Energy and Sustainability Topics – Electricity - A first primer

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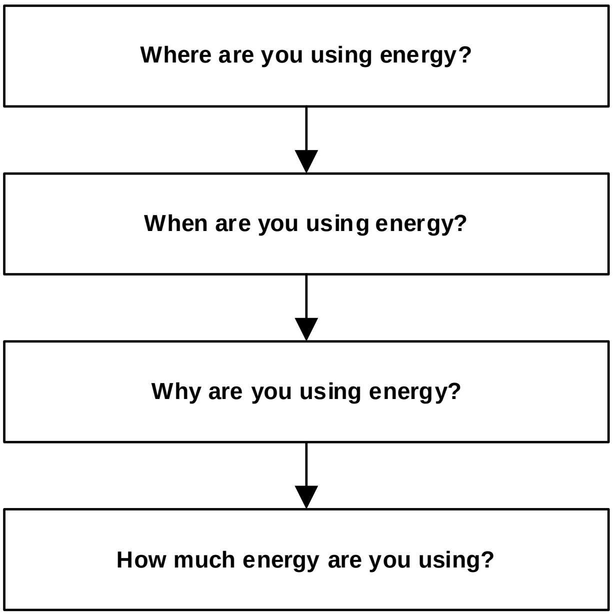
1. A structured approach



2. Where are you using energy?

Glass processing uses energy for four basic reasons:

- To drive motors.
- To generate heat.
- To provide cooling.
- To provide light.

This guide covers all of these areas but the first task is to assess where you are using energy.

The initial survey

The most rapid assessment method is to take a walk around the site to observe where and how large are the motors and heaters. Ask operators and factory staff (particularly the maintenance staff) how the electrical and other energy inputs are laid out.

Note what loads exist, how long they are used and how the power is distributed. The information will provide a base to start your improvements.

Lighting is a topic that can often be used to demonstrate the value of energy study. Look for areas where lights are on and there are no people.

- Note which areas have the largest electrical load.
- Look for the largest machines - they will most likely also have the largest motors and create the largest load, when used. Is the insulation in good condition (if present).
- Which motors are left running?
- Does the compressed air pressure need to be so high, or the vacuum so low?
- Which lights and heaters are still on?
- Where can you hear steam and compressed air leaks?
- Which cooling water pumps (and chillers) and vacuum pumps are still running? Is the lighting dirty or broken?

- Why are the motors that size and would a smaller motor be more efficient?

Do not aim to make accurate measurements. Tour the factory to gain an impression of where the largest number of motors and the biggest motors are located.

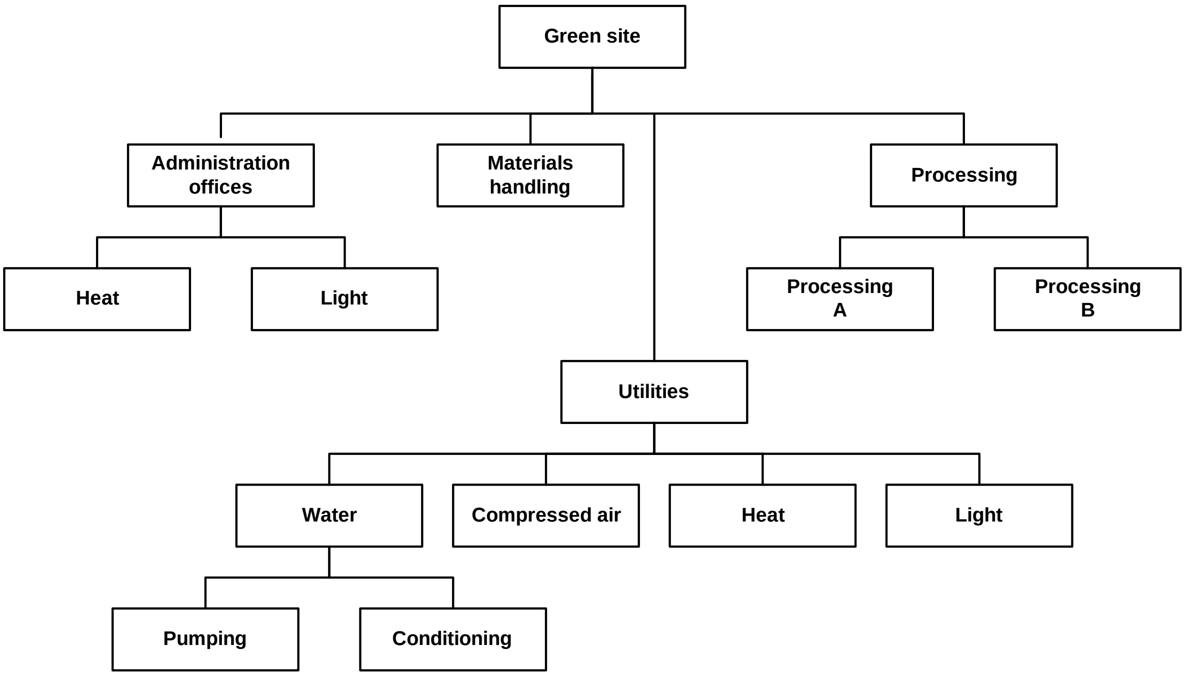
Challenge whether there are any good reasons why machines need to be kept idling to be ready for the next production run. Use this walk round as an opportunity to check on simple maintenance measures and ask yourself questions about accepted practices.

Repeat the tour during a lunch break and again, after normal working has ceased. At this stage look for machines that are still running and lights that are on continuously.

Do not seek high accuracy at this stage - you need to get a feel for the operation before you can start to improve it! The important thing is to carry out a survey as soon as possible. You cannot start saving money until you have found out where you are wasting it!

The survey results

Construct a diagram of energy distribution similar to that shown below.



This will help to ensure that no part of the site is overlooked. Based on what you have discovered and your knowledge of normal plant utilisation, construct a very approximate pie chart for the energy usage of the site.

Look at the company's electricity account and convert the areas of your pie chart into real money.

Work out what would be the savings if each area were reduced by 10%.

Comparison of your pie chart with the example may identify some areas for further investigations and encourage you to have a closer look at some sections of the factory. This may need some measurements to find out:

- Where is the excess energy being used?
- Can some of it be eliminated?

Look at how your electricity distribution system is laid out, and you should find a more sensible number of groupings of electricity use. Often all the motors, heaters, and ancillaries for an individual machine are supplied from the same substation, distribution board, or main feeder cable. Sensible choices for metering can only come from knowledge of the distribution layout.

3. When are you using energy?

The demand cycle

Energy is most obviously used when work is in progress but most glass processing machines require a period of running before 'good' production can begin. Similarly, most processes use electricity to provide direct heat and these heaters must have sufficient time to reach the required temperature and for the machine be at a steady state. These requirements create a climate in which it is usual and expected to see machinery running 'idle' and using power. Similarly, when work ceases for any reason, there is a time before the machine can be switched off. In glass processing there is inevitably a time delay between production start-up or shut down and energy usage.

The situation is best illustrated by plotting a graph of the instantaneous load at intervals during the day. Larger companies can have this done for them by the electricity supplier. Their supply meter is likely to be linked directly to the supply company's computer and able to be interrogated at half-hourly intervals over an extended period.

For companies not having this type of meter, manually reading the meter, borrowing or hiring a portable kit or having an external company do the measuring can produce the same type of graph.

Some electricity contracts have 'time-of-day' conditions that affect the cost. Is the current working pattern making the best financial advantage of this fact, or is the advantage outweighed by other factors? Would a revised contract be to the company's advantage, particularly if this clause was replaced by a more appropriate arrangement?

The base load

Once you have a view of the load at various times of day you can start to isolate the 'base load', this is the load that has nothing to do with production volumes and is related only to services and waste. The base load is a significant area to start work for overall energy reduction, to use a financial analogy it is the 'overhead' energy that you are paying for whether you are producing good product or not.

An alternative method of finding the 'base load' is to note the meter reading at the end of each shift along with the production volume and to build up a history of total site electricity use. Calculate the kWh used and the production volume between consecutive readings, and plot these on a graph. How scattered these points are will depend on some factors such as the range of products you make, and how well you are managing your energy use. Draw the best straight line through the points and see if there is a pattern to the points that lie above and below the line. You will find that the line you have drawn doesn't pass through the origin but has a substantial intercept on the y axis. This intercept is the 'base load' for your site and shows that a lot of your energy use is not related to production volume.

The peak demand

Peak demand can have a big influence on energy costs.

Part of your electricity bill is based on your allowed site maximum demand, and these costs can sometimes be reduced by scheduling machine operation so that the all the individual maximum demands do not come at the same time, avoiding a spike in total factory demand.

Individual motors are often oversized for the actual demand profile (most engineers and designers build in a reasonable margin of safety). This avoids overtaxing and burning out motors, but actually costs a surprising amount. Each motor has an efficiency curve which falls off very rapidly away from the design rating, and large savings can be had by fitting variable speed controllers in some cases, or even by replacement with a smaller motor from the factory maintenance stock.

Monitoring and targeting

Getting the data is one thing, but it won't save you money unless you use it to improve your understanding of where you are using and wasting energy, and act on it! A standard method has been developed called 'Monitoring and Targeting' or 'M&T', which helps you get this right. Many companies also supply spreadsheet and other software packages to automate what might otherwise be a time-consuming chore.

4. Why are you using energy?

The average processing costs

The alternative method for finding base load will give a good idea of the amount of energy you are using on each day or shift of factory operation. The daily energy usage can easily be converted to an energy usage per kg of good product (in kWh/kg) and this can be compared to industry averages to provide some ideas for targets in your general energy usage. It might only take a few minutes at the end of each shift to note the meter reading along with the production data and to build up a history of total site electricity use but the information can be very useful.

The results should allow you to pick up patterns in when energy usage is high and when it is low. This will allow you to start to ask some questions about specific products, processes and operating procedures.

- Does a particular product or use more energy to process?
- Does a particular shift use more energy than another shift?
- Which machines affect the energy usage?
- What things was the factory doing on low energy usage days and how can you keep doing these?
- What things was the factory doing on high energy days an how can you stop doing these?
- How do you compare to the industry averages?
- Why are you paying to use so much electricity in lunch breaks, production run changes, overnight, and over weekends?

This is similar to measuring the miles per gallon in your car. Each time you fill up you note the date, mileage and volume of fuel to fill the tank. The values will be affected by type of route (motorway/country road), whether you felt like driving fast, how many passengers you had, and weather conditions, but they will also give information about the mechanical condition of your car. The average m.p.g. will decline between services, and will often show a marked improvement when you replace worn parts. Work out how much money you might save, and you might be convinced to service the car more often! Work out what you might save if your energy consumption was at the industry average and you will be convinced of the need to take energy management seriously.

Monitoring and targeting (again)

An important part of M&T is setting standard energy uses and achievable but challenging performance targets. There are basically three types of targets and standards:

- The internal ‘historical’ target using internal results previously achieved.
- The ‘external’ theoretical target using results from research information.
- The ‘external’ comparison target using benchmark information from other manufacturers with no evidence that it is either achievable or challenging.

The choice of target type chosen is an internal issue but it is important that whichever target type is chosen it is both challenging and achievable.

Internal targets are easily obtained but they may not be adequately challenging.

External theoretical targets from machinery manufacturers and research associations give theoretical (or experimentally measured) ‘minimum’ values for energy consumption for particular product types, polymers, and processes.

External comparison targets or benchmarks are very difficult to define because of the variety of operations and products and the difficulty in defining an industry ‘standard’.

5. How much energy are you using?

If energy is to be managed the first essential is to acquire the knowledge to enable the energy bill to be understood and the amounts checked.

Supply companies generally bill industrial users monthly, basing the charges on a variety of formulae and the quantity of electricity.

A provision of the Electricity Privatisation Bill was to give industrial users the option of negotiating a contract for their supply. Set tariffs exist but are negotiable. The actual quality of energy supplied is not negotiable and is regulated by Statute.

Statutory provisions also require the quantity to be metered and this is done as the supply cable enters the site. The metering is the property of the supply company and must be maintained in an accurate state by them. They will read the meter at appropriate intervals, create the bill, and expect it to be paid. Meters are generally very reliable, providing accurate readings over many years, so unless a metered reading is obviously erroneous, they will not check the accuracy of the metering equipment. Minor errors will easily go undetected. It is therefore bordering on the foolhardy for a company not to check their electricity bill. By the same token the company must be able to read the meter for themselves.

- Accompany the supplier's meter reader when the meter reading is made.
- Keep a record of the meter reading and of the time that it was made.
- Plot a graph of the number of days since the previous reading, and the usage.
- On the same graph plot some crude measure of the company output - kg or tonnes - machine hours etc. This will start to give an idea of the rate of energy usage and allow you to start to exercise some control over the amount of energy you are using.

The measure of how much?

The simple question of 'How much energy are you using?' is complicated by the way generators and suppliers of electricity design their tariffs to suit their generating equipment and schedules. The way you purchase your electricity does not save you energy directly, but can save you money. It is an important factor in providing a justification for many energy saving measures. Energy efficiency measures can give a smoother, less peaky, electricity demand profile that will reduce charges based on maximum demand and power factor.

Tariffs

Tariffs are designed to encourage people to use more electricity at times when the supplier would otherwise have too much capacity and it is up to the user to select the tariffs that give the best deal for their particular work pattern. A tariff can consist of a price per unit, (pence/kWh) and additional charges (not based on volume of consumption), which depend on:

- Maximum Power Requirement (MPR)
- Maximum Demand (MD)
- Power Factor (PF)
- Load Factor (LF)

Short explanations of these are given on the opposite page.

Peak demand lopping

Some processors use 'peak demand lopping' to reduce the MPR and MR and thus reduce the overall costs or to remain within the constraints of the existing electrical connections. Solutions include the standard option of staggered start-up of machinery and the use of supplementary diesel generators which cut in to provide site generated power if the total demand approaches that of the MPR or MR. The capital cost of the generator can be high but can also be very favourable compared with the cost of upgrading the MPR and the additional costs that the upgraded MPR brings.

Maximum Power Requirement (kVA)

This is the maximum current that a site is able to draw at the supply voltage without triggering the main circuit breakers and trips. If a site exceeds the MPR the trips will operate.This can mean an extended interruption to production, and the supplier will usually levy a charge for the overload. A site will be charged to increase its MPR, since the supplier has to upgrade the distribution system.
Energy efficiency measures can minimise the additional demand caused by an expansion in production capacity, and avoid the cost of increasing the MPR.

Tips:
Stagger start-ups to avoid exceeding MPR.
Match MPR to real requirements to reduce costs.
Get the MPR right for new premises to avoid costly charges.
Consider negotiating an annually based MD instead of an MPR charge.

Maximum Demand (kVA or kVAh)

This a measure of actual current drawn at the supply voltage, usually averaged over half an hour. MD meters measure the cumulative value (kVAh) of instantaneous actual energy use (kWh) divided by Power Factor. These are reset to zero after half an hour, and record the maximum value reached over all the half hour periods since the pointer was last reset. The MD is noted at each billing period and the MD pointer is reset to zero.

Tips:
Stagger start-ups to avoid exceeding MD.
Give machinery time to stabilise before starting up new processes.

Power Factor

Electrical machinery induces a phase shift between supply voltage and current if it has a high reactive impedance (inductance or capacitance). Lightly loaded machinery tends to have a high phase shift, and thus a low power factor. The chargeable units of electricity consumption are kWh. Electricity suppliers don't like low power factors because they must have a high distribution network capacity for a low consumption charge. Low power factors can cause problems with running the distribution network.

Tips:
Run electric motors energy efficiently to get power factors close to 1.
Some supply areas make an additional charge if the PF is below a given value.

Load Factor

This is a measure of the number of hours a day that the user draws from the supply. A 9-hour single shift working pattern gives a load factor of 9/24, i.e. 37.5%. Variable "peaky" aggregate electricity demand forces the supplier to have standby capacity that runs only on peak demands. The supplier has the same fixed costs maintaining a distribution system that is used for 8 hours/day as for one that is used for 24 hours/ day, but less consumption revenue to offset them.

Tips:
Running for greater than a single 8 hour shift will reduce load factors.
Can certain operations be run outside the main shift pattern e.g. regrinding.