Six-Sigma Approach to Energy Management Planning

Article *in* Strategic Planning for Energy and the Environment · January 2014

DOI: 10.1080/10485236.2014.10781519

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Jim Lee, Kirkrai Yuvamitra
Kelly Guiberteau
Theodore A. Kozman

ABSTRACT

Most companies would like to reduce costs of providing goods and services while the government and society are pushing for more "green" practices. By developing an energy management plan, a company can find a systematic way to reduce energy usage and operating costs at the same time. This article presents a six-sigma based energy management planning procedure, focusing on five major steps: define, measure, analyze, improve, and control. An overview of the major energy-consuming equipment in manufacturing industries is provided. Different energy-saving opportunities are then investigated. The results from this research provide information and a clear understanding for establishing an energy management plan, which can be used as part of the ISO 50001 implementation.

Keywords: Energy management plan, six-sigma approach, energy audit, energy saving technology, ISO 50001.

INTRODUCTION

Energy management plan (EMP) is a summary of activities which should be taken by a company to save energy and costs. The activities suggested are normally very cost-effective requiring very little budget [1]. The EMP reported in this article is developed after energy audits performed by Louisiana Industrial Assessment Center (IAC) for several oil equipment and service industries. Louisiana IAC provides energy, productivity, and waste assessments at no cost or obligation to eligible small and mid-sized manufacturers in Louisiana. To apply for an assessment, contact Dr. Ted Kozman, director of the center.

The objectives of an EMP are to improve energy efficiency, reduce cost, and conserve natural resources. The specific goals are to (1) continuously improve energy efficiency by establishing and implementing an effective energy management plan while providing a safe and comfortable work environment, (2) suggest an action plan with economic analysis, and (3) encourage continuous energy conservation through work and personal activities by employees. A six-sigma approach involving define, measure, analyze, improve, and control is used to describe the five main steps in the energy management plan [2].

The development of an EMP can be considered as the first step to achieve ISO 50001, a world-class energy management standard [3]. While EMP is used to identify energy-saving opportunities and tools, ISO 50001 is designed to help companies evaluate and prioritize the implementation of energy-efficient technology and promote efficiency throughout the supply chain. Superior Energy Performance (SEP) [4] is an ANSI/ANAB-accredited certification program that builds on ISO 50001 to provide industrial and commercial facilities with a pathway to continuously improve energy efficiency while boosting competitiveness.

Demonstrations of SEP can be found through the US Department of Energy [5].

This article focuses on the use of the six-sigma approach in energy management planning. Figure 1 shows a flow chart for the six-sigma approach, and the major steps are discussed in the following sections.

DEFINE TEAM AND BUDGET

The first step in the energy management plan is to establish an energy team and to provide a budget for implementation. They are discussed below.

Establish Energy Team

An energy team is needed to integrate energy management activities by measuring and tracking energy performance, analyzing, planning, and implementing specific improvements. The size of the energy team will vary depending on the size of organization. In general, four types of team members are needed:

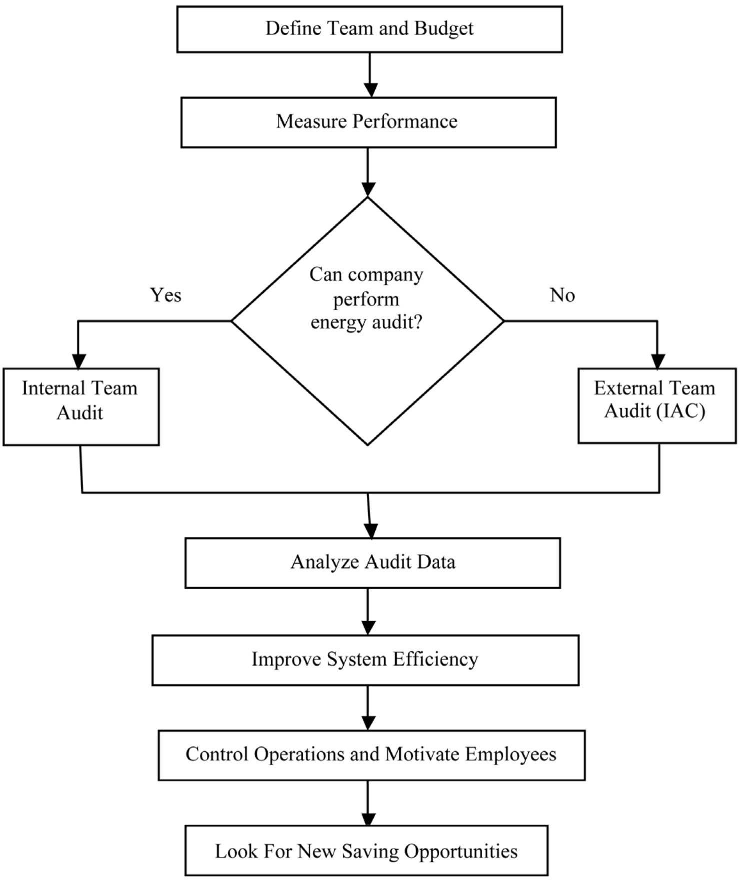

Figure 1. Energy Management Plan Flow Chart

- *Energy Director*: An energy director should be a member of senior staff with both a technical background and familiarity with the organization. Most importantly, an energy director must understand how energy management helps the organization achieve its objectives and goals. The responsibilities for energy director are:
  — Directing and coordinating the overall energy management operations.
  — Acting as the point of contact for senior management.
  — Creating the formal action plan.
  — Establishing and directing the energy team.
  — Providing budget for implementation.

- Measuring, analyzing and monitoring progress.
- Establishing a recognition and reward program.

- *Project Engineer*: The project engineer provides the team with technical specification information on the various production equipment. The engineer is also responsible for researching new technologies to further improve energy savings.

- *Maintenance Supervisor*: The maintenance supervisor provides system operation and maintenance scheduling to implement the action plan.

- *Department Representative*: The department representative works with the maintenance supervisor for implementation.

Provide Budget for Implementation

Reasonable budgeting is imperative for implementing an energy management plan. This should be made available under company guidelines. Budget allocation should be known to the energy team at the start of the year. According to the data provided by the Louisiana Industrial Assessment Center [6], the average implementation budget for a mid-sized manufacturer is around $40,000 to cover insulation, maintenance, and installation of energy-saving devices. The flowchart for the define step is shown in Figure 2.

MEASURE PERFORMANCE

An energy audit can be used to measure the performance in energy management. Understanding how energy is used can help the organization evaluate current performance and identify opportunities to conserve energy. An energy audit can be performed either by an internal audit team(s) or by an outside service.

An outside service, like those provided by Industrial Assessment Centers throughout the US, will look at basic energy consumption practices and will often not get involved with specific key processes important to the manufacture or maintenance of a product. The advantage of an internal audit is that the energy team would be more familiar with the manufacturing process and more comfortable making suggestions for energy reductions within a specific process.

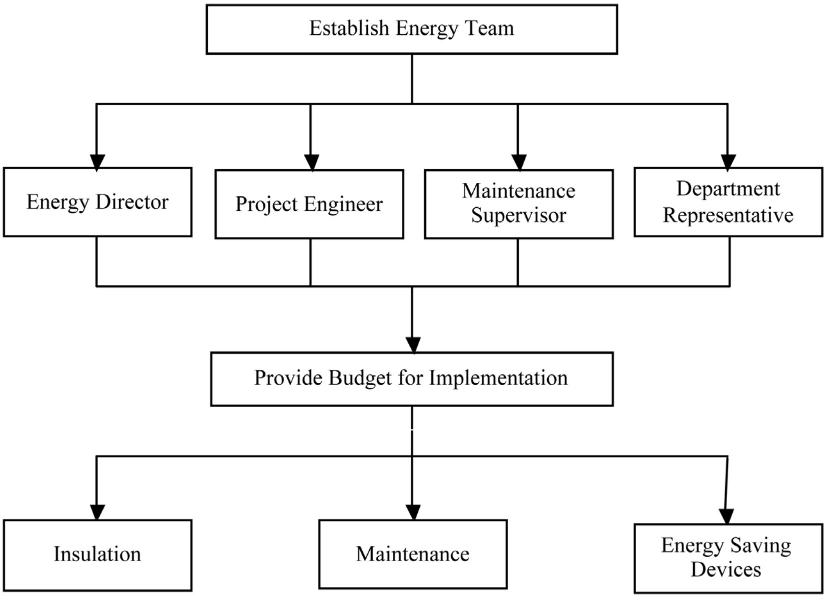

Figure 2. Define Team and Budget Flow Chart

The main disadvantage of an internal team is by being too comfortable with current practices, the team sometimes will miss obvious opportunities for improvement. Another disadvantage of an internal audit is a lack of experience with identifying multiple means of reducing energy. Therefore, the best way to perform an energy audit is to initially have an outside team come in and give an internal energy team the steppingstones of where to start reducing energy. The two steps in an energy audit are pre-audit data collection and on-site technical audit. They are discussed below.

Collect Pre-energy Audit Data

Pre-energy audit data collection is the preparation step for an on-site technical energy audit session. The data collected include utilities bills (types of energy usage, amount of energy usage, energy costs), types of equipment involved in the processes (size, hours of operation), wastes, recyclables, and production. The pre-energy audit data allow the energy team to identify what they need to look for and what data they need to gather while performing the audit. A sample data collection form for a pre-energy audit is shown in Table 1.

Table 1. Sample of Pre-energy Audit Data Collection Form

Company: ABC Manufacturing			**Plant Supervisor:** John Crisler		
Energy Data					
Energy Usage per Year	19,152,000 kWh/yr (Electricity) and 4,227 MMBtu/yr (Natural gas)				
Energy Cost ($/unit)	0.05353 $/kWh (Electricity) and 11.63 $/MMBth (Natural gas)				
Energy Tax ($/unit)	0% (Electricity) and 0% (Natural gas)				
Energy Cost ($/yr)	1,025,232 $/yr (Electricity) and 49,152 $/yr (Natural gas)				
Comment:					
Plant Production Data					
Shift	**Time**	**Hours**	**Days/Week**	**Weeks/Year**	**Hours/Year**
Shift 1	07.00 am – 3 pm	8	5	52	4080
Shift 2	3 pm – 11 pm	8	5	52	4080
Shift 3	-	-	-	-	-
Comment:					

Equipments					
Types	**Location**	**# Units**	**Size**	**Operating Condition**	**Time of Operation**
Boilers (gas)	Boiler room	1	150 Hp	Steam pressure 75 psi 250 F	7 am – 11 pm
Compressed air	Outside	1	185 HP	120 psi	7 am – 11 pm
HVAC	Office	3	24,000 Btu	72 F	7 am – 4 pm
Comment: 1 HP of boiler is equal to 33,475 Btu/Hr					

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Perform Technical Energy Audit

During the technical energy audit of the entire facility, real-time data are recorded by the audit team and any missing information from the pre-energy audit is gathered from the management. The data gathered during the audit will be analyzed later to identify opportunities to conserve energy and for implementation. The focus areas during these audits are:

- Heat loss for boilers
- Lighting count: including type, how it is being used, and lighting intensity
- Air decay test and operating pressure to identify air leaks in compressed air systems
- Operation time and setting for HVAC systems

The flowchart for the measure performance step is shown in Figure 3. A sample audit data collection form for boilers is shown in Table 2.

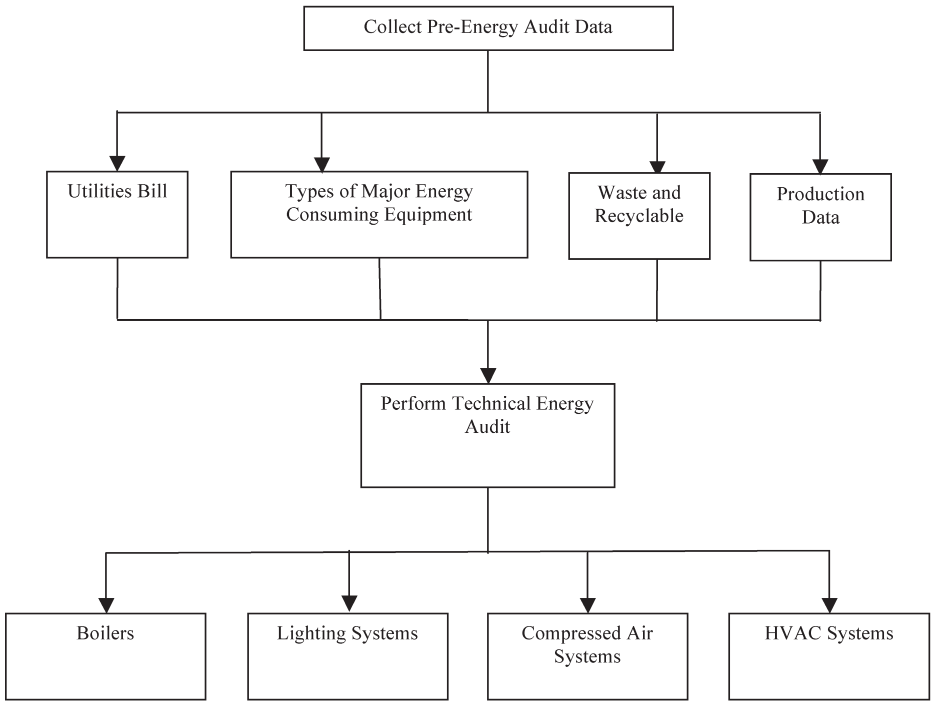

Figure 3. Measure Performance Flow Chart

Table 2. Sample of Technical Energy Audit Data Collection Form for Boilers

Company: ABC Manufacturing			**Plant Supervisor:** John Crisler		
Boilers Data					
Type	**Location**	**Boiler Number**	**Size**	**Time of Operation**	**Operating Condition Include Operating Temp**
Gas	Boiler room	1	150 HP	7 am – 11 pm	75 psi 250 F

Infrared Pictures

Picture No.	**Boiler Number**	**Hot Spot Area (ft^2)**	**Hot Spot Length/Surface Area (ft)**	**Hot Spot Location**	**Hot Spot Temp (F^o)**	**Ambient Temp (F^o)**
1	1	25	2.36	valve	126.9	80
2	1	3	0.75	Firebox cover	333.8	80

Comment:
1 Hp is assumed to be 34.5 Lbs/Hr of saturated steam flow rate at 0 psig and 212 F^o
Focus on any surface temperature that is over 140 F^o (Based on OSHA Safety Standards)

ANALYZE AUDIT DATA

Analyzing data collected from the audit helps an organization develop a better understanding of current energy usages and determine the required budgets for implementing an energy management plan. Energy saving opportunities are identified while the cost savings, implementation costs, and payback period are calculated. The results will be used in developing energy saving goals and an action plan. A flowchart for analyzing audit data is shown in Figure 4, and Table 3 provides a sample analysis.

Identify Saving Opportunities

The first step in analyzing audit data is to identify saving opportunities. Table 3 shows a list of saving opportunities based on an audit to an oil equipment and service industry. For example, the audit data reveal that the surface temperature of the boiler is over the safety standards, so the saving opportunity for a boiler is to install boiler insulation.

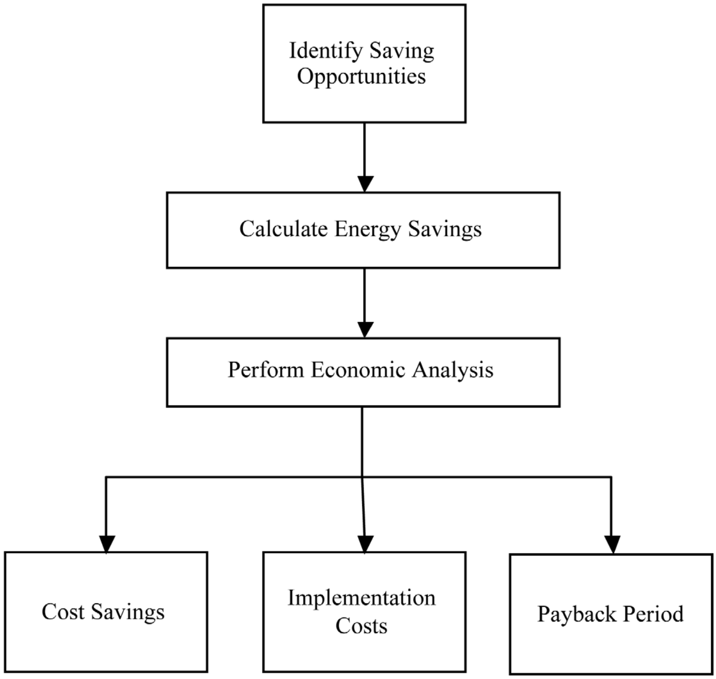

Figure 4. Analyze Audit Data Flow Chart

Table 3. Saving Opportunities, Resources Saving Per Year, Energy and Cost Savings, Implementation Costs and Payback Period

#	Saving opportunities	Energy savings per year	Cost savings ($/yr)	Implementation Costs ($)	Payback period (yr)
1	Insulate surface for hot processes	13 MMBtu	$145.00	$356.00	2.45
2	Preventive maintenance for group lighting replacement	3,424 labor hours	$102,711.00	$10,348.00	0.1
3	Repair leaks in compressed air system	324,606 kWh	$17,376.00	$12,200.00	0.7
4	Reduce number of lights	89,463 kWh	$4,789.00	$5,670.00	1.18
5	Install Vending Mizers	17,472 kWh	$935.00	$1,838.00	1.96
6	Insulate surface for cold processes	645 kWh	$35.00	$56.00	1.62
7	Utilization of occupancy sensor lighting controls	11,311	$606.00	$4,020.00	6.64
8	Replace lighting with more efficient lights	6,839 kWh	$366.00	$3,220.00	8.8
Total		-	$126,963	S37,708	-

Calculate Energy Savings

After the saving opportunities are identified, the next step is to estimate energy savings. For example, the savings of installing boiler insulation can be estimated using DOE tool 3E Plus with the following input parameters:

- Indoor wind speed five mph
- Mean surface temperature
- Ratio of length and area of hot surface
- Insulation thickness of one inch (fiberglass foam, 450F MF BLANKET, Type II)

Perform Economic Analysis

The economic analysis involves estimating (1) cost savings, (2) implementation costs, and (3) payback period for each of the saving opportunities identified earlier. The cost savings can be either energy cost savings or labor cost savings. For example, the cost saving for installing boiler insulation is calculated by the amount of energy savings multiplied by the energy cost per unit.

Implementation cost is calculated based on the cost of material and the labor cost. For example, implementation cost for boiler insulation is calculated using the total area of hot surface and unit labor cost. The labor cost is calculated based on assumption that a single labor hour will result in the installation of insulation over a $3ft^2$ area. A simple payback period can be calculated by the costs of implementation divided by annual cost savings.

IMPROVE SYSTEM EFFICIENCY

Once the audit data have been analyzed, the next step is to improve system efficiency. The activities include (1) develop an energy saving goal and (2) develop an action plan. The flowchart is shown in Figure 5.

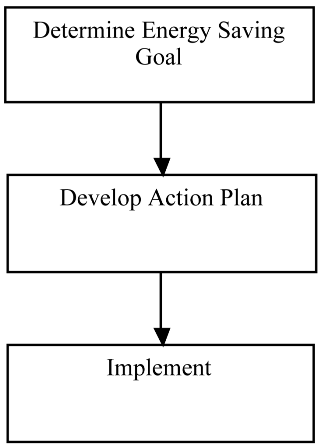

Figure 5. Improve System Efficiency Flow Chart

Determine Energy Saving Goal

An energy saving goal is needed to drive energy management activities and promote continuous improvement. The percentage saving is normally 5%-15% at the end of first year for total energy saved. The following year's goal is normally 3%-5%.

Develop Action Plan

After the saving goal is determined, a detailed action plan must be developed to implement the recommendations. The plan must include the performance target, time line, and department roles for the plan. It is imperative that the energy team procures the budget needed to achieve the implementations. The plan should start with the safety issues and then move to opportunities with the highest potential cost savings. A sample action plan may include the following activities:

- Insulating of surface for hot processes (ten labor hours)
- Preventive maintenance for group lighting replacement (159 labor hours)
- Repair leaks in compressed air system (305 labor hours)
- Reduce the number of lights (189 labor hours)
- Install the Vending Mizers (1.5 labor hours)
- Utilization of occupancy sensor lighting controls (34 labor hours)
- Replace current lighting with more efficient lights (15 labor hours)

Implement

After the action plan has clearly been stated, the next step is to start implementing. People can make or break an energy management plan, so it is important to gain the support and cooperation of key individuals at different levels within the organization.

CONTROL OPERATIONS AND MOTIVATE EMPLOYEES

In energy management, a control strategy is needed to (1) monitor the progress of implementation, (2) make implementation sustainable, (3) monitor the savings incurred, and (4) motivate the employees for continuous improvement. The monitoring progress can be performed by periodic monthly reports which show progress on any work being done. These reports can also monitor the electrical bills each month to show a drop in electrical usage. The control operations and motivate employees flow chart is shown in Figure 6.

Perform Preventive Maintenance

After implementation, it is important to sustain the improvements and to avoid future failures by preventive maintenance. The recommended activities for various equipment are summarized below.

Boiler Preventive Maintenance

- Inspect all refractory surfaces visually daily, such as the boiler door.

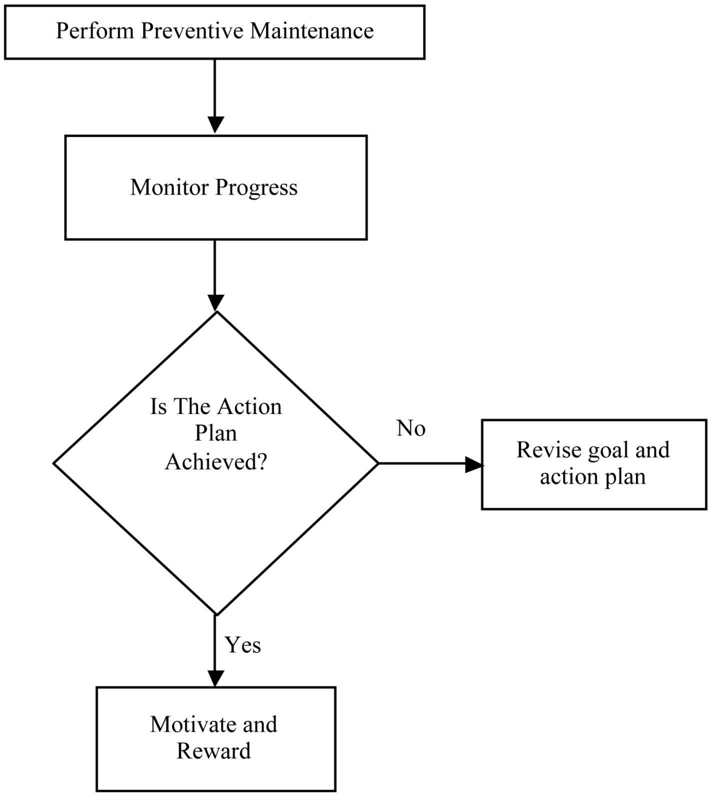

Figure 6. Control Operations and Motivate Employees

- Clean the surface of the boiler daily if the fireside or waterside is dirty.
- Make sure that the air duct supply is clean week to week.
- Check the fuel filter weekly to make sure that there will be enough fuel supplied for higher loads.
- Check the wiring monthly.
- Check for leaks along the supply lines weekly.
- Keep a daily record of fuel consumption and operating conditions.

Compressed Air Systems Preventive Maintenance

- Determine the amount of air leaking in a system using a decay test. The test can be done in an air system by measuring the drop in air pressure over a period of time (about 120 seconds).
- Find and fix air leaks as they occur in the system. Air leaks can be found through a bubble test for smaller leaks or though acoustic

leaks. Once leaks are fixed, the air pressure can be lowered.
- Operate the system at the optimum pressure requirement, usually 100 psi.
- Turn off the air system when compressed air is not in use.

Lighting Systems Preventive Maintenance
- Cleaning of lenses or skylights: Cleaning allows more light to enter the work space and reduces the need for excessive lighting fixtures. This could also be considered a safety hazard if dust collects on the lens of a light fixture and ignites by the heat of light.
- Group lighting replacement: In most production areas, high ceilings are used along with metal halide bulbs, which require the use of a man-lift to change the bulbs. Group lighting is when lights are sectioned into four groups, and every six months, a maintenance team would change all of the lights in a section, regardless of whether the bulbs are burnt out or not. The maintenance crew would not return to replace these bulbs until their recommended life (about 2 years) is spent. The time saved in man-hours by doing this type of light replacement is greater than the cost of throwing away light bulbs that are not burnt out.

HVAC Systems Preventive Maintenance
- Inspect and refill refrigerant fluid to required level every six months
- Clean dirt and sludge from evaporator and condensate coils once a year.
- Lubricate the fan motor and fan blade once a year.
- Inspect the compressor and tubes for leakages once a year.
- Check all connectors, breakers, and wires for damage once a year.
- Clean or replace air filters once every four months.

Monitor Progress

To monitor progress of the work done for implementation, the following steps can be used:
- Review the weekly report for progress on implementation.
- Review monthly report for the amount saved.
- If the action plan is not achieved, revise the goal and the action plan.
- If the action plan is achieved, go to step 5.3 and look for new saving opportunities.

Motivate and Reward

Offering incentives is one way to create interest in energy initiatives and to foster a sense of ownership among employees. There are many ways to motivate employees such as [7]:

- Internal competition: Use tracking sheets, scorecards, etc. to compare performance of similar facilities and foster a sense of competition.
- Recognition: Highlight and reward accomplishments of individuals, departments, and facilities.
- Financial bonuses and prizes: Offer cash bonuses and other rewards if goals are met.

CONCLUSIONS

Energy savings can come as a result of managing existing systems or from using new technologies. There are several systems in which most companies can save money such as boiler, compressed air, lighting, and HVAC. These saving opportunities are identified through energy audits and implemented through activities related to preventive maintenance, replacement of old technology, and equipment workload balance.

As part of a company's initiative to lower the energy cost, it is important to have an energy management plan and an energy management team in place. The energy team will follow the plan to develop management commitment, perform energy audits, implement the action plan, track the implementation, and develop a rewards system for continuous improvement. Having a well-organized and devoted energy team is important in making progress on energy management.

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ABOUT THE AUTHORS

Jim Lee is a professor of mechanical engineering at the University of Louisiana Lafayette and associate director of Louisiana Industrial Assessment Center. He received his M.S. and Ph.D. degrees in industrial and management engineering from the University of Iowa. His research areas include simulation, statistical analysis, decision support systems, and computer-integrated production systems. Email: jlee@louisiana.edu

Kirkrai Yuvamitra received his M.S. degree from the Department of Mechanical Engineering, University of Louisiana at Lafayette. He has worked for the Industrial Assessment Center at the University of Louisiana at Lafayette and performs numerous energy assessments of industrial facilities throughout the region. His research areas include combustion analysis of DME in CI engine, maintenance of CHP systems, Lean Six-Sigma and energy management planning. Email: kirk.yuvamitra@yahoo.com

Kelly L. Guiberteau received her B.S. and M.S. degrees in mechanical engineering from the University of Louisiana at Lafayette. She is the lead student for the Industrial Assessment Center at the University of Louisiana at Lafayette, and her research interests include energy management, integrated product and process design, and wave energy. Email: kguiberteau@gmail.com

Theodore A. Kozman is a professor of mechanical engineering, University of Louisiana Lafayette. He is director and founder of Louisiana Industrial Assessment Center to assist manufacturing in reducing energy, waste reduction and productivity improvement. He received his Ph.D. in engineering science and mechanics from the University of Tennessee. Email: kozman@louisiana.edu