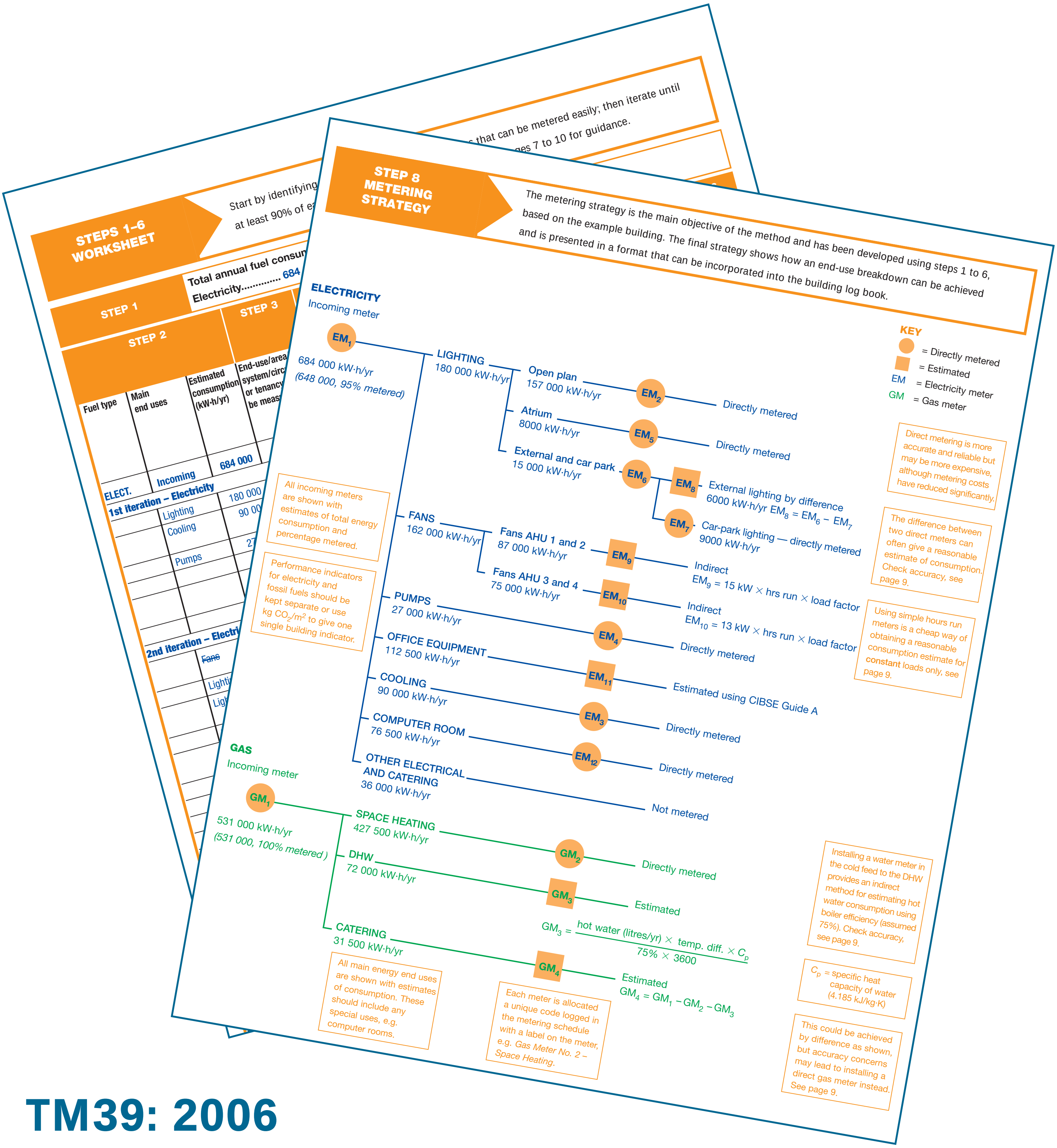
Building energy metering

CIBSE
Engineering a sustainable built environment



TM39: 2006

Corrections and Amendments

TM39: Building Energy Metering

Page 15, section 9.2: the paragraph: 'Where sub-metering...approved by OFGEM' should be deleted.

Building energy metering

A guide to energy sub-metering in non-domestic buildings

CIBSE TM39: 2006

Engineering a sustainable built environment

The Chartered Institution of Building Services Engineers
222 Balham High Road, London SW12 9BS

Registered charity number 278104

ISBN-10: 1-903287-70-7
ISBN-13: 978-1-903287-70-5

Typeset by CIBSE Publications

Printed in Great Britain by Latimer Trend & Co. Ltd., Plymouth PL6 7PY

Note from the publisher

This publication is primarily intended to provide guidance to those responsible for the design, installation, commissioning, operation and maintenance of building services. It is not intended to be exhaustive or definitive and it will be necessary for users of the guidance given to exercise their own professional judgement when deciding whether to abide by or depart from it.

Foreword

The late Peter Drucker, renowned management 'guru', said, "If you can't measure it, you can't manage it!". He probably did not have the energy use of buildings in mind when he said it, but it is as relevant to the measurement and management of building energy consumption as to any other resource use.

Most buildings have incoming meters for billing purposes. They measure the total input of the specific fuel to the site. Regular meter readings will provide some information about the overall energy consumption, but it reveals little about where the energy problems lie. Installing sub-metering throughout a building to monitor the specific uses of the fuel being metered can help identify which end-use or service (e.g. lighting, fans, pumps etc.) is performing well, or badly, allowing more targeted action.

Sub-metering provides the measurements to identify where and when energy is being wasted. Designers wanting to deliver good practice design should incorporate sub-metering in buildings in order to provide the occupier with the systems to enable the building to be managed properly. Facilities managers should assess their existing buildings to see where metering would help improve building management.

The case for sub-metering is now sufficiently well established that in England and Wales Part L of the Building Regulations requires installation of sub-metering for new non-domestic buildings and also, in some cases, for refurbishment. Sub-metering contributes to good energy management, and the strategy for energy metering in a building should be included in the building log book (which is also a requirement of the Building Regulations in England and Wales).

Good metering underpins the energy monitoring and targeting process which is an essential part of energy management. The guidance in this TM will enable energy managers to ensure that they are getting the information they need from their meters, to enable them to deliver added value to their business through good energy management.

This TM is an updated version of General Information Leaflet 65 (GIL 065): *Metering energy use in non-domestic buildings*. GIL 65 was first published by the Energy Efficiency Best Practice Programme, and subsequently adopted by the Carbon Trust. CIBSE wishes to acknowledge the permission and support of the Carbon Trust for the updating of the material for publication as CIBSE TM39.

Principal author

Phil Jones (Building Energy Solutions)

TM39 Steering Group

This TM is a revision of the Carbon Trust General Information Leaflet 65 (GIL 065): *Metering energy use in non-domestic buildings*, which was first published in 2002. It was revised with the help of contributions from various sources, under the overall responsibility of the CIBSE Publications, Research and Outputs Delivery Committee, chaired by Brian Moss.

Acknowledgements

CIBSE acknowledges the support of the Office of the Deputy Prime Minister in the production of this revision.

Permission of the Carbon Trust to revise and reproduce material from GIL 65 is gratefully acknowledged. Crown copyright material is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland under licence number C02W0002935.

Editor

Ken Butcher

CIBSE Research Manager

Dr Hywel Davies

CIBSE Publishing Manager

Jacqueline Balian

Contents

Building energy metering

1 Introduction

Good metering is a fundamental energy monitoring and targeting tool and an essential part of energy management.

Most buildings have meters on the energy supplies for billing purposes but these do not indicate why and where a building is performing badly. Sub-metering energy end-uses such as lighting, fans or pumps provides the means to identify where and when energy is being wasted. To reduce energy consumption and carbon emissions, building designers should incorporate sub-metering in new designs so that systems can be managed properly. Facilities managers should assess their existing buildings to see where extra metering would help improve building management.

All owners and operators of existing buildings could benefit from implementing a comprehensive metering strategy to help manage the energy consumption in their buildings more effectively.

Although the capital cost of individual meters has reduced in recent years, the cost of installing direct metering throughout a large building can still be significant. However, it is not always necessary to install large amounts of direct metering to establish end-use energy consumption. This document includes a number of less expensive measurement and estimation options for sub-metering that are appropriate for energy monitoring (see section 7).

Sub-metering in itself does not save energy. It is action taken as a result of installing and using meters that can achieve quantifiable energy savings. Meters that are selected and installed correctly provide the information for the monitoring and targeting process that is an essential part of energy management.

Action taken as a result of installing and using meters often save 5–10% of the energy being metered. Sometimes they can save more. For example, a meter that identifies pumps being left on for 24 hours per day, seven days a week, may save 60% of the energy passing through it, whereas a meter measuring well-controlled services, or a meter that is not read (or not acted on) will save nothing.

Manual meter reading can be time consuming and, as a result, often slips down the priority list. Modern automatic monitoring and targeting (aM&T) systems can help save energy by identifying energy wastage quickly using the minimum staff resources. While this TM provides a manual approach to meter reading, aM&T systems are more appropriate for many sites (see sections 2 and 10).

Better information leads to better buildings, with lower running costs and reduced environmental emissions.

Sub-metering is now a statutory requirement for some buildings in the UK. This is addressed in more detail in section 2. However, sub-metering is good practice and offers significant benefits which can be realised outside the scope of the regulations and outside the UK. This publication is therefore relevant to potential users wherever their buildings are located.

2 Benefits of sub-metering

2.1 General

Metering end-use energy helps:

- establish the breakdown of energy use within a building, i.e: ‘Where does it all go?’
- provide a better perspective on building operation
- identify where energy use is greatest
- identify what the minor loads are
- promote a detailed assessment of demand patterns and benchmarking to identify end-uses that are untypically high
- allow patterns of energy use to be monitored
- reveal useful trends between, say, day/night, summer/winter, weekday/weekend
- provide one year moving averages cumulative sum (CUSUM) plots comparing actual consumption with targets
- spot things going wrong before it is too late
- operators to understand and manage their buildings better, resulting in greater energy savings
- provide feedback to: building designers; building operators; manufacturers; government and supply side industry on performance achieved, helping them improve performance by setting better targets
- gain BREEAM credits (in some cases)
- designers complete the building log book (see box below)
- demonstrate compliance with building regulations (see section 3 and Appendices A2 and A3).

This document should be read in conjunction with:

- Good Practice Guide 348: *Building log books — a user's guide*[4]
- CIBSE TM31: *Building log book toolkit*[5]
- CIBSE TM22: *Energy assessment and reporting method*[6]

2.2 Enhanced Capital Allowances for aM&T

Automatic monitoring and targeting (aM&T) equipment helps save energy by identifying energy wastage and ensuring the long-term effectiveness of other energy efficiency investment measures (see section 10).

100% first-year Enhanced Capital Allowances (ECAs) are available on spending covering full aM&T systems or for equipment used as an element which completes a whole aM&T system. Qualifying aM&T equipment must be an element of a complete installation that measures, records, transmits, analyses, reports and communicates energy management information. This will usually consist of:

— meters and transducers

— some means of capturing, retrieving and storing the data electronically

— analysis, production and communication of consumption management reports.

This tax benefit is usually worth around 7–8% of the capital cost of the equipment. Details are available at the ECA website (www.eca.gov.uk). A CIBSE briefing on Enhanced Capital Allowances[1] is included on the CD-ROM that accompanies this publication.

3 Regulatory requirements

Part L of the Building Regulations for England and Wales[2] cover energy efficiency requirements and since 2002 have recognised the valuable role of metering by including requirements for sub-metering in non-domestic buildings. To enable building operators to manage energy use effectively, systems should be provided with appropriate energy meters. In new buildings, installing sub-meters that enable at least 90% of the estimated annual energy consumption of each fuel to be accounted for is considered reasonable provision. In some cases work carried out in existing buildings should include installation of appropriate sub-metering. Some off the detailed provisions of the Approved Documents L2A[3] and L2B[4] for England and Wales are included in Appendix A1.

In Scotland, the Building (Scotland) Regulations 2004* and the supporting guidance provided in Section 6 of the Technical Handbooks apply and in Northern Ireland Part F (Conservation of fuel and power) of the Building Regulations (Northern Ireland) applies.

* At the time of publication, the Scottish Executive is considering proposals for amending the energy standards in the Building (Scotland) Regulations 2004 and the supporting guidance provided in Section 6 of the Technical Handbooks.

At the time of publication, this TM supports the energy efficiency requirements of the Building Regulations in England and Wales with the following more detailed recommendations.

To enable owners or occupiers to measure their actual energy consumption, the building engineering services should be provided with sufficient energy meters and sub-meters. The owners or occupiers should also be provided with sufficient instructions including an overall metering strategy that show how to attribute energy consumptions to end uses and how the meter readings can be used to compare operating performance with published bench-marks. This document provides guidance on developing metering strategies.

Reasonable provision would be to enable at least 90% of the estimated annual energy consumption of each fuel to be accounted for. Allocation of energy consumption to the various end uses can be achieved using the following techniques:

— direct metering

— measuring the run-hours of a piece of equipment that operates at a constant known load

— estimating the energy consumption, e.g. from metered water consumption for hot water services (HWS), the known water supply and delivery temperatures, and the known efficiency of the water heater

— estimating consumption by difference, e.g. by measuring total gas consumption and estimating the gas used for catering by deducting the measured gas consumption for heating and hot water

— estimating non-constant small power loads using the procedure outlined in chapter 11 of CIBSE Guide F: *Energy efficiency in buildings*[5].

Reasonable provision of meters would be to install incoming meters in every building greater than 500 m^2 gross floor area (including separate buildings on multi-building sites). This would include:

— individual meters to directly measure total electricity, gas, oil and LPG consumed within the building

— a heat meter capable of directly measuring the total heating and/or cooling energy supplied to the building by a district heating or cooling scheme.

Reasonable provision of sub-metering would be to provide additional meters such that the following consumptions can be directly measured or reliably estimated (see above):

— electricity, natural gas, oil and LPG provided to each separately tenanted area that is greater than 500 m^2

— energy consumed by plant items with input powers greater or equal to that shown in Table 13 of Approved Document L2[3,4] (ADL2) (reproduced here as Table 1)

— any heating or cooling supplied to separately tenanted spaces; for larger tenancies, i.e. those with floor areas greater than 2500 m^2, direct metering of the heating and cooling may be

Table 1 Size of plant for which separate metering would be reasonable (ADL2[2] Table 13)

Plant item	Rated power input / kW
Boiler installations comprising one or more boilers or CHP plant feeding a common distribution circuit	50
Chiller installations comprising one or more chiller units feeding a common distribution circuit	20
Electric humidifers	10
Motor control centres providing power to fans and pumps	10
Final electrical distribution boards	50

appropriate, but for smaller tenanted areas, the heating and cooling end uses can be apportioned on an area basis.

— any process load that is to be discounted from the building's energy consumption when comparing measured consumption against published bench-marks.

4 Using this document

This document aims to help designers to satisfy good practice requirements for the provision of sub-metering in non-domestic buildings. It will also help facilities managers introduce sub-metering in their existing buildings. It should be used to optimise the cost of metering against practicality; the value of the information gained and future energy savings. A step-by-step method is provided, illustrated by a worked example, that enables:

— selection of appropriate ways of metering energy use

— provision of information for building owners and occupiers.

Where appropriate, designers, installers and facilities managers should consider full metering of all end-uses using automatic monitoring and targeting (aM&T). For more information see section 10.

Enough direct metering should, where possible, be installed to measure all significant services and end-uses in non-domestic building.

The method (see Figure 1) in this document is iterative and it will almost certainly be necessary to go back and modify the initial proposal in order to reach the 90% metering level. The method can be used in new buildings or to introduce sub-metering in existing non-domestic buildings.

TM39 recommendation

Sub-metering should enable at least 90% of the estimated annual energy consumption of each fuel to be allocated to specific energy end uses, i.e. what it is used for rather than where in the building it is used.

Objectives of TM39

This document provides a practical method for developing a metering strategy that can:

— provide a clear approach to sub-metering

— optimise cost, practicality and savings

— help designers to comply with Part L of the Building Regulations

— improve building operators' understanding of their buildings

— help identify energy savings resulting in reduced CO_2 emissions and running costs

Used correctly, metering can typically result in savings of 5–10%, and sometimes more.

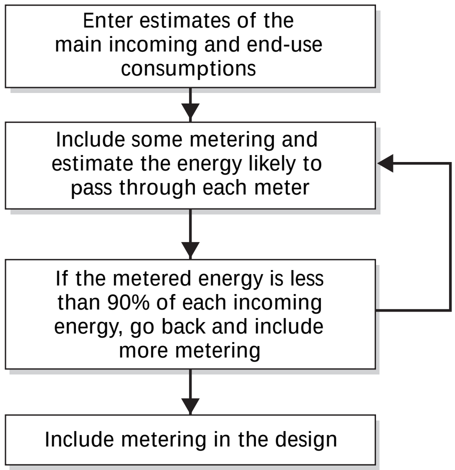


Figure 1 TM39 method

When carrying out a replacement of a controlled service or fitting then the relevant part of the metering strategy should be prepared or revised as necessary, and additional metering provided where needed to enable the energy consumption of the replacement service or fitting to be effectively monitored.

The method is set out in a series of worksheets that act as tools for designers. The objective of the method and the resulting sub-metering is to help facilities managers understand and manage their buildings better by measuring end-use consumption and comparing the results with benchmarks.

Well run buildings — the virtuous circle

'A high standard of energy efficiency is a good indication of high management standards. Efficiently run buildings tend to have design and operational arrangements that produce good staff relations and satisfied occupants.'

From CIBSE TM22: *Energy assessment and reporting method*

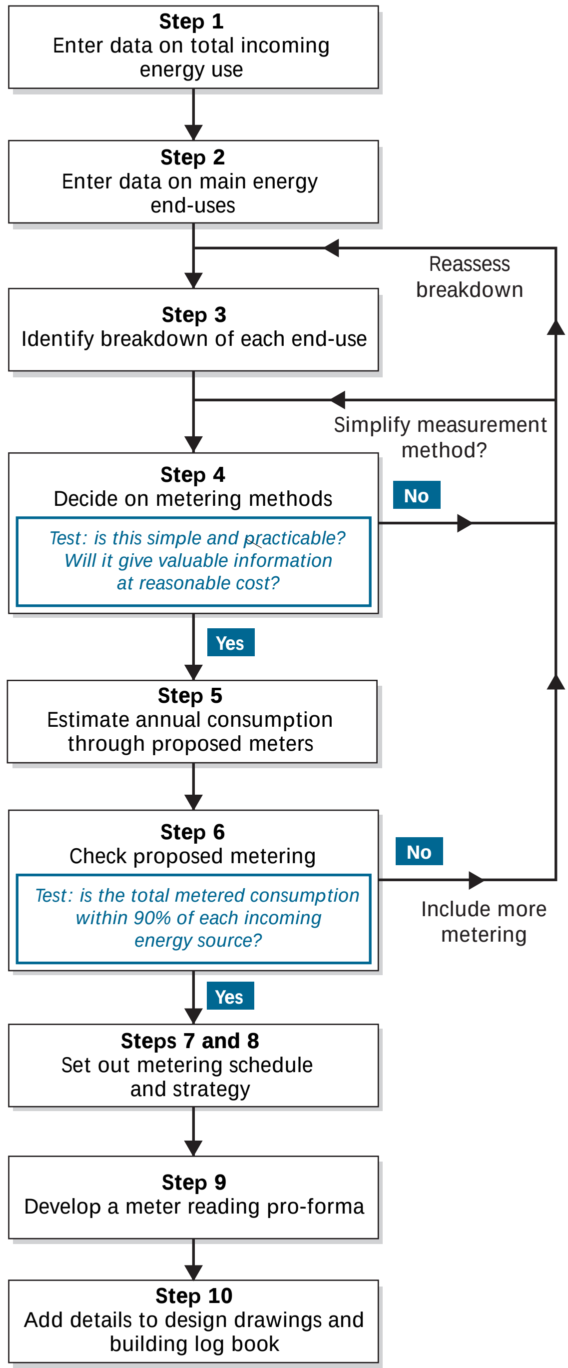


Figure 2 Ten step approach

5 Overview of the method

This section describes a step-by-step method for developing a sub-metering strategy that covers 90% of the total consumption of each fuel (see Figure 2 for a summary of the method and following pages for more detail on each step).

In essence, the method is an iterative process that allows the proposed metering to be compared with the predicted energy use of the building. If the initial proposal covers less than 90% of incoming energy use, it will be necessary to incorporate additional meters. If the proposal covers more than 90%, then the metering strategy and schedule can be prepared (see Figure 3).

Initially, all the data about the likely energy requirements of the building must be gathered together and entered into a spreadsheet. The proposed metering is then selected and

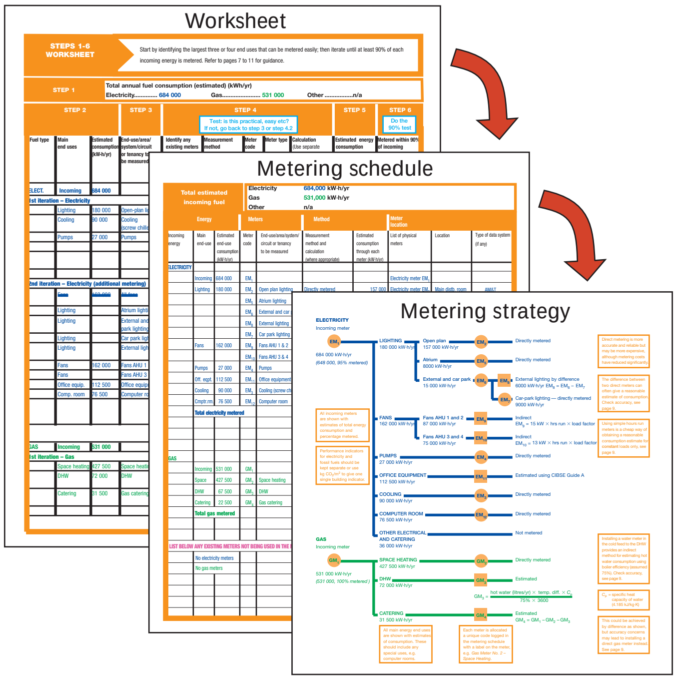


Figure 3 Overview of method

the proposals tested. This sequence is repeated as many times as necessary (steps 1 to 6). Finally, the data needed for the building's construction, commissioning and operation is prepared (steps 7 to 10).

6 Estimating energy uses

6.1 Understanding the building's energy use

Before the metering strategy can be developed it is necessary to have a clear picture of how energy from each fuel source (electricity, gas etc.) will be used in the building.

One of the main tools for end-use analysis is the energy assessment and reporting method detailed in CIBSE TM22[6]. This approach, with its associated software package, was developed for offices and has supplementary data that allows it to be used in banks and agencies, hotels and mixed-use (industrial) buildings. The approach can also be modified for use in any other building. TM22 provides three progressive levels of building assessment:

— *Stage 1*: a quick assessment in terms of energy use per unit floor area

— *Stage 2*: an improved assessment accounting for special energy uses, occupancy and weather

— *Stage 3*: a detailed assessment of the energy end-uses and systems.

TM39 recommendation

Wherever possible, install incoming meters in every building on multi-building sites and for individual tenancies in multiple tenancy buildings to measure directly the total electricity, gas, oil and LPG consumed within the building(s).

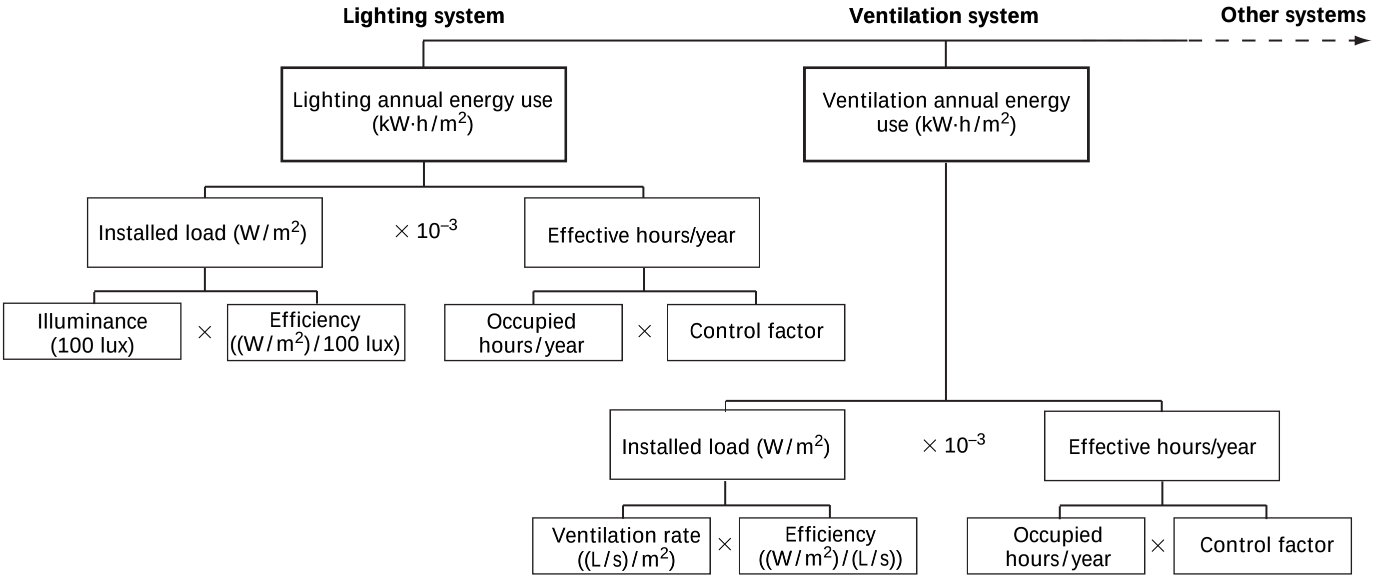


Figure 4 Part of a tree diagram showing two of the electricity end-uses

Each stage requires more detailed data inputs but provides a more detailed assessment of the energy uses. Special/atypical end-uses such as computer rooms, restaurants and car parks are separated out of the analysis at stage 2.

In a new-build situation, designers should be estimating the energy use of the systems that they are including throughout the design process and recording this in the building log book (see CIBSE TM31[7]). TM39 assumes that such a detailed analysis of energy end-uses is already available. A detailed assessment of the building and all energy end-uses will provide the most accurate picture of total energy use. It should be borne in mind that the building operator may use these estimates as targets in future. Facilities managers in existing buildings can use TM22 to develop a breakdown of end-uses.

In essence, the detailed assessment in TM22 requires the energy use of all equipment to be estimated in as much detail as possible. For example:

— fan consumption (kW·h/m^2 per year) = (kW/m^2) × hours run × load factor

— lighting consumption (kW·h/m^2 per year) = (kW/m^2) per 100 lux × illuminance (100 lux) × operating hours × control factor.

The data on individual energy uses are best understood by entering them onto a tree diagram (Figure 4). This provides a useful overview of the building. The upper lines of the tree are the 'coarse' picture; the more branches are added, the finer the detail. The value in each box is obtained by multiplying the two values in the boxes below. The main end-uses can be added together to obtain an estimate of total consumption.

Bear in mind that the data being compiled can be used to benchmark the building both at the design stage and during operation. Therefore it is essential to compare like with like, and to use the same definition of floor area (most commonly gross floor area, as defined in TM22[6]). Consumption data relating to different fuels should be presented separately.

Remember to include end-uses such as corridor lighting, toilet extracts, conference rooms, reception areas, car park lighting and security systems. TM22[6] and CIBSE Guide F[5] give further examples of end-uses.

6.2 Benchmarking

CIBSE and others publish benchmarks for various types of non-domestic buildings (see section 12). The tree diagram technique can be used to see how might perform compared to the benchmark for a typical building by inserting actual and benchmark data at each branch of the tree (see Figure 5).

As well as being an essential preliminary step in the overall design, this technique enables benchmarking throughout the design process across all levels of detail.

Examples of benchmarks include:

— incoming energy consumption (kW·h/m^2 per year)

— energy consumption of each system (kW·h/m^2 per year)

— installed equipment loads (W/m^2)

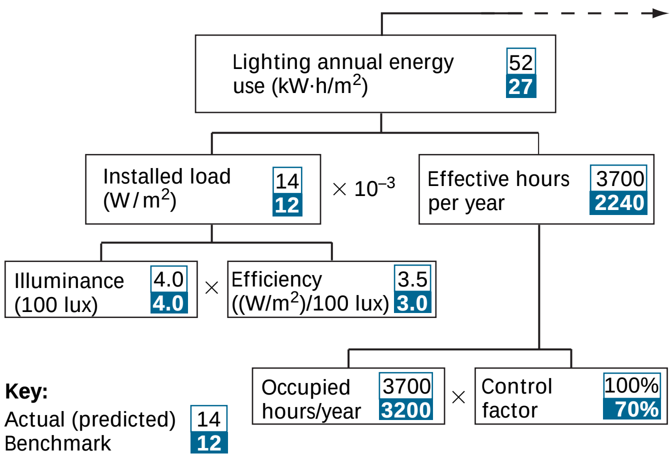


Figure 5 Part of a tree diagram with values for predicted energy use and benchmark data for comparison during the design process

— efficiency indicators, e.g. fan efficiency* (W/(L/s)) or lighting efficiency* (W/m^2 per 100 lux)

— service level, e.g. lighting (lux) or fans ((L/s)/m^2)

— operating hours (hours per year)

— control (management) factors.

Figure 6 shows how a building operator could use the information to compare actual operation with published benchmarks.

* The measurement of efficiency in both these cases is 'specific power', for which a low value is preferable.

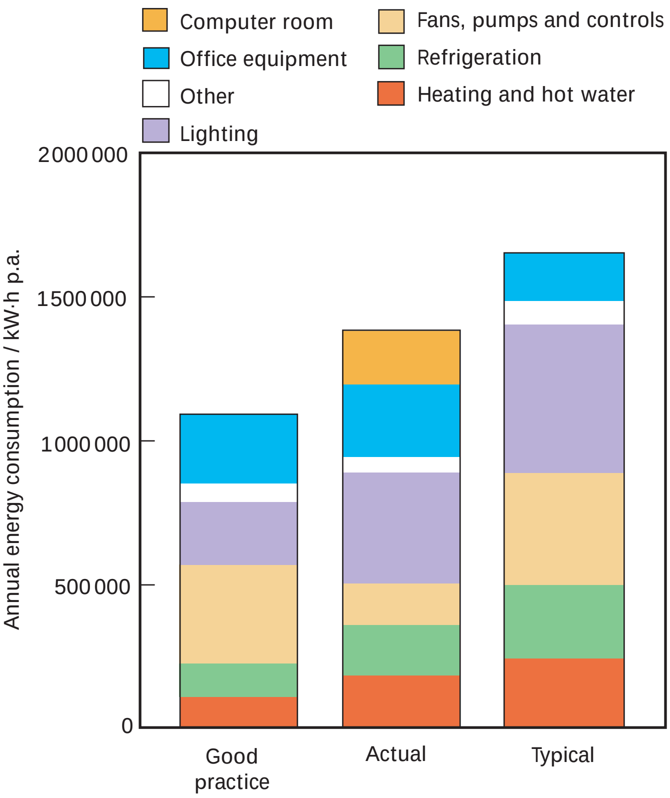


Figure 6 Chart showing how a building operator might use information from meters to compare actual consumption with published benchmarks

7 The method

7.1 Developing a metering strategy

Having gathered together all the details about the building's energy requirements, the metering strategy may be developed. This is illustrated in the worked example below. The blank worksheets included as Appendix A1 (and on the accompanying CD-ROM) may be used to develop the strategy for a particular building.

7.2 Worked example

The data presented below and on the sample worksheet (see page 11) refer to a typical new-build office. The building is of medium thermal weight brick construction with mainly open-plan areas. For the purposes of benchmarking, Energy Consumption Guide ECG019[8] divides office buildings into four types. The example building is considered to be a 'Type 3' building.

During the design process, the design team estimated the energy use of the building. Their energy-use tree is presented in Figure 7.

The main features of the example building are as follows:

— Treated floor area is 4500 m^2 on two floors with an external car park at the front of the building.

— Central boilers supply low pressure hot water (LPHW) space heating, and separate central gas storage heaters provide domestic hot water (DHW).

— Air handling units provide heating and cooling, but have no humidification.

— Catering is by a mixture of gas and electric appliances. The dishwasher is supplied from the main DHW system.

— Lighting is fluorescent throughout except for the external sodium lighting, which includes an open car park area.

— There is a dedicated computer room with its own air conditioning.

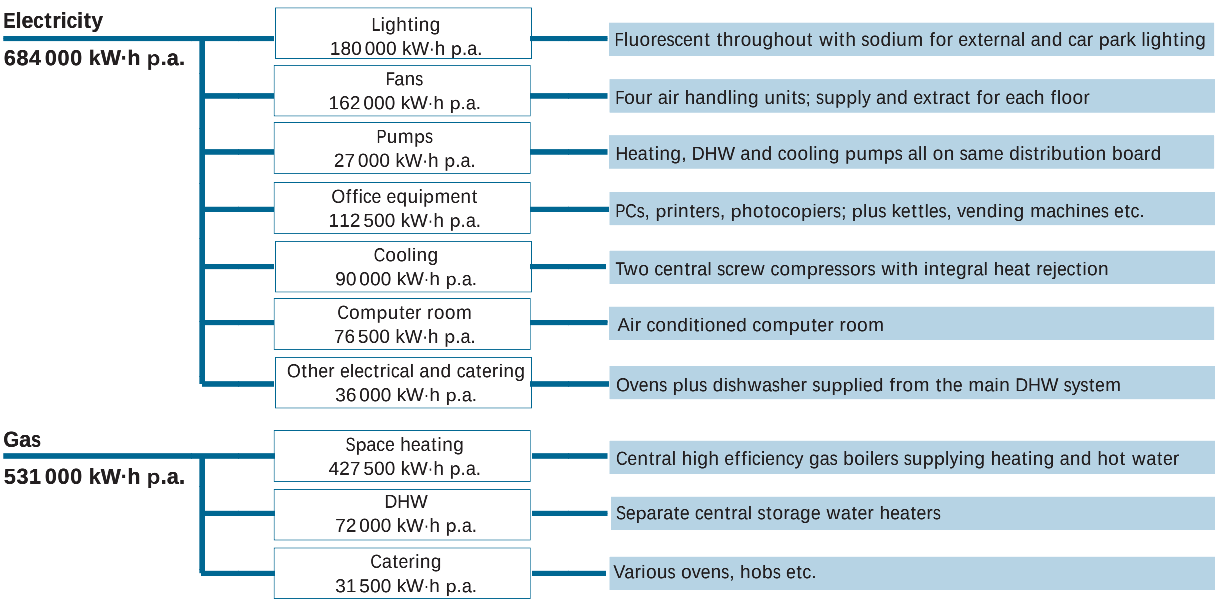


Figure 7 Estimated energy usage in example building

Step 1: Enter data on incoming energy use

Enter the total estimated consumption for each fuel type in the 'Step 1' box.

'Fuel type' means electricity, gas, oil and LPG. Solid fuels are difficult to meter and the energy consumption related to solid fuel combustion will need to be inferred.

The estimated total fuel consumption for each fuel type can be taken from the upper, 'coarse' level of the tree diagram. In existing buildings, this will come from the main 'billing' meter readings. The main incoming meters should always be included in the metering strategy as they are the basis for payment and as such require approval by the Office of Gas and Electricity Markets (OFGEM).

Any renewable energy source should be treated as another incoming energy with an appropriate incoming meter. It is also beneficial to treat water in the same way as energy and to apply the '90% rule'.

Step 2: Enter data on main energy end-uses

Enter the energy type, use and estimated consumption of the main end-uses in the 'Step 2' columns.

For the first iteration, identify three or four end-uses (the largest end-uses) that can be metered easily (e.g. lighting, cooling, fans). These data can usually be found in the second level of the tree diagram.

Remember that the building operator may use these estimates as targets in the future.

Tip: consumption data for different fuels should be presented separately.

Step 3: identify breakdown of each end-use

In the 'Step 3' column, insert a brief description of how the main end-uses that can be easily measured, can be broken down by area, system, circuit or tenancy.

Sometimes it is difficult to meter main end-uses. In this situation, metering sub-divisions of the main end-use may be an easier option and will provide more detail for the building's operator. Take account of distribution requirements, layout and physical location.

Breakdown of end-uses can be by:

— *area*: e.g. floor 1, 2 , 3 … or zone 1, 2, 3 … etc.

— *system*: e.g. AHU 1, 2, 3 … or boiler 1, 2, 3 … etc.

— *circuit*: e.g. circuit 1, 2, 3 … or distribution board 1, 2, 3 … etc.

— *tenancy*: e.g. tenancy 1, 2, 3 … etc.

For subsequent iterations, use the more detailed data that can be found at the lower levels of the tree diagram (e.g. break down lighting into its components — atrium lighting, car park lighting etc.).

For instance, on the second iteration of the worked example, lighting is divided into three separate end-uses in order to meter the total.

TM39 recommendations

Reasonable provision of sub-metering would be to provide additional meters such that the following consumptions can be directly measured or reliably estimated...

... energy consumed by plant items with input powers greater or equal to that shown in Table 13...

... any process load ... that is to be discounted from the building's energy consumption when comparing measured consumption against published benchmarks.

At this stage, particular large loads like chillers and boilers must be identified for sub-metering. Table 13 of ADL2 (reproduced as Table 1, see page 3) sets out the equipment and sizes where sub-metering should be installed. This includes all process loads such as computer rooms, manufacturing plant and hospital sterilisation plant to allow these to be discounted from the building energy consumption.

Step 4: decide on metering methods

Use steps 4.1 to 4.4 to help develop a metering strategy.

(*a*) Step 4.1: identify any existing meters (existing buildings only)

Facilities managers introducing sub-metering in an existing building may find that some sub-metering already exists. If so, these meters can be included at this stage in the method, provided that they will add useful information to the monitoring process. Conduct a survey and enter details of any existing sub-meters in column 4.1. Make a record of any existing data connections with BEMS or AM&T systems.

In some cases, existing sub-meters may be measuring energy flows that do not contribute to the overall metering strategy. These should not be included in the method or in the final metering strategy where, for example, meters measure energy flow through a main riser which is a mixture of lighting, small power and HVAC systems. Where the information is of no great value, facilities managers should avoid wasting staff time in taking regular meter readings for no practical benefit. However, it is still worth recording at the bottom of the metering schedule the existence of the meter, its location, what it measures and any existing data connections. This record can then be included in the building log book to prevent confusion about existing meters that are not shown in the strategy.

Where existing building services undergo significant alteration (e.g. when replacing boilers) then the upgraded system must include appropriate metering. (Guidance on this is set out in, for example, Building Regulations Approved Document L2B: *Conservation of fuel and power in existing buildings other than dwellings*[4]. See Appendix A2 of this TM for further information.) The metering schedule/strategy must be updated accordingly or, where they do not exist already, new ones should be developed to cover the upgraded system. In this case, the following steps only apply to metering the upgraded system and the

90% test at step 6 would not apply. The resulting strategy might only cover a small part of the overall end-use tree although this might give scope to deduce some of the other energy end-uses.

(*b*) Step 4.2: select how to meter main end-uses

For end-uses that do not already have metering, select a metering method and enter details in column 4.2.

Ideally, all energy consumption should be directly metered, but this is not always practical or cost effective. CIBSE recommends that it is good practice that at least 90% of each incoming energy be accounted for through the use of metering. Various estimation methods can be used where direct metering is impractical. This allows flexibility in order to:

— overcome practical installation problems

— optimise capital and installation costs

— integrate metering into the services as they are designed

— ensure that operators have a practical method for establishing an audit of energy use.

Using a combination of the five methods (see Figure 8), a metering strategy can be developed that is likely to comply with building regulations energy efficiency requirements while ensuring that the level of metering is appropriate, practical and cost effective for the building or design.

The five methods are:

— *Direct metering*: provides high accuracy and increased reliability in the overall energy audit. Many end-uses can be directly metered using standard electricity, gas, and oil meters. Some may require heat meters or steam meters.

Tip: direct metering might include meters that are built into equipment like variable speed drive controls and uninterruptible power supplies. However, check the accuracy of these before using the readings.

— *Hours-run meter* (constant loads only): can measure the operating hours of a piece of equipment that operates at a constant known load/speed (e.g. a fan). (Energy consumption (kW·h/year) = power (kW) × hours-run (h) × load factor). This provides a relatively cheap and simple way of reaching a reasonable estimate of consumption.

Tip: check accuracy — it is always better to measure the true power (W) being drawn than to rely on nameplate ratings. Measuring current provides only an intermediate level of accuracy.

— *Indirect metering*: readings from an indirect meter can be used to estimate energy consumption (e.g. measure cold feed water consumption and temperature difference to estimate hot water consumption). This is a relatively cheap and simple way to reach a reasonable estimate of consumption (see Figure 9).

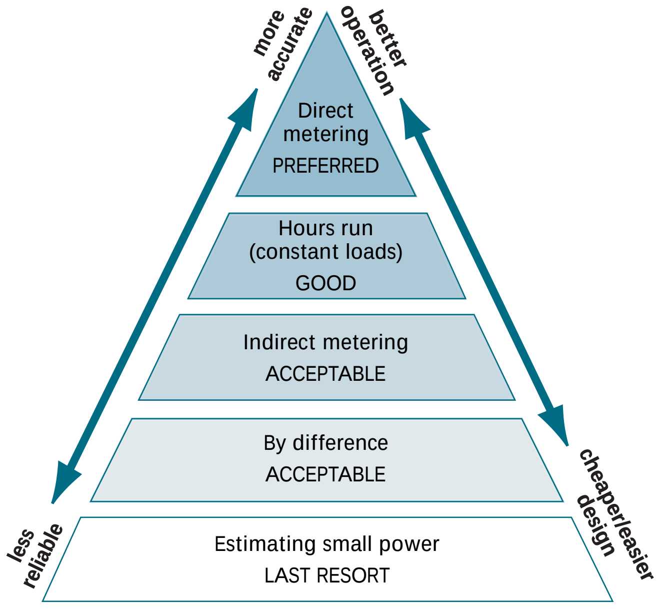
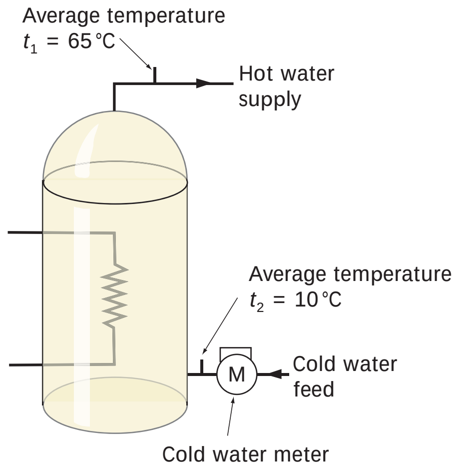


Figure 8 Five methods for determining energy consumption



$$\text{Estimated consumption} = \frac{\text{Metered feed water (litre/year)} \times \text{temp. difference (K)} \times C_p}{\text{Boiler efficiency} \times 3600}$$

$$= \frac{844\,574 \times (65 - 10) \times 4.185}{0.75 \times 3600} = 72\,000 \text{ kW·h/year}$$

Figure 9 Example of indirect metering

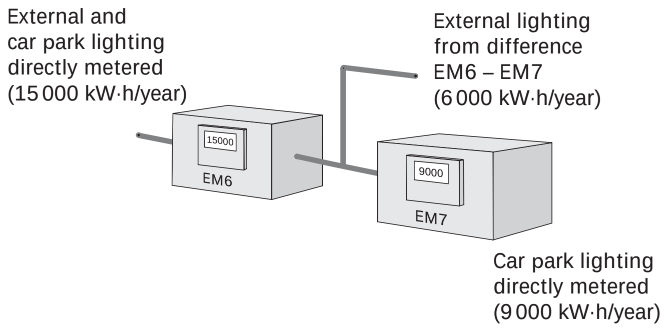


Figure 10 Example of metering by difference

Tip: check accuracy — poor estimation of temperatures and boiler efficiencies, for example, could result in a very poor estimate for annual energy use. The building operator should be advised to supplement estimates with spot measurements of temperature and boiler efficiency. Boiler efficiency will be much lower in summer on combined heating and hot water systems.

— *By difference*: two direct meters can often be used to estimate a third end-use by difference. For example, measure the total consumption of external plus car park lighting, then measure just the car park lighting consumption separately. The difference between the two will give an estimate of the external lighting consumption (see Figure 10).

Tip: check accuracy — in particular, this method should not be used if the value subtracted is an estimated value because the cumulative accuracy will be very poor. Subtracting a small consumption from a large consumption is also to be avoided because the margin of accuracy of the large meter may be greater than the consumption recorded by the smaller meter.

— *Estimates of small power*: reasonable estimates of small power (office equipment etc.) can be achieved using existing methods without installing extensive metering (see CIBSE Guide F: *Energy efficiency in buildings*[5], chapter 11).

Tip: check accuracy — e.g. poor estimation of actual power consumption for office equipment, or for its usage, could result in a very poor estimate of annual consumption. The building operator should be advised to supplement estimates with spot measurements of actual power and usage.

(*c*) Step 4.3: allocate a code to each meter

Set up a clear coding system to identify each meter in the building (for example, EM1 for electricity meter 1 and GM1 for gas meter 1, etc). Enter details in the 'Step 4.3' column.

This information will be passed to the building operator via the 'metering schedule', which shows what is being metered and the meter location.

(*d*) Step 4.4: select the meters

Select the types of meters required and enter the details in the 'Step 4.4' column. For uses that are not directly metered, note down the calculation method in the adjacent column.

For the first iteration, it is acceptable simply to identify a generic meter (electricity, gas etc.). As the strategy is developed these meters need to be specified, costed and any practical installation issues/problems identified and solved. Cost should be borne in mind but accuracy should be the determining factor in deciding whether to meter directly.

Size the meter to match the actual throughput; accuracy decreases when very small throughputs are measured. Smaller meters will cost less and may be more accurate but flow rate and pressure drop need careful consideration.

Test at step 4.4:

— Is all major plant metered?

— Re-check at this stage that sub-metering for all process plant, and all equipment detailed in Table 13 of ADL2 (reproduced as Table 1, see page 3), has been included in the strategy.

— Process loads need to be metered so they can be discounted from the building's energy consumption. These could include computer rooms, dealing rooms, telecommunications equipment, swimming pools and manufacturing processes.

It is almost always cost effective to purchase meters that allow connection to an aM&T system or building energy management system (BEMS). If there is a BEMS where heat needs to be measured, it can be considerably cheaper to install a flow meter and temperature sensors and allow the BEMS to do the calculations although accuracy will be significantly less than an integrated heat meter. Installation issues and connecting to aM&T systems and BEMS are considered in section 10.

Table 2 illustrates some of the issues that must be considered when selecting meters. Costs represent installations in existing buildings and may be considerably less in new build situations.

Tip: hours-run meters are very cheap and easy to install.

Tip: modern energy meters can now automatically switch from measuring heating to measuring cooling when metering the energy supplied by, for example, reversible heat pumps.

Table 2 Key considerations when choosing meters

Metered service	Type of meter and approximate installed cost	Typical accuracy	Key issues
Electricity	Single phase: £100–£200 Three phase: £500 upwards	± 1%	Single or three phase? Are current transformers needed? (required for all loads over 100 A)
Gas	Diaphragm: £300–700 Turbine £700–£1300	± 2%	Pressure drop? Pressure and temperature compensation needed? (May cost an extra £1000)
Oil and water	Oil: £350–£2800 Water: £250–£700	± 1%	Strainer to avoid blockages?
Heat	Electromagnetic: £450–£1200 Turbine: £400–£900	± 3 to 5%	Electromagnetic are more accurate. Dirty systems can be a problem.

Test at end of step 4:

- Before moving on, check the practicality of the metering method proposed for each meter:
  - (*a*) Is the meter easy to install in this location/system?
  - (*b*) Will it give valuable information on where energy is being used?
  - (*c*) Is this the simplest and most cost-effective method?
  - (*d*) Is this within the budget constraints?
- If not, go back to step 3 and identify a more suitable breakdown of end-uses (finer or coarser).
- Alternatively, go back to step 4.2 and identify a different way of metering.

Step 5: estimate annual consumption through proposed meters

Using the data from the tree diagram, estimate the total annual energy consumption through each meter. Enter the data in the 'Step 5' column.

Estimates should be made throughout the design process of the energy use of all the systems included. These energy requirements should be compared with the targets set in the design brief to ensure that the building is as energy efficient as possible (see section 6.2).

Step 6: test if metered energy is within 90% of incoming

For each energy type, add together the consumptions listed at step 5. Divide that figure by the estimate of total incoming fuel requirements (step 1). If the resulting value is less than 90%, go back to step 3 and include more metering.

Test at step 6:

- For each energy type, if the total sub-metered is greater than 90% of the total estimated incoming fuel then move on to step 7.
- If not then go back to step 3 to include more metering.

A worked example of steps 1 to 6 is shown as Figure 11.

Step 7: set out metering schedule

Once the proposal has passed the 90% test, a schedule of meters is drawn-up to include meter codes, locations etc., grouped by end-use.

A suggested layout is shown as Figure 12 (page 12), based on the data gathered for the worked example. The schedule must include estimates of consumption for each meter. A blank schedule is provided in Appendix A and on the accompanying CR-ROM.

Step 8: set out metering strategy

Once the proposal has passed the 90% test, a diagrammatic 'metering strategy' should be prepared. This should include meter codes and estimates of consumption for each meter. The metering strategy is the main objective of the method. A suggested layout is shown in Figure 13 (page 13), based on the data gathered for the worked example. The final strategy shows how an end-use breakdown can be achieved and is presented in a format that can be incorporated into the building log book.

Step 9: develop a meter reading proforma

The procedures for monitoring building energy performance are underpinned by setting up an easy to use meter reading proforma. Once the metering strategy and schedule have been established, then a meter reading proforma should be developed that is tailored to the specific building, see Figure 14 (page 14).

All the meters in the strategy should be included with the meter name and code at the top of two columns (for meter readings and consumption (kW·h)). A template version of the meter reading proforma is provided on the accompanying CD-ROM. This tailored meter reading proforma allows regular main and sub-meter readings to be recorded and kept in a separate file (not in the log book). Check that the meters read in kilowatt-hours (kW·h), otherwise use an appropriate factor to convert to kW·h, see CIBSE Guide F[5] or obtain the appropriate factors from the utility invoices.

Step 10: add details to design drawings and logbook

Incorporate the metering decisions on the design drawings. This will require a clear specification of each meter, including any connections to BEMS or aM&T. Meters for billing purposes must be approved by OFGEM. Sub-meters for energy management purposes can be specified using BS 8431[9].

The final schedule of meters and metering strategy, including the estimates of energy use, must be included in the building logbook in order to assist the building operator in monitoring building performance.

STEPS 1–6 WORKSHEET

Start by identifying the largest three or four end uses that can be metered easily; then iterate until at least 90% of each incoming energy is metered. Refer to pages 7 to 10 for guidance.

STEP 1 Total annual fuel consumption (estimated) (kW·h/yr)

Electricity.............. 684 000 Gas...................... 531 000 Other ....n/a

STEP 2			STEP 3	STEP 4					STEP 5	STEP 6
				Test: is this practical, easy etc? If not, go back to step 3 or step 4.2						Do the 90% test
Fuel type	Main end uses	Estimated consumption (kW·h/yr)	End-use/area/ system/circuit or tenancy to be measured	Identify any existing meters (Existing buildings only) Step 4.1	Measurement method Step 4.2	Meter code Step 4.3	Meter type Step 4.4	Calculation (Use separate sheet if necessary and reference here)	Estimated energy consumption through meter (kW·h/yr)	Is metered within 90% of incoming? Yes/No If not go back to Step 3
ELECT.	Incoming	684 000				EM_1				
1st iteration – Electricity										
	Lighting	180 000	Open-plan lighting		Directly metered	EM_2	Electricity		157 000	
	Cooling	90 000	Cooling (screw chillers)		Directly metered	EM_3	Electricity		90 000	
	Pumps	27 000	Pumps		Directly metered	EM_4	Electricity		27 000	
								Total metered	274 000	274/684 = 40%
					Is this 90% of incoming electricity?					**No! – add more metering**
2nd iteration – Electricity (additional metering)										
	~~Fans~~	~~162 000~~	~~All fans~~		~~Directly metered~~	~~EM~~	~~Electricity~~			Rejected as impractical
	Lighting		Atrium lighting		Directly metered	EM_5	Electricity		8000	
	Lighting		External and car park lighting		Directly metered	EM_6	Electricity			
	Lighting		Car park lighting		Directly metered	EM_7	Electricity		9000	
	Lighting		External lighting		Estimated by difference	EM_8		$= EM_6 - EM_7$	6000	
	Fans	162 000	Fans AHU 1 & 2		Indirect (hrs run)	EM_9	Hours run		87 000	
	Fans		Fans AHU 3 & 4		Indirect (hrs run)	EM_{10}	Hours run		75 000	
	Office equip.	112 500	Office equipment		Estimated (CIBSE)	EM_{11}			112 500	
	Comp. room	76 500	Computer room		Directly metered	EM_{12}	Electricity		76 500	
								Total metered (1st and 2nd iteration)	648 000	648/684 = 95%
					Is this 90% of incoming electricity?					**Yes!**
GAS	Incoming	531 000				GM_1				
1st iteration – Gas										
	Space heating	427 500	Space heating		Directly metered	GM_2	Gas		427 500	
	DHW	72 000	DHW		Estimated from h/w consump.	GM_3	Cold water		72 000	
	Catering	31 500	Gas catering		Estimated by difference	GM_4		$= GM_1 - GM_2 - GM_3$	31 500	
								Total metered	531 000	531/531 = 100%
					Is this 90% of incoming gas?					**Yes!**

Figure 11 Worked example: steps 1–6

STEP 7 METERING SCHEDULE

The metering schedule below has been developed using steps 1 to 6, based on the example building. The final schedule is presented in a format that can be incorporated in the building log book.

Total estimated incoming fuel		
	Electricity	684,000 kW·h/yr
	Gas	531,000 kW·h/yr
	Other	n/a

Energy			Meters		Method		Meter location		
Incoming energy	Main end-use	Estimated end-use consumption (kW·h/yr)	Meter code	End-use/area/system/ circuit or tenancy to be measured	Measurement method and calculation (where appropriate)	Estimated consumption through each meter (kW·h/yr)	List of physical meters	Location	Type of data system (if any)
ELECTRICITY									
	Incoming	684 000	EM_1				Electricity meter EM_1		
	Lighting	180 000	EM_2	Open plan lighting	Directly metered	157 000	Electricity meter EM_2	Main distb. room	aM&T
			EM_5	Atrium lighting	Directly metered	8 000	Electricity meter EM_5	Main distb. room	aM&T
			EM_6	External and car park	Directly metered	n/a	Electricity meter EM_6	Ext. sub room	aM&T
			EM_8	External lighting	Est. by difference	6 000			
			EM_7	Car park lighting	Directly metered	9 000	Electricity meter EM_7	Main distb. room	aM&T
	Fans	162 000	EM_9	Fans AHU 1 & 2	Indirect (hours run)	87 000	Hours run 1	Plant room 2	aM&T
			EM_{10}	Fans AHU 3 & 4	Indirect (hours run)	75 000	Hours run 2	Plant room 3	aM&T
	Pumps	27 000	EM_4	Pumps	Directly metered	27 000	Electricity meter EM_4	Boilerhouse	aM&T
	Off. eqpt.	112 500	EM_{11}	Office equipment	Estimated (CIBSE)	112 500			
	Cooling	90 000	EM_3	Cooling (screw chillers)	Directly metered	90 000	Electricity meter EM_3	Chiller room	aM&T
	Cmptr.rm.	76 500	EM_{12}	Computer room	Directly metered	76 500	Electricity meter EM_{12}	Comp. vent. room	aM&T
	Total electricity metered					**648 000**			
					% metered	648/684 = 95%			
GAS									
	Incoming	531 000	GM_1				Gas meter GM_1		
	Space	427 500	GM_2	Space heating	Directly metered	427 500	Gas meter GM_2	Boilerhouse	aM&T
	DHW	67 500	GM_3	DHW	Est. from h/w consumption	72 000	Cold water meter	Boilerhouse	aM&T
	Catering	22 500	GM_4	Gas catering	Est. by difference	31 500	Gas meter GM_4	Kitchen	aM&T
	Total gas metered					**531 000**			
					% metered	531/531 = 100%			
LIST BELOW ANY EXISTING METERS NOT BEING USED IN THE METERING STRATEGY									
	No electricity meters								
	No gas meters								

Figure 12 Worked example: step 7 — metering schedule

TM39 recommendation

Provide additional meters such that the following consumptions can be directly measured or reliably estimated:

… electricity, gas, oil and LPG provided to each separately tenanted area

… any heating or cooling supplied to separately tenanted spaces. For larger tenancies, such as those greater than 2500 m^2, direct metering of the heating and cooling will be appropriate, but for smaller tenanted areas, the heating and cooling end-uses can be apportioned on an area basis.

STEP 8 METERING STRATEGY

The metering strategy is the main objective of the method and has been developed using steps 1 to 6, based on the example building. The final strategy shows how an end-use breakdown can be achieved and is presented in a format that can be incorporated into the building log book.

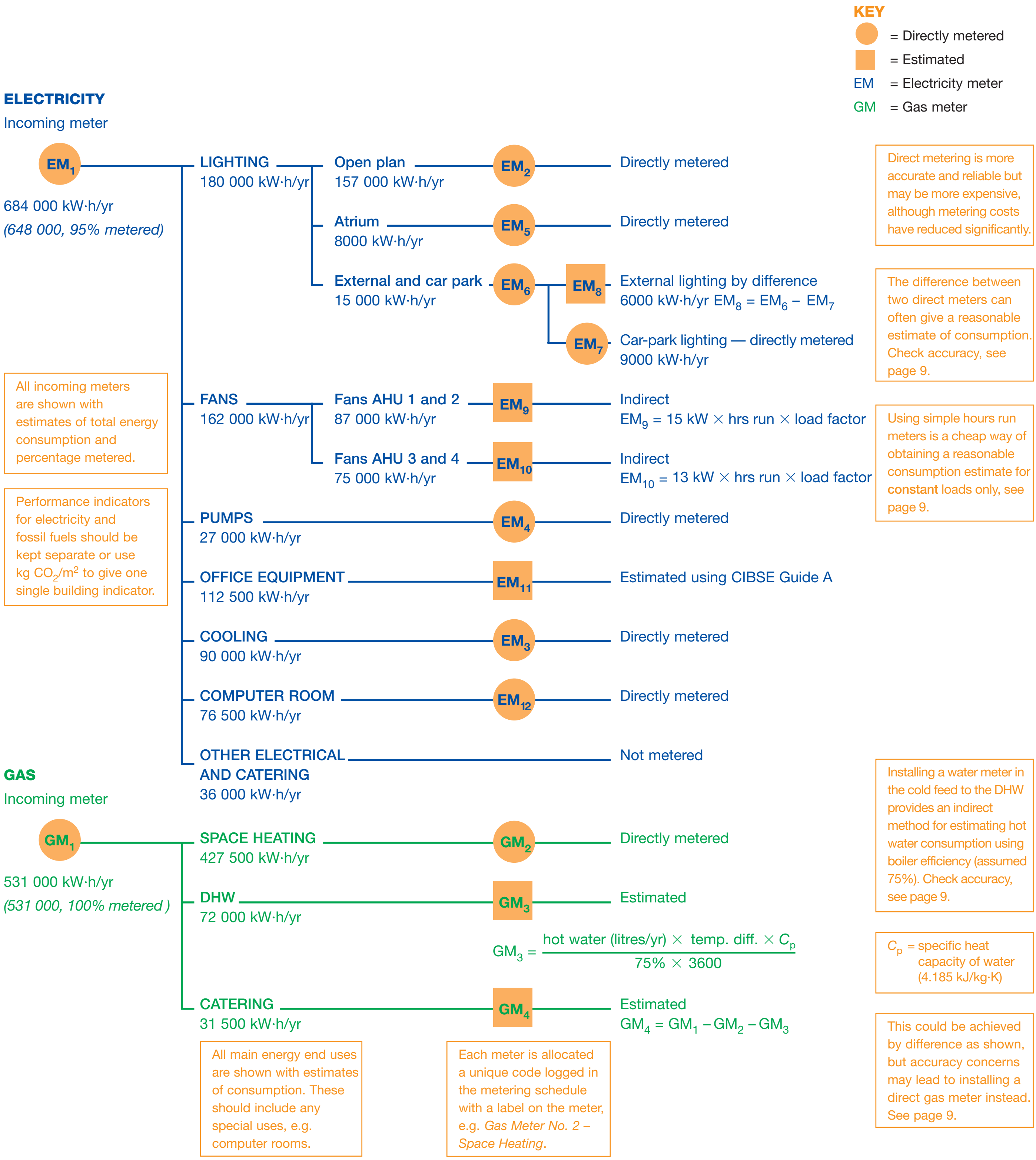


Figure 13 Worked example: step 8 — metering strategy

TM39 recommendation

Install incoming meters in every building greater than 500 m² gross floor area (including separate buildings on multi-building sites). This would include ..... a heat meter capable of directly measuring the total heating and/or cooling energy supplied to the building by a district heating or cooling scheme.

ELECTRICITY CONSUMPTION								
Year	2002	EM_1 Main electricity meter		EM_2 Lighting riser 1		EM_3 Lighting riser 2		etc.
Date	Time	Meter Reading	Consumption (kW·h)	Meter reading	Consumption (kW·h)	Meter reading	Consumption (kW·h)	
4.1.02	15:30	2,635,572		226,724		373,345		
4.2.02	11:00	3,256,147	620,576	258,323	31,599	408,888	35,543	
4.3.02	10:30	3,870,326	614,178	287,049	28,727	441,200	32,312	
5.4.02	13:30	4,503,697	633,371	313,478	26,428	470,928	29,727	
4.5.02	15:00	5,162,659	658,962	341,630	28,152	502,593	31,666	
4.6.02	16:00	5,834,416	671,757	367,771	26,141	531,998	29,404	
3.7.02	9:45	6,506,174	671,757	396,785	29,014	564,633	32,635	
4.8.02	10:15	7,165,136	658,962	428,097	31,312	599,853	35,220	
4.9.02	12:30	7,830,495	665,360	457,973	29,876	633,458	33,605	
4.10.02	15:45	8,470,264	639,769	485,263	27,290	664,154	30,697	
5.11.02	16:15	9,084,442	614,178	511,691	26,428	693,881	29,727	
4.12.02	8:15	9,705,018	620,576	540,418	28,727	726,194	32,312	
4.1.03	9:00	10,312,799	607,780	571,443	31,025	761,091	34,897	
		ANNUAL TOTAL	**7,677,227**		**344,719**		**387,746**	

GAS CONSUMPTION								
Year	2002	GM_1 Main gas meter		GM_2 Space heating boilers		GM_3 Domestic hot water heater		GM_4 Estimated catering gas (= GM_1 - GM_2 - GM_3)
Date	Time	Meter reading	Consumption (kW·h)	Meter reading	Consumption (kW·h)	Meter reading	Consumption (kW·h)	Consumption (kW·h)
4.1.02	15:30	2,155,378		2,021,106		187,334		
4.2.02	11:00	2,723,986	568,608	2,526,416	505,310	226,450	39,116	24,181
4.3.02	10:30	3,113,228	389,242	2,854,867	328,452	264,018	37,567	23,223
5.4.02	13:30	3,400,781	287,554	3,082,257	227,390	301,198	37,180	22,984
4.5.02	15:00	3,614,418	213,637	3,233,850	151,593	339,539	38,342	23,702
4.6.02	16:00	3,754,766	140,347	3,309,646	75,797	379,430	39,891	24,660
3.7.02	9:45	3,817,437	62,671	3,309,646	0	418,160	38,729	23,942
4.8.02	10:15	3,883,241	65,804	3,309,646	0	458,825	40,666	25,139
4.9.02	12:30	3,947,792	64,551	3,309,646	0	498,716	39,891	24,660
4.10.02	15:45	4,202,295	254,503	3,499,138	189,491	538,995	40,278	24,733
5.11.02	16:15	4,618,682	416,388	3,852,855	353,717	577,724	38,729	23,942
4.12.02	8:15	5,158,891	540,209	4,332,899	480,045	614,904	37,180	22,984
4.1.03	9:00	5,939,288	780,397	5,052,966	720,067	652,084	37,180	23,150
		ANNUAL TOTAL	**3,783,910**		**3,031,860**		**464,750**	**287,300**

Figure 14 Example of a tailored meter reading proforma (based on the building used for the worked example)

8 The building log book

CIBSE recommends that, at least for new construction, information about the building and its services installations be provided to the owner/occupier of all new non-residential buildings. They are also recommended in existing buildings where systems such as boilers and air conditioning are altered significantly. CIBSE TM31: *Building log book toolkit*(7) gives further guidance on these issues.

The building log book may be thought of as similar to a car handbook, although the building log book goes further as it provides a place in which to record maintenance, energy performance and changes to the building. Typical contents are shown in the box opposite, but the building log book should provide:

— a summary of the building (this previously did not exist in any documentation)

— a key reference point (where it exists at all, information is commonly found in a range of documentation)

— a source of information/training (giving all those working on the building a good understanding of the basic design philosophy)

— a day-to-day log (i.e. somewhere to record energy performance and changes to the building).

CIBSE TM31 provides a toolkit for the log book author. The size of a log book should reflect the size and complexity of the building in order to keep it a useful and easily accessible summary. In all but very small premises, less than 20 pages is unlikely to include all the necessary information. Similarly, log books greater than 50 pages are unlikely to function as an easily accessible management summary. The toolkit also includes a simplified template for small business premises having a floor area not greater than 200 m^2. Using this will result in a much smaller and less detailed document and may be used for small offices or small tenancies in a much larger building.

Guidance to help facilities managers to obtain the greatest benefit from their log books is available in Good Practice Guide GPG348: *Building log books — a user's guide*(10). This shows how to use a log book on a day-to-day basis and

Typical contents list for a building log book:

1 Updates and annual reviews
2 Purpose and responsibilities
3 Links to other key documents
4 Main contacts
5 Commissioning, handover and compliance
6 Overall building design
7 Summary of areas/occupancy
8 Summary of main building services plant
9 Overview of controls/BMS
10 Occupant information
11 Metering, monitoring and targeting strategy
12 Building energy performance records
13 Maintenance review
14 Results of in-use investigations

Appendix: relevant certificates/test results

how to conduct an annual review as part of the organisation's quality assurance procedures. This review ensures that the log book is up-to-date and includes any alterations to the building and its services. GPG 348 also provides worked examples of how to record building energy performance compared with benchmarks and compared to designer's estimates of what the building should use.

9 Tenancies and district heating

9.1 Metering tenancies

Direct metering is always preferred. However, it may be impractical in tenancies supplied by central services, e.g. central air-handling plant. In smaller tenancies it is acceptable to measure the central plant and allocate the consumption based on the floor area being supplied. Although this is not ideal, it is better than having no idea of consumption at all. It may be possible to make this allocation more appropriate by adjusting for hours of use in specific areas and to take account of any significant special uses of the central services, e.g. computer suites.

In speculative developments, tenancy sizes and layouts are seldom known at the design stage. In this case include a coarse level of sub-metering, e.g. floor by floor, and provide guidance for those fitting out the building on the additional sub-metering that will be required to meet building regulations energy efficiency requirements.

Landlords should always ensure that all tenants are aware of their energy consumption/expenditure. This information should not be hidden within the rent as that prevents good energy management. Direct and accurate billing encourages tenants to use energy wisely. Automatic billing systems are available to do this and should be included wherever possible.

Where sub-metering is to be used to bill the tenant then, under the 1989 Electricity Act, the landlord becomes the authorised energy supplier and the meter must be approved by OFGEM.

9.2 Metering district heating or cooling

In very small buildings it may be impractical or too expensive to install heat metering and an estimate based on spot checks and floor area may suffice.

Where sub-metering is to be used to invoice tenants on the district heating/cooling system then the main system operator becomes the authorised energy supplier and the billing meter must be approved by OFGEM.

10 Automatic monitoring and targeting (aM&T)

Metering, communications technology and analysis software have all become less expensive whilst becoming increasingly reliable. Automatic monitoring and targeting (aM&T) equipment helps save energy by identifying energy wastage quickly using the minimum staff resources. These systems provide a best practice approach by collating raw data from a combination of meters, sensors and other field devices solely for the purposes of aM&T. Measuring devices will range from meters providing a pulse output to those with internal registers/accumulators and those producing coded data streams. Software is used to analyse the data automatically in order to highlight energy problems. Automatic monitoring and targeting systems usually include:

— automatic collection of metered data from a range of utility devices at regular intervals
— transmission of data to the aM&T software for processing
— user adjustable collection intervals
— automatic identification of data collection failures, missing data and failure of communication
— delivery of data in standard format for use in other software applications
— software that collates/analyses the data and produces outputs that highlight waste and compares energy performance against established benchmarks.

100% first-year Enhanced Capital Allowances (ECAs) are available on spending covering equipment for use as part of an aM&T system (see section 3).

There are a variety of ways that meters can interface with the data infrastructure such as direct network connection (IT/ethernet, process networks, radio and web-enabled measurement) as well as BEMS and dedicated data loggers. The power of modern meters and systems is such that they can readily integrate these sources to take advantage of where the data infrastructure and meters are physically located, e.g. BEMS might be used in a plant room whereas a gas meter on a site boundary might use a radio link.

If aM&T is not affordable, it is still almost always cost effective to purchase meters that allow connection to an aM&T/BEMS, either to promote future connection or even to use with temporary data logging equipment. This can provide an invaluable means of investigating atypical consumption.

Automatic monitoring and targeting is ideal in larger buildings, for a large stock of buildings or on multi-building sites. They also promote the introduction of 'energy cost centres' to improve energy management and reduce costs. Automatic systems should reduce the personnel required for monitoring and may provide results more rapidly.

Manual meter reading only provides a basic view of energy consumption. It is often too onerous for busy building operators, they may reduce the frequency of reading, and consequently might not spot dynamic wastage that occurs at specific times of the day. Equally, the number of meters and their location may make it impractical to carry out manual meter readings; aM&T presents a best practice alternative.

Tip: automatic metering can be achieved using a BEMS and standard monitoring and targeting (M&T) software, but a dedicated aM&T system will probably provide a more tailored solution in many instances.

Tip: where possible, use communicating meters that produce coded data streams as they provide precise readings by communicating the meter reading on their face rather than relying on less precise pulse outputs.

Tip: traditionally, pulse output meters are used to allow counters to be read or directly connected to a BEMS. However, pulsed meters can sometimes give false readings due to unreliability, contact bounce, etc.

11 Putting the plans into action

11.1 Installation, commissioning and beyond

Metering needs careful attention during the installation, commissioning and handover stages to ensure that the details in the schedule and metering strategy included in the building log book are an accurate record of the installed system.

Meters must always be installed and commissioned in line with the manufacturer's instructions in order to ensure accuracy and good operation. A commissioning report should be provided to authenticate this. At the very least, facilities managers should check the installation against the schedule of meters and the design drawings, with spot checks to establish that readings fall into the range of expected values.

Each installed meter should be labelled with the end-use being measured and the meter code allocated by the designer, as shown on the schedule of meters. At the commissioning stage, the sum of all the sub-meters should be checked to ensure it is reasonably close to the main meter reading, allowing for end-uses not metered, which may be up to 10%, and for differences in accuracy, compensation etc. Significant differences should be investigated.

Tips:

— *Electricity meters*: check that any current transformers are matched to the meters, and the correct meter factors are used. Also check that current transformers are installed the correct way round, otherwise the load on one phase can negate those of the others.

— *Oil, water and heat meters*: must be installed in straight pipework to ensure accurate operation. (The manufacturer will specify how many 'pipe diameters' of straight pipe should be allowed before and after the meter.) Specify this on the design drawings and check it at the commissioning stage.

  Install oil, water and heat meters in clean systems, avoiding heating/cooling systems that carry significant amounts of sludge and particulates. Dirty systems reduce accuracy, reliability and can ultimately lead to blockages. Some meters (e.g. oil) may need to have a strainer installed to prevent blockages.

— *Gas meters*: to ensure accuracy, adjust readings to compensate for pressure and temperature of the supply, particularly where large volumes are being measured. The lack of temperature/pressure compensation can sometimes explain differences between the sum of sub-meters and the main incoming meter.

11.2 Fit-out

Where buildings undergo a fit-out stage, any alterations to the services that affect the metering (e.g. adding local air conditioning systems to centralised background air handling) must be logged and the schedule/strategy should be updated accordingly. These alterations must not conflict with the metering strategy. In other words, they must still allow the operator to identify where 90% of each incoming energy is being used.

11.3 Alterations to plant

Where existing building services undergo significant alteration at any stage in the building's life then the upgraded system must include appropriate metering (e.g. when replacing boilers). The metering schedule/strategy must be updated accordingly or, where they do not exist already, new ones should be developed to cover the upgraded system. Guidance on this is given in the Building Regulations Approved Document L2B: *Conservation of fuel and power in existing buildings other than dwellings*(4). It is essential to integrate any plant and metering alterations fully into the basic metering strategy and to ensure that the 90% rule (see above) is adhered to. New equipment (e.g. a computer suite) must include metering facilities and these should be fully incorporated in the metering schedule/strategy.

11.4 Using meters

Building operators need to put the metering strategy into action. They should identify which meters should be read, when and by whom.

There is no benefit in having sub-meters that are not read regularly. Facilities managers should put in place a regular meter reading programme using the meter reading pro-forma (Figure 14) tailored to the building. Where this requires excessive staff time, consider linking the meters to a BEMS or an automatic meter reading system (see section 10) to improve efficiency. However, the frequency of monitoring is a fine balance between too often and too seldom. Too many readings can cause 'data overload' and the wider picture becomes unclear. Taking readings and calculating end-use consumptions can then become too onerous, leading to a complete breakdown of monitoring. Too few readings could result in a picture of energy use that is too coarse and does not identify atypical consumption.

The overall picture of end-use energy may only need to be done quarterly in smaller buildings. Larger buildings (above say 2500 m^2) might need to be benchmarked monthly to gain good control of the building and its energy use.

Ensuring data accuracy is a key part of the monitoring process. Typically, meters are misread with decimal points in the wrong place etc. This can be minimised by providing a standard meter reading sheet with the correct number of digits and the units specified.

11.5 Using the results

The data will also need some analysis to establish areas of excessive consumption that require further investigation. Once a picture of the energy end-uses has been established, facilities managers should make comparisons with currently available benchmarks (from the Carbon Trust or CIBSE Guide F(5)) and the original estimates of consumption made by the designer, see Figure 15. This process is set out in the building log book.

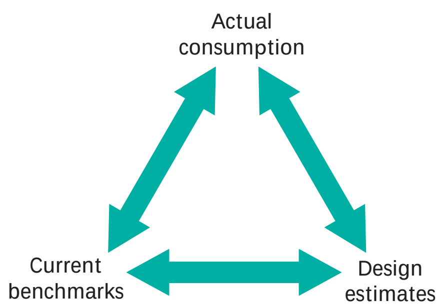


Figure 15 Comparing actual consumption with design estimates and current benchmarks

Keeping track of energy use is a vital part of a managerial attitude in which facilities managers are concerned about their energy costs and, if they are high (or increasing), helps to identify ways of reducing them.

11.6 Using demand patterns

Energy demand patterns can be obtained easily using aM&T systems and BEMS. Half-hourly data on incoming energy are also available from most energy suppliers (Figure 16). These demand patterns can be very useful for investigating faults or atypical consumption. Clear analysis is essential; excessive print-outs and complicated analyses are often the downfall of monitoring systems.

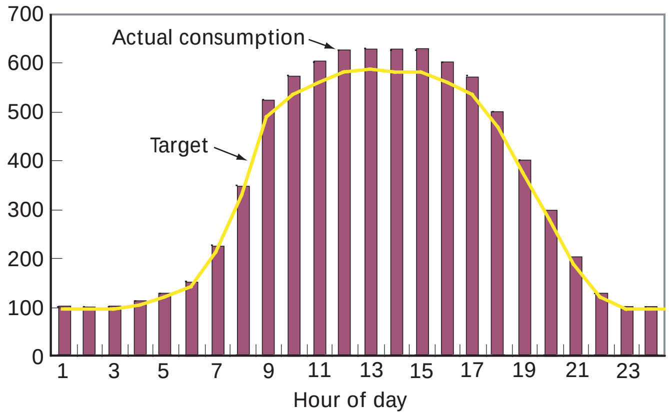


Figure 16 Typical energy demand pattern

Consumption profiles give an immediate indication of where and when the problem has occurred, e.g. high base/overnight load, out-of-hours consumption (start-up and shut-down), which would otherwise not be seen.

12 Other sources of information

12.1 Further reading

12.1.1 General

Special issue on post occupancy evaluation *Building Research and Information* **29** (2) (March/April 2001)

Bordass W T *Flying Blind: Everything you always wanted to know about energy in commercial buildings but were afraid to ask* (London: Association for the Conservation of Energy) (2001)

Energy assessment and reporting method CIBSE TM22 (London: Chartered Institution of Building Services Engineers) (2006)

Field J, Soper J, Jones P, Bordass W and Grigg P Energy performance of occupied non-domestic buildings *Build. Serv. Eng. Res. Technol.* **18** (1) (1997)

BS 8431: 2004: *Code of practice for electrical static metering for secondary or sub-metering* (London: British Standards Institution) (2004)

12.1.2 Building regulations

The Building and Approved Inspectors (Amendment) Regulations 2006 Statutory Instruments 2006 No. 652 (London: The Stationery Office) (2006) (London: The Stationery Office) (2006)

Conservation of fuel and power in new buildings other than dwellings) The Building Regulations 2000 Approved Document L2A (London: NBS/RIBA Enterprises) (2006)

Conservation of fuel and power in existing buildings other than dwellings The Building Regulations 2000 Approved Document L2B (London: NBS/RIBA Enterprises) (2006)

Technical standards for compliance with the Building Standards (Scotland) Regulations 1990 (as amended) (London: The Stationery Office) (2001)

Conservation of fuel and power Building Regulations (Northern Ireland) 1994 Technical Booklet F (London: The Stationery Office) (1999)

12.1.3 CIBSE publications

Building log books: a guide and templates for preparing building log books CIBSE TM31 (London: Chartered Institution of Building Services Engineers) (2006)

Energy efficiency in buildings CIBSE Guide F (London: Chartered Institution of Building Services Engineers) (2004)

12.1.4 Carbon Trust publications

For information on benchmarking, energy management, metering etc. visit the Carbon Trust website (www.thecarbontrust.co.uk) or call the helpline on 0800 585794. Relevant publications include the following.

Energy Consumption Guides

ECG019: *Energy use in offices*

ECG035: *Energy efficiency in offices — small power loads*

ECG036: *Energy efficiency in hotels — a guide for owners and managers*

ECG054: *Energy efficiency in further and higher education — cost-effective low energy buildings*

ECG072: *Energy consumption in hospitals*

ECG073: *Saving energy in schools. A guide for head teachers, governors, premises managers and school energy managers*

ECG075: *Energy use in Ministry of Defence establishments*

ECG078: *Energy in sports and recreation buildings*

ECG081: *Energy efficiency in industrial buildings and sites*

Good Practice Guides

GPG348: *Building log books — a user's guide*

GPG231: *Introducing information systems for energy management*

GPG287: *The design team's guide to environmentally smart buildings*

GPG310: *Degree-days for energy management*

Other publications

Good Practice Case Study GPCS334:*The benefits of including energy efficiency at the design stage*

Fuel Efficiency Booklet FEB 21: *Simple measurements for energy and water efficiency in buildings*

General Information Leaflet GIL049: *Low cost automatic meter reading system — using low power radio*

12.2 Useful websites

The Carbon Trust: www.thecarbontrust.co.uk

Chartered Institution of Building Services Engineers (CIBSE): www.cibse.org

The Energy Savings Trust: www.est.co.uk

Office of the Deputy Prime Minister (Building Regulations for England and Wales): www.odpm.gov.uk/buildingregulations

The Office of Gas and Electricity Markets (OFGEM): www.ofgem.gov.uk

British Institute of Facilities Managers (BIFM) (includes suppliers of meters and aM&T systems): www.bifm.org.uk

Energy Systems Trade Association (ESTA): www.esta.org.uk

Enhanced Capital Allowances Scheme: www.eca.gov.uk

The Energy Institute: www.energyinst.org.uk

Usable Buildings Trust: www.usablebuildings.co.uk

References

1 *The Enhanced Capital Allowance Scheme for energy saving plant and machinery* CIBSE Briefing 4 (London: Chartered Institution of Building Services Engineers) (2002)

2 The Building and Approved Inspectors (Amendment) Regulations 2006 Statutory Instruments 2006 No. 652 (London: The Stationery Office) (2006) (London: The Stationery Office) (2006)

3 *Conservation of fuel and power in new buildings other than dwellings)* The Building Regulations 2000 Approved Document L2A (London: NBS/RIBA Enterprises) (2006)

4 *Conservation of fuel and power in existing buildings other than dwellings* The Building Regulations 2000 Approved Document L2B (London: NBS/RIBA Enterprises) (2006)

5 *Energy efficiency in buildings* CIBSE Guide F (London: Chartered Institution of Building Services Engineers) (2004)

6 *Energy assessment and reporting method* (London: Chartered Institution of Building Services Engineers) (to be published in 2006)

7 *Building log books: a guide and templates for preparing building log books* CIBSE TM31 (London: Chartered Institution of Building Services Engineers) (2006)

8 *Energy use in offices* Energy Consumption Guide ECG019 (The Carbon Trust) (available from www.thecarbontrust.co.uk)

9 BS 8431: 2004: *Code of practice for electrical static metering for secondary or sub-metering* (London: British Standards Institution) (2004)

10 GPG348: *Building log books — a user's guide* (The Carbon Trust) (available from www.thecarbontrust.co.uk)

Appendix A1: Worksheets to support the method

Copies of these worksheets and the meter reading proforma are provided as Microsoft® Excel workbooks on the accompanying CD-ROM.

STEPS 1–6 WORKSHEET	Start by identifying the largest three or four end uses that can be metered easily; then iterate until at least 90% of each incoming energy is metered. Refer to pages 7 to 10 for guidance.

STEP 1	Total annual fuel consumption (estimated) (kW·h/yr) Electricity ________ Gas ________ Other ________

STEP 2			STEP 3	STEP 4					STEP 5	STEP 6
				Test: Is this practical, easy, etc? If not, go back to Step 3 or Step 4.2						Do the 90% test
Fuel type	Main end uses	Estimated consumption (kW·h/yr)	End-use/area/ system/circuit or tenancy to be measured	Identify any existing meters (Existing buildings only) Step 4.1	Measurement method Step 4.2	Meter code Step 4.3	Meter type Test: Is all major plant metered? Step 4.4	Calculation (use separate sheet if necessary and reference here)	Estimated energy consumption through meter (kW·h/yr)	Is metered within 90% of incoming? Yes/No If not go back to Step 3

STEP 7 METERING SCHEDULE	Set out metering schedule

Total estimated incoming fuel	
	Electricity ________ kW·h/yr
	Gas ________ kW·h/yr
	Other ________ kW·h/yr

Energy			Meters		Method		Meter location		Data connection
Incoming energy	Main end-use	Estimated end-use consumption (kW·h/yr)	Meter code	End-use/area/system/circuit or tenancy to be measured	Measure method and calculation (where appropriate)	Estimated consumption through each meter (kW·h/yr)	List of physical meters	Location	Type of data system, if any
	LIST BELOW ANY EXISTING METERS NOT BEING USED IN THE METERING STRATEGY								

Appendix A2: Extracts from Approved Documents L2A and L2B relating to sub-metering

Text shown in red is extracted from the Building Regulations[2] and the associated Approved Documents[3,4].

The Building Regulations require that:

L1. Reasonable provision shall be made for the conservation of fuel and power in buildings by: …

c. providing to the owner sufficient information about the building, the fixed building services and their maintenance requirements so that the building can be operated in such a manner as to use no more fuel and power than is reasonable in the circumstances.

A2.1 New buildings

The Regulations require appropriate metering when constructing new buildings so that building operators will have a clear way of establishing where energy is being consumed

From Approved Document L2A: *Conservation of fuel and power in new buildings other than dwellings*:

Energy meters

43 Reasonable provision for energy meters would be to install energy metering systems that enable: at least 90% of the estimated annual energy consumption of each fuel to be assigned to the various end-use categories (heating, lighting etc.). Detailed guidance on how this can be achieved is given in CIBSE TM39; and

a. the performance of any LZC system to be monitored; and

b. in buildings with a *total useful floor area* greater than 1000 m^2, automatic meter reading and data collection facilities.

Table 3 in ADL2A indicates that where automatic monitoring and targeting with alarms for out of range values are included then the Building (carbon dioxide) Emissions Rating (BER) can be reduced by 5%.

Sub-metering is also required when refurbishing existing buildings and when replacing controlled services in existing buildings. For example, where boiler replacement is undertaken then the new installation requires metering and a log book.

From Approved Document L2B: *Conservation of fuel and power in existing buildings other than dwellings*:

43 Controlled services

Where the work involves the provision or extension of controlled services, reasonable provision would be to …

e. Demonstrate that reasonable provision of energy meters has been made for effective monitoring of the performance of newly installed plant (see paragraphs 69 to 71); and

f. Demonstrate that the relevant information has been recorded in a new log book or incorporated into an update of the existing one as described in paragraphs 91 to 94.

Energy meters

70 Reasonable provision for energy meters in existing buildings would be to install energy metering systems in the building services systems provided as part of the works in accordance with the recommendations in CIBSE TM39.

71 In addition to this:

a. Meters should be provided to enable the performance of any LZC system provided as part of the works to be separately monitored; and

b. in buildings with a *total useful floor area* greater than 1000 m^2, the metering system should enable automatic meter reading and data collection.

A2.2 Consequential improvements

Sub-metering is also required when consequential improvements need to be made where the proposed work includes extensions, the initial provision of building services or an increase in installed capacity of services.

The Regulations state that:

17D.–(1) Paragraph (2) applies to an existing building with a total useful floor area over 1000 m^2 where the proposed building work consists of or includes:

a. an extension; or

b. the initial provision of any fixed building services; or

c. increase to the installed capacity of any fixed building services.

From Table 1 of Approved Document L2B: *Conservation of fuel and power in existing buildings other than dwellings*:

Table 1	Improvements that in ordinary circumstances are practical and economically feasible
5	Installing energy metering following the guidance given in CIBSE TM39.

Appendix A3: Frequently asked questions about sub-metering and Part L of the Building Regulations for England and Wales

1 Are the main energy meters sufficient to meet the requirements of Part L?

Not usually — Part L requires sub-metering of energy end-uses throughout the building and the method in this document helps you determine where sub-metering might be installed.

2 Can I use estimation methods to determine all the energy end-uses?

No — the only end-use that can be fully estimated is small power. Other end-uses require metering, although some of this can involve less accurate techniques to infer consumption from other measurements.

3 Can I mix direct metering with other less accurate means of determining consumption?

Yes — Part L provides the flexibility to combine various approaches to metering (see page 8).

4 Can I use an hours-run meter to measure variable loads like boilers or chillers?

No — because the loads vary, just measuring the time the plant is operating will not provide any indication of consumption (see page 8).

5 Can I rely on meters that are internal to devices and control systems?

Yes — in most cases it should be possible to use measurements from electricity meters that are built into equipment like variable speed drive controls and uninterruptible power supplies. However, check the accuracy and avoid problems raised in item 4.

6 Can I use the TM39 method for existing buildings?

Yes — building operators can use the method to determine where to install sub-metering. Step 4.1 brings any existing sub-metering into the strategy.

7 Do I need to provide instructions as to how to use all the sub-meters to compare consumption with benchmarks in order to meet Part L?

Yes — most of this is built into the diagrammatic metering strategy as that indicates how to determine the main end-use (lighting, fans etc.) from the sub-meter readings. However, a few short paragraphs in the building log book may help support this.

8 How do I separate lighting and small power when they are supplied from the same distribution board?

Where this is the case then small power can be estimated (using the approach set out in CIBSE Guide F) then subtracted from a sub-meter at the distribution board measuring the joint supply. The difference will give an indication of lighting consumption. This is far from ideal and will not provide an accurate measure but it may sometimes be the only option, particularly in existing buildings. It is preferable to supply lighting and small power separately so that direct metering can be installed.

9 What do I do in a shell-and-core situation where a fit-out stage will take place?

Determine the appropriate metering for central plant/services then hand the draft metering strategy to the fit-out team for completion once the final services have been designed. Where possible, make provisions for sub-metering local services and recommend these to the fit out team.

10 What sub-metering provisions should be made for subtenancies?

Tenancies over 500 m^2 need meters on the incoming energy supplies. Where possible, tenancies over 2500 m^2 should also have any central services measured (see page 9).

11 Should sub-meters to be connected to a building energy management system (BEMS) or automatic monitoring and targeting (aM&T) system?

Yes — in new buildings over 1000 m^2. However, connection would be regarded as good practice in refurbishment in order to make it easier for building operators to take, and use, sub-meter readings (see section 10). The greater the number of sub-meters, the more cost effective it will be to connect these to a BEMS or to install a dedicated aM&T system to minimise staff time in taking readings.

12 Do I need to include metering when replacing plant in existing buildings

Yes — sub-metering and a log book should be provided for all plant that has undergone significant alteration. For example, where boiler plant is replaced then the new installation should include appropriate sub-metering.

13 Can I just install meters on the main risers?

That is not really reasonable provision as described in paragraph 43 of ADL2A. A metering strategy should allow the consumption of the main end-uses to be determined and compared with appropriate benchmarks. Individual electrical risers usually supply a range of end-uses and metering these will not provide information of any great value to the building operator.