Fuel Efficiency Booklet 21

Simple measurements for energy and water efficiency in buildings

BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

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Contents

1 Introduction

Most organisations are aware of the need to use energy and water efficiently, and to minimise any waste of these utilities. This Guide describes how to take simple measurements to identify opportunities for eliminating such waste. It concentrates on services where excess use is common, eg areas which are overheated or too brightly lit, or where the building is unnecessarily serviced outside occupied hours.

This Guide is directed at the needs of managers, rather than specialist engineers and technicians, and will enable them to identify the areas with the greatest potential savings to their organisation.

1.1 About this booklet

This booklet is divided into two distinct sections. The first section describes a structured approach that should be used to identify waste for a number of building services. The second section provides more detailed advice on how some of the measurements should be taken.

The approach recommended is based on:

- measuring the current levels of energy and water use
- comparing these with norms or acceptable service levels
- identifying areas where improvements are likely to be achievable
- suggesting appropriate follow-up activities to verify that the situation has improved.

This guidance is aimed at busy individuals who do not necessarily have a technical background. The emphasis is on checks that are simple to implement and quick to perform, which are likely to produce measurable savings.

A practical approach has been adopted, concentrating wherever possible on taking measurements using existing equipment. If additional instrumentation is needed, guidance is given on the choice, purchase, and use of the equipment required for the more specialised measurements. A great many useful measurements can be carried out with equipment costing less than £250. There is often potential to save 20% of the energy used, and the payback period for this expenditure will in most cases be only a few days to a few months.

1.2 Potential savings

The ultimate aim of this booklet is to identify wastage that can be eliminated cost effectively, and not necessarily to optimise performance. Noticeable and worthwhile savings should be obtained without extreme measures which could antagonise staff who would then resist any changes.

The potential for energy savings identified within this guidance is based upon seeking answers to the following questions:

- does any equipment operate out of hours unnecessarily?
- are existing service levels in excess of best practice?

The total annual spend on energy in the UK is £58 billion (1998). For many buildings 20% can often be saved through simple good housekeeping measures.

2 A structured approach

This section will identify:

- measurements which are likely to lead to noticeable savings
- quick checks which provide reassurance of satisfactory performance
- areas where more detailed investigations may lead to larger savings.

In general, the savings available are the difference between typical operation of the building and 'best practice' operation.
In broad terms, best practice buildings use only 50-60% of energy used by typical buildings. This represents a significant financial saving with direct impact on the organisation's operating costs.

The 'low-hanging fruit' should be tackled first, the priority being an assessment of energy and water consumption out of occupied hours. The results should be used to identify further savings for occupied periods by comparing consumption levels with standards.

2.1 Identifying waste

This section is concerned with taking measurements to identify the various areas of waste, assessing the size of the problem and suggesting follow-up action.

The majority of energy and water consumed out of hours is unnecessary. Similarly, where a service is being provided to a higher level than is strictly necessary for business needs there is an opportunity for reduction. Eliminating this wastage will bring immediate returns both in financial and environmental terms. Cost savings are a very effective incentive, but the importance of minimising emissions of greenhouse gases is increasingly being recognised.

2.2 Water

The amount of water used in an empty building should be minimal. All that is normally required is a small amount for well-controlled urinals, and final top up of storage tanks. Anything else is usually waste.

Water and sewage charges account for roughly 15% of running costs for the majority of buildings. Each cubic metre saved will reduce combined water and sewage charges by approximately £1.

The balance between the costs of checking for leaks, and the cost of wasted water must be assessed. Typical check intervals for readily accessible meters will be one to three months. Information from large estates indicates that after three years with no water leak checks, approximately one-third of all premises had water leaks meriting attention.

Rule of thumb

Less than 35 litres overnight per 100 persons in an average office or school is indicative of satisfactory operation. Establishments such as hospitals with 24-hour occupancy will have higher usage.

Action

Quantify the out-of-hours consumption by noting the time taken for one revolution of the water meter's dial (use the second hand on a wrist watch). The figures inscribed on the faceplate of the meter will give the calibration units needed for this calculation. Alternatively, take the water meter reading at the end of the day when tanks would have re-filled, and again before water is used first thing in the morning or over the weekend.

If the reading is higher than the rule of thumb figure, repeat the measurement. In the interim, check for any obvious water waste.

(NOTE: Water meters can fail, and it is always worth opening a few taps when the building is empty to ensure that the meter records consumption at low as well as high flow rates.)

The water meter should also be read at one-hour intervals throughout a normal working day. The purpose is to detect any period of high use and to identify its cause. For example, some kitchen staff may leave hot water running for appreciable periods just to warm pans.

Compare water meter readings with those quoted on water bills. If you don't know where the water meter is, ask the Water Board.

Equipment

The following equipment can be used:

- existing water meters
- wrist watch with a second hand
- long screwdriver (that can be used as a 'sounding rod').

Follow up

Check for water wastage. Many of the following indicate the need for maintenance.

- Look for taps dripping or left running.
- Patches of green in an otherwise dry area of grass may indicate an underground leak.
- Look for signs of water running to waste, such as lime scale or algae below overflow pipes.
- Look for signs of leaking radiators (drips or staining) and water loss in boiler houses or plant rooms.

Sounds associated with water leaks can be noisy and are easiest to hear early in morning before the building gets noisy or traffic builds up. A long screwdriver can be used as a 'sounding rod' by placing the handle against your ear while the blade is in contact with the water pipe.

Water used for horticulture, car washing and even urinals accounts for a significant proportion of usage. All of these areas should be reviewed. It is often worth installing automatic controls for urinals, especially in buildings where the weekly hours of occupation are low.

Tips

Boilers can start operation as early as 05.30 and noises caused by pumps travel long distances through pipework. Hence, it is necessary to either listen for leaks before that time or to temporarily isolate all boiler plant. If you find significant leaks, there is a possibility that you have been overcharged for sewerage disposal. Normally, sewerage is charged in proportion to the volume of water entering the building. If water from the leak has not been returned to the sewer, then a refund is possible. Large refunds are not unknown.

Modern meters have greater sensitivity at low flow rates. Therefore, if your meter is replaced, carry out a water leak check at the earliest opportunity.

Safety

Ensure that pedestrians cannot fall into an open meter reading pit.

2.3 Electricity

The following items might use electricity in a well-run building when no one is there:

- security equipment (alarms)
- security lighting
- computer networks
- vending machines/water coolers
- heating/ventilation plant for pre-heat
- domestic refrigerators in offices
- telephone equipment and fax machines.

Anything else is usually waste.

Electricity costs are a major contributor to variable overheads and are frequently in excess of half the total utilities spend. There is a high probability of identifying unnecessary electricity use outside occupied hours. This can be caused by a wide variety of electrical equipment left running, regardless of the need. Lights are regularly left on and personal electric heaters are common during cold weather.

Fixed plant (eg heating, ventilation and air conditioning) operating outside of occupancy or during overlong pre-heat periods can account for a large proportion of the electricity bill. Savings can often be achieved by simply adjusting time settings or replacing controls.

Rule of thumb

The level of night-time electricity use is typically 20-45% of the peak load during occupied hours. Efficient operation is usually characterised by a figure of 5-15%.

Action

Checks should be carried out during periods of peak demand (generally between 10.00 and 12.00 and between 14.00 and 16.00) and in the evening after working hours/staff have gone home.

Large sites (ie those with electricity bills in excess of £20 000 per year) are usually metered by ‘code of practice’ meters which record electricity consumption for every 30 minute period for each day. This data will usually be available from your electricity supplier. If you do not have a ‘code of practice’ meter then, using any conversion factors printed on the meter, take meter readings over five minute intervals. Alternatively, record the time interval taken for each incremental change in the reading. The meter will record electricity consumption in kWh, and this can be converted to electrical demand (measured in kW) by multiplying by 60 and dividing by the time interval in minutes.

If the night-time electricity consumption is higher than the rule of thumb figure, repeat the measurement. In the interim, check for any obvious waste.

Compare electricity meter readings with those quoted on monthly electricity bills.

Equipment

The following equipment can be used:

- existing electricity meter
- wrist watch with a second hand.

Follow up

Check for electricity wastage.

- Look for lights left on unnecessarily overnight, particularly in unoccupied areas.
- Review the use of personal electric heaters.
- Review settings and operation of time controls, eg for heating systems.
- Review the operation of PCs and office equipment.

Tips

Institute a procedure in each department of ‘last one out turns off the lights’.

Ensure that cleaners only have lights on in their immediate work area, and corridors and stairways needed for safe movement. It is a common practice of some cleaners to switch on all lights and then leave them on until each area is completed.

Use security or post-room staff to identify wasteful use of electricity or to take meter readings.

PCs have energy-saving features, eg they can power down monitors if inactive for a pre-set period of time.

Promote a ‘minimum energy day’ where everyone, just for that day, does their best to turn off all lights and office equipment when not needed. This can set a baseline consumption that will identify the readily achievable savings. Repeat this exercise on an annual basis.

2.4 Heating and hot water

Overheating is one of the most common forms of waste for heating and hot water, and one of the easiest to address. Often all that is required is the adjustment of existing controls.

Underheating can also be an expensive problem if electric heaters are used to supplement normal heating systems. Electricity can cost more than five times that for boiler fuel for equivalent heat outputs.

Buildings take time to heat up. Hence, when the building is cold, such as after a cold weekend, the building needs to be pre-heated for a longer period. In smaller buildings a time switch may be set to turn on the heating at, say, 6 am in preparation for occupancy at 8 am. Larger buildings should have an optimum start controller that adjusts the start time to ensure that the switch-on time is at the last possible moment. Thermostats and time switches are often set to bring heating up to temperature well before occupancy. Measurements of this wasted heating time show that occupancy temperature is often reached one to two hours before necessary.

While gas and oil energy costs (per kWh) are lower than those for electricity, an appreciable saving can nevertheless be made. Furthermore, while heating systems are active, pumps and fans consume electricity, which may account for 5-8% of the fossil fuel costs.

Where hot water is stored it should be heated to a temperature of 60°C in order to eliminate the presence of legionella. This is most efficiently achieved by using time controls to heat the entire contents to 60°C throughout for an hour when there is no draw off (usually at night).

Rule of thumb

An increase in space temperature of 1°C will increase heating costs by 5-10%.

A building that is up to occupation temperature for 12 hours a day instead of 10 hours a day is wasteful. The increase in fuel consumption is approximately 7% for each hour the building is heated unnecessarily. Good optimum start controllers achieve the desired inside temperature within 20 minutes of the desired start time on 60% or better of 'starts' during the heating season. This compares with the 10-15% achieved by many low-cost controllers with inferior performance.

Action

During occupied hours, check room air temperature as indicated by Factory Act thermometers.

Look for windows being left open that may indicate excessive temperature, or supplementary heaters which might highlight inadequacies in the heating system.

During unoccupied hours, check that heating is off and that boilers, pumps and fans are not running. Sometimes boilers 'cycle' outside occupied hours, remaining hot and thus wasting fuel – check to ensure that this is not the case.

Measure when the 'desired inside temperature' is first achieved, and adjust the time switch appropriately (see 'Space heating' on page 6).

Check whether hot water is at an acceptable temperature, and that it is only available during working hours.

Equipment

The following equipment can be used:

- thermometer (calibrated mercury bulb thermometer or accurate digital thermometers are ideal)
- wrist watch with a second hand.

Follow up

Reset thermostats and time settings for heating controls. Introduce changes slowly or at the beginning of a heating season – the building occupants will adapt their dress to the environment. Ensure that time controls are installed that can 'recognise' the day of the week.

Rebalance systems to ensure that there are no hot or cold spots.

Tips

Space heating and hot water should only be provided when staff are present and not at other times. Outside working hours, only rarely will setback temperatures of greater than 5-8°C (to protect building contents and prevent pipes from freezing) be justifiable.

Setting thermostats to a higher temperature than is required will only affect the final temperature, and does not increase the speed at which the building temperature rises.

During cold weather snow will begin to melt on the warmest parts of the roof which may indicate areas of poor-quality insulation.

3 Measurement programme

A systematic approach to taking measurements should be adopted. This is to ensure that meaningful results are obtained and that it is possible to take appropriate action based on the results obtained. For example, measurements involving boiler systems taken during the summer months will provide results that relate to the provision of hot water. Similar measurements taken during the winter months will include the provision of heating and hot water, but the information gathered during the summer will enable the two components to be separated.

The following sections relate to measuring the lighting and heating levels in various work areas, with the ultimate requirement being to ensure that they are adjusted (generally downwards) in accordance with current best practice.

3.1 Space heating

Unlike lighting, which is instantly available, the temperature in a building takes an appreciable time to build up and, similarly, to decay. In addition, it is likely to be greatly affected by heat gains from the sun and other heat sources.

The desired inside air temperature should be achieved within the limits of +2°C and -1.5°C for most of the building between, say, 10 am and 4 pm. This should be a requirement for satisfactory building operation, with tests regularly carried out to check compliance. Consequently, measurements need to be taken at various stages during the heating cycle of the working day.

There are a number of factors that impinge on personal comfort, including the way in which the temperature varies within the room. A number of measurements are required to determine how well the heating systems are performing. Furthermore the person carrying out the measurements must be aware of factors which are likely to effect the accuracy of the results.

For example, where occupants find that they are uncomfortably warm, they will often open windows. While this will make them more comfortable, any measurements taken will not be meaningful for evaluating the performance of the heating system.

Heating inputs, and the resultant temperatures, are often not well balanced throughout a building. This effect can be magnified where there are internal sources of heat such as computers and electrical equipment. In addition, people generate heat at a rate of around 100 W per person.

There are different temperature requirements for different work areas. More energetic activities require lower temperatures for comfort. Generally temperatures of 19-21°C are comfortable for sedentary work, falling to 15°C or below for manual activities.

Instrumentation

There are a number of different types of thermometers.

The widely available mercury (or alcohol) in glass thermometer is relatively low cost, and is ideal for measuring the temperature of a fluid, eg water or air, even though they are delicate and have to be read with care. Furthermore, mercury glass thermometers are often accurate to within 0.1°C, and make an ideal calibration reference for other thermometers.

Bulb thermometers should be held in place for several minutes to allow sufficient time to settle to a representative temperature. Unless there is a specific reason, all thermometers should measure temperatures away from any sources of heat or cold spots.

Thermocouples have measuring probes consisting of a junction of two dissimilar metals, the most widely used probe being Type K.

Figure 1 Band probe sensor

Figure 2 Using a band probe to measure water flow temperature at a radiator

The sensor probes are normally at the end of a 1 m cable and are available in a number of physical forms to meet specific applications – general purpose, air temperature, insertion, surface and surface band probe.

The band probe is the most useful type. The thermocouple, in the form of a thin springy band, just projects beyond protective guards in the head of the probe. This ensures good thermal contact and thus accurate and consistent measurements when pressed against the surface to be measured. The sensor has a very low mass and is therefore very responsive to changes in temperature, and is well suited to making air temperature measurements, especially if the sensor head is moved in the air. When the sensor is attached to a pole, the 1 m cable is long enough to enable the temperature of all but the highest ceilings to be measured.

Infrared thermometers take the form of a hand-held probe. When pointed at an object they indicate the surface temperature by measuring the heat radiated from that surface. While relatively expensive (£100+) they have the convenience of being able to measure floor, ceiling, wall and other temperatures from a distance.

Data logging

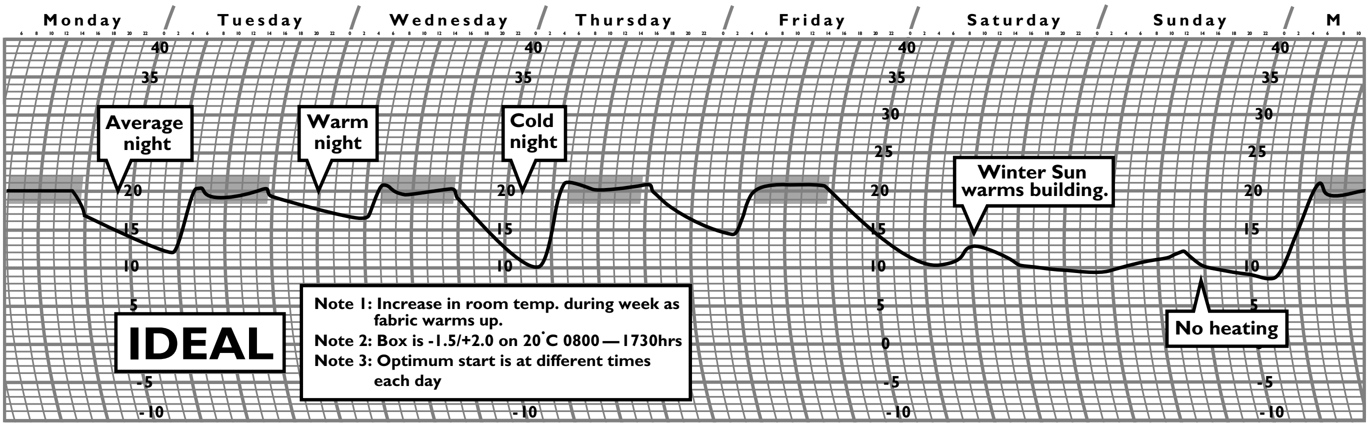
Data loggers are an alternative to taking manual readings. They are particularly useful where several readings are required over a period of time.

Some low-cost logging can be satisfactorily achieved by the use of a standard video recorder with time-lapse facilities, focused on the output of a gauge or dial. In addition, low-cost battery-operated data loggers are now available which are no larger than a few centimetres in diameter. When used in conjunction with associated infrared transmitters and computer software, they are especially useful for out-of-hours recording.

Many low-cost instruments have operating ranges of 0-30°C which is adequate for most interior air temperature measurements.

Low-cost ‘hockey-puck’ data loggers recording a single variable are available for approximately £100, with additional sensor modules costing approximately £50 each. Thermograph (chart recorders) can be hired for relatively small sums (approximately £30/week). These are normally calibrated immediately before issue. Some suppliers also offer an ‘interpretation’ service.

The following thermograph chart displays the temperature in a well-controlled building over a period of one week. Satisfactory temperatures are achieved during occupied periods, and the heating starts earlier during colder weather when the building temperature falls to lower levels overnight.



3.2 Lighting

Lighting is a major consumer of electrical power in buildings and their surroundings. Consequently, inappropriate lighting is a major source of waste. This can be due to either lighting being at a higher level than is needed, or being switched on when there is no business or safety reason.

Lighting on at too high a level

This can only be checked with a light meter. Lighting levels are frequently 30-50% higher than those recommended in the table below. In many cases where sufficient daylight exists, lights remain on wastefully.

Lights not turned off

When the building is unoccupied during evenings and weekends most, if not all, of the lighting can be switched off. Occasionally background lighting is needed for security or safety purposes. A lesser cause of waste, but one that is important because it can be managed, is unnecessary use of lights by the cleaners.

Instrumentation

Light meters for measurements in offices and factories will typically be able to measure interior lighting levels between 5 lux and 1000 lux to an accuracy of better than 5%. Street and security lighting levels are typically in the range 1-20 lux and require more specialist meters at greater cost.

Typical budget level instruments cost £40 to £70. Photographic light meters are not suitable for these measurements. Professional instruments used by lighting specialists cost £300 or more. NAMAS traceable (National Measurement Accreditation Service) Certificates of calibration are normally available at additional cost for all instruments.

Approach

Having determined the category to which each part of the premises belongs, the lighting levels should be measured in each area, using a light meter, with all the lights switched on. This should be done either early morning or late afternoon to determine the lighting levels when there is little prevailing sunlight.

The light levels for each type of area should fall within the appropriate range indicated in the table below. Anything higher is usually wasteful.

Variations of 20% within a room are quite common, being brightest immediately below light fittings. Daylight can impact on these dramatically and variations will be greatest at the perimeter of the room.

Different levels of lighting are required for different situations, as listed below:

	Lighting levels	
	Hours/year	**Light levels (lux)**
Offices	2500	400-500
Warehouses	3000	100-200
Corridors and stairs	As required	200
Close detailed work	As required	1000-2000
Security and perimeter lights	As required	3-5
Street lighting ‘A’ roads	As required	20
Domestic living room	N/A	100-200

Typical rooms have a 2% daylight factor, ie when the lighting levels out of doors are around 10 000 lux (equivalent to a moderately bright overcast day), then 2% of this will appear within the room. This would add an average of 200 lux to any artificial lighting level throughout the room, with higher levels close to windows or rooflights. For factories with rooflights the daylight factor can reach 10%, providing an additional 1000 lux.

Repeating a selection of measurements when the sun is high in the sky, will rapidly show when and where the prevailing natural lighting will allow all or some of the artificial light to be turned off.

Planned inspections during the day and early evening will identify those lights which have been left switched on unnecessarily.

Low-cost logging

This can be achieved by analysis of security video tapes and/or by use of standard video cameras with time-lapse features. Similarly, a time-lapse camera attached to a PC may be used. Analysis will show when the area is occupied and by whom, and can indicate whether it is lit by daylight or artificial light.

To identify total lighting electricity consumption a simple test approach can be performed as follows. When the building is unoccupied note the base load electricity consumption using the incoming electricity meter (see 'Electricity' on page 4) with and without all lights on. Select a time – generally during the daytime over the weekend – when very little electrical equipment is being used, and the loads are steady.

1. Identify from electricity meter readings what the consumption is without lighting.
2. Turn on the lights to identify usage.
3. Turn off the lights. Usage should return to 1. above.

Analysis

A quick overall performance guide based on standard office lighting levels is as follows.

Poor	20 W per square metre
Acceptable	13 W per square metre
Good	11 W per square metre

Follow-up actions (see also 'Electricity' on page 4)

Contact the person with responsibility for lighting maintenance and seek advice and a plan for bringing actual into line with needs.

Carry out random checks to see how many lights remain on unnecessarily – during the working day, at the beginning and end of the working day and outside occupied hours.

Ensure that for future refurbishment or maintenance works, performance specifications include lighting levels and that these are checked prior to acceptance.

3.3 Boiler houses

Boiler combustion should be set up for economical operation using instruments that measure the temperature of the flue gases and the completeness of combustion. Measurements in this area can have safety implications, and only appropriately trained personnel should undertake these tasks.

Many performance measurements should be undertaken as part of standard maintenance procedures with the results being recorded and supplied as part of normal maintenance reporting. Maintenance technicians will be able to advise on the appropriate figures for your particular boilers. However, the figures below are a guide for the various types of boiler.

It is quite common to have 7-10% O_2 and 3-5% CO_2 in the flue gases. This is indicative of supplying more air to the boiler than is necessary for efficient combustion. This additional air is being heated unnecessarily as part of the process of turning fuel into heat. High excess air may be due to the burner being badly commissioned, inappropriately selected or in poor condition. The person responsible for boiler maintenance should address all of these concerns.

High temperatures for flue gases also represents waste, and can indicate that the burner is oversized (the boiler surfaces cannot transfer the heat from burning the fuel). Although lower flue temperatures are indicative of efficient heat transfer, they should not differ significantly from the figures below. With the exception of condensing boilers, reliable operation requires combustion gases to remain above dew point temperature to avoid corrosive condensation products forming on the boiler surfaces, reducing boiler life.

Boiler type	Flue gas temp (°C)	% O_2	% CO_2	Net efficiency
Old cast iron boilers, oil/gas (1970 vintage)	280-320	3-5	9-12	70%
Steel boilers, oil/gas (1970 to early 1980s)	220-250	3-5	9-12	75%
Modern steel/cast iron, oil/gas	180	3-5	9-12	78%
Modern compact gas (1990s)	150	3	N/A	82%
Gas condensing	50-80	3	N/A	87-92%

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1A Energy audits for industry
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3 Economic use of fired space heaters for industry and commerce
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7 Degree days
8 The economic thickness of insulation for hot pipes
9A Economic use of electricity in industry
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10 Controls and energy savings
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14 Economic use of oil-fired boiler plant
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Fuel Efficiency Booklets are part of the Government's Energy Efficiency Best Practice programme, an initiative aimed at advancing and promoting ways of improving the efficiency with which energy is used in the UK.

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