Energy Management Principles and Practice

A companion to BS EN 16001:2009

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BSi

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Preface

BSI commissioned me to write this book because they recognized that BS EN 16001:2009, the management systems standard for energy management, only provides a framework for energy-saving activities and procedures and does not give any guidance as to what, in practice, the energy manager should do. Nor could it; the subject is too big, the applications too diverse and solutions are continually evolving. Moreover, the standard has to be prescriptive, whereas an enterprise needs to make its own commercial decisions about what might or might not be appropriate.

It is 20 years or so since the last UK textbooks on energy saving were published. The rise of the World Wide Web, a tsunami of fragmented free publications from the late lamented Energy Efficiency Best Practice programme, and a decline in energy management as a full-time vocation following energy market deregulation put paid to book-publishing on this topic, leaving only relatively expensive reference guides aimed at the technical expert. Publication of BS EN 16001:2009 and soon ISO 50001 are evidence of a resurgence in this area and this book is intended to support that by providing, in one slim volume, a rounded appreciation of the core techniques – human, technical and analytical – that the part-time energy manager needs to know about. For those who want technical depth or further advice, I have provided pointers to other resources, often (but not exclusively) via the website that I set up in 1996 to provide practical advice to energy managers.

Acknowledgements

I did not get here unaided. The list of people who have inspired, advised and assisted me over my career is huge but, at the risk of offending those I do not have space to mention, I would like to single out two. Peter Harris taught me how to analyse energy data effectively and his methods were the foundation for almost everything I have subsequently achieved, including injecting some crucial features into BS EN 16001:2009. I hope he will be proud to have inspired Subclause 3.5.1. I would also like to acknowledge John Mulholland, my director when I was at NIFES Consulting Group. His knowledge and experience of the human-factors aspects of energy management are second to none and my skills as a trainer benefited greatly from his mentoring. Working as a consultant at NIFES was invaluable, not just because it is a community of energy experts, but because of the range and calibre of the clients that I worked for and the experience that I gained.

This book is dedicated to my ever-supportive wife, Kate.

Introduction

Energy management is all about reducing the cost of energy used by an organization, now with the added spin of minimizing carbon emissions as well. Reducing energy costs has two facets: price and quantity. This book is exclusively concerned with the latter. It does not discuss competitive procurement or invoice validation. Nor does it discuss carbon emissions reduction beyond what will be achieved incidentally through energy saving. This means you will not find anything in this book about alternative energy sources, renewables, carbon trading or fuel substitution. In these respects the following chapters have the same scope as BS EN 16001:2009, albeit approached from the perspective of practical energy-saving action rather than the overarching administrative framework within which that action is taken.

Although the book is designed to be used quite independently of BS EN 16001:2009, it is worthwhile addressing what the standard regards as the defining objective: meeting your organization’s energy policy. Why might you need a policy, and what should it look like?

At the corporate or strategic level, an energy policy is a public commitment or undertaking which states, for the benefit of employees and contractors, what the organization expects of them in general terms and what the organization’s objectives are in energy terms of its overall energy performance. It defines the scope and boundaries of the organization’s energy management system and provides a framework for action. Subclause 3.2 of BS EN 16001:2009 adds that the policy needs to include three specific commitments:

1. To continual improvement in energy efficiency;
2. To ensure the availability of information and of all necessary resources to achieve objectives and targets; and
3. To comply with all applicable requirements (legally required or voluntarily agreed to by the organization).

Of these commitments, the first two are crucial since they bind the senior management of the organization to creating the necessary environment and resources to make progress.

There is no one policy that fits all possible scenarios but the model in Figure 0.1 is suggested as a starting point.

Proposed text	**Comments to be taken into account during drafting**
(*Name of organization*) is committed to continuous improvement in the efficiency with which energy is used, and the avoidance of energy waste.	
The scope of this policy covers all our buildings, processes and transport operations.	*This will need to be customized to your particular organization and might, for example, be extended to include business travel, raw materials or even non-energy supplies. It may need to state explicitly that it includes outsourced operations and services.*
Our first objective is to reduce our total energy consumption each year by *x* % after taking account of changes in levels of activity, weather and other relevant factors.	*There is a danger here of setting a goal which is either unachievable or too easy. In some ways it may be preferable not to set a specific percentage, especially as the percentage which can be saved would usually be expected to decline year on year as the quick wins are exploited.*
Our second objective is to reduce the carbon intensity of our energy purchases by *y* % year on year.	

Figure 0.1 — *Model energy policy*

Proposed text	Comments to be taken into account during drafting
We undertake to comply not only with all relevant legislation relating to energy use but to additional voluntary requirements which may be agreed from time to time.	
We undertake to provide the resources • to plan and supervise the necessary projects and programmes; • to maintain an energy management system compliant with BS EN 16001:2009; • to monitor energy performance; and • subject to justification on reasonable criteria, to fund physical improvement projects.	
We undertake to carry out such awareness-raising, training and maintenance optimization programmes as may be required in pursuit of improved energy efficiency and reduced losses.	

Figure 0.1 — *Model energy policy*

Proposed text	Comments to be taken into account during drafting
We expect staff and contractors alike to support our objectives and to cooperate actively in achieving them.	
We will publish the results each year.	

Figure 0.1 — *Model energy policy*

So much for the corporate policy. You will probably also want to develop technical policies defining in detail how things are to be done. For instance, what lighting levels will be provided in corridors? Will computer workstations be turned off at night? The idea is to define a common set of expectations and to remove the need for debate at the micro-level. Technical policies provide ready-made answers to common everyday questions, and are the tactical counterpart of what the corporate policy does at a strategic level.

The basics

Improving energy efficiency is, in part, a technical pursuit with a scientific basis. However, although some aspects are undeniably highly specialized, the essential science should be familiar to most readers (perhaps dimly) from their school days and where BS EN 16001:2009 (Subclause 3.4.2) calls for the energy manager to be appropriately qualified, I read this to mean that a basic grasp of physics and chemistry would be expected.

This section reviews some of the fundamental scientific concepts needed for the job, and other more specific topics are introduced in individual sections where they may be helpful.

Energy and power

In BS EN 16001:2009, energy is defined as ‘electricity, fuel, steam, heat, compressed air and other like media’ (your physics teacher probably defined it more rigorously as ‘capacity to do work’ but the real-world definition is better for our purposes). When we buy or use energy it may be billed or reported in a variety of units of measurement, but all have their equivalents in kilowatt hours (kWh) which is how most practitioners commonly express energy consumption.

Some of the conversion factors are given in Table 0.1.

‘Power’ has a quite specific meaning: it is the rate at which energy is delivered, commonly expressed in watts (W) or kilowatts (kW), although horsepower (HP) will also come to mind in some contexts. Because both are measures of power, there is a conversion factor between the two: 1 HP is equal to 0.746 kW.

The energy used by a piece of equipment running at fixed power for a certain time is the time multiplied by the power. A 3 kW heater running for two hours will use $3 \times 2 = 6$ kWh. A 55 HP diesel engine running flat out for two hours will deliver $55 \times 0.746 \times 2 = 82.06$ kWh.

Table 0.1 — *Energy conversion factors*

Energy source	Measured units	To get kWh multiply by	Notes
Electricity	kWh	1	—
Natural gas	m^3	10.7	1
Natural gas	100 cubic feet	30.3	1
Natural gas	kWh	1	1
Natural gas	therm	29.31	1
Diesel or 35-second gas oil	litre	10.6	
Heavy fuel oil	litre	11.4	
Propane	tonne	13 780	
Propane	kg	13.78	
Coal	tonne	9 000	2
Coal	kg	9	2
Steam	tonne	630	3

[1] Depending on pressure, temperature and calorific value
[2] Highly variable between types
[3] Dependent on pressure

Power factor

In an electrical circuit, power is calculated by multiplying voltage and current together. In the case of mains power, where the current alternates, this relationship holds true at any given instant, so the *instantaneous* power will vary as the voltage and current continuously vary through the cycle. However, in order to deliver the maximum useful power, the current and voltage must be exactly in step. If they are not – for example if the load characteristics make the current waveform lag slightly behind the voltage waveform – then throughout the cycle either the voltage will coincide with a current that is less than it would have been or the current coincides with a voltage that is lower than it would have been had they been in step. Indeed, there will be four occasions in each cycle when the instantaneous power is zero (two when the current is zero, and two when the voltage is zero). The result: less power will be developed for a given current. The *power factor* is the ratio between delivered useful power and what it would have been with perfect synchronization of current and voltage.

Poor power factor means that a higher-than-necessary current must be drawn in order to deliver the required useful power. This increases the load on supply cables and switchgear, increases line losses and (depending on the tariff) can impose higher supply-capacity and maximum-demand charges.

Efficiency

This is another word that has quite a narrow meaning in the context of energy management, where it refers to the ratio between useful energy output and energy input. Examples might be the useful heat output from a boiler divided by the amount of fuel put in; or the work done by a car engine relative to diesel consumed. Take the earlier example of the engine which delivered 82.06 kWh over two hours. If it used 25 litres of fuel in the process, how efficient was it? From Table 0.1 we see that 25 litres of diesel contain 25 × 10.6 = 265 kWh. So the efficiency of the engine was 82.06 / 265 = 30.9 %.

In common parlance ‘efficiency’ is often used interchangeably with ‘efficacy’ or ‘effectiveness’. If the occupants of a building tell you its heating system is efficient, they usually mean that it keeps them warm, not that the boilers are well-tuned and properly controlled to minimize standing losses. Beware also when promoting ‘efficiency savings’ as this term has connotations of downsizing and redundancies.

Energy balance

Most people talk about 'consuming' energy (be it in the form of gas, oil, electricity, heat, compressed air or steam) but purists would argue that we don't consume energy, we merely convert it from one form to another. Nobody seriously argues that we stop using the term 'consume' but the point about conversion is important in a way. In the engine example, we used 265 kWh of chemical energy in the diesel fuel to generate about 82 kWh of useful mechanical work. But as energy cannot be destroyed, where did the missing 183 kWh go? It came out as heat in the exhaust and cooling system. There is an overall balance between what goes in and what comes out. We will encounter a similar argument when we discuss combustion efficiency in section 2-3.

Heat and temperature

Heat is one manifestation of energy. A flow of heat can be expressed in energy units (such as kWh). You can meter, buy, or use a quantity of it. The engine in the earlier example produced it by converting chemical fuel energy. Ten tonnes of steel at 300 °C contains twice as much heat as five tonnes at 300 °C.

Temperature, by contrast, is just a measure of how hot something is. You cannot buy or use temperature; it is not a form of energy. You can see how different heat and temperature are if you think about taking some ice from the freezer and adding heat to it. At first, starting from a temperature of −15 °C (for example), its temperature rises as it absorbs the heat. When it reaches melting point, it continues to absorb heat as it turns to water. During this process, its temperature stays constant at 0 °C but its heat content continues increasing (if you completely stop adding heat, the ice-water mix does not change). Once it is all melted, the liquid water continues to absorb heat and its temperature starts climbing again until it reaches the boiling point, whereupon the temperature again stops rising while the water evaporates. Only when there is no more liquid left can the water, now as vapour, start to increase in temperature (and become what is called 'superheated'). With a few odd exceptions that don't go through a liquid phase, as you add heat to any solid its temperature rises unevenly, remaining on a plateau while it is melting or vaporizing before following the same trajectory back down as it first condenses to liquid and then solidifies when heat is removed from it. Common physical manifestations of this are:

a) Your drink with ice in it starts to warm abruptly once all the ice has melted; and
b) Boiling a pan of water rapidly does not raise its temperature.

One finicky point you will need to know. When engineers and scientists talk about temperature *differences* they use a unit of measurement called a kelvin represented by a capital K. One kelvin is numerically equal to a one-degree difference between two temperatures in Celsius (centigrade degree in the old nomenclature); when it is 19 °C indoors and 5 °C outside, the temperature difference is 14 K.

1. Information and human factors

1-1 Monitoring energy consumption

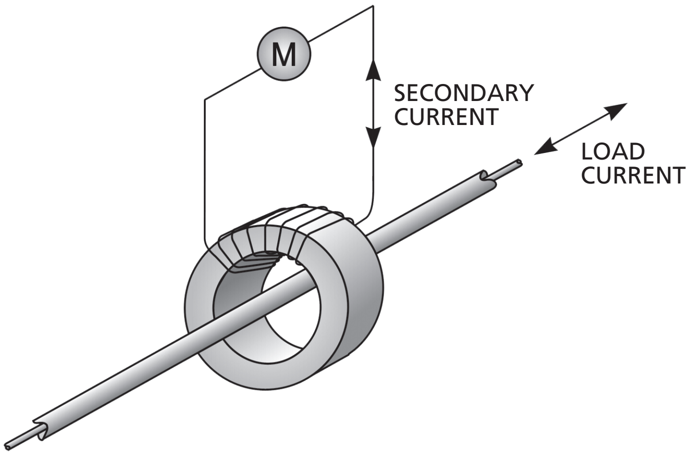
To manage energy successfully, you need to measure how much you use. This means taking your own meter readings rather than relying on figures provided by the utility companies. How frequently you get your meters read depends on your circumstances. Subclause 3.5.1 of BS EN 16001:2009 places an obligation on the organization to monitor, measure and record significant energy consumption 'at defined intervals'. My usual guidance is to consider a weekly regime as the best starting point. Monthly monitoring, which has historically been the norm, is too blunt an instrument for major users while fine-grained data (30-minute intervals or less) brings attendant problems of data overload and difficulties in interpretation and analysis. BS EN 16001:2009 calls for 'energy factors' to be recorded as well. By this it means weather data, usually in the form of degree-day figures (also discussed later), production statistics, and the like — what in normal energy management terminology would have been called 'driving factors'. When we come to discuss understanding patterns of energy consumption, the value of this data will become clear but suffice it to say, for now, that both consumption and driving-factor information need to be synchronized and collected at intervals to match your required interval of assessment and reporting.

Energy-metering technologies

Many readers will be happy to make do with existing metering, but some may need to install additional meters in order to separate out significant energy uses or to measure flows of product. To get the best accuracy, it is important to choose an appropriate measurement technology although cost is always an issue. Fortunately, BS EN 16001:2009 does not lay down accuracy standards. Subclause 3.5.1 merely stipulates that accuracy and repeatability should be 'appropriate' and for routine energy management the requirement is actually quite relaxed since you will mainly be interested in changes and trends.

Electricity meters

Modern electricity meters are solid-state electronic devices which are either directly connected in the supply cabling or (usually) where the measured current exceeds 100 A, indirectly through current transformers (CTs). A CT typically consists of a ring of magnetic material through which the power cable passes. The load current then induces a voltage in a secondary winding. It is this voltage which is sensed by the meter. The advantage of indirect connection is that the meter can be mounted in a convenient location remote from the power cable where it may be easier to read and multiple meters can be marshalled together.



Source: Annabel O'Keefe

Figure 1.1 — *A current transformer produces a secondary current which can be measured by a remote meter*

For the sake of accuracy, CTs should be matched to the current they will be measuring. On a three-phase supply, one CT is needed per phase and care must be taken that all are properly connected: having one disconnected will reduce the measurement by one-third, while one connected the wrong way around will reduce the measurement by two-thirds. Such faults may go undetected for years, giving incorrect results and ultimately causing embarrassment. More advanced meters nowadays include on-board diagnostics which aid correct commissioning and prevent these problems; they can also report power quality, harmonics, power factor and other parameters.

Where it is not possible to disconnect the power cable to thread it through the CT, split-core types can be used which clip over the cable. There are even flexible types where space is limited.

Flow meters

There are numerous technologies available for measuring gas, steam, compressed air, oil and other fluids but even if you know what liquid or gas is being measured, other questions will have a bearing on the choice of metering technique:

- What is the expected temperature range?
- What is the maximum expected pressure?
- What maximum and minimum flow rates need to be accommodated?
- What is the maximum acceptable pressure drop?
- In some cases, how much straight pipe is there upstream and downstream?
- In some cases, is electrical power available?
- If measuring a liquid, what is its viscosity? Is the viscosity likely to vary significantly?
- What is the state of the measured liquid (dust, dirt, bubbles, etc.)?

This is definitely a case where advice from a consultant (or metering supplier with a wide product range) will be invaluable. But for now here is some very general guidance for the more common applications.

For gas supplies, turbine meters would be the usual choice for large meters (pipe sizes of 200 mm and over).

Source: Chris Morris

Figure 1.2 — *Cutaway view of a turbine meter*

Otherwise rotary positive-displacement or bellows types would normally be used. The latter are limited to low-pressure applications.

For oil, a positive-displacement type of meter would be the typical choice.

For compressed air submeters, turbine meters are unsuitable because they are easily damaged by sudden pressure fluctuations and entrained dust or water droplets. Orifice plates are a robust solution where the flow rate is constant; otherwise either thermal-mass or vortex meters should be employed. Both of the latter impose a relatively low pressure drop, making them attractive for retrofit applications. Pressure and temperature correction is likely to be needed.

For steam the best candidates are likely to be vortex meters and variable-area orifice meters such as the Spirax Gilflo, unless the flow rate is unlikely to vary, in which case a fixed orifice meter might be an option. Pressure and temperature correction are definitely required in all cases.

For water and other clean liquids, positive-displacement and multi-jet meters are acceptable. Vortex and orifice meters are more tolerant of suspended contaminants but the latter are only accurate over a narrow range of flow rates. Electromagnetic meters may also be considered as long as the fluid is electrically conductive.

Data collection

You may collect the data automatically, manually, or both, but where manual readings are involved it is worth paying attention to the following points of policy, preparation and practice:

Policy

- Decide at what interval to read the meters – monthly or weekly, for example – and set a target reading time such as, say, the first working day of the month, or 7 am each Monday morning.
- Make someone responsible for taking the readings and nominate a deputy to cover for absences.

- State how much leeway is allowed on meter-reading date and time.
- Make arrangements to collect driving factor information such as production, degree day figures at the same intervals as meter readings.

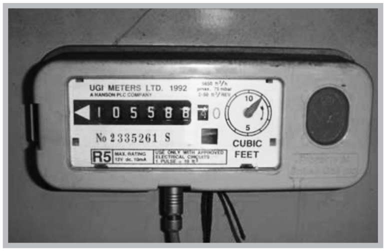
Preparation

- Create a checklist of meters to be read.
- In the case of multi-rate meters (those with day/night or normal/low registers), say which registers are to be read and recorded. Some electricity meters (such as ‘Code 5’ meters in the UK) may record consumption in several distinct time bands.
- Record the meters’ attributes: what commodity they measure, their location, units of measurement (including any multiplier factor such as ×10), number of readout digits, serial number and other salient facts.
- Consider fixing a durable label or tag near the meter to identify what it is measuring. Don’t fix it to the meter itself in case it is later swapped out.
- If appropriate, prepare forms on which meter readings can be recorded. Include provision for time as well as date if readings are more frequent than once a month. It is useful to show the meter serial number if known and also any special access requirements (e.g. who holds the keys, swipe card or access codes).
- Take an initial set of readings for the record. This will help resolve ambiguous or suspect readings later.
- Brief the nominated meter readers and provide training, especially relating to meters with which they are not familiar.
- If possible, disable any ‘reset-to-zero’ buttons.
- Check the security of power supplies to meters and ancillaries (where relevant). If interruptions are a risk, it may be necessary either to secure the supply or read the meter more frequently.
- In the case of natural gas supplies, identify where on the bills the calorific value and the correction factor for temperature and pressure are shown. These will be needed to convert the volumetric gas measurement to energy terms.

Practice

When you, your staff or contractors read your meters they should:

- Do so as close as possible to the target day and time;
- Check each serial number or other unique identifier against that expected;
- Always record the date and time on which each meter reading is actually taken (the actual date and time as distinct from when it was supposed to be taken);
- Record the reading exactly as it appears on the meter. Show all the digits, including the decimal fraction if there is one (decimal fraction digits may be indicated by a contrasting colour scheme) and any fixed zero printed on the face of the meter. In Figure 1.3, the gas meter reading should be written down as 10558840;
- Gas-meter readings are usually volumetric and must be corrected for temperature and pressure variations (unless the meter has a built-in corrector) and for calorific value;
- Remember that the register displayed on most half-hourly electricity meters is not the total units consumed but rather the cumulative units for the rate band active at the time of reading. Use the button provided to step through the available readout registers to obtain the totals you want.
- On remote readouts with reset buttons, do not reset to zero after reading the meter;
- When meters are exchanged, take readings from both; note the date and register the attributes of the new meter on the central record;
- For unmetered commodities held in bulk on site, record their stock levels at the same time as the readings are taken on meters and the quantities of all deliveries received since the last stock-level entry.



Source: NIFES

Figure 1.3 — *This meter should be read as 10558840 cubic feet*

For sites with numerous meters, it may be cost-effective to invest in a handheld electronic meter reading device to replace paper forms. This can be programmed to organize walk orders and check that readings are sensible as they are entered, reducing the risk of misreads and subsequent revisits or estimates. They can also save time by replacing manual data entry with digital data import.

Any device with an internet connection and a web browser can also be used as a meter data entry terminal by using the MeterPad web service. This provides a private, password-protected central database for the storage and retrieval of meter readings. Although it requires a little effort to set up, it then provides a highly-organized framework within which meter readers can, for example, preview earlier readings or leave comments for other users sharing their data; it also creates an inventory of meters and their attributes.

Automatic meter reading

An automatic meter reading (AMR) system will fulfil two distinct requirements: facilitating remote readings, and providing fine-grained consumption histories. AMR is thus beneficial in the following circumstances:

- A dispersed estate of multiple sites;
- Unattended outposts;
- Areas with access restrictions (tenants’ areas, hazardous areas);
- Where numerous readings need to be synchronized, even if only on a weekly or monthly basis;
- Where information is required with minimum delay;
- Where you want to monitor consumption within restricted time-bands, for example to enable time-of-day billing of tenants’ supplies.

Some users will already have data collection capability in place, either through a building energy management system (BEMS) or, in an industrial context, a supervisory control and data acquisition (SCADA) system. Others will need to install some or all of the infrastructure from scratch and, in some cases, new compatible metering may be required.

AMR technology is too complex and diverse to deal with here. Do not be paralysed by the seemingly overwhelming choice of communication options and do not be tempted into thinking there is a ‘one size fits all’ solution. Most reputable providers of data collection systems will use a variety of techniques suited to the circumstances of individual meters.

Also, be sceptical of end-to-end solutions from single vendors. Companies that excel at data collection often lack the know-how to analyse and present data effectively, a topic which is addressed in section 3-3. Split the project into two aspects:

- Metering, data collection and communications; and
- Analysis and reporting functions.

The interface between the two is a database and that is also the place where diverse inputs such as manual meter readings and driving-factor data are merged with AMR data. This philosophy, furthermore, gives you the flexibility to have multiple AMR vendors if convenient.

1-2 Understanding patterns of use

A word of warning: this section contains some algebra, but don’t worry if it doesn’t go in first time. All I want you to appreciate is that there is often a way to calculate *expected* energy consumption from other independently measured management data.

The point is that the overworked dictum ‘you cannot manage what you do not measure’ does not quite tell the whole story. It is all very well to measure and record precisely how much energy you have used; the big question is whether it was the *appropriate* amount. That is a question we can’t answer unless we understand, and can explain, patterns of consumption in relation to prevailing circumstances by which I mean the weather, level of production activity or other external driving factor. Traditionally, consumption that varies because of such external factors has been treated as hard to manage and the best treatment that many people achieve is to ‘adjust’ their consumption data to take account of what are seen as external disturbances that are somehow distorting the results. I suggest that this is a wrong-headed approach.

Let us think about two simple scenarios: a factory which uses energy to process a homogeneous product and the heating system in a building. Start with the factory first. It should be evident that the more of a product they make, the more energy the factory will require. It is quite plausible that each unit quantity of product requires a certain amount of energy so that there is a simple proportionality between the two. We could say that:

$$E = \mathrm{m}P \qquad \text{(i)}$$

where:

E is the production energy requirement;

P is the production output;

m is a constant specific to the process in question.

However, in real life things are not so simple. Usually, there is some constant background demand for energy in addition to what goes directly into the product. This might be heat losses in the case of gas or other uses like lighting and extract ventilation in the case of electricity. Whether the constant background energy requirement is associated with the process equipment or just other continuous uses sharing the same meter, we can allow for it in the formula by adding an extra term:

$$E = \mathrm{c} + \mathrm{m}P \qquad \text{(ii)}$$

where:

c represents the fixed demand in a given interval of time (one week, say)

Readers may recognize this formula as the equation of a straight line and one of the things we can try, when developing a model of how energy consumption relates to a driving factor like production throughput, is to plot our data on a scatter diagram of weekly energy against weekly production to see if such a straight-line relationship seems to apply. This has been done in Figure 1.4. In a case like this, where we do indeed see a relationship, we can superimpose a best-fit line and this gives us numbers for c (the intercept on the vertical axis) and m (the gradient of the line) in energy units per unit of output. This straight-line 'performance characteristic' enables us to estimate what the energy demand ought to have been, given what the output was.

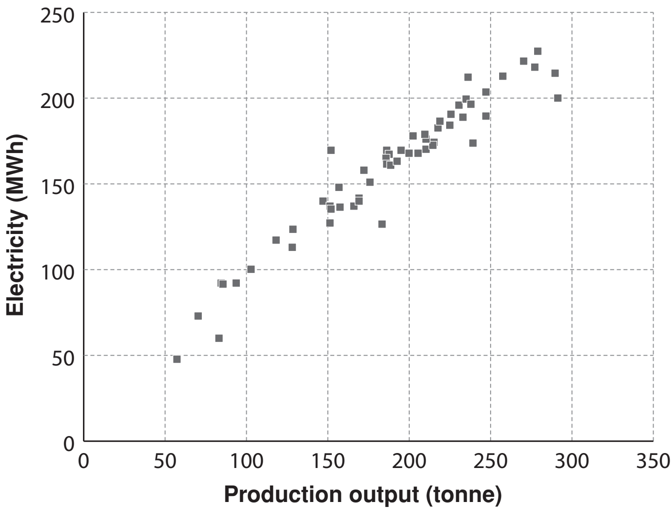


Figure 1.4 — *A scatter diagram of weekly electricity consumption and production output reveals the underlying relationship*

In Figure 1.5, we see this illustrated. We draw a vertical line at the prevailing production output and where this crosses the performance characteristic we can read off the expected consumption. This will come in useful later because it gives us a yardstick against which to assess the energy we have actually used. We can detect exceptions (section 1-3) and evaluate savings relative to where we would otherwise have been (section 3-5).

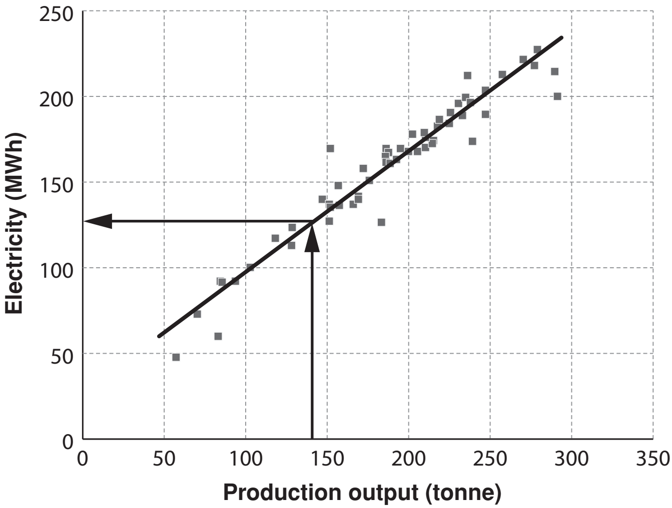


Figure 1.5 — *Superimposing a performance characteristic line enables us to estimate, for any weekly production output, what the electricity consumption should be*

Could we have done the same thing for the building heating system? As it turns out, the answer is yes. Figure 1.6 shows the weekly gas demand in a building; it is higher in winter weeks than at other times.

Figure 1.7 meanwhile shows something called the degree-day value. This is a number, calculated each week from the recorded outside air temperature, representing how cold each week was.

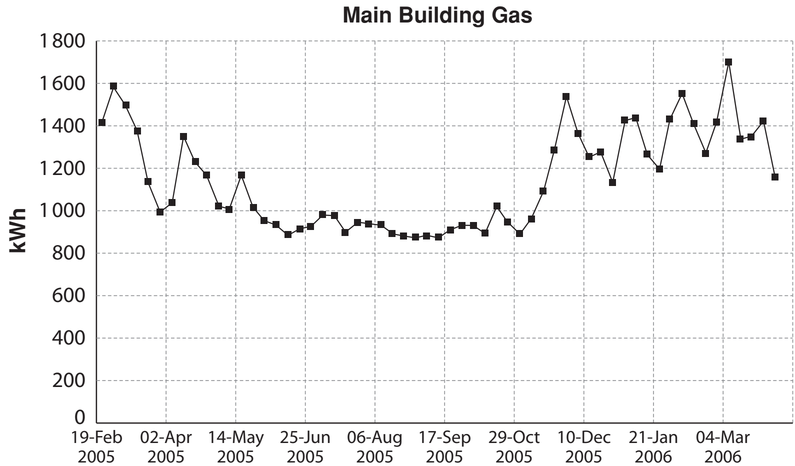


Figure 1.6 — *Trend in weekly gas consumption where there is some space-heating load*

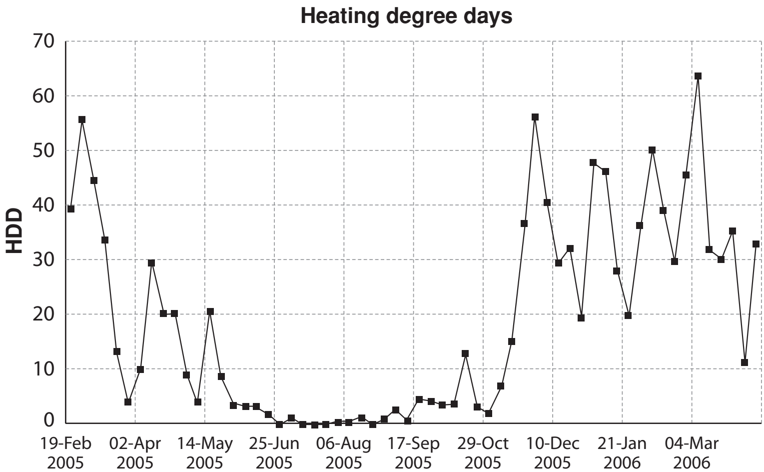


Figure 1.7 — *Corresponding history of the weather expressed as heating degree days*

The exact methods need not concern us: the important thing is that the annual profile of degree-day values resembles the profile of gas consumption and, if we plot weekly gas consumption against the weekly degree-day values on a scatter diagram as in Figure 1.8, we see the familiar straight-line relationship. If the weather measured in degree days for any given week is assigned the symbol W, we can write the formula:

$$E = \mathrm{c} + \mathrm{m}W \qquad \text{(iii)}$$

to describe the relationship. This is exactly analogous to the production example and if we know how cold the weather was (in degree days) for a particular week, we can now estimate the expected energy consumption.

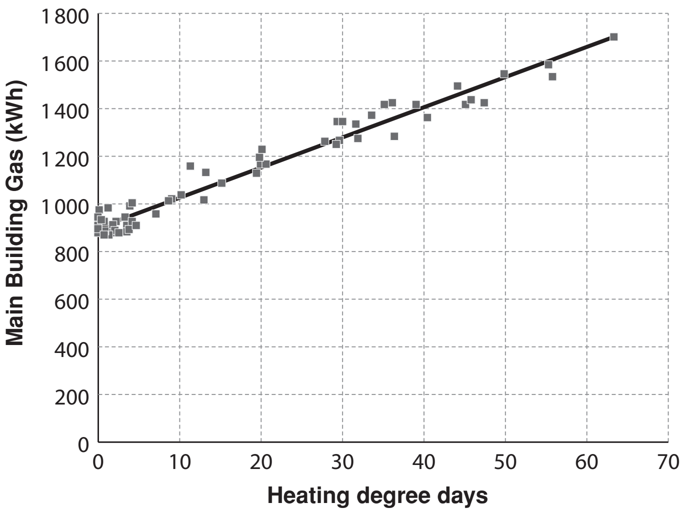


Figure 1.8 — *A scatter diagram of gas consumption against heating degree days shows the relationship between the two, which can then be used to estimate weekly expected gas consumption for given weather conditions*

Simple straight-line relationships of this sort will be found to apply in many circumstances but naturally there will be cases which are more complex. One of the common complications is where several products with different energy intensities are made on a shared facility. Here it is necessary to measure or estimate what each product's energy intensity is and build a slightly more elaborate equation. For example, a commercial bakery might produce loaves of bread, tarts and rolls. If bread loaves are found to need m_1 kWh per tonne, tarts m_2 kWh per tonne, and rolls m_3 kWh per tonne, expected energy consumption in a given week can be deduced from the formula:

$$E = c + (m_1 \times B) + (m_2 \times T) + (m_3 \times R) \qquad \text{(iv)}$$

where:

B is the known tonnage for the week of bread loaves;

T is the known tonnage for the week of tarts;

R is the known tonnage for the week of rolls.

We can elaborate further and allow for the weather: if the heating is on the same meter and its requirement is found to be m_4 kWh per degree day, the formula would be extended thus:

$$E = c + (m_1 \times B) + (m_2 \times T) + (m_3 \times R) + (m_4 \times W) \qquad \text{(v)}$$

In fact there is no limit to how many factors one might wish to take into account, nor how complex the formula might turn out to be, although obviously one prefers to keep things as simple as possible. But however simple or elaborate the formula, the underlying point is this: having measured the relevant driving factors, we can use the formula to calculate expected consumption. In other words, we can explain consumption and thereby detect deviations from expected values. Subclause 3.5.1 of BS EN 16001:2009 places an obligation on the compliant organization to do exactly that.

1-3 Detecting and prioritizing exceptions

It is good practice (and an explicit requirement of BS EN 16001:2009) to keep a register of opportunities for saving energy. Opportunities will originate from energy surveys, from suggestions made by staff or contractors and from the detection of what BS EN 16001:2009 calls 'accidental excess consumption' caused by minor faults, human error, and so on: what we would call 'exceptions'.

The energy manager in a large organization could have hundreds or even thousands of metered streams of consumption to deal with and the traditional method of detecting exceptions was to assess the monthly consumption through each against some yardstick (maybe the consumption in the same month the year before) and to set a percentage variation limit on the deviation which would trigger an alarm if breached. Results are very often reported simply by flagging the supposed exceptions on general summary tabulations or, at best, by extracting a list of those streams which are supposedly out of limits. Leaving aside the use of a monthly assessment interval (which I would regard as too long), this methodology, which has unfortunately become the basis of some energy-management software products, is crude, unreliable and inefficient.

A much better approach can be found in better commercial monitoring and targeting (M&T) packages and can readily be implemented in a home-grown spreadsheet-based energy monitoring scheme. It simply requires that you have, in each practicable case, a formula for calculating expected consumption from the known values of the driving factors ('energy factors' in BS EN 16001:2009) as outlined in section 1-2. Given the driving-factor data for the week in question, your software can thus assess the deviation (in energy-unit terms) from expected consumption and it is the size, and more specifically the cost, of this deviation which determines its importance. Percentage is secondary: a big percentage deviation on a minor consumption stream could be less

Source: Chris Morris

Figure 1.9 — *When this non-return valve failed on a plant, hundreds of pounds a week was wasted on extra electricity for the compressor*

significant than a moderate deviation on a large one. A small absolute deviation on an expensive commodity may be more important than a bigger deviation in something cheaper.

Once we have a cash value for the deviation for every targeted stream for the week we are reporting, we need to find an efficient way to present the information to the user and the best method — which may seem obvious — is simply to rank the report in descending order of the costs of deviations. Such a report is called an Overspend League Table and it has the following attributes and advantages:

- The most important deviations are always at the top of the first page;
- It will be immediately clear which, if any, consumption streams are worth pursuing. If the biggest deviation is not costing too much, you can get on with other work and not waste time;
- No specialist energy knowledge or computer skills are needed;
- Other consumables like water, chemicals, and so on can be integrated into the same management report;
- There is no limit to the number of streams reported (because of the way the important cases float to the top).

There is one final refinement that I would suggest and that is to have within your M&T scheme a way of recording typical variability for each monitored stream; in other words, the limits of normal deviation in unit terms. Some streams will exhibit more variability than others because in some cases the formula for calculating expected consumption will work well with only a small error under normal conditions, while in others the uncertainty will be much greater. Suppose for example you had two electricity-consumption streams, one which normally varied by plus or minus 500 kWh in the week and the other plus or minus 7 000 kWh. If both experience excess consumption of 2 500 kWh, the apparent cash loss would be the same in both cases but only the first would be treated as a significant deviation. As we want to avoid both spurious alerts and the possibility of missing things, we must tune our assessments of individual streams' behaviour and filter the results accordingly.

Figure 1.10 is an overspend league table implemented in a spreadsheet and includes lettering to indicate significance. The symbol H indicates unusually high excess consumption and L indicates consumption significantly below expectations. Otherwise the deviation can be assumed to be within the normal range. Where data gathering has been taken care of, it takes only a few moments a week to generate this report. It does not need to be published or circulated: its purpose is to support a decision about what (if anything) needs to be pursued. It is all about enabling the energy manager to ask the right questions of the right person at the right time.

Overspend league table for week ending 01/10/2009

Stream	Apparent overspend	Actual units	Expected	
North factory - treatment plant electricity	**£386**	1627	995	**H**
Building 1 - milling and grinding electricity	**£273**	277016	272474	
Building 3 - air compressor electricity	**£216**	63881	60291	
East factory - cooling tower makeup water	**£175**	3540	3254	
Building 3 - Nitrogen flow	**£159**	360137	350186	**H**
North factory - EZ Klenz	**£140**	86295	77564	**H**
Primary processing - office elec	**£70**	35654	34500	
Primary processing - HVAC elec	**£50**	8331	7500	**H**
Building 1 - effluent	**£44**	2254	2182	
Building 1 - lighting electricity	**£33**	23130	22579	
Building 3 - cooling tower electricity	**-£9**	33446	33584	
Building 1 - kitchens electricity	**-£11**	7203	7388	
East factory - flue scrubber water	**-£61**	475	575	**L**
Building 1 - main inlet water	**-£62**	11228	11330	
Building 1 - chillers electricity	**-£71**	29045	30227	
Building 1 - air compressor electricity	**-£72**	44934	46127	
Building 1 - incinerator gas	**-£126**	18692	25000	**L**
Building 1 - N2 plant elec	**-£135**	133539	135781	**L**

Figure 1.10 — *The overspend league table*

It is good practice to keep a record of any significant excess consumption that you detect and to track this through to resolution. In fact BS EN 16001:2009 makes this a requirement. A word of caution, however — you should check all the data before doing so and not just the consumption data. Remember that an error in degree-day figures, production or other driving factor could equally be to blame for spurious reports.

1-4 Raising awareness and motivation

Although energy efficiency is a technical topic, the solutions are not all technological. Human factors — attitudes, knowledge, awareness and skills — will be a significant energy aspect for most organizations because while it is true that people cause some energy waste, they also hold three keys to improvement:

1. Changing their behaviour;
2. Being vigilant for waste;
3. Suggesting improved working methods or technical innovations.

But improvements will not happen spontaneously. People need help and guidance. We need to think about:

- Their levels of energy awareness;
- Their attitudes;
- What motivates them; and
- What knowledge (or even practical skills) they might need.

What motivates people? A good way to start finding out is by asking them. The very act of pounding the beat, chatting with folk informally about their views on energy and the environment, will itself start to raise the profile of the subject. Some will mention problems you did not realize existed: obstacles that perhaps can readily be corrected ('I never turn any of these lights off because I don't know which switch controls which area'). Others will volunteer ideas which up until that moment they have kept to themselves. If you let the conversation roam, you will find clues about things which might act as motivators ('I wish they'd plant some trees around the car park'). Of course you will get moans and grumbles as well: 'It's always freezing in here on Monday mornings'. This is important. You need to be in a position to do something about genuine minor grievances like this. The complaints you hear will have been made many times before and — as far as the complainer can see — ignored. If the problem is one which can be solved, it will be important for you to resolve it because otherwise it will be a demotivator. But sometimes the problem itself is not what demotivates: *it is the fact of the complaint being ignored*. If you follow up an issue and then go back to explain why it can't be resolved, that in itself may be such an improvement on earlier responses that your dissatisfied occupant becomes an ally.

For medium to large organizations, a questionnaire can then be designed using some of the clues that face-to-face interviews reveal. NIFES Consulting has done a lot of these, both paper-based and on-line, and uses a scoring technique that allows the workforce's profile to be plotted on a grid of motivation against awareness. The aim is to move people towards the high-motivation, high-awareness zone and out of the others. It is not always a question of people scoring low in both dimensions: those who are aware but unmotivated need different treatment from those who are highly motivated but lack awareness of what to do. Some people in that category present a perverse risk in that they may take initiatives which, being ill-informed, are counter-productive. Over the years a pattern has emerged from these studies which is that people are motivated most by having a top person from the organization visit their department on a walkabout energy survey. The things they value least are electronic communications.

The internet needs to be used with caution. My colleagues at NIFES have tried it for online questionnaires and found that exclusive reliance on internet surveys can skew the response by excluding those workers (such as domestics and catering staff in hospitals, or machine operators in factories) who do not have access to the internet or intranet and who, paradoxically, may be among the most important people to target. So they now provide paper questionnaires as a complementary input channel.

Fostering positive attitudes is not easy, but my experience has generally been that unless morale is at rock bottom, people will usually engage in a helpful way with something as worthy as environmental improvement. Motivation comes in many forms, of which money is perhaps the least effective and the most risky. People value learning about energy saving in the home, for instance, as a by-product of being trained about energy in the workplace. Reduced energy use, when it is achieved by avoiding operating equipment needlessly, also means reduced wear and tear, fewer breakdowns and even, in some cases, reduced noise nuisance.

Awareness-raising will be the least of your problems because everything you do (including asking people about their attitudes) will automatically improve it. Just bear in mind that there are at least two categories of awareness that you will want to test. One is awareness of how and where the organization uses energy; the other is awareness of what individuals can and should be doing to minimize consumption. Historically, we have also tested awareness of climate change and its causes but this is now much less important because people today are either aware of the issue through media exposure or want to argue about whether it actually exists which does not help us.

Providing training (even very brief sessions) can help enormously, not just by helping people to work in an energy-conscious way, but also by creating a break from normal routine and even providing a bit of fun. For some key workers, that essential bit of skills training may contribute directly to energy saving. In 1986 when I was working for Gloucestershire County Council, we spent just under £12 000 on off-the-job energy training days for school caretakers. Not only did we raise their awareness; we found we had (quite accidentally) improved their attitudes and motivation by providing them with the first training most had ever had. They enjoyed meeting each other and several went on to make valuable energy-saving suggestions. One moved to a large college where he single-handedly saved two-thirds of the cost of the programme. Three years later (and after I had left), the County Council was still attributing those training courses with energy savings worth over £80 000 a year. They had recouped their investment 20 times over; now that's what I call a payback

The benefits of improved awareness fade with time so how often should you refresh an awareness campaign? Twice a year? Every three years? The answer is to use your energy monitoring and targeting scheme to detect loss of momentum. You will also find that it produces charts that can be used to provide feedback to staff.