE ANALYSIS

Analyzing historical energy consumption and costs, provides a basis for more in-depth analysis of energy performance. It provides the data needed for comparing performance. Comparative analysis provides information in the form of the charts, diagrams, etc. This method of statistical analysis considers energy use determinants such as production and generates management information on energy use trends and relationships that can be used to analyze performance and control future performance [8].

IV.1.1 MONTHLY ENERGY CONSUMPTION

Energy consumption data collected from Feb'15 to Jan'16 shows that average energy consumption per month is about 91,303 kWh/month which costs around Rs. 7,44,116 at the average rate of Rs. 8.23/kWh.

Company unit is divided in different sections like machine section, lighting section, air conditioners and refrigeration and so on. Machines section includes sixteen injection molding machines (12 vertical and 4 horizontal) and 6 stamping machines. Lighting section includes tubes, fans, personal computers and other small electrical appliances. Fig. 1 shows that company is having steady energy consumption flow in almost all months except for May'15 and June'15.

IV.1.2 ENERGY CONSUMPTION (EC) IN LIGHTING SECTION

In this section, lights are consuming more energy, so obvious EMOs lie for florescent tubes, bulbs, etc. Lights consume maximum kWh which is 4160 kWh/month. It is then followed by compressors, fans, ACs and Refrigeration and Computer with values 3,432 kWh/month, 1,022.32 kWh/month, 445.64 kWh/month, 187.2 kWh/month respectively.

Sample calculations for fluorescent tubes:

TT has two types of fluorescent tubes:

- 11 W (11 no of tubes)
- 28 W (235 no of tubes)

Total watts consumed = (11×11) + (28×235)
Total watts (W)= 120618 W
Total kW = 120.61 kW
1 kW = 1 unit
Total units = 120.61
Rate of electricity = Rs. 8.47
Working days = 26
Working hours = 18 hrs.
Total electrical bill = Total units × Rate × no. of days
= 120.61×8.47×26

Total bill for tubes = Rs. 26,560.73

Table (4): Electricity bills from Feb'15 to Jan'16

Month	Units Consumed (kWh)	M.D. Actual (kVA)	M.D. Billing (kVA)	P.F.	Days	L.F.	Billing Amount (Rs.)	Avg. Unit Cost (Rs./kWh)	Current P.F. Incentive
Jan-16	96,290	212	641	0.992	26	20	779,880	8.10	20,226.13
Dec-15	92,580	223	641	0.99	26	20	799,030	8.63	23,628.28
Nov-15	80,030	211	641	0.989	26	18	701,540	8.77	21,915.49
Oct-15	91,130	217	641	0.987	26	19	787,230	8.64	23,369.16
Sep-15	87,340	199	641	0.983	26	19	741,720	8.49	51,554.14
Aug-15	83,670	194	641	0.98	26	18	717,060	8.57	21,178.95

Jul-15	89,590	213	641	0.982	26	19	772,760	8.63	20,047.98
Jun-15	135,480	328	641	0.985	26	30	1,086,257	8.02	20,735.54
May-15	132,400	321	641	0.983	26	28	838,639	6.33	37,389.25
Apr-15	94,610	270	641	0.984	26	21	784,108	8.29	33,324.13
Mar-15	58,620	240	641	0.991	26	12	496,158	8.46	37,949.28
Feb-15	53,890	150	641	0.981	26	13	425,015	7.89	37,017.23
Total/Avg.	1,095,630			0.985			8,929,397	8.23	348,335.55

Above table summarizes one year electricity bill. These values are directly taken from monthly electricity bills of an industry. Table gives information about electricity consumption, electricity amount, power factor, contract demandand maximum demand of an industry. Such table makes it possible to have a clear look at electricity usage pattern of an industry.

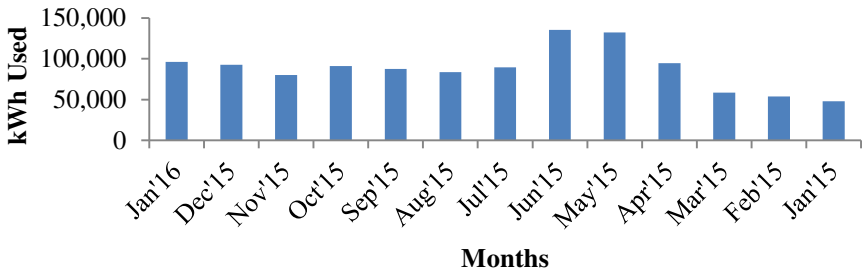


Figure (1): EC per month

Figure 1 gives details of energy consumed (kWh) per month. Company unit is divided in different sections like machine section, lighting section, ACs and refrigeration and so on. All months show high energy consumption with an average of 87, 972 kWh/month. This chart shows that company is having steady energy consumption flow in almost all months.

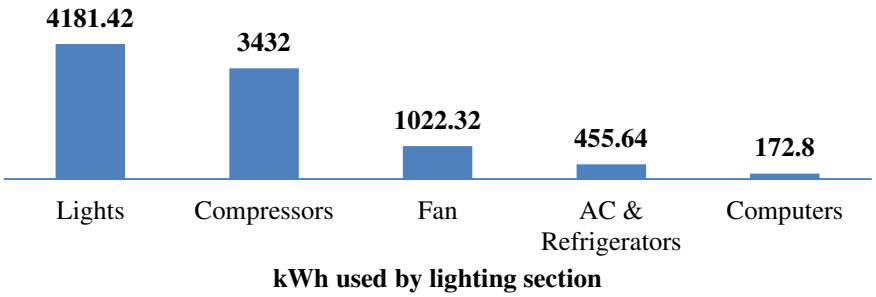


Figure (2): EC in lighting section

In this section lights are consuming more energy so obvious EMOs lie for florescent tubes, bulbs, etc. Lights consume maximum kWh which is 4160 kWh/month. It is then followed by compressors fans, ACs and Refrigeration and Computer with values 3,432 kWh/month, 1,022.32 kWh/month, 445.64 kWh/month, 187.2 kWh/month respectively.

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 2, March 2015 |

IV.1.3 ENERGY CONSUMPTION IN MACHINES

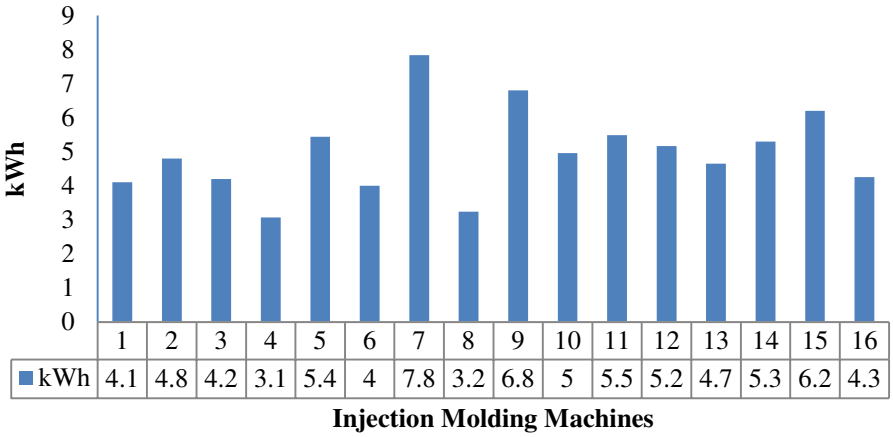


Figure (3): EC by molding machines

Molding Machine no. 7: -

Total kW	=	7.83kW
1 kW	=	1 unit
Units used in a day	=	187.92
Rate of electricity	=	Rs. 8.23
Working days	=	26
Working hours	=	24hrs
Total electrical bill	=	One day units × Rate × days
Total electrical bill	=	187.92 × 8.23 × 26
Total electrical bill	=	Rs. 40,211.12

Electricity bill amount for 16 injection molding machines is Rs. 420,655.26. This is 61% of total electricity consumption by the facility.

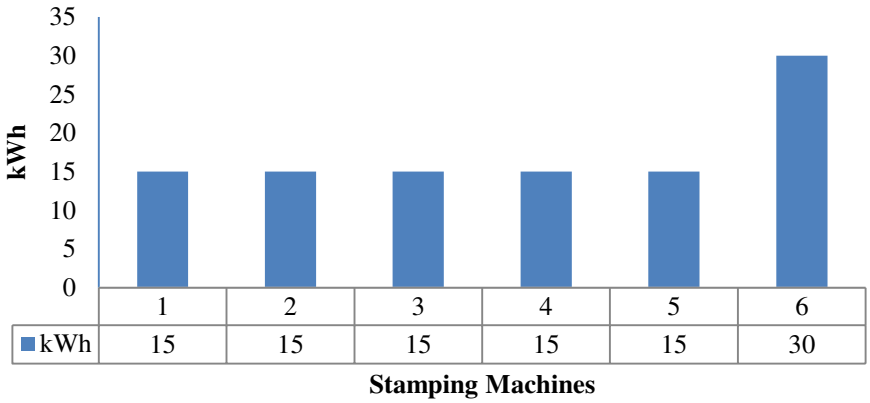


Figure (4): EC by stamping machines

Stamping Machine no. 5: -

Total kW	=	15 kW
1 kW	=	1 unit
One Day Units	=	120 units
Working days	=	26
Working hours	=	8hrs.
Rate of electricity	=	(Rs.) 8.23
Total electrical bill	=	One day units × Rate × days
	=	120 × 8.23 × 26
Total electrical bill	=	Rs. 25,677.6

Electricity bill for all six stamping machines costsRs.184,984.80. This amount is almost 28% of total electricity bill.

IV.1.4 TOTALENERGYCONSUMPTION

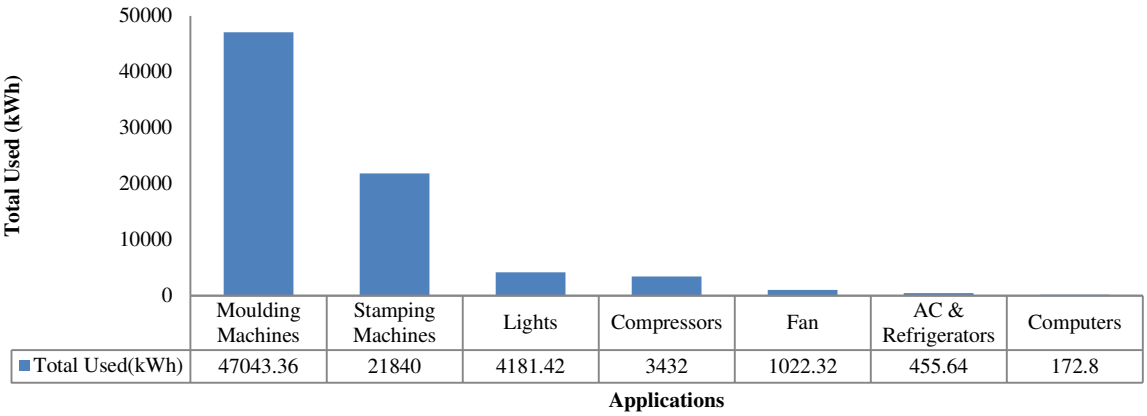


Figure (5): Total energy consumption by various applications

Primarily it can be concluded that injection molding machines will lead to major EMOs. Contribution of all section shows that exact contribution of all applications. Above chart gives energy consumption of all sections present in an industry.

IV.1.5 OVERALL APPLICATION WISE CONSUMPTION PATTERN

From figure (6), major applications are recognized as molding and stamping machines. Other sections cause little contribution but significant energy and money can also be saved by installation of technologies like BMS. Our primary EMOs lies in injection molding machines section.

This can also be explained by using Pareto chart principle. The Pareto principle, also known as the 80-20 rule, and the law of the vital few states that, for many events, roughly 80% of the effects come from 20% of the causes [4]. Thus according to Pareto principle, 80% of total energy consumption is due to 20% of total applications.

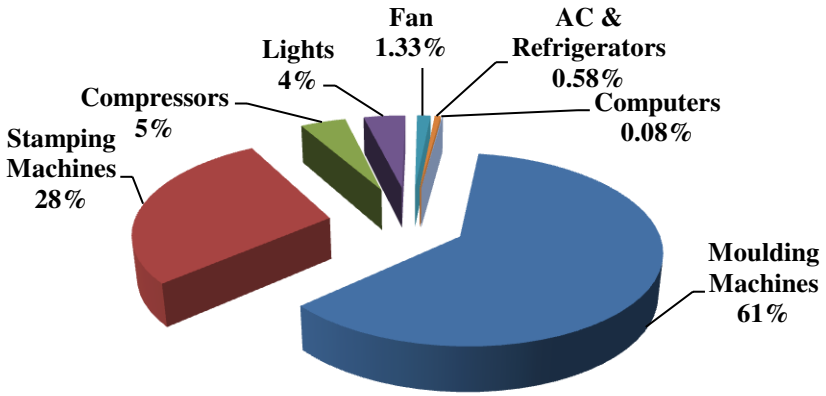


Figure (6): Application wise % EC

Above chart tells that 61% energy is consumed by injection molding machines and then 28% by stamping machines which is also shown by Pareto Chart. EMOs from these sections will lead to greater savings in terms of energy and money.

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 2, March 2015 |

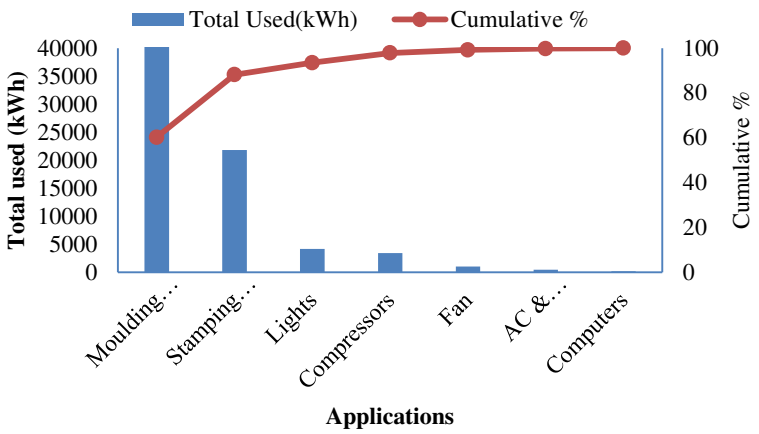


Figure (7): Application vs. Total kWh used(Pareto Chart)

From the figure (7), it can be concluded that 80% of total energy is consumed by molding and stamping machines. The principle states that, for many phenomena, 20% of invested input is responsible for 80% of the results obtained. Pareto principle says that 80% of total energy consumption is due to 20% of total applications. From the chart it can be concluded that 80% of total energy is consumed by molding and stamping machines. Analysis is done for stamping and molding machines.

IV.1.6 INJECTION MACHINE EMOs

In comparative analysis it is seen that major EMOs are found in injection molding machines. To reduce energy use by motors, Variable Frequency Drives (VFDs) are installed in machines. It is also known as Variable Speed Drive (VSD), Adjustable Speed Drive (ASD), and Variable Voltage Variable Frequency Drive (VVVF) [5]. Variable Frequency Drives (VFD) change the speed of motor by changing voltage and frequency of the power supplied to the motor.

Advantages of VFDs [5], [6]: -

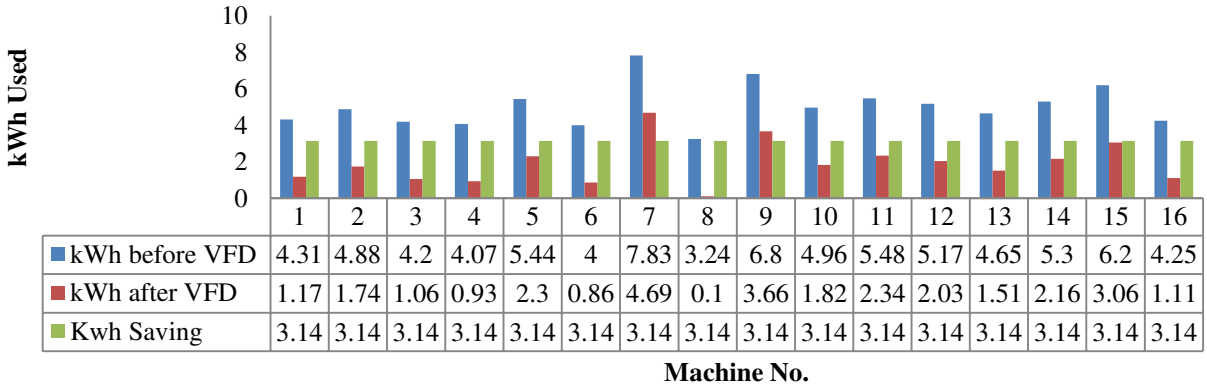
•Large energy saving at lower speed

•Increased life of rotating components due to lower operating speed

•Reduced noise and vibration level

•Reduction of thermal and mechanical stresses

Installed VFD saves 3.14 kWh per machine. All VFDs maintain the output voltage to frequency ratio constant at all speeds [5]. So saving is same in all machines. Energy saving in molding machines is shown in figure (8).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
kWh before VFD	4.31	4.88	4.2	4.07	5.44	4	7.83	3.24	6.8	4.96	5.48	5.17	4.65	5.3	6.2	4.25
kWh after VFD	1.17	1.74	1.06	0.93	2.3	0.86	4.69	0.1	3.66	1.82	2.34	2.03	1.51	2.16	3.06	1.11
Kwh Saving	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14

Figure (8): Molding Machine Energy Saving

This chart gives the information about energy saving and energy usage before and after recommendations of injection molding machines. Figure provides the necessary analysis.

IV.2 ECONOMIC ANALYSIS

Economic analysis deals with the money investment in the project. In this analysis different types of methods are used to find out whether the investment is successful or not. It checks the economic feasibility like Simple Payback Period,

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 2, March 2015 |

Internal Rate of Return and Net Present Value etc. out of which simple payback period is sufficient. Simple payback period is the time required to recover all the money invested in the project [7].
Simple Payback Period (SPP) is the time length required to recover the cost invested in project. SPP is an important economic analysis. It provides the information about when all the money invested in the project will be recovered. Better investment is one with shorter payback period.

$$\text{SPP}=\frac{\text{Cost of Project}}{\text{Annual Saving by the project}}$$

Economic analysis here is shown for one injection molding machine which is as follows.

$$\text{Payback Period}=\frac{Cost\ of\ Project}{Annual\ Saving\ by\ the\ project}$$

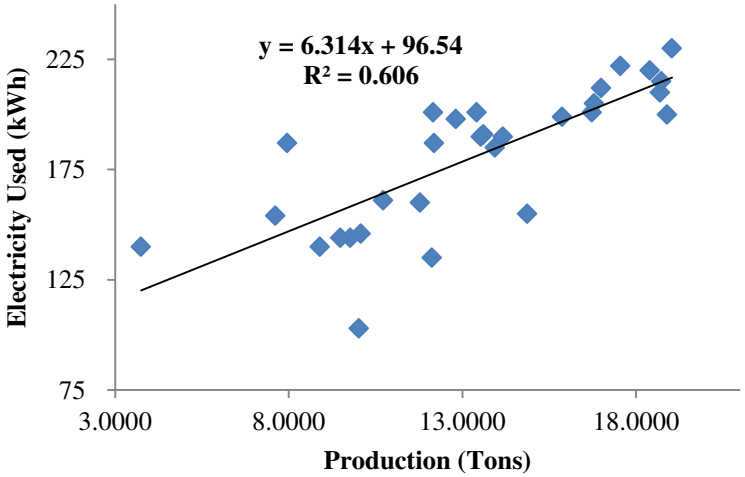
Cost of project (VFD)= Rs. 66,220
Annual Saving= Rs. 186,063.84

$$\text{Payback Period} = \frac{66220}{186063.84}$$

Payback Period (years) = 0.355 years or 4-5 months.

V. REGRESSION ANALYSIS

In statistical modeling, regression analysis is a statistical process for estimating the relationships among variables. This analysis is used for prediction and forecasting, where its use has significant overlap with the corresponding field. It is used for understanding how independent variables are related with dependent one. Fig. 10 shows the regression analysis of company's production data for injection molding machines vs. kWh. Regression analysis methodology would involve the following [8] steps:
•Collect and record energy and driver data
•Use regression analysis to investigate what drives energy use and establish a baseline relationship for energy consumption.



Figure(9): Regression Analysis

For above regression analysis we have obtained following equation:
***y* = (6.314×x) + 96.54**
kWh Used = 6.314× Production (tons) + 96.54
R^2 = 60.6%

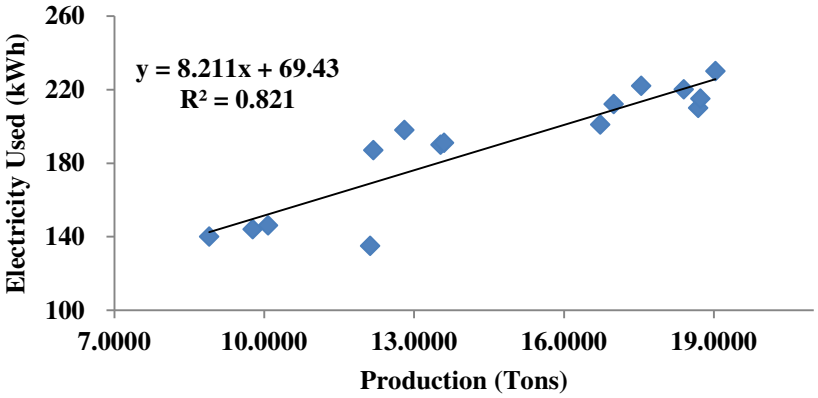


Figure (10): Baseline Regression Analysis

For above regression analysis we have obtained following equation:

***y* = (8.211×x) + 69.43**

Electricity (kWh) = 8.211× Production (tons) + 69.43

R^2 = 82.1%

With the help of above equation CUmulative SUM (CUSUM) analysis is performed. Analysis shows that CUSUM difference is positive 54 kWh. This means it is possible to save energy up to 54 kW per hour from 16 injection molding machines. Thus, ideally, each machine will save around 3.375 kW per hour. Out of this 3.375 kWh of energy, 3.14 kWh can be saved by using VFD as discussed above. Thus the remaining 0.235 kWh can be saved by other different methods. All energy saving methods is given in recommendations.

VI. RECOMMENDATIONS

Recommendations are the summary of energy saving methods for facility. Some recommendations are provided to increase machine efficiency and some for improving building efficiency. For TT recommendations are given in two ways.

i. Increasing machine efficiency

ii. Increasing building efficiency (Building Automation System)

VI.1.1 POWER FACTOR (PF) INCENTIVE

The variation of power factor for last one-year is shown in the fig. 12 and is tabulated in Table (5).

Table (5): P.F. for period Feb'15 to Jan'16

Month	PF	Current Incentive in Rs.	Max. Incentive in Rs.
Feb-15	0.991	20226.13	28316.58
Mar-15	0.991	23628.28	33079.58
Apr-15	0.984	21915.49	51136.15
May-15	0.983	23369.16	54528.02
Jun-15	0.988	51554.14	72175.79
Jul-15	0.982	21178.95	49417.53
Aug-15	0.980	20047.98	46778.61
Sep-15	0.983	20735.54	48382.93
Oct-15	0.987	37389.25	52344.95
Nov-15	0.989	33324.13	46653.77

Dec-15	0.990	37949.28	53128.99
Jan-16	0.992	37017.23	51824.12
Avg.	**0.987**	**29027.96**	**48980.59**

The value of power factor obtained for last year is found to be satisfactory [9]. But still there is a chance for improvement so that more incentive can be obtained. Table (6) shows variation in incentive depending upon the range of PF. Power factor incentive is given on amount of energy charges + FAC + Fixed/Demand charges.

Table (6): Incentive Scheme of Maharashtra State Electricity Board

Sr. No.	Range of PF	PF Level	Incentive (%)
1	0.951 to 0.954	0.950	0
2	0.955 to 0.964	0.960	1
3	0.965 to 0.974	0.970	2
4	0.975 to 0.984	0.980	3
5	0.985 to 0.994	0.990	5
6	0.995 to 1.000	1.000	7

Thus, from table (5) and table (6), it be seen that if power factor maintained constant in the range of 0.995 to 1.000, the effective incentive will amount to 7% reduction in monthly electricity bill. Thus, monthly, around average Rs. 48980.59 can be gained instead of gaining average Rs. 29027.96.

VI.1.2 HOT AIR RECYCLER

Injection molding machines require preheating of material. This is done in hopper of injection molding machines. In hopper material is heated as per requirement of the product. They are heated at a temperature of 170°C to 220°C. Here hot air gets wasted in the form of exhaust air. This air can be utilized again in the hopper. So it is possible to save energy. This saved energy can be directly measured with the help of energy meter connected to hopper.

Table (7): Machine recommendations and Overall Bill Reduction

Recommendation	Annual Saving		Investment Needed Amount (Rs.)	Payback Period (Months)
	kWh	Amount (Rs.)		
VFD (6Machines)	135,648	1,116,383.04	397,320	4.27
Contract Demand	252	55,440	Negligible	-
Power Factor Incentive	21,486	1,81,927.9	10,000	Less than a month
Hot Air Recycler	35,712	293,909.76	160,000	6.63
Total saving	193,098	1,647,660.7	567,320	4.13

VI.2 BUILDING EFFICIENCY RECOMMENDATIONS (BMS)

Building management term is related to the Building Automation System (BAS). BAS consists of sensors which help in reducing energy consummation. These sensors ideally save 30-40% energy.

1. PIR Occupancy sensors in conference room and war room.
2. Start and stop timers for ACs in conference and war room.
3. Status alarms for injection molding machines. Smoke detector in machine section.
4. Carbon dioxide and monoxide sensors in machine section

VI.3 GENERAL RECOMMENDATIONS

1. Turn off the lights when not required.
2. Consider employing IR sensors, motion sensors, automatic timers, dimmers and solar cells.
3. Clean tubes and bulbs regularly. Change of conventional lights by CFL or LEDs.
4. Set the thermostat of room air conditioner at 25˚C (77˚F) to provide most comfort at least cost. A good air conditioner cools and dehumidifies a room in about 30 minutes, so use a timer and leave the unit off for some time.

| ISSN: 2395-7852 | www.ijarasem.com | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 2, Issue 2, March 2015 |

5. Clean the air-conditioner filter every month. Turn off your home office equipment when not in use.
6. A computer that runs 24 hours a day uses more power than an energy-efficient refrigerator. Setting computers, monitors, and copiers to use sleep-mode when not in use helps cut energy costs by approximately 40%.
7. Battery chargers, such as those for laptops, cell phones and digital cameras, draw power whenever they are plugged in and are very inefficient.
8. Shutting computers down when you are finished using them actually reduces system wear - and saves energy.

VII. CONCLUSION

A famous quote "Energy saved is energy generated". A well-managed energy program can be a successful method to reduce energy consumption.
Overall conclusion for the project is as follows:
•Energy consumption before recommendations = 1,095,630 kWh/year
•Energy consumption after recommendations = 902,532 kWh/year
•Total investment needed = Rs. 567,320
•Total saving after recommendations =Rs. 1,647,660.7
•Payback period of the project = 4.13 months

ACKNOWLEDGEMENT

The authors would like to express gratitude to Terminal Technologies (I) Pvt. Ltd., Chakan, Pune for providing this opportunity in conducting the audit.

REFERENCES

[1] S. U. Kulkarni, K Patil., "Energy Audit of an Industrial Unit – A Case Study", International Journal of Emerging Science and Engineering (IJESE), Volume-2, issue 1, page no. 22-26, November 2013.
[2] Canadian Industry Program for Energy Conservation (CIPEC), Handbook: "Energy Saving Toolbox – An Energy Audit Manual and Tool", October 2015.
[3] L.C. Witte, P.Schmidt, Dr. Brown, "Industrial Energy Management and Utilization" Hemisphere publishing corporation, New York, USA, 1987.
[4] Bunkley. Nick ,"Joseph Juran, 103, Pioneer in Quality Control Dies", New York Times, March 3, 2008.
[5] Neetha J., Mohandas R., and Suja C R., "Energy Saving Mechanism Using Variable Frequency Drives", International Journal of Emerging Technology and Advanced Engineering, Volume 3, issue 3, page no. 784-790, March 2013.
[6] P. G. Kini, R. C. Bansal, "Energy Efficiency in Industrial Utilities, Energy Management Systems", ISBN: 978-953-307-579-2, 2011.
[7] M.B. Raghav1, M. S. Srijaa, G. S. Rao, K. N. Bhavya and Y. Suchitra, "Energy Conservation and Audit - A Case Study", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Volume 2, issue 10, page no. 4957-4966, October 2013.
[8] Handbook: Energy Monitoring, Targeting and Reporting.
[9] Power Factor Improvement Article first published online: DOI: 10.1111/j.1559,3584.1945.tb01693.x,18 MAR 2009.