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Part of any successful energy management program is well designed and conducted energy audits. Basically, there are three types of energy audits. They are 1) Gross, 2) Detailed, and 3) Walk-Through Survey. Unfortunately, the literature seldom distinguishes between the three resulting in some confusion.

This paper helps clear that confusion by defining each type, giving examples of their application, and presenting directions or guidelines. Forms for each type of audit are included with the examples.

The forms and instructions have been developed under a program at Oklahoma State University designed to research and disseminate information to help industry better weather the energy crisis. All forms and instructions have been tested in actual industrial situations and are available from the authors.

INTRODUCTION

Industry is facing a potentially severe problem in the availability and cost of energy. The ever increasing cost and dwindling supplies of readily usable energy are the jaws of a vice rapidly closing in on industry profits. Statistics are boring, but there are many signs that the United States uses a disproportionately large amount of energy. Those in the know predict energy supplies will continue to dwindle and energy costs continue to rise. Some are predicting a 3 to 10% increase per year above the basic rate of inflation. Some are also predicting that curtailments, brown outs, and even periods of no supply will soon be commonplace.

Fortunately, much can be done. Energy cost reductions of 5 to 15% the first year are not unusual. Eventual reductions of 30% can usually be obtained and a few industries have achieved 50% reductions. The first 15% or so usually occurs with little or no capital investment. How are these savings identified or located and what projects should be done first? These questions and others can be answered with carefully conducted energy audits.

This paper discusses the use of different types of energy audits in identifying the potential areas of savings and the direction an energy management program should take. It distinguishes between the types of audits and their functions. Examples are illustrated.

PURPOSE OF AUDITS

Once management has committed themselves to an energy management program, its first objective should be to conduct energy audits. Why? Energy audits are excellent tools to 1) measure and monitor a company's energy consumption pattern, and 2) provide a direction for energy management activities. To do this, three types of audits may be necessary. They are 1) Gross Audit, 2) Detailed Audit, and 3) Walk-Through Survey. The sophistication of the audits will depend upon the company's size, manpower, and cash flow.

TYPES OF ENERGY AUDITS

Gross

The gross audit is a simple procedure that allows a firm to determine monthly energy consumption and costs by energy source. Using this information, one can calculate total energy consumption and cost and can monitor energy consumption over time to measure the success of the energy management program.

At least a year's data from past records is required for the gross audit. Two years would be better but one year is sufficient. This data should include all energy (electricity, natural gas, oil, coal, purchased steam, gasoline and any other sources used). Most of these records are available from accounting departments and/or the local energy suppliers.

It is suggested that BTU (British Thermal Unit) be used in describing energy consumption because it is a convenient measure. This way energy from various sources can be compared on the same basis and the total amount of energy used can be measured. In keeping track of consumption it is important that some benchmark be used such as BTU/Unit of production or BTU/Square foot of manufacturing space.

An example form is illustrated in figure 1 at the end of the paper. This form was developed for the Machinery Manufacturing Industry (SIC 35) of Oklahoma as part of an ongoing research program. Forms for eight other major SIC classifications are being developed and are available. Other examples of forms may be found in (1), (2), (3), and (5). The forms may differ to some degree from one another but the overall purpose is the same. The difference may be due to the individual industry involved and the availibility of technical assistance. Because the gross audit is relatively easy to complete, it is suggested that it be conducted every month thus closely monitoring the effects of energy conservation efforts.

Once the gross audit has been completed, management can begin to answer several important questions.

* What is the total energy cost of the company?
* Is energy cost increasing and by how much?
* What energy source is being used the most?
* If 10% savings is typical of an energy management program, what would that mean to the company in dollars?
* What goals should be set for energy savings?

The answers to these questions will be unique for each company. For example, one printing firm in Oklahoma (4) found that it was spending $6,600 a year on energy when it was felt that much less was being spent. This was a considerable sum for a small printing shop. They also discovered that their energy cost was increasing and not due to rate increases but a combination of increased production and waste particularly in lighting.

Once the major areas of consumption have been determined, the firm needs to identify where this energy is being used by conducting a detailed audit.

Detailed Audit

This audit allows a company to pinpoint exactly where the energy is used and how much is being consumed in the operation. Thus, a detailed audit identifies the major energy consumer units and consequently where the real potential savings are. This information is very useful in selecting projects so attention can be focused on the costly areas. At first, one may find conducting a detailed energy audit costly, time consuming, and a little difficult. Consequently, some do not conduct this audit and still have a very successful energy management program. As energy costs rise, however, more and more companies will conduct detailed audits to improve their profits.

The total energy consumption included in the detailed audit should realistically agree with the total figure given in the gross audit. However, common sense indicates attention should be focused on the few large consumers, not the numerous small ones. Therefore, the detailed audit should account for about 80% of the total energy consumed and the cost thereof. Usually, this can be done quickly for a relatively small list of equipment. Since the demand for heating ventilation and air conditioning equipment is seasonal, it seems better to do the detailed audit for months where little demand occurs (e.g., May, June, September, October in most places). This way, the process equipment can be accounted for and the heating ventilation and air conditioning estimates as the surplus in other months (often gas for heating and electricity for cooling).

Because of the technical nature of this audit, it may require the aid of a shop foreman or engineer who is familiar with all the processes. In addition, one should be aware of some of the subtleties when dealing with electricity, i.e., fluorescent lights, induction and three-phase monitors. There are many excellent instruction booklets available [(3), (4), (5), (7), and (8)] which discuss these and many other points. Figures 2 and 3 are examples of detailed audit forms for electrical, natural gas and gasoline equipment.

The printing firm mentioned earlier found that its single major user of electricity was lighting and estimated that it could save $325 per year by reducing the wattage of the bulbs. Heating and air conditioning was another area for major savings discovered by the audit. Finally, they investigated going from a commercial rate to a demand billing rate and found it to be more economical.

The detailed audit may require substantial manpower. Therefore, the frequency by which it is done will depend upon management resources; but it probably should be done every year or so, at a minimum.

While the detailed audit is being done, the walk-through survey may be initiated. Thus, allow the company to investigate projects which have a quick return and encourage further development of the company's energy program.

Walk-Through Survey

The purpose of a walk-through survey is to provide a list of Energy Conservation Opportunities (ECO) for consideration by management. A checklist is used to ensure a rather long initial list of ideas.

Checklists are available from numerous sources [(3), (4), (5), and (6)]. An example checklist is listed at the end of this discussion. One or more persons familiar with the operation should take the checklist and walk through the facilities identifying the areas that are on the checklist which can be improved upon. This list of ideas is then taken back to management for action. Some of these ECO's will have little or no capital requirement while some will require substantial amounts. One must determine what projects the firm wants to explore based on its policies and cash flow situations.

The walk-through audits can usually provide a list of low cost/no cost ideas that can generate 5 to 15% savings. In addition, it can aid in getting the energy program off to a good and quick start.

WALK-THROUGH CHECKLIST

Heating, Ventilation, and Air Conditioning

1. Inspect all outdoor air dampers. They should be as air tight as possible when closed, and closed whenever possible.

2. Inspect filters carefully. Institute air filter inspection/replacement schedule. Their replacement schedule will depend upon your particular operations.

3. Reduce air exhaust as much as possible. Use exhaust fans only when necessary.

4. Install timers to control ventilation and electrostatic precipitators.

5. Set thermostats at lower temperatures in colder weather (approximately 68°F) and at higher temperatures in hot weather (approximately 78°F). Adjust further at night (approximately 55°F week nights and 45°F on weekends for heating, similar setups for cooling). If a timer is used, turn system on prior to plant start-up to avoid overload and turn off prior to departing to allow for "coast down."

6. Consider 24-hour or 7-day timers for thermostats. This can pay off quickly for most firms.

7. Consider the use of economizers and enthalpy controls (i.e., use outside air for conditioning). Contact the authors or see a local expert for more information.

8. Manage solar loads (utilize the sun in the winter and provide shade or use tinted glass in the summer).

9. Consider storm or double glazed windows and doors.

10. Check heating, ventilation and air conditioning ductwork for leaks (especially at joints) and be sure all ductwork is insulated.

11. Consider lowering ceilings to reduce the area required to heat and cool. Also, consider spot exhausting to remove heat from specific sources and possible reuse of waste heat.

Lighting

1. Use natural light wherever possible. Use task light (small lamps directly on the work) whenever feasible.
2. Keep surfaces of light bulbs, tubes, and reflectors clean at all times.
3. Eliminate or reduce lighting of displays and signs (indoors and outdoors).
4. Change to more efficient light sources. Incandescent to fluorescent and investigate the possible use of high or low pressure sodium lamps.
5. Use color schemes inside and out for reflection of light and solar radiation.
6. Consider use of separate switches on perimeter lighting which may be turned off when natural light is available.

Electricity

1. Do not use electric motors that are larger than necessary. Keep them turned off when not in use.
2. Turn off all electrical equipment when not is use (check to see if the equipment is using electricity even when turned off - eliminate if possible).
3. Ensure that all electrical wiring is in good condition.
4. Schedule major electrical consumers to lower peak demand.
5. Check energy efficiency ratings, power factors, etc., to ensure equipment itself is not an energy waster.
6. Consider use of multiple speed motors or variable speed drives for variable pump, blower and compressor loads.
7. Use capacitors to improve plant factor.

Boiler Management

1. Improve boiler efficiency and consider combustion monitoring equipment.
2. Repair hot water leaks and reduce temperature (e.g., 110° to 120°F).
3. Eliminate all leaks in steam and water handling systems. Insulate pipes and ducts - especially where they pass through unconditioned spaces.
4. Shut off pilots in gas furnaces in summer months. (Consider electronic ignition devices.)
5. Adjust pilots to proper operating levels. Tune and keep all combustion fired equipment in peak operating condition.
6. Consider recovering energy from wasted flue gases which have high temperatures and other waste heat recovery ideas.
7. Review steam-trap size and type for most efficient operation and proper installation.
8. Use minimum steam operating pressure and minimize venting to atmosphere.
9. Maintain daily efficiency check on boilers and condensate return.
10. Adjust burners for proper flame patterns.
11. Reduce water flow rates to a minimum in all flushing and cleaning processes.
12. Use only as much hot water as needed; for domestic use, 105° to 120°F is adequate.

Air Compressors

1. Repair air compressor leaks and reduce overall pressure.
2. Clean or replace compressor inlet air filters frequently.
3. Shut down air compressors when idle.
4. Relocate air inlets to cooler locations.

Miscellaneous

1. Consider new paints and cleaning compounds requiring less heat to dry or cure.
2. Repair faulty insulation in furnaces, boilers, etc.
3. Cover open tanks with floating insulation to minimize energy losses.
4. Heat treat parts only to required specifications or standards.
5. Optimize production lot sizes and inventories.
6. Reduce scrap.
7. Use gravity feeds wherever possible.
8. Specify energy efficiency (EER) on all new equipment purchases.

SUMMARY CONCLUSION

This paper has discussed three types of energy audits: 1) Gross, 2) Detailed, and 3) Walk-Through Survey. The Gross Audit identifies the major areas of consumption. The Detailed Audit analyzes how the energy is used within the facilities. Finally, the Walk-Through Survey uses checklists of common ideas to create an initial list of low cost/no cost ideas to generate quick savings and to get an energy program off to a quick start. These three audits will play an integral part in the success of any energy program. They enable management to answer many questions concerning their unique energy situation thus allowing them to plan for the future and design a successful energy management program.

Date of Audit ____________

Date of Last Audit ____________

GROSS AUDIT OF ALL ENERGY RESOURCES

Form A

Year __ Month	Units of Production (1)	Electricity						Natural Gas			Gasoline			Other Fuels Type:			Monthly Totals			Comments
		KWH (2)	KW Demand Actual (3)	(4)	Power Factor (5)	Total Cost (6)	(2)x A MBtu/Mo. (7)	MCF (8)	Total Cost (9)	(7)x B MBtu/Mo. (10)	Gallon (11)	Cost (12)	(10)x C MBtu/Mo. (13)	[illegible] (gal, ft3, ton, etc.) Specify (14)	Cost (15)	[illegible] (16)	[illegible] Cost (17)	[illegible] (18)	[illegible] (19)	
[illegible]																				
Conversion Factors		A = [illegible]						B = 1,000,000 [illegible]			C = 130,000 [illegible]			D = ______ [illegible]/Unit specify						

Figure 1. Gross Audit

Date of Audit ____________

Date of Last Audit ____________

DETAILED AUDIT
For
Electrical Units

____ page of ____ pages

Form B

Description of Unit	Rated Horsepower[A] (1)	Wattage[B] (2)	Operating Hours (3)	"Avg"[C] Average Load (4)	(2) X (3) X (4) X1.732[D] WH (5)	(5) ÷ 1000 KWH (6)	(6) X 10,000 BTU (7)	Comments
TOTAL								

A: One horsepower equals 746 watts.
B: This can be taken off of the nameplate of equipment.
C: For Motors: Average load is usually 70%, therefore insert .70.
If wattage has been measured use 1.0.
For Fluorescent Tubes: Add 20% for ballast; i.e. insert 1.20.
D: If 3-phase unit multiply by 1.732, otherwise use 1 and proceed.

Figure 2. Detailed Audit for Electrical Units

Date of Audit ______________

Date of Last Audit__________

DETAILED AUDIT
For
Natural Gas and/or Gasoline Units

page of pages
Form C

Description of Unit	Natural Gas				Gasoline			Comments
	KCF/HR (1)	(1) x 10^6 BTU/HR (2)	Operating Time (3)	(2) x (3) BTU .. (4)	Miles or Hours (5)	Gallons (6)	(6) x(1.3 x10^5) BTU (7)	
TOTAL								

Figure 3. Detailed Audit for Natural Gas and/or Gasoline Units

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BIOGRAPHICAL SKETCH

Wayne C. Turner - Dr. Turner is a Professor of Industrial Engineering at Oklahoma State University. A registered engineer in Oklahoma, he was co-author of the Oklahoma Basic and Supplemental Energy Conservation Plans. He is winner of numerous teaching awards and has published extensively in several areas including energy management. He is presently Director of the Oklahoma Industrial Energy Management Program.

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James M. Phillips - Mr. Phillips is currently a graduate student in Industrial Engineering at Oklahoma State University. He has worked in the steel and rubber industry as well as serving two years with the United States Peace Corps in Kenya, East Africa. He has given numerous talks and papers on energy manage-

ment and has conducted several conferences in the area. His current research includes Energy Audits and Energy Management.