Module 9: 7 Steps for Energy Management

While this course focuses primarily on the non-technical aspects of energy management, it is important to bear in mind that it is management of technical systems. An essential component of the energy manager's role is to put in place a means of routinely assessing energy performance and identifying opportunities for savings. Module 9, adapted from a CBLA Energy Management Workshop, ***Motivating Sustainable Energy Management in Industry***, concludes the course by presenting a practical methodology known as "The 7 Steps".

Module 4 Learning Objectives

After completing this Module, you will be able to:

- Advise on the implementation of a systematic assessment of energy systems and identification of savings opportunities.

9.1 Managing Energy Costs

Energy management takes many different forms. It may vary from capital intensive installation of new, more efficient technology to simple maintenance and operational activities that ensure equipment and systems use energy efficiently and effectively. It may involve "fuel switching" to energy sources that are inherently more economical for a given application.

Since we can't manage what we don't understand, it is important for managers to learn how energy behaves, how it can be most effectively used, and how energy-efficient technologies can benefit their operations.

The truth is that most facility managers are able to devote only a small amount of time directly to energy management. This does not rule out effectiveness, however. Experience has shown that as an owner, manager or operator involved with an industrial or commercial facility, you already possess invaluable knowledge about the operation of that facility. This — together with some basic knowledge about energy and the rules by which it works — will allow you to identify energy saving opportunities, and make changes that will save your organization money.

9.2 Overview of the 7 Steps

In order to manage your energy costs you will need to understand:

- your present usage and what influences it,
- what opportunities there are to reduce your present usage?

The Seven Steps provides a methodical approach to developing this understanding in two distinct stages as outlined in the following sections.

9.2.1 Understand Your Present Usage

The first phase involves gaining control of your present usage, its cost, historical and ongoing variability, and physical distribution. ***This phase involves analyzing usage starting at the point of purchase and working towards the point of use.***

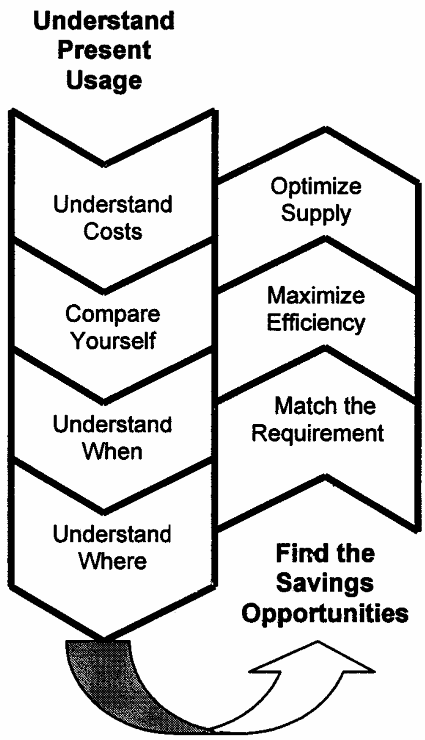


Figure 9.1: 7 Steps to Energy Efficiency

Step 1: Understand your energy costs

Unlike other commodities that may be sold by the pound, the cost of energy that your facility uses is influenced by a variety of factors. The cost of electricity, for example, depends upon:

- **Demand - the rate, or how fast the electricity is used.**
- **Energy - how much electricity you use.**
- **Time-of-Use - when the electricity is used.**
- **Power Factor - your apparent rate of use versus your real rate of use.**

Thermal fuels are simpler to understand than electricity; they are typically sold by mass or volume, although the usable energy content of the various fuel quantities can vary widely (as in the various grades and sources of coal, for example).

The overall objective of Step 1 is to develop a clear understanding of **the incremental cost of energy** — that is, what will the next unit bought or saved be worth?

Step 2: Compare yourself

Two kinds of comparison are pertinent: **external, and internal**.

External comparisons:
- How does your level of energy consumption compare to other similar industries, facilities and sites?
- What level of consumption is achievable with the best operating practices and industry benchmarks?

These external comparisons will be valuable in developing realistic savings expectations, sometime called **targets**.

Internal Comparisons:

- How does your consumption or energy performance this month compare with last month, or the best month in the past two years, for example?
- How does one site in a multi-site operation compare with another?

There may be variation from month to month, or from site to site, in your level of energy efficiency. Minimizing this variation will yield savings.

Step 3: Understand when energy is used

The cost of electricity is influenced by the demand and time-of-use. The electrical demand profile clearly shows the **rate** of use of electricity over time. It is a key management tool for the demand component of your electricity bill.

Step 4: Understand where energy is used

Treat energy as you would any other purchased product. Building an inventory of your electrical loads and uses of thermal energy will enable you to focus on the largest and, consequently, the most expensive consumers.

9.2.2 Identify Savings Opportunities

The second phase seeks to identify the savings opportunities in a sequence that will be the most cost effective. We want to make sure that we concentrate on the housekeeping measures (operational) before we invest money in new equipment (technological measures). ***The key is to look for opportunities, starting at the point of use, working back to the point of purchase.***

Step 5: Match usage to requirement

The first and most important step in realizing savings opportunities is to match what you actually use to what is needed. The key consideration here is the **duration** of use and the **magnitude** of use.

For example, fuel savings will result from shutting down a process heater running for 12 hours when it is only actually required for an 8 hour shift. Or, there are electricity savings available by avoiding throttling of the output of an oversized pump.

Step 6: Maximise system efficiencies.

Once the need and usage are matched properly, the next step is to ensure that the components of the system meeting the need are operating as efficiently as possible. In this step the impact of operating conditions, maintenance and equipment/technology will be considered.

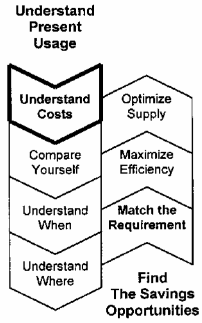
Step 7: Optimise the energy supply.

Steps 5 and 6 will reduce your requirement for energy. Step 7 seeks the optimum source or sources for your overall energy requirement. This may include such considerations as heat recovery systems, alternative tariff structures, alternative fuels, or even larger measures such as a co-generation or combined heat and power (CHP) system.

The 7 Steps: Step-by-Step

9.3 Step 1: Understand your Energy Costs

9.3.1 Electricity Metering



A first step in developing an energy management strategy is understanding how your facility's electricity use is metered. There are various metering technologies in use which differ in a number of ways, including the following:

- Whether or not demand is metered
- How demand is measured (kW or kVA).
- How the information is measured, stored and displayed - thermal (dials) or electronic (digital display).

The term **demand** generally refers to the average value of power measured over a given time interval. Maximum demand is the highest demand value registered during any given period.

Energy (kWh) is the product of power over time, the sum of all the instantaneous power measurements during a period (i.e., how much electricity was used).

These two quantities—maximum demand and energy—are measured by your electric meter and are used to determine the amount of your monthly electric bill.

9.3.2 The Electricity Bill

The next step after developing an understanding of how electricity is metered is applying billing tariffs to those metered values to determine your monthly costs. This section explains tariffs or tariff structures and calculations necessary for the conversion of metered values to cost.

The electricity bill from each utility is unique, but the information provided on the bill on most cases will include at least the following items:

1) *Kilowatt Hours Used (kWh)* - This is the energy consumed since the previous meter reading and may include values for the on/off peak periods. The definition of the on- and off-peak periods is provided by the utility on the bill or on the published tariff. Typically on-peak periods may be: 0:800 to 21:00 and off peak periods: 21:00 to 0:800. Often holidays are included in the off-peak period.

2) *Billing Demand (kW and/or kVA*) - This is the maximum demand experienced during the billing period. One or both of these values may be measured and listed. If both are provided, the power factor is at the time of the maximum demand. Also, the value of the maximum demand for both the on-peak and off-peak periods may be listed.

3) *Tariff Code* - Determines which billing tariff is applied to the energy and demand readings. This will depend on your particular utility.

4) *Days* - Number of days covered by the current bill. This is important to note because the time between readings can vary anywhere within ±5 days, making some monthly billed costs artificially higher or lower than others.

5) *Reading Date* - This is in the box called "Service To - From". The days covered and reading date can be used to correlate consumption or demand increases to production or weather dependent factors.

9.3.3 Understanding How You Are Billed - The Tariff

The tariff determines how much a customer is charged for different units of electrical use. The tariff applied to a customer depends on such things as:

- The annual kilowatt hour consumption and peak demand
- The voltage level at the metering point
- Any interruptibility agreement with the customer
- The nature of the operation or the facility (commercial vs. industrial)
- The ownership of transformers serving the customer

Rates applied to electricity demand and consumption vary from region to region in South Africa, from season to season, and from day to day, and from hour to hour. To illustrate, one tariff is summarized in Table 9.1. In this case a demand charge that varies only by season is applied at R15.38 x maximum KVA in the summer, and R17.08 x maximum KVA in the winter. Consumption charges vary by time of day, with peak, standard and off-peak rates as shown.

Table 9.1: Sample Electricity Tariff

Time of Use	Summer (Sept. to May) Cents/kWh (approx.)	Winter (June to August) Cents/kWh (approx.)
Mon – Fri 0000 – 0600	8.9	9.9
Mon – Fri 0600 - 0700	15.5	17.0
Mon – Fri 0700 – 1000	27.7	41.2
Mon – Fri 1000 – 1800	15.5	17.0
Mon – Fri 1800 - 2000	27.7	41.2
Mon – Fri 2000 – 2200	15.5	17.0
Mon – Fri 2200 - 2400	8.9	9.9
Sat 0000 – 0700	8.9	9.9
Sat 0700 – 1200	15.5	17.0
Sat 1200 - 1800	8.9	9.9
Sat 1800 – 2000	15.5	17.0
Sat 2000 - 2400	8.9	9.9
Sun All Day	8.9	9.9

9.3.4 Incremental Cost of Electricity

What will the next kWh purchased or saved be worth? A common, **but incorrect** answer to this question is the average cost per kWh.

- **Why is the average cost per kWh wrong?** Adding or subtracting 1 kWh to or from your consumption would obviously affect the bill differently depending on when the change occurred. Using the summer rates to illustrate, on peak this kWh would cost R0.277, while off peak it would cost R0.089. These are the **incremental** costs per kWh, in the first instance higher than the average cost, and in the second, lower by a significant difference.

- **What if the action influenced both the demand (kVA) and energy (kWh)?** If there was a maximum demand change associated with the energy change, the incremental cost change would be greater. That is, if the energy consumption change was caused by a change in the maximum demand of, say 1 KVA, there would be an additional impact on the bill equal to the demand charge of R15.38 in the summer or R17.08 in the winter. Again, the average cost per kWh would not properly represent this difference.

  Clearly, understanding the incremental cost of electricity is important for correctly estimating the value of energy management measures.

9.3.5 Sources of Thermal Energy

There are many thermal energy sources available. The characteristics of a selection of sources are as follows:

Fuel Oils
- Can be transported to remote locations via train, truck, ship, etc.
- Can be stockpiled on site (with adequate storage).
- High heat content.
- On-site tank storage required.
- Larger boiler equipment necessary than for LPG.
- May need to be heated to flow and atomize properly.
- Produces more pollution on combustion than LPG.
- Potentially high sulphur content can damage stack as well as the environment if the fuel is not burned properly.
- Non-renewable resource.

Natural Gas
- No on-site fuel storage required.
- Clean-burning, low sulphur content.
- High heat content (37.6 MJ/m^3)
- Combustion equipment design is relatively compact and simple.
- Transported under pressure - potential for safety hazard if mishandled.
- Only available through pipeline distribution network.
- Non-renewable resource.

LPG
- Clean-burning, low sulphur content.
- High heat content
- Combustion equipment design is relatively compact and simple.
- Transported under pressure—potential for safety hazard if mishandled.
- Non-renewable resource.

Coal

- Large domestic reserves.
- Relatively inexpensive.
- Potential for use in different forms (chunk, powder, slurry, etc.).
- Higher sulphur and ash content, burns dirty.
- Large on-site storage required.
- Combustion and waste handling equipment necessarily large and complex.
- Low heat content.
- Non-renewable resource.

9.3.5.1 Thermal Energy Content of Fuels

There are two values for the energy content of fuels, *Higher Heating Value* (HHV) and *Lower Heating Value* (LHV). The difference between them is that the LHV does not include the latent energy in the water formed during combustion (and thus is a lower value). In Europe the LHV is commonly used as the energy content value while in North America the HHV is the standard.

All thermal energy values quoted in this document refer to the HHV.

Table 9.2: Representative Heating Values of Fuels

Fuel	SI Units	Imperial Units
Propane	25.3 MJ/l	109,000 Btu/gal(UK)
Wood	19.9 MJ/kg	8600 Btu/lb
Natural Gas	37.6 MJ/m^3	1,008 Btu/ft^3
Electricity	3.6 MJ/kWh	3413 Btu/kWh

9.3.5.2 Purchasing Natural Gas

Natural gas is an emerging thermal energy source in South Africa. Natural gas tariffs are similar in complexity to electricity tariffs, but somewhat different in characteristics and vary according to the specific conditions of each gas utility. The tariff applied to a large volume customer may depend on such things as:

- Total monthly purchase.
- Maximum (negotiated) daily consumption (i.e. “Contracted Demand”).
- No. of days using an amount equal to the Contracted Demand
- No. of days exceeding the Contracted Demand (“Overrun”).
- Direct purchases at source delivered through the utility’s pipeline network.
- A clause obliging the customer to turn off the service within a given time frame (“Interruptible Tariff”)
- Time of year the gas is purchased.

9.3.5.3 Fuel Tariffs and Billing

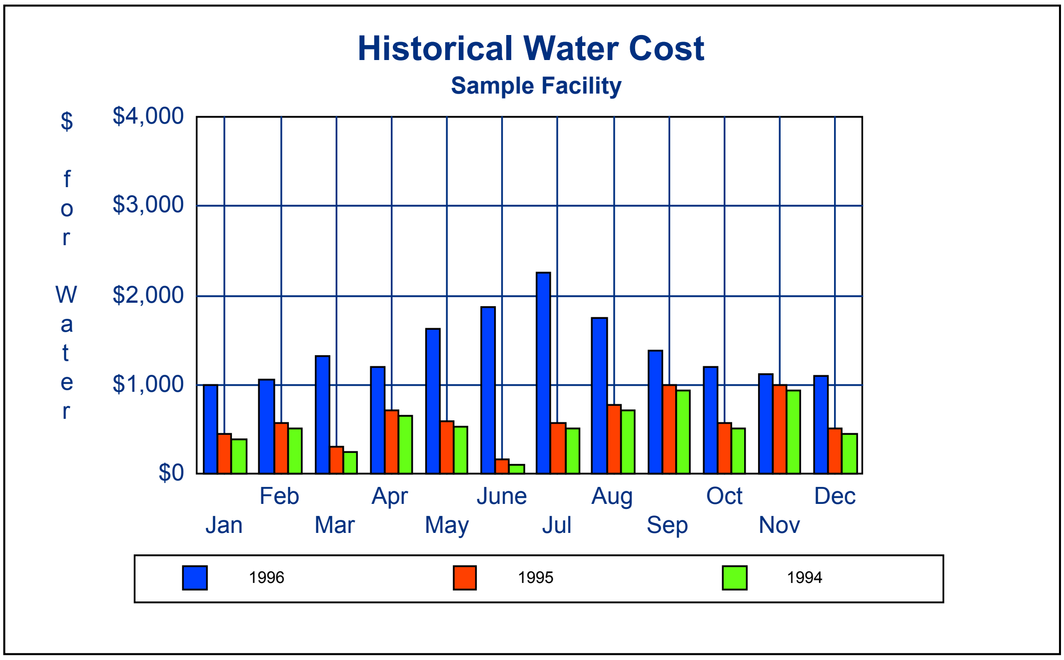
Propane and Fuel Oil tariffs are typically set by the fuel companies. Propane and Fuel Oil are both sold on a per litre basis, and are delivered to the user via delivery truck or possibly pipeline for very large consumers. The purchase price is uniform per litre for a given fuel type, regardless of the quantity purchased. Although the price paid per litre to the supplier can be negotiated, the contracted price will usually be dependent on the quantities used.

9.4 Water Consumption

In many industrial operations, in addition to being a commodity with its own supply constraints, water use and energy use are linked due to the fact that water is typically pumped, heated or chilled. Water consumption can be analysed using the MT&R techniques discussed in Module 7.

Energy savings accompany water savings, sometimes representing greater value in terms of money than the water itself. Historical water costs can be determined and compared as illustrated in Figure 9.2.

Figure 9.2: Historical Water Cost Example

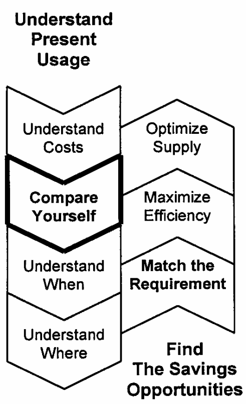


Often the metered water volumes are used to determine the volumes for sewer charges. In industry where there is significant evaporation of purchased water it may be possible to obtain a credit for reduced sewer volumes.

9.5 Step 2: Compare Yourself

Consider the following questions.

- How does the present level of energy consumption in your plant compare to that of last month or last year?
- Do you use more or less energy to manufacture your products or operate your building than the average for your industry?



The answers to these questions can begin to reveal the extent of the overall energy saving opportunity for your plant or facility. From a planning perspective the answers will also allow you to set realistic savings targets for your energy management program. On an ongoing basis, the analysis necessary to answer these questions forms an important energy management activity — that of monitoring and targeting.

9.5.1 *Tabulation of Electricity Data*

Energy consumption data is available from you own accounting records. Utility and fuel supplier invoices contain valuable information about consumption that may be tabulated.

Table 9.3 is a generic billing history table with some columns for derived numbers:

Table 9.3: Generic Electricity Billing History

Historical Raw Data				Derived Data					
Billing Month	# of days	Demand	Energy	Daily Energy	Energy Cost %	Demand Cost %	Total Cost	Blended Cost	Load Factor

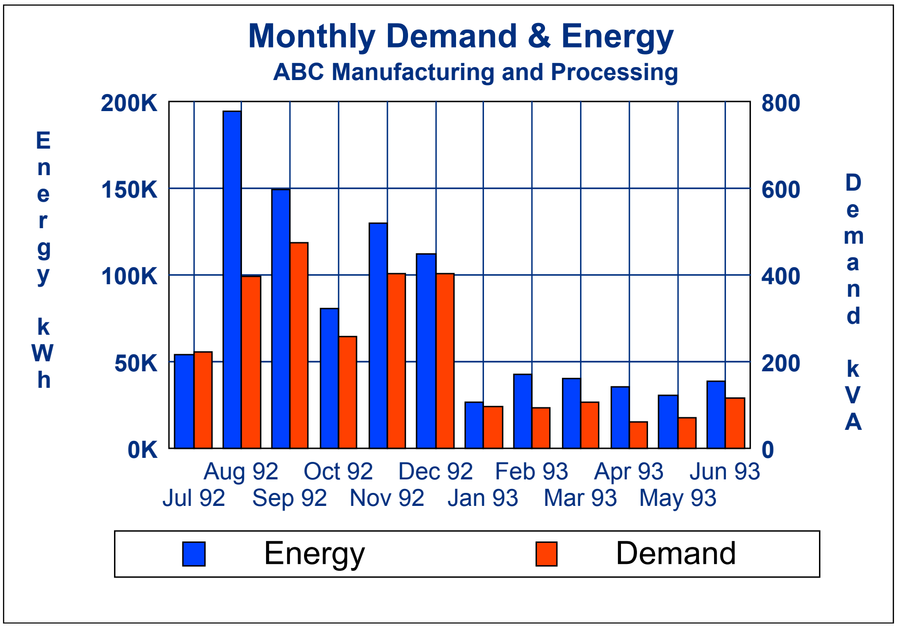


Figure 9.3 Historical Demand and Energy Graph

Starting with the basic historical billing data, a number of calculations may be performed on the data. Some of the major calculations which may be done are:

kWh/Day: kWh in period ÷ Days. Since reading periods can vary, kWh/day is more useful for spotting consumption trends than billed kWh.

Load Factor: kWh ÷ (kW x Days x 24 Hrs./Day). If metered in kVA and power factor (P.F.) is known, substitute kVA x P.F. for kW. If P.F. is not known, assume 90%. Load factor is an indication of the percentage of time the plant is operating on peak.

Cost calculations: Cost of demand, energy and total cost.

Cost Distribution between Demand and Energy: These numbers, along with load factor, can indicate trends or anomalies in energy and demand usage.

Energy and Demand Intensity: Dividing the annual energy consumption (kWh) and the annual peak demand (kW or kVA) by the building area (m^2.) or production can provide useful comparisons to other similar facilities and operations.

Average Energy Cost (Blended rate): The average cost is simply the entire electrical bill (including demand and energy costs) divided by the energy (kWh) used. As noted earlier, it is wise not to use this number when calculating savings. Electricity billing calculations are much more complex than that.

A simple but effective way to view electricity consumption history is in the form of a graph as shown in Figure 9.3.

9.5.2 Tabulation of Fuel Consumption Data

Wherever possible, record data in physically measurable units (cubic meters, kWh, etc.). Avoid units such as Rands which can fluctuate over time (e.g., via utility tariff changes, product price changes, etc.). Where two different energy sources feed thermal energy data into the same process, it may be necessary to convert them to a common unit. In a spreadsheet program, units may be adjusted as needed after the quantities are entered in their original units. Enter the data in a table such as:

Table 9.4: Sample Energy Consumption Data

ABC Widgets Inc.		
Thermal Energy Breakdown		
Date	Purchased Oil (Litres)	Total Energy (GJ)
Jan-94	531,000	20,521
Feb-94	559,000	21,599
Mar-94	520,000	20,081
Apr-94	420,000	16,609
May-94	445,000	17,182
Jun-94	237,000	9,137
Jul-94	256,000	9,868
Aug-94	284,000	10,964
Sep-94	193,000	7,431
Oct-94	354,000	13,651
Nov-94	497,000	19,183
Dec-94	507,000	19,557
Totals:	4,803,000	185,783

Interpolating Periodic Data (If Necessary): Normally it is easiest to analyze energy use on an actual-month basis. In the case of fuel delivered or meters read at uneven intervals (e.g. fuel oil delivered by truck), it is necessary to interpolate between deliveries to attribute the fuel use to the proper month in which it was consumed.

9.5.3 *Tabulation of Other Data*

After gathering and tabulating energy use data, it is necessary to determine what factors influence energy usage and what data, if any, can be gathered about these factors. These may include:

Table 9.5: Other Data

Factor	Data	Units
Product	Product quantities	Quantities, volumes, etc.
Weather	Outside air temperature	Degree-days
Occupancy	Occupied Time	Hours, shifts, days, schedules etc.

Continuing the example of fuel consumption, we determine that weather and production are the only two factors influencing the fuel consumption tabulated. The weather (degree-day data from the local weather office) and production data (numbers of widgets) for the period corresponding to the fuel data, are gathered and entered into the table:

Table 9.6: Sample Energy/Production Analysis

ABC Widgets Inc.				
Thermal Energy Breakdown				
Date	Purchased Oil (Litres)	Total Energy (GJ)	Weather (Degree-Days)	Product (000's)
Jan-94	531,000	20,521	723.2	48
Feb-94	559,000	21,599	658.3	64
Mar-94	520,000	20,081	589.6	59
Apr-94	420,000	16,609	379.5	64
May-94	445,000	17,182	262.8	89
Jun-94	237,000	9,137		75
Jul-94	256,000	9,868		81
Aug-94	284,000	10,964		90
Sep-94	193,000	7,431		61
Oct-94	354,000	13,651	280.3	55
Nov-94	497,000	19,183	419.8	79
Dec-94	507,000	19,557	678.6	45
Totals:	4,803,000	185,783	3992.1	810

Weather data for June to September is ignored, making the assumption that there is no space heating during this period; this also assumes that there is no air conditioning during the period.

9.5.4 *Analysis of Data*

The benefits of tabulating bills over time and doing these simple calculations are:

- To make an initial correlation between the energy and demand figures, and the operation of the plant. An example of the correlation is provided in the next section.

- To set a savings objective or target.
- To reveal, and flag any unexpected increases in demand and/or consumption. Later we can track down and, where necessary, correct the condition causing the increase.
- To confirm the savings expected from any energy conservation measures that have been implemented. As an example, we should be able to ensure that new Building Management Systems are delivering savings on an on-going basis.
- To evaluate and compare the energy and demand of one building to another or to standards ("benchmarks") on the basis of area, or energy density. Additional information must be known such as heated or cooled areas (sq. ft. or sq. m.), type of heating fuel, etc. These types of calculations are also known as energy use intensity, energy budget, and demand density.

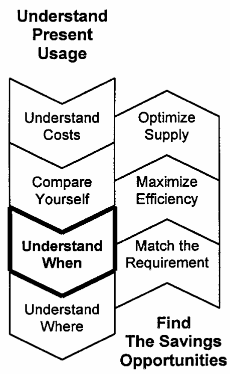
There are two principal types of comparisons that can be made here:

- **Historical** An internal comparison of your energy consumption, for instance July this year to July last year, or all of 2003 to all of 2002.
- **Benchmark** An external comparison of your overall energy consumption levels to external references or benchmarks.

The relative merits of benchmarks have been discussed in connection with monitoring and targeting in Module 7.

9.6 Step 3: Understand When Energy is Used

9.6.1 The Demand Profile



The demand profile for a facility, building, service entrance or any user of electricity is simply a record of the power demand (rate of energy use) over time. Its purpose is to provide detailed information about how the facility, as a whole, uses energy. It is, in essence, the "electrical fingerprint" of the facility. The demand profile builds an understanding of when energy is used.

The simplest demand profile would be a series of manual utility meter readings recorded monthly, daily, hourly, or, if possible, more frequently. The particular time interval used will depend on what the information in the demand profile is to be used for. Table 9.7 is a sample of a manually recorded hourly demand profile.

The information required for a monthly demand profile is present on most utility invoices. In that case there would only be twelve values available for a year. An alternative to the tabulation of demand readings shown in Table 9.7 would be a graph similar to that shown in Figure 9.8. This method of presentation facilitates comparison of the relative demand levels throughout the day, and a quick identification of the hours of peak power demand along with start-up and shut-down characteristics.

Table 9.7: Manual (Tabular) Demand Profile

Hour	kW	Hour	kW	Hour	kW
1:00 am	45	9:00 am	120	5:00 pm	110
2:00 am	47	10:00 am	122	6:00 pm	82
3:00 am	43	11:00 am	121	7:00 pm	60
4:00 am	46	12:00 pm	100	8:00 pm	61
5:00 am	45	1:00 pm	124	9:00 pm	63
6:00 am	62	2:00 pm	135	10:00 pm	61
7:00 am	69	3:00 pm	120	11:00 pm	65
8:00 am	95	4:00 pm	123	12:00 pm	50

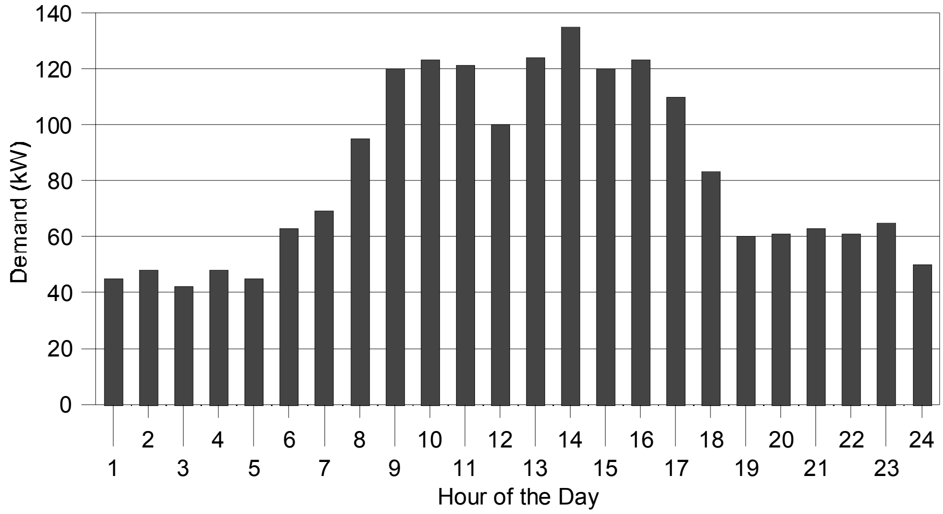


Figure 9.4: Graphical Demand Profile

The most commonly used form of the demand profile is similar to that illustrated in Figure 9.5. The profile covers a period of approximately 24 hours; slightly more than 24 hours is better than less. The demand (in this case kW) appears on the vertical axis, while the time, in hours, appears on the horizontal axis

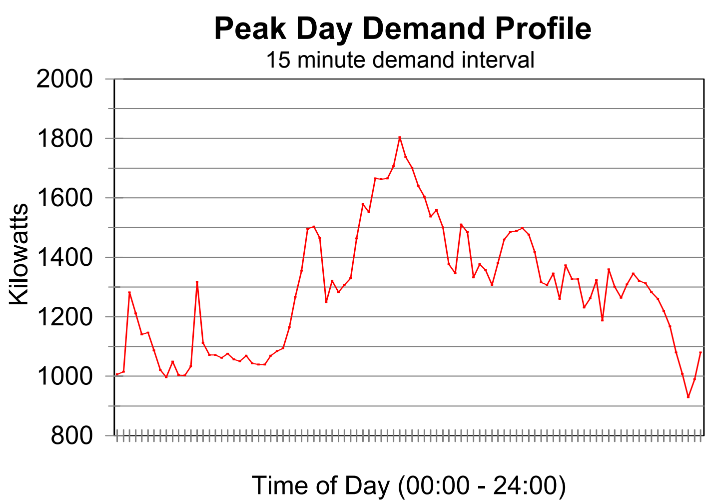


Figure 9.5: 15 minute Interval Demand Profile

A recording power meter was used to generate this demand profile. Readings are generally recorded automatically, less than one minute apart. In some cases, the readings may be adjusted by the recording instrument to match those that would be taken from the utility meter.

The profile shown in Figure 9.5 contains real power information measured in kilowatts (kW). More sophisticated recording power meters are capable of recording these values and others, including three phase voltage, current, power factor and power quality parameters. Comparing Figures 9.4 and 9.5 clearly shows the advantage of using a recording power meter. Significantly more detail is available, although the hour by hour profile remains a valuable starting point.

9.6.2 Analyzing the Demand Profile

The information that may be obtained from the demand profile is not limited to that mentioned above; these are some of the most obvious items. Profiling not only the facility as a whole, but also departments or sections, will allow the development of detailed knowledge of the facility's power demand habits.

The demand profile is the electrical "fingerprint" of a facility's electrical consumption patterns. Key information may be obtained by reading or interpreting the profile, loads that operate continuously and could be shut down, loads that contribute unnecessarily to the peak demand, or possibly loads that are operating abnormally and require maintenance.

Many electrical loads leave behind very distinct fingerprints as they operate. By recognizing the patterns associated with each component, it is possible to identify the contribution of various loads to the overall demand profile.

Table 9.8: Demand Profile Factors

Information	Description
Peak Demand	The time, magnitude and duration of the peak demand period or periods may be determined.
Night Load	The demand present at night (or during unoccupied hours) is clearly identified.
Start-Up	The effect of operation start-up(s) upon demand and the peak demand may be determined.
Shut-Down	The amount of load turned off at shut-down may be identified. This should equal the start-up increment.
Weather Effects	The effect of weather conditions upon the demand for electricity can be identified from day to night (with changing temperature), and from season to season by comparing demand profiles in each season.
Loads that Cycle	The duty cycle of many loads can usually be seen on the demand profile. This can be compared to what is expected.
Interactions	Interactions between systems may be evident, for example, the increased demand for electric heat when ventilation dampers are opened.

Occupancy Effects	Often the occupancy schedule for a facility is reflected in the demand profile, if not, this could identify control problems.
Production Effects	As in the case of occupancy, the effect of increased load on production equipment should be evident in the demand profile, again, its absence may be evidence of problems.
Problem Areas	A short-cycling compressor is usually easy to spot from the demand profile.

9.6.3 Obtaining a Demand Profile

Facility demand profiles may be obtained by a number of methods including:

- Periodic utility meter readings.
- Recording clip-on ammeter measurements.
- Basic and multi-channel recording power meters.
- A facility energy management system (EMS).
- A dedicated monitoring system.

While the first method above is the cheapest and simplest to implement, the data it produces is limited. At the other end of the spectrum, dedicated monitoring systems are expensive and complex to set-up and use, but yield a wealth of information, from real power to power quality.

Whatever technique is used, it is important that the demand profile be measured at a time when the operation of the facility is typical and, if at all possible, the peak demand is equal to the maximum demand as registered by the utility meter for the current billing period. This is important since the overall objective in measuring the load profile is to identify which loads contribute to the billed peak demand.

A Dedicated Monitoring System

At a minimum, such a system would measure the power consumed at the service entrance. Typically, such systems are implemented to provide sub-meter information for selected parts of the overall facility. Monitoring systems are generally designed for accurate measurements and effective data storage and presentations. Measurements of many other parameters may be correlated with demand to aid in the analysis of the demand profiles. Dedicated monitoring systems are generally at the core of larger fully integrated monitoring and tracking systems.

9.6.4 Opportunities for Savings in the Demand Profile

Often, opportunities for savings can be found in the demand profile. The following are typical examples of savings opportunities:

- ❑ A peak demand that is significantly higher than the remainder of the profile for a short amount of time is an opportunity for demand reduction by scheduling.
- ❑ A high night load in a facility without night operations presents an opportunity for energy savings through better control or possibly time clocks.
- ❑ Loads that cycle on/off frequently during unoccupied periods suggests that possibly they could be shut down completely.

- ❑ High demands during breaks in a production operation or insignificant drops at break times suggests that equipment idling may be costly, consider shutdown.

- ❑ Make sure that systems are not starting up before they are needed and shutting down after the need is past. Even 1/2 hour per day can save a significant amount if the load is high.

- ❑ Peak demand periods at start-up times suggest an opportunity for staged start-up to avoid the peak.

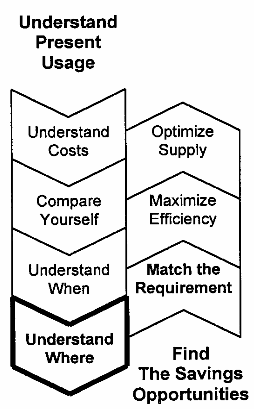
- ❑ If the billed demand peak is not evident on a typical demand profile, this suggests that the load (or loads) which determine the demand may not be necessary (if they only operate once in a while). Consider scheduling or shedding these loads. Also check the billing history to see if the demand peak is consistent.

- ❑ A large load that cycles frequently may result in a higher peak demand and a lower utilization efficiency than a smaller machine running continuously. Consider the use of smaller staged units or machines. Such a strategy may also reduce maintenance since machine start/stop results in increased wear and tear.

- ❑ Short cycling loads are a clue to potential maintenance savings and failure prevention.

In some cases, non-essential loads may be temporarily disconnected during peak periods. This practice is commonly referred to as *peak shedding* or *peak shaving*.

9.7 Step 4: Understand Where Energy is Used



Businesses use inventories to keep track of many items. An inventory of the uses of electricity and thermal energy will help to develop a baseline that will allow you to focus your energy management efforts upon the areas of greatest opportunity.

9.8.1 The Electrical Load Inventory

Making a list or inventory of all loads in a facility answers two important questions:

- **Where** is the electricity used?

- **How much and how fast** is electricity used in each category?

Often the process of identifying categories of use allows waste to be easily identified, and this often leads to low cost savings opportunities. Identifying the high-consumption loads lets you consider the best savings opportunities first.

Because the inventory also quantifies the demand (or "how fast") associated with each load or group of loads, it is invaluable in further interpretation of the demand profile.

Table 9.9 is a sample load inventory taken from a small industrial plant. There are several loads including lighting, pumps, process equipment and an air compressor.

The punch press appears in the inventory twice, once for each mode of operation. When idling, the press consumes far less power than when engaged.

Table 9.9: Sample Load Inventory for Industrial Plant

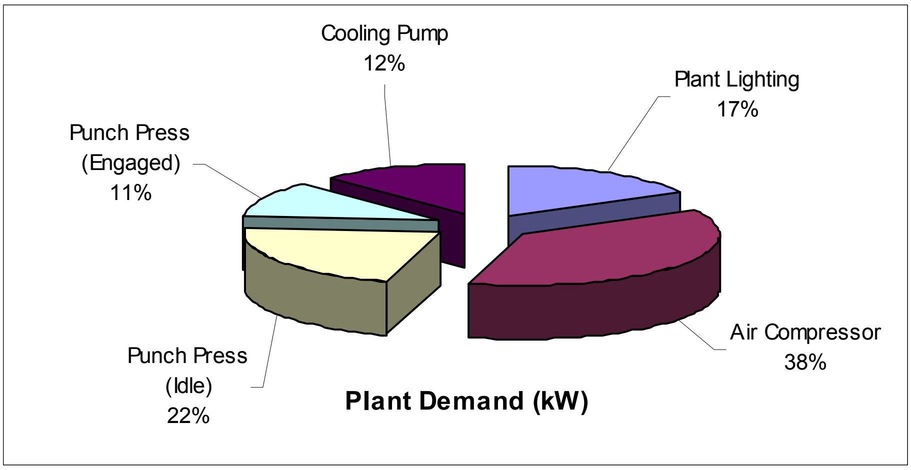
Load Description	Quantity	Unit kW	Total kW	Diversity Factor	Peak kW	Hours	Energy kWh
Plant Lighting	50	0.5	22.5	100%	22.5	400	9,000
Air Compressor	1	50.0	50.0	100%	50.0	732	36,600
Punch Press (Idle)	2	15.0	30.0	100%	30.0	300	9,000
Punch Press (Engaged)	2	75.0	150.0	10%	15.0	40	6,000
Cooling Pump	1	20.0	20.0	80%	16.0	150	3,000
Total Load					**133.5**		**63,600**

The equipment data in Table 9.9 was obtained from a survey of the plant; a simple spreadsheet was used to calculate the peak demand and energy values according to the calculation method outlined in Table 9.10.

Table 9.10: Sample Load Inventory Calculations

Data-entry Item	Units	Description
Quantity	(a number)	The quantity of this particular item.
Unit Load	kW	The load in kW for one of this particular load.
Total kW	kW	Quantity. x Unit Load.
Hrs/Period	hours	The estimated hours of use per period
kWh/Period	kWh	Total kW x Hrs/Period
On @ Peak	Yes/No	Is this load on during the peak period identified in the demand profile?
Diversity Factor (Div'ty Factor)	0 - 100%	That fraction of the total load that this particular item contributed to the peak demand.
Peak kW	kW	If the load is on peak, then this value equal to the Total kW x Diversity Factor

Finally, the load inventory data can be represented graphically to show the distribution of demand and energy consumption. It is interesting to note the difference between the graphs, revealing that any given load may have a greater impact upon demand or energy depending upon its size and mode of operation.



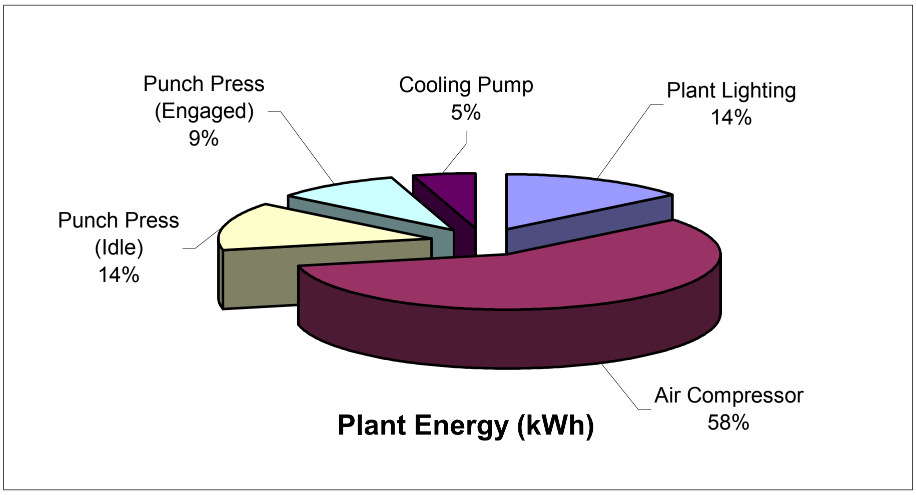


Figure 9.6: Breakdown of Plant Demand and Energy

9.8.2 Thermal Energy Inventory

An energy flow diagram provides a way to visualize the thermal energy flows in a facility and to begin to develop an inventory of the uses and outflows.

Often, the process of preparing a list or inventory of energy use reveals unknown or overlooked instances of waste of energy and possibilities for heat recovery—a technique for re-using waste heat flows.

9.8.2.1 Energy Flow Diagram

The energy consumed in industrial plants takes many forms. Typically, a facility will purchase an energy source such as coal or fuel oil to generate heat for a variety purposes. In most cases, electricity will be purchased for use in lighting, motors and in some cases as a source of heat.

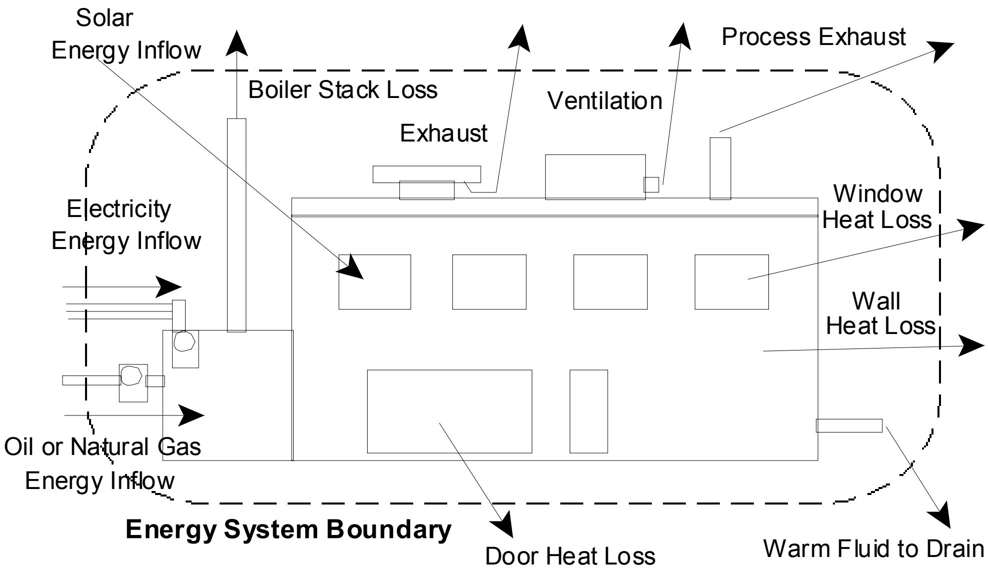


Figure 9.7: Facility Energy System

One of the most basic principles of the world in which we live—the First Law of Thermodynamics—is that energy cannot be created nor destroyed, but simply converted from one form to another. Energy is often purchased in a chemical form, such as coal or oil, and then converted to thermal energy or heat. Steam, hot water and air help to transport heat through and out of a facility. When studying and analyzing energy usage it is necessary to define a boundary around a plant or building which encloses the specific energy system being studied. This is depicted in Figure 9.7.

A financial auditor balances a corporation's financial books by ensuring that the expenses (money outflows) equal the income (money inflows). Likewise, an energy auditor will balance all energy outflows against energy inflows. Unlike financial systems however, this input versus output balance must exist physically; otherwise, the facility would quickly heat up or cool down without limit. As the energy inflows are usually metered, they are easily quantified. The Energy Outflow Inventory attempts to account for all energy leaving the facility.

As illustrated in Figure 9.7, energy inputs cross the energy system boundary at various points of entry. In the case of electricity, gas, and oil, these are discrete locations such as the electrical service entrance and fuel delivery pipes. In contrast, solar energy enters in a more diffuse way through those building walls and windows that are exposed to the sun. Some energy outflows occur at discrete points of exit such as drain pipes, chimneys, and exhaust fans, but some of a facility's energy also leaves in diffuse fashion through its walls and windows. Although incoming energy may cross the energy system boundary in a variety of forms, energy almost always leaves the facility in the form of heat. There are exceptions, which include certain processing plants, where some of the incoming energy leaves in chemically-bound form in the product that the plant produces.

The step preceding the development of an energy balance is the preparation of an energy flow diagram. A simplified version of an energy flow diagram is shown in Figure 9.8.

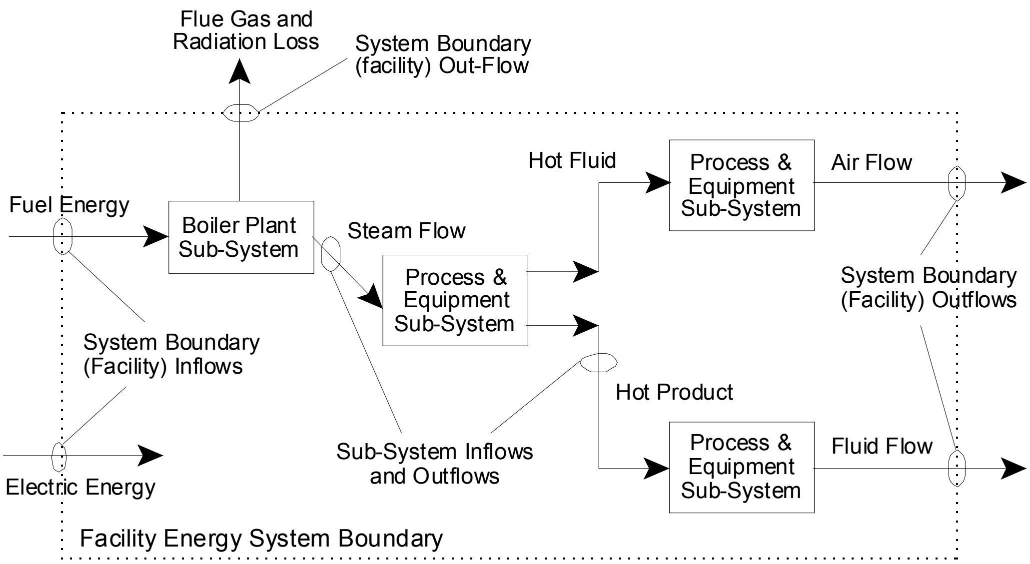


Figure 9.8: Energy Flow Diagram

The process of preparing a diagram similar to this for your facility will help to develop an understanding of precisely where energy is used. It will also provide a valuable reference later when you begin to look for savings opportunities. Each of the flows can be scrutinized for reduction opportunities. This diagram is also useful when considering recovering heat from the various necessary energy outflows.

9.8.2.2 Begin to quantify flows

In conjunction with building an energy flow diagram it is useful to begin to quantify the flows of energy in terms of rate (kW or kVA) and amount (GJ per day, month or year).

The information necessary to perform these energy calculations is readily available for many pieces of equipment and processes:

Nameplate Ratings - equipment specifications provide thermal energy requirement data.

Steam Flow - there may be steam flow metering available in your plant. Steam consuming equipment will have a specified requirement for steam flow rate.

Hot Water Flows - many waste energy flows are warm or hot fluids which may be easily quantified by the common formula:

Heat Flow Rate = Mass Flow Rate (kg/sec) x Temperature Difference (°C) x C

The resulting units are kilowatts (kJ/s), the constant C is the specific heat of the fluid. For water the value of C=0.0042 kJ/kg.

9.8.2.3 The Energy Impact of Water Efficiency

Water efficiency and energy efficiency go hand-in-hand. Although paybacks on water efficiency measures may be attractive on their own, they can be made all the more so when the value of energy saved is factored in (or *vice versa*).

Water that is saved by efficiency measures in a plant will often have been

- heated
- or chilled
- and/or pumped
- and/or treated with chemicals (as with boiler feed water).

Saving the water also saves the intrinsic energy or the contained chemicals.

As with energy, an inventory and calculated balance of water end-use versus overall consumption is a good starting point for the identification of opportunities. Figures 9.9 and 9.10 below illustrate the results of a water inventory and balance.

The Energy Analysis Toolkit - [Water Audit Tool]

File Edit Window Recalc Help

Annual Water Volume Balance & Summary

Area of Water Consumption	Graph Legend	Sub-Metered m³	Sub-Metered %	Calculated m³	Calculated %
Main Production	Prod'n	15,600	12%	8,928	7%
Service Area	Service	6,700	5%	7,056	5%
Mechanical Systems	Mech Eqp	78,000	60%	79,200	60%
Landscaping	Landscape	16,000	12%	18,000	14%
Fleet Washup	Fleet	12,000	9%	15,120	11%
Other Production	Other	1,000	1%	3,600	3%
		129,300	100%	131,904	100%

Total consumption based on device/process calculations:	131,904 m³
Total consumption based upon water records for year 1996:	134,800 m³
Difference from calculated for the year 1996:	2,896 m³
Relative difference:	2 %

Figure 9.9: A Water Inventory and Balance

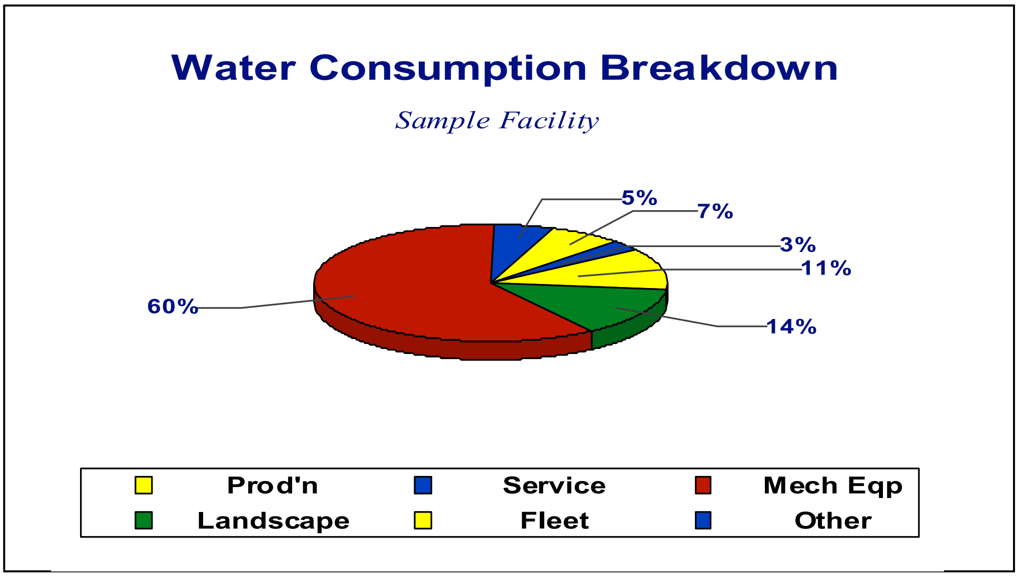


Figure 9.10: A Graphical Presentation of the Water Inventory Summary

9.8.3 Benefits of Energy Inventories

Cost Allocation. Ultimately, costs for each of the uses and energy flows could be calculated by applying the unit cost of thermal energy as calculated in Chapter 3. This would provide a good baseline or guide as to which processes and systems are your most expensive users of energy.

A starting point for any energy management program. It provides a reference point against which to assess opportunities. The maximum that an energy opportunity can save is what is presently used. The load and water inventory provides this information.

A clear picture of where energy and water is being used. It allows you to prioritize and concentrate your actions on the big consumers.

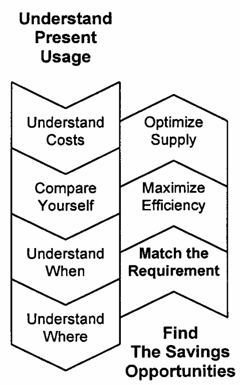
Benchmarks for comparison. Demand intensity (Watts/m^2), energy intensity (kWh/ m^2) or production efficiency (kWh/unit) broken down by component (lighting, cooling, production etc.). These numbers can be useful when compared to design or target benchmarks.

A framework for ongoing monitoring. It allows you to begin to reconcile/understand increases in future consumption. The key monitoring points can be identified from the inventory.

Energy is a manageable business expense. The load inventory provides information that is necessary for good energy management.

9.8 Identify Savings Opportunities: A Critical Assessment

All energy consuming equipment and systems were design to meet a specific need. This may be as simple as providing illumination in the case of a lighting system – or far more complex as in the case of an integrated processing plant.



In identifying energy savings opportunities we are endeavouring to reduce the level of energy use while still meeting the original requirement.

How can this be accomplished? To some extent the solution will depend upon the details of each circumstance. Some common situations are listed below. You may be able to think of a few more:

- The original requirement for which the system was designed has changed – the original system may be over or under sized for the new requirement.
- The requirement is not continuous – the system was not designed to be shut down.
- The requirement varies with time – the system has little or no capacity control.
- The system/equipment is old – new technology is now available.
- Energy costs were not an issue when the equipment/system was designed/installed.
- Maintenance is deferred or absent – the equipment continues to operate.

♦ The operational practices associated with system/equipment are – "the way it's always been operated".

♦ The level of energy consumption is not monitored or known.

9.8.1 A Critical Assessment

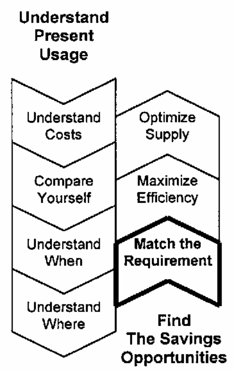
The assessment of savings opportunities involves a process that begins at the point of end-use, where the requirement is met, and proceeds methodically back towards the point that energy is obtained or purchased:

1. ***Begin with the requirement.***
2. ***Ensure that that requirement is valid today and profile any variation.***
3. ***Next, make sure that the system operates in a way that meets the requirement as closely as possible both in time and magnitude.***
4. ***Now, consider the way that the existing equipment or system is operated.***
5. ***Look for ways to operate and maintain the equipment at higher efficiencies.***
6. ***Next, look at the existing technology – could it be modified to operate at a higher efficiency?***
7. ***Is new technology available that is more efficient?***
8. ***Finally, consider the energy source – is there an alternative that is more cost effective.***

The sequence of actions in this assessment is important. It would not be logical to install a new technology without clearly defining what the requirement was, and sizing it to that requirement. In a similar fashion the return on investment for a piece of energy efficient technology will depend upon the operating times – any action which changes the operating times must at least be considered first.

There are three distinct steps in this critical assessment sequence described above.

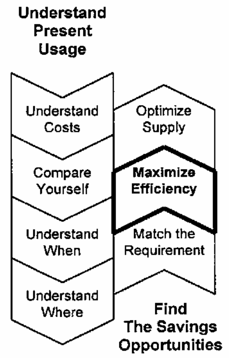
9.9 Step 5: Match Usage to Requirement



The first and most important step in realizing savings opportunities is to match what you actually use to what is needed. The key consideration here is the **duration** of use and the **magnitude** of use.

Examples:
- ❑ Reduce the operating times of idling air compressors.
- ❑ Re-train operators in equipment operation.
- ❑ Turn-off lights in unoccupied areas.
- ❑ Provide specific task lighting – and lower area lighting.
- ❑ Moderation of chilled water temperatures with cooling requirement.
- ❑ Match steam pressure output of boiler to maximum requirement – avoid pressure reducing valves (PRV's).
- ❑ Replace 1 large boiler with 3 smaller units of equal capacity and sequence their operation to match need.
- ❑ Reduce moist air infiltration into storage coolers and freezers.
- ❑ Eliminate throttling the output of cooling pumps to match flows by:
  - Trimming pump impeller
  - Resizing the pump
  - Installing a variable speed drive (VSD) on pump motor.

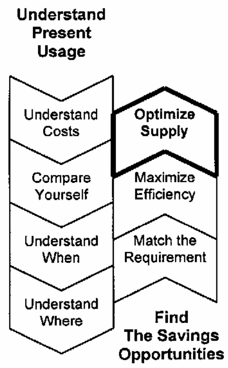
9.10 Step 6: Maximise System Efficiencies.



Once the need and usage are matched properly, the next step is to ensure that the components of the system meeting the need are operating as efficiently as possible. In this step the impact of operating conditions, maintenance and equipment/technology will be considered.

Examples:
- ❑ Monitor combustion efficiencies daily and adjust combustion controls accordingly.
- ❑ Repair leaking steam traps.
- ❑ Return condensate to boiler from process areas.
- ❑ Reduce piping flow restrictions in chilled water loops.
- ❑ Insulate steam pipe fittings.
- ❑ Replace air compressors with a newer, higher efficiency unit.
- ❑ Clean air filters on a regular basis.
- ❑ Clean and lubricate electric motors regularly – ensure operation at the correct voltage.

9.11 Step 7: Optimise the Energy Supply.



The first two steps will reduce your requirement for energy. At this point it is logical to seek the optimum source or sources for the net energy requirement.

Examples:
- ❑ Heat Recovery – utilizing waste heat sources to displace purchased energy
- ❑ Heat Pumps – capturing heat from low grade or heat source waste heat source
- ❑ Co-generation – generating heat and electrical power on-site.
- ❑ Renewables – solar, wind or other renewable sources.
- ❑ Competitive Supplier – negotiating supply contracts at a lower net price.

These three steps together make up the second part of the Seven Steps to Energy Efficiency.

The actions taken to reduce energy consumption can be categorized into two types:

- Changing the operation of the existing systems and equipment.
- Changing the system or equipment technology

Operational actions tend to be lower in cost to implement. Often, energy savings opportunities involving some type of operational action will be ***called low cost or housekeeping measures***.

In contrast, those measures that require investment in new technology will tend to have a higher cost of implementation. These actions are sometimes referred to as ***retrofit measures.***

A good energy saving project will combine both operational and technological actions to achieve attractive savings, with a good return on investment.

9.12 Assessing the Benefit

A comprehensive assessment of the benefits and costs associated with an energy savings opportunity extend well beyond the cost of the energy involved and in many cases may involve:

Benefits:

- direct energy savings
- in-direct energy savings
- comfort/productivity increases
- operation & maintenance cost reductions
- environmental impact reduction

Costs:

- direct implementation costs
- direct energy costs
- in-direct energy costs
- operation & maintenance cost increase

Typically, the direct energy savings and costs are the most easily quantified. The load and energy inventories provide a good basis for these calculations.

The indirect energy savings and costs tend to be more obscure and often result from the interaction of systems. Consequently, a strong technical knowledge is required for proper assessment. Nevertheless, the savings and cost can be substantial and should not be overlooked.

The most difficult impacts and those with potentially the highest cost impact are those on comfort and productivity. While not necessarily quantifiable, these impacts must be considered – if for no other reason than to avoid any potential negative impact. These issues are discussed further in the next section.

9.12.1 Assessment of Disadvantages Associated with Savings Opportunities

The assessment of savings opportunities is generally conducted from a cost/benefit perspective. First, what are the savings (or the benefits) associated with the opportunity, and second, what is the cost of implementation required to realize the opportunity? Depending on the type of economic analysis used, consideration may also be given to the cost of maintenance with and without implementation.

A further and often overlooked consideration is the indirect costs which may be associated with the action to be taken. These can include such things as a reduction in illumination level and heating cost increase when lighting is reduced, since energy for lighting will contribute to building heating in the cooler season.

An extreme indirect cost could be the reduction in personal productivity due to unexpected reductions in light levels or, possibly, a safety problem created by an improperly located motion detector that switches lights off when a space is still occupied. It becomes clear that even the most attractive savings opportunity may not be attractive when all impacts are considered.

Often these costs are declared "unforeseen". A thorough assessment should anticipate the majority of them, and clearly identify the associated risks before any changes are implemented.

Another consideration that is neglected is the technical/economic risk associated with the planned implementation. Savings are not always guaranteed. It is unlikely that a motion detector installed to switch lighting in a heavy traffic area will pay back. Replacement of a poorly loaded motor with an energy-efficient motor may result in a lower overall efficiency owing to the partial load characteristics of the energy-efficient motor. When the savings predicted depend on varying operating conditions or occupant habits, there is a risk that the savings expected may not be realized, or realized to a lesser extent.

In these cases, the indirect costs are, in fact, uncertain savings. A conservative assessment would be based only on certain savings. If the uncertain savings actually occurred, then this would be a bonus.

In summary, consider not only the direct costs but also the impact that the planned implementation will have upon occupants, comfort, productivity, safety, equipment maintenance, along with any potential interactions between the new equipment and existing systems and the likelihood that the savings expected will be realized.

9.12.2 Savings

There are potentially three areas of savings to be directly realized from implementing an energy savings opportunity.

The first two of these savings are associated with electricity. Savings could result from reductions in demand, or energy, or both. This situation may be complicated by the complex rate structures or tariffs incorporating such features as time of use demand ratchet clauses.

The most reliable method of estimating the actual electricity cost savings is a comparison of monthly and annual bills calculated from before and after the proposed action. Quick estimates may be made from the incremental costs of demand and energy:

Electrical Energy Savings:

These would simply be equal to the energy saved (kWh) times the incremental energy rate (R/kWh), almost always the last block energy rate.

Electrical Demand Savings:

If the action implemented has a measurable effect on the peak demand, the demand saving would be equal to kW or kVA saved times incremental demand rate (R/kW or kVA)

Fuel Energy Savings:

While fuels are typically purchased with a simpler price structure than electricity some natural gas rates can be quite complex involving factors such as the contracted daily demand and interruptible contracts. In this instance, as in the case of electricity, comparison of before and after bill calculations would yield the most reliable savings estimates.

Quick estimates may be made from the incremental costs of fuel. In any calculation of thermal savings the actual end-use savings must be “grossed up” by the combustion equipment efficiency. Hence, the cost savings can be estimated from the end-use saving by:

$$Fuel\ Savings = \left(\frac{End\ Use\ Savings\,(GJ)}{Boiler\ Efficiency}\right) x \frac{1}{\left(GJ/_{Unit}\right)} x\ Incremental\ Cost/_{Unit}$$

In addition to the direct electricity and fuel savings calculated on the measure itself, there may be other considerations:

Indirect savings such as:

- Reduced air conditioning (A/C) loads due to more efficient or switched lighting or motors.
- Reduced maintenance costs; many incandescent lighting retrofits pay for themselves on the basis of maintenance cost reduction alone. The energy savings are a bonus.
- Less re-lamping labour and lamp cost from switching to a longer-life lamp.
- Increase in employee productivity from converting to a higher quality light source or providing more effective ventilation and exhaust.
- Increase in motor life, hence reduced replacement cost, due to improved maintenance – the direct savings would be less energy consumption from a more efficient motor.

9.12.3 Costs

When evaluating the cost of implementing a measure, be sure to include all the costs, including:

- ♦ Initial cost of implementing the retrofit (quotes by contractors).
- ♦ Decrease in equipment life due to increase in switching, e.g., a standard 40W Rapid Start fluorescent tube operated for 10 hours per start will last 28 000 hours. The same tube operated only 3 hours per start will last 20 000 hours.
- ♦ Any increase in maintenance costs such as higher cost lamps and ballasts, higher cost of repairs or lower life of any replacement energy-efficient equipment.
- ♦ Training costs to ensure proper operation of the new energy efficient technology.

9.12.4 Environmental Impact

Measures to improve energy efficiency will reduce emissions in two ways:

- ♦ Energy efficiency measures for on-site combustion systems such as boilers, furnaces or ovens will reduce emissions in direct proportion to the fuel savings. These are termed direct impacts.
- ♦ Reduced electrical consumption will lead to emission reductions at the electric power generating station, or the mitigation of other environmental impacts related to hydroelectric stations. These are termed indirect impacts.

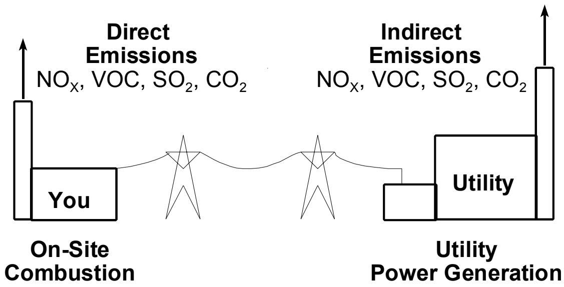


Figure 9.11: The Environmental Impact of Energy Use

Emission factors for various energy sources relate energy production to these gaseous pollutants. Although the emission of NOx, SOx and VOCs are important from the point of view of urban air pollution, the emission of CO_2 as a greenhouse gas is a concern in light of the climate change issue and the potential for achieving carbon emission reduction credits.

Table 9.11 gives some typical CO_2 emission factors. These factors are expressed on a per equivalent kWh basis. The factor for electricity reflects the power generation mix in South Africa, and the efficiency of transmission and distribution to the end-user's service entrance.

The factors for the fuels are calculated from the heating value of the fuel, converted to kWh. Calculated emissions would be based on actual fuel consumption rather than energy delivered to the end-use, because this quantity would not allow for conversion efficiency and other losses.

Table 9.11: CO_2 Emission Factors for Various Fuels

Energy Source	Emission Factor (kg CO_2/ekWh)
Electricity from grid	0.90
Coal	0.33 (2.44 tonnes CO_2/tonne coal) typical[1]
Heavy Fuel Oil	0.26
LPG	0.21
Natural Gas	0.19

9.13 Summary

The benefits that may be derived from energy management impact on organisational competitiveness and energy security, overall performance efficiency, product quality, and environmental compliance. The means of achieving are within the capacity of every organisation to develop, given a commitment to do so. While some additional competency development related to the tools and strategies outlined in this workshop may be needed, our experience suggests that every organisation can begin their journey towards improved energy efficiency tomorrow.

9.13.1 How Do We Begin?

The answer to this question, of course, depends on where your organisation is today. Some companies are well down the road towards energy efficiency, and are looking for incremental improvements that the methods introduced in this workshop may aid. Others truly are looking for a starting point.

International experience with energy-managing organisations suggests that virtually every company can benefit by:

- Mapping out a strategic plan for the implementation or advancement of energy management practices, beginning with efforts to prepare the organization and gain control of current energy use—as discussed in Module 2;

- Assessing the organisational management climate that supports energy management, using the energy management matrix discussed in Module 3, and taking action to move upscale in these critical factors;

- Implementing energy use information management practices—using data that are currently available to begin with, applying the techniques of MT&R discussed in Module 7, investing in new measurement, data collection and analysis systems when the benefit of doing so becomes apparent;

- Deploying knowledgeable plant personnel to assess current energy use and to identify savings opportunities, following the user-friendly 7 Steps approach described in this Module.

The effort does pay off! Good luck!