

Energy assessment and reporting method

CIBSE TM22: 2006



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Guidance on system requirements and using the computer files is provided in Appendix A4.

Foreword

The purpose of this publication is to make available a procedure for assessing the energy and systems performance of buildings, and to provide support for legislative developments on the energy labelling of buildings including the EU Energy Performance of Buildings Directive⁽¹⁾. The procedure has been updated from the 1999 edition to improve ease of use and to fully integrate its building sectors.

The TM22 procedure forms the basis of well received initiatives including the PROBE investigations⁽⁶⁾ and Energy Consumption Guide ECG019: *Energy use in offices*⁽⁴⁾. It has been developed over a number of years from initial work by William Bordass. The publication has been funded by the Carbon Trust, and by the CIBSE Research Fund. It has also relied on the support and interest of members of the CIBSE and the British Institute of Facilities Management (BIFM).

The TM22 publication was drafted from previous BRE-funded work by Target Energy Services, with assistance from Building Energy Solutions, and was reviewed by a voluntary task group of CIBSE members. At an early drafting stage, two workshops were held to obtain feedback on what CIBSE and BIFM members would require of the procedure.

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Energy assessment and reporting method

1 Executive summary

This document describes a method for assessing the energy performance of an occupied building based on metered energy use, and includes a software implementation of the method.

Recent UK and European initiatives mean that the benefits of performance assessment are being backed by legislation. This document and its software provides support for these assessment needs.

While primarily directed at assessing energy performance, the procedure has a wide range of uses for building managers, design professionals, and energy management specialists contributing to the ‘virtuous circle’ of good building energy management and satisfied occupants.

The assessment procedure offers three main options:

- *Option A:* Simple building assessment of the actual carbon dioxide emissions per unit floor area based on the metered energy use of a building of a single type with no more than two energy supplies (electricity and fossil fuel).
- *Option B:* General building assessment of the actual carbon dioxide emissions per unit floor area based on the metered energy use of a building or site which can have zones of different types and non-standard occupancy and energy uses.
- *Option C:* Systems assessment against benchmarks for the building systems.

The assessment approach described in this document will enable the user to undertake the calculation of emissions that is due to be introduced for publicly accessible buildings under the EU Directive on Energy Performance of Buildings⁽¹⁾. It follows the principles set out in CIBSE Guide F: *Energy efficiency in buildings*⁽²⁾, and can make use of data available from a building log book produced according to CIBSE TM31⁽³⁾. It provides a highly effective way to introduce feedback into the process of design, construction and evaluation, especially for buildings with services sub-metered in accordance with Part L⁽⁴⁾ and CIBSE TM39: *Building energy metering*⁽⁵⁾.

The approach includes quality assurance features which ensure that data and procedure standards are maintained. This also allows completion of an assessment with data to hand, which will be flagged as not quality assured.

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.

The assessment process can help improve not just energy management but building design and management: the investigations and actions required to improve energy efficiency also tend to improve building design, management and occupant satisfaction.

This document describes the method and shows:

- how different users can benefit from the method (section 3)
- the key elements of the detailed assessment procedure (section 4)
- how to specify an assessment and its time requirement (section 5)
- how to use the software (section 6).

The 2006 edition of TM22 updates the previous (1999) edition as follows:

- it describes procedures that will contribute to compliance with emerging energy performance legislation
- it combines the four building types into a single menu-driven procedure
- it includes explicit treatment of on-site CHP and renewables

- it acknowledges any green tariffs without affecting the main assessment
- it offers simplified options for system performance estimation and assessment.

Although this updated edition has been prepared with a view to supporting the UK implementation of the Energy Performance of Buildings Directive⁽¹⁾, TM22 is suitable for use by engineers and facilities managers as part of a systematic programme of good practice energy monitoring and management.

2 The EU Directive on Energy Performance of Buildings

The European Directive on Energy Performance of Buildings⁽¹⁾ required a range of building energy labelling measures to be implemented in the UK. This is likely to be called the ‘building operational rating’ in the UK. TM22 option A provides a supporting procedure for simpler situations, and the general option B for more complex buildings or where building performance needs to be adjusted to standard conditions.

The need to consider only building services energy use — excluding, for example, desk equipment in offices — can be accommodated by option C, systems assessment.

The Directive contains requirements for labelling of all buildings at the time of construction, major alteration, sale or rent, which is likely to be called the ‘asset rating’. When such a rating is available for a building, it can provide a valuable comparison basis for subsequent assessment of the actual performance using option C.

3 Tools for building professionals

3.1 Energy assessors

Specialists involved in labelling and assessment of buildings’ energy performance may use the assessment options to provide assessments for building occupiers, managers, designers or operators.

3.2 Building managers

A building manager can use an overall assessment to establish if there is a problem with a particular building’s energy use by looking at energy consumption indices against benchmarks as illustrated in Figure 1, or against other buildings in an estate if appropriate.

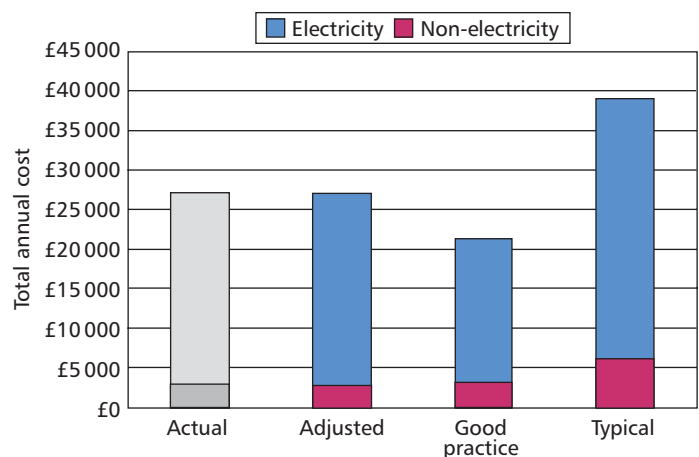


Figure 1 Comparing actual building energy cost with benchmarks using an overall assessment

Where building performance is poor, and the reasons are not self evident, TM22's system assessments (Option C) can be used to understand at a system level the reasons for high energy usage and identify causes and measures for improvement.

3.3 Facilities managers

Using information from an overall assessment, a facilities manager can use TM22 to provide a measure of how the building is working, for use in management reporting and planning.

A systems assessment can be used as a significant part of a wider building review and, if carried out at the detailed plant level, can improve occupant satisfaction by helping understand plant control arrangements, feedback and complaint paths, operating regimes and system capabilities.

An assessment can:

- reduce operating costs by identifying poorly performing buildings and systems, and the reasons for poor performance and possibilities for improving measures
- support building managers by providing authoritative evidence of good performance and high management standards, or by concluding that certain systems are under-performing, in need of investment, or not being appropriately operated by staff, contractors or occupants
- prioritise actions and investments by identifying where significant problems lie and the benefits of rectifying them
- provide feedback for new buildings by explaining good performance or shortcomings in terms of the building design, commissioning and management.

Figure 2 illustrates how the annual energy cost of a building's systems can be compared with benchmarks. The metered data has low lighting energy, humidification and office equipment which are all at or lower than 'good practice', but ventilation, pumps and controls are high: at or above 'typical' levels.

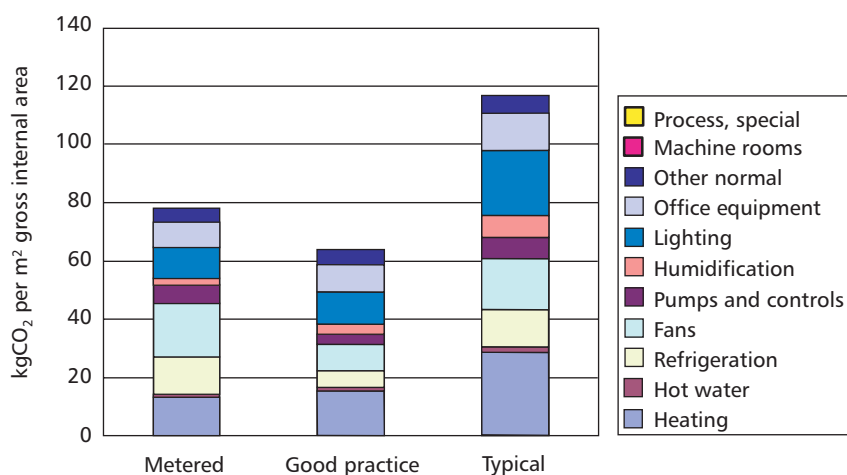


Figure 2 Comparing system costs with benchmarks; CO₂ emissions as kgCO₂ per m² gross internal area

3.4 Building designers and procurers

Building design team members can compare design stage assessments of buildings and individual systems with benchmarks, and can later add actual energy use data to complete the loop and see how a building performs in practice.

Building procurers can use the system to set benchmarks at the briefing stage, which can be for a whole building, for building services or for individual systems. Design calculation performance can later be compared with targets, and finally annual energy consumption in use assessed.

3.5 Energy management specialists and surveyors

As part of an energy survey, the assessment may be used to rate a building, and assess individual systems even when there are few systems data. This is of considerable interest when evaluating energy saving measures.

Where more accuracy is required, the optional 'Plant' module can be used to assess a building looking at individual plant items, their installed power, hours of use and utilisation. This feature in systems option C is compatible with earlier procedures, but has extra features to help evaluate energy saving measures

High-level analysis of systems in terms of asset, occupancy and management is then possible using the energy tree diagram approach, see Appendix 8.

4 Description of the TM22 procedure

4.1 Main procedure options

The features provided to address both the regulatory requirements and the needs of building professionals include the three main options and techniques which deal with common requirements. The options are arranged as follows.

Option A: Simple building assessment

A one-page assessment of a simple building which has just one building type with at most two energy supplies including grid electricity, with no special energy use or occupancy features. The assessment is based on overall energy use although the electricity and non-electric supplies are assessed separately so that the different costs and environmental impacts of the fuels may be established. Default carbon and building use factors are used.

Option B: General building assessment

An overall assessment of a more complex building which can include areas of different building types, with up to five energy supplies and special features or non-standard usage which are accounted for by exclusions or adjustments.

Option C: System assessment

Assessment of the energy performance of individual systems in a building against benchmarks for that building. The system energy use data can be obtained from:

- metered energy data required for compliance with the Building Regulations (e.g. from building log book)
- modelled energy use such as from design calculations
- a detailed survey of plant and usage using the optional 'Plant' module.

Flexibility and ease-of-use are addressed by providing navigation buttons which take the user through the pages of the procedure in a route determined by the initial choice of option as described above. The route can be re-run to review or modify information, and the choice of main option can be changed to allow a different level of assessment.

4.2 Quality assurance

Quality assurance is addressed by providing menu selections for critical data items such as energy consumption and floor area. These have a 'source of information' list from which the user must select the actual source, and in each case only certain responses obtain quality approval. Data which are not approved are still used, so the assessment can continue, but with the quality issue flagged. The quality assurance level achieved does not affect the calculation itself.

4.3 Selection of building types, energy supplies and services features

The possibility of buildings comprising more than one building type is addressed by allowing up to four zones within a metered building or site. The building type of each zone can be set independently — the benchmark and special energy use aspects of each are considered separately but combined in overall energy and system benchmarks.

The method allows for the possibility of having a number of energy supplies, each of which can be from a wide range of standard, renewable and communal sources. Up to five energy supplies are allowed, each of which can be any of the supplies listed. Default carbon factors can be overridden with data which may or may not be quality-assured. The simple building assessment assumes grid electricity and up to one other supply (typically gas or oil), but if this is insufficient the general building assessment (Option B) can be carried out and the number of supplies specified.

4.4 Allowing for systems not included in the benchmarks

Special process energy uses are non-building services energy uses which can be usefully and validly excluded from benchmark comparisons. The exclusion process has strong quality assurance implications to prevent abuse. Each building type has certain defined 'special uses' which can be validly excluded from the metered energy to obtain a fair assessment. To be removed from the building total, the quantity of special energy use must be quality assured such as from metered energy.

Examples of special use categories are as follows:

- regional server room in a high street bank or agency
- employee catering in offices or mixed-use industrial buildings
- main computer room or machine room with associated air conditioning.

If allowance for process energy is claimed, but the energy is not metered (or otherwise approved), or if the energy is not validly categorised as 'process', the assessment is completed but the results are qualified and flagged as 'for information only'. This is seen as a useful approach when trying to assess the 'real' performance of a building, albeit not necessarily a performance that could be certified.

4.5 Allowing for different use and occupancy

Adjustments are changes made to the building's (or in some cases the benchmarks') energy use to provide a more useful and valid comparison. This has quality assurance implications to prevent abuse, it is specifically referred to in the EU Energy Directive⁽¹⁾, which calls for assessment of building performance under normal operating conditions. The approach is to request quality assured data in the various adjustment areas which include:

- *weather-dependence of heating*: heating energy is pro-rated to degree days with allowance for a fixed proportion of system base load.

- *occupancy*: information is requested about occupancy hours and after-occupancy use, during the week and at weekends. Calculated effects are applied separately to heating and non-heating energy use as derived from benchmarks.

The following are not included in the simple building assessment (option A) but are allowed for in the general building assessment (option B) and the systems assessment (option C) because they affect system and overall energy use:

- workstation density and IT power: effects are calculated based on the density of workstations and the extent of use of laptops
- services options such as changing energy sources for heating, hot water and cooling.
- the presence of humidification and its energy source.

Weather dependence of cooling is not currently implemented although provision for this adjustment is included once the adjustment procedures are sufficiently well established.

5 Specifying an assessment

The procedure options used will depend on whether the assessment is being used for legislative purposes or for information. Legislative requirements include a building assessment for the Energy Directive⁽¹⁾. Informative objectives include developing and understanding of the building for information gathering required under Building Regulations Part L⁽⁴⁾ and engineering assessment of building to understand and improve its overall performance or the performance of its systems.

Supporting an assessment for the Energy Directive is likely to require an overall assessment of the building or site using option A or option B. Option B can allow for extended occupancy, weather effects and certain special energy uses which may be excluded from the comparison.

An engineering assessment of a building can be at the overall building level (using option A or B), or at the system level using option C.

If a building has on-site CHP or renewable sources of energy, these will be accounted for in the option A or option B main assessment by the naturally reduced metered energy onto the site. However, a separate assessment of the building and systems performance is provided (accessible from the results of option B) which is independent of any on-site CHP or renewables. This latter assessment is more useful when looking at the building as the sum of its energy using systems, and is also therefore used for any subsequent systems analysis.

For a building or site with low-carbon energy supplies option B provides an assessment with these supplies taken into account. This is an additional assessment (included on the option B results page) provided for information and the main assessment is not affected.

To help understand the performance of a building and its systems, option C provides for different ways to obtain systems energy use which can be compared with benchmarks to grade each system.

Metered energy use for individual systems is increasingly available as required by the Building Regulations Part L⁽⁴⁾ from 2002.

Calculated or modelled energy use data for individual systems are also increasingly available from the design stage or subsequently. These can be usefully compared with metered energy use or the system benchmarks, even if the calculations do not include all systems and energy uses.

Estimated energy use for individual systems can be obtained using the 'Plant' sheet accessible from the systems main screen in option C. The 'Plant' sheet allows detailed analysis of the equipment and plant in a building in terms of its connected power and usage. Techniques are described for recording and reconciling these data as in TM22: 1999⁽⁶⁾ stage 3 and used extensively for PROBE⁽⁷⁾ and other research.

Option C allows comparison of one (or two) of the above sets of systems energy data and appropriate system benchmarks. In addition a temporary set of system data may be directly entered for initial or 'what if?' investigations.

In each case the assessor has the option to use just the data provided or to complete the system data set, from limited data, using an automatic procedure based on an appropriate distribution of unallocated (total metered) energy to systems whose data has not been entered. This is a highly efficient way of proceeding when the consumption of critical or major systems is known but other systems have not been investigated — they can be 'filled-in' automatically.

General guidance on time requirements:

- The simple building assessment (option A) requires only a few items of data, typically less than ten, to include building floor area and annual energy consumption. If these data are available, the assessment takes a few minutes. Obtaining these data for an unfamiliar building can take one or two hours and may require information to be requested from utilities.
- The general building assessment (option B) can be carried out in the same time as the simple assessment — again the availability of basic energy and area data is normally the deciding factor. If the exclusion and adjustment options are used with this option, the assessment time increases and, although it may take less than half an hour, this can increase to half a day if data such as occupancy patterns and degree days have to be obtained.
- If the systems assessment (option C) is used without any extra system data to provide background data for energy measures evaluation, an assessment may take only a few minutes. In this case the software can pro-rate the systems energy use of the actual building to provide an estimate of energy use for each system.
- If the systems assessment (option C) is used with metered data, then this can take up to half a day, but if these data are available, for example from a building log book or from a previously set-up initiative, then the assessment may take half an hour or less.
- If the systems assessment (option C) is used with the 'Plant' worksheet, this requires a detailed plant and systems survey which may need two days for a 1000 m² building and four days for a 10 000 m² building, depending on its complexity. These times may be increased for surveyors who are not familiar with the procedure.

6 Using the software

6.1 General

The TM22 software is in the form of a Microsoft™ Excel workbook suitable for PC or Macintosh. Installation and system requirement notes are provided in Appendix 4. It is recommended that the TM22 workbook file in use is saved using a name relating to the building or project.

If available on the user's system, the ability to print results as an Adobe™ PDF document provides quicker output using less (or no) paper and small output file sizes for easier transmission or storage of results, with no need for recipients to run Excel. This is described further in Appendix 4.

After starting the software the initial data are entered to identify the building and assessor. The main option A to C must then be selected (the options are described in section 4 above); this is not a final decision as the user has an opportunity to select a different option after each assessment.

Appendix 5 gives an annotated description of each sheet in the procedure.

6.2 Procedure

Open the software file to obtain the opening page:

- Click on the start button to obtain the initial data page.
- Enter building identification address, assessor information and assessment date.
- Proceed to 'Main Menu' page.

'Main Menu' page:

- Click on a main procedure option button A to C (these are described in section 4).
- Optionally initialise the data for whole procedure (this will erase any data already entered and is not normally required).
- Optionally view the procedure map.

Option A: Simple building assessment

'Basic Data' page:

- Enter a reference for this assessment (this is free text and is used to identify the assessment).
- Select the building type, the building sub-type, and the source of these data items.
- Select an option for specifying building size — generally gross or net floor area.
- Enter building size according to this basis, and the source of this data item.
- Enter annual electricity use in kW·h, and the source of this data item.
- Select the type of the second energy supply, e.g. natural gas or oil.
- Enter annual energy use for the second supply in kW·h, and the data item source.
- Review quality assurance status and consider alternative data sources if full quality assurance is required but not achieved.
- Click on 'Next' button to obtain the assessment results.

'Options A and B Results' page:

- Review results.
- Select a different carbon basis for results, if required.
- Select a different floor area basis for results, if required.
- Click 'Overview Page' to obtain certificate information, and then 'Return' button.
- Click on 'Next' button to proceed to print and review options.

'Finish' page:

- Click 'Print Results' button to print pages.
- Click 'Return to Main Menu' button to review or revise the assessment.

*Option B: General building assessment***'Building Types and Size' page:**

- Select the number of building zones and for each zone:
 - select the building type and sub-type, and the supporting information
 - enter the size measurement basis and building size and the supporting information.
- Review quality assurance status and click 'Next' button.

'Energy Use' page:

- Select the number of energy supplies and for each supply:
 - optionally enter a free text description
 - enter the consumption in kW·h
 - optionally enter the annual cost and the percent VAT rate included
 - select the supporting information for the energy consumption
 - optionally enter site carbon intensity factors and the supporting information (generally default values can be used, and changed values affect the benchmarks as well as the building emissions and so do not affect grades for each energy source)
 - optionally enter green energy carbon intensity factors (these affect the building emissions only and so tend to improve grades significantly for the separate 'green energy' result; no supporting information is requested as the improved grades are for information only and do not affect the main assessment).
- Optionally click on the 'Change Specials' button in which case, on the 'On-site Combined Heat and Power, Renewables and Special Energy Uses' page:
 - enter any net generated CHP energy, enter any net increase in delivered fuel and select the supporting information
 - for any on-site renewables, enter a free text description, any net electricity supplied, any net non-electricity supplied, and supporting information
 - for any authorised special (non-benchmark) energy uses, enter a free text description, electricity use, non-electricity use and supporting information
 - review quality assurance status and click 'Return' button.
- Select energy sources and enter their annual energy consumption data.
- Optionally provide information on special energy uses.
- Optionally provide information on non-standard systems and building use.
- Proceed to obtain assessment results.
- Select required carbon, cost or energy basis for results.
- Select floor area type or building total for results.

Option C: Systems assessment

- Provide (or re-use if entered) building and energy information as for option B above.
- Proceed to ‘Systems’ page.
- Optionally enter metered systems energy data.
- Optionally enter design calculation data.
- Optionally undertake detailed site assessment and enter plant and usage data.
- Optionally enter estimated or other systems data (directly onto ‘Systems’ page).
- Select which one or two of the above four sources are required for comparison with system benchmarks.
- Select whether the systems energy data should be ‘auto-completed’ by the software, i.e. that any entered systems data are used but the remaining systems are filled out in harmony with system benchmarks and overall actual energy use. This is useful if few or no systems data are available but this feature requires some care in use.
- Proceed to summary table and charts page.
- Select required carbon, cost or energy basis for results.
- Select floor area type or building total for results.

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Appendix A1: Glossary

Adjusted performance indices: performance indices that are altered in order to take into account special end uses and conditions which differ from those in the benchmark.

AGT: a measure of performance which compares actual to two benchmarks ('good practice' and 'typical'). AGT varies from 0% at good practice (GP) to 100% at typical. At 28% below good practice, AGT is -28%, at 35% above typical AGT is 135%; it is defined as follows:

- If actual is less than good practice, AGT is the negative percentage difference from good practice (GP), i.e.: $AGT = (\text{actual} - GP) / GP$
- If actual is between good practice and typical, AGT is the percentage weighting: $AGT = (\text{actual} - GP) / (\text{typical} - GP)$
- If actual is greater than typical, AGT is the percentage multiplier: $AGT = (\text{actual} / \text{typical})$
- The parameter $(AGT + 1)$ is similar to the CEN 'Classification' parameter.

Benchmark: representative value of a parameter, for a category of building (possibly with a specified quality or efficiency level) against which an individual building performance indicator or index is compared.

Building type: distinguishable class of building, defined by the building form, services and processes that are present.

Delivered energy: the energy purchased by the consumer that crosses the site boundary.

End use categories: groups of end uses that, by convention, normally correspond with the major building subsystems.

End use: any item or group of items that consume energy.

Gross floor area: total building area measured inside external walls.

Net floor area: agent's lettable area (i.e. gross area minus common areas and ancillary spaces).

Normalised performance indices: a total delivered energy per m^2 performance indicator adjusted to take account of factors such as geographic location and hours of use to allow comparisons to be made between buildings.

Performance indices: indices, calculated in $kW \cdot h/m^2$, kg of CO_2 emissions/ m^2 or $£/m^2$, that describe the energy and environmental performance of the building and allow the building to be compared with yardsticks, other buildings, or to be monitored year on year.

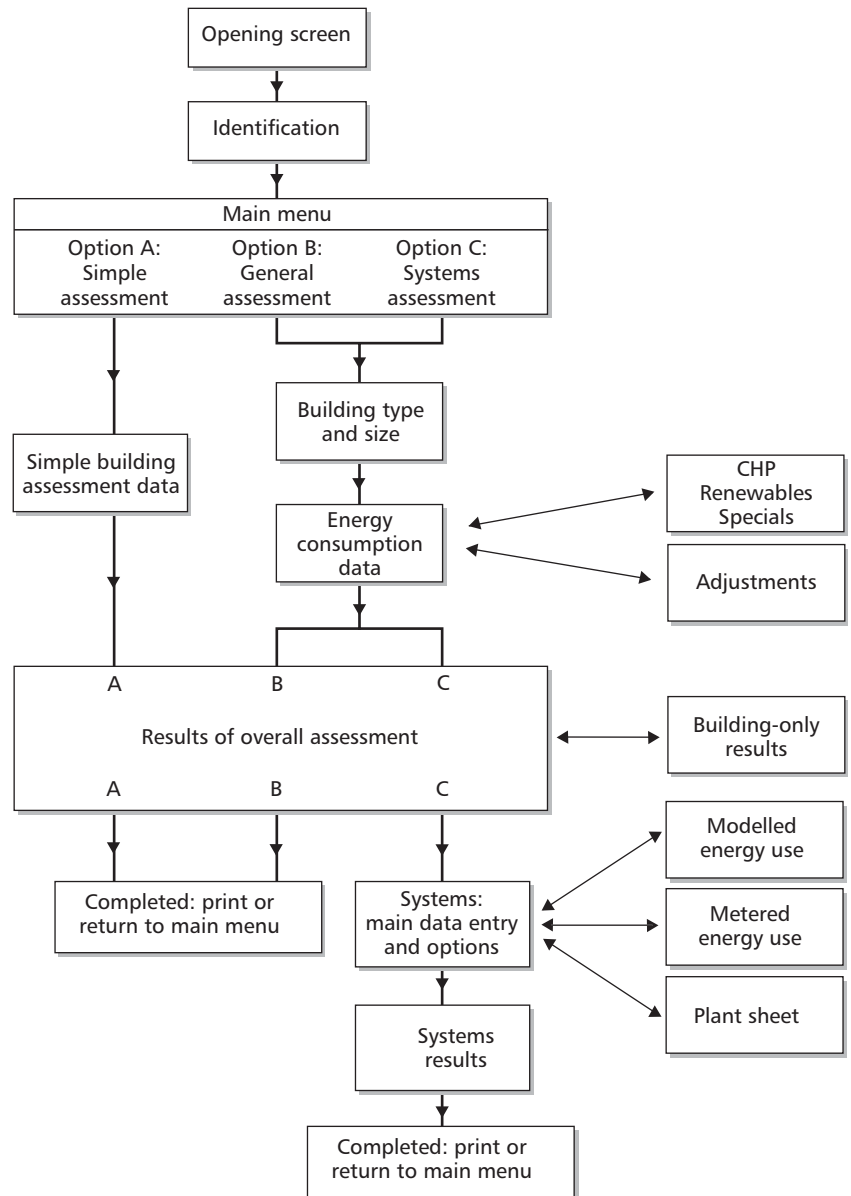
Reconciliation of metered energy use: the process of ensuring that the sum of selected energy consumptions balance with the appropriate total metered energy consumption. This can be carried out for more than one total at a time, and should always involve a review stage to ensure that all values are reasonable (for example that consumptions obtained by subtraction are of the right order of magnitude).

Special end uses: end uses additional to those which make up the delivered energy consumption yardstick for a building.

Treated floor area: gross area less plant rooms and other areas (e.g. stores, covered car parking and roof spaces) that are not directly heated.

Yardstick: representative value of a parameter, for a category of building (possibly with a specified quality or efficiency level) against which an individual building performance indicator or index is compared (synonymous with *Benchmark*).

Appendix A2: Flowchart



Appendix A3: Principles of energy assessment

Principles which have been used as guidance for developing the energy assessment and reporting method are listed below, together with an associated general procedure for assessment. The principles arose as criteria for evaluating methods in a range of projects and these proved to be valuable and resilient.

Statement of principles:

- (1) The objectives of any energy assessment procedure should be clearly established and described.
- (2) Users of the procedure may need careful guidance on the appropriate type of energy analysis for their purposes.
- (3) Definitions for all significant terms should be in keeping with an overall structure for building and energy data, which avoids ambiguity and duplication and allows easy comparison. Any extra effort required for this compatibility should be minimised.
- (4) Data should be recorded and wherever possible presented without adjustment.
- (5) Consumption data relating to different fuel types should be recorded and presented separately.

- (6) When quantitative data are recorded or presented, associated descriptive data should be available to allow the quantitative data to be assessed in context.
- (7) The accuracy requirements for critical data should be stated or assessed by the method. The implications of missing or poor data should be established.
- (8) Calculation procedures should be appropriate to the accuracy of the required result and should be designed to request no more information than necessary.
- (9) Where possible a layered approach of increasing complexity should be used for data collection and input so that more information only need be sought where it is required.

Generalised assessment procedure:

- (1) Collect appropriate data on building design, construction, systems, occupancy and management.
- (2) Collect appropriate data on energy use and building extent such as floor area or volume.
- (3) Produce simple indices of energy use as a ratio of delivered energy to the measure of extent (for example kW·h of annual energy use per m² of floor area). There will normally be one index per fuel because the costs and environmental impacts of different fuels vary greatly. Overall indices of cost or CO₂ can generally be simply obtained from the individual fuel indices if required.
- (4) Categorise the building so that its performance can be compared with buildings of a similar type, and obtain energy consumption yardsticks for the type of building. Overall cost or CO₂ yardsticks may be available or can generally be simply obtained from fuel yardsticks if required.
- (5) Consider unusual or atypical aspects of the building and its use, and allow or adjust for these if appropriate.
- (6) Compare the performance indices of the building with the performance yardsticks to obtain an assessment of the building. For example, the assessment may be low/medium/high consumption or good practice/typical or pass/fail.
- (7) Relate the building assessment to the observed fabric, plant and usage.
- (8) Present building indices, yardsticks and assessment, with critical descriptive and category information. Present the explanation of the assessments obtained and note where assessments or their explanations are uncertain.
- (9) If significant aspects of the building performance remain unexplained, consider starting from step 1. with more detailed observation, analysis of records or goal-directed measurements to further explain the building performance. If appropriate, use more detailed performance indices and yardsticks such as for individual end-use categories (for example heating and lighting).

Appendix A4: System requirements and installation

The software provided is in the form of a single spreadsheet workbook which requires, on a PC, Microsoft™ Excel 2002 or compatible software. It is designed to be usable with Macintosh OSX systems using Excel from Microsoft Office 2000 for Macintosh or compatible software.

Printing and disseminating TM22 results can be achieved directly from Excel. If more than one or two assessments are to be made, printing is easier if Adobe™ PDF files can be generated on the user's system. This may require the installation of Adobe™ Acrobat, in which case a convenient approach is to change the default printer to the Adobe PDF

printer while working on TM22 and then using the normal 'Print' buttons in the procedure.

To install the TM22 procedure it is recommended that the blank workbook file is copied onto the working part of your system, ensuring that this file is protected from change. The blank file should be renamed (and protected again) if changed or customised, for example by including your assessor details or making display defaults more convenient.

To use the procedure, open the blank file, agreeing if necessary to the option (which must be enabled on your system) to make use of macros; the macros in the provided blank workbook file are for calculation purposes and were custom written for the TM22 procedure. Proceed using the 'Start' button, saving the workbook at an early opportunity with a relevant filename, and saving occasionally thereafter and at completion.

Appendix A5: Annotated list of sheets

The worksheets in the procedure are listed below. Each sheet has the following information:

- *Title*: as printed at the top of the screen.
- *Sheet tab name*: the short name used in formulae, as shown on the Excel sheet tab.
- *Status*: indicating when the screen is shown or available.
- *Description*.

The first three sheets are shown for all assessments. Subsequent screens may or may not be shown depending on the main option or sub-options selected.

The order of the sheets in the procedure is as required for printing, so results pages generally come before the associated data entry pages. The procedure's navigation buttons will take the user in the appropriate order for data entry.

There are no hidden sheets but the navigation buttons will only reveal sheets that users require to complete the procedure. Other sheets can be accessed by activating Excel's standard sheet tabs option. This may be useful for understanding how the procedure works but is not recommended for normal use.

Sheets are generally protected to help reduce erroneous changes and overwriting of formulae but the sheets are not password-protected, so the protection can be removed, if desired, to allow tracing of formulae. Changing of formulae or content of the software is strongly discouraged and renders the software unsupported by CIBSE.

1 *Front sheet*

Sheet tab name: Opening

Status: Always shown after opening a blank workbook.

Description: This is the screen shown when the procedure is opened.

2 *Identification of building and assessor*

Sheet tab name: Identification

Status: Always shown after opening a blank workbook.

Description: This screen allows information to be entered concerning the identification of the building and of the assessor.

3 *Main menu*

Sheet tab name: Objective

Status: Always shown after opening a blank workbook.

Description: The user must select one of the three main options that dictate the route followed by the procedure:

- main option A for a simple building assessment
- main option B for a general building assessment
- main option C for a systems assessment.

This screen is also used, if required, to initialise input data (except identification data), or to view the procedure map. There is a button to reveal sheet tabs although it is not recommended that tabs are used for navigation.

4 *Results of overall assessment*

Sheet tab name: S2Results

Status: Shown when main options A, B or C are selected.

Description: Summarises the rating and assessment results, with key input data, for the assessment. Includes options to change the basis of results between CO₂ and carbon, and to select the floor area metric used (for example gross or net lettable). Includes options to view the results for the building systems (without the benefit of on-site CHP and renewables) or to view an overview page.

5 *Additional assessment results for building systems without the benefit of any on-site CHP and renewables*

Sheet tab name: S2Bldg

Status: Shown optionally (when main options B or C are selected) from the 'Results of overall assessment' (S2Results) screen.

Description: Duplicates the 'Results of overall assessment' (S2Results) screen but with the effects of CHP and renewables discounted and with any adjustments applied to benchmarks. The building is viewed as the sum of its energy using systems so the effects of energy source systems (such as on-site solar or wind power, or CHP) are excluded. Also here, as in option C, adjustments such as for weather are made to the benchmarks and not to metered energy, so the metered energy can be compared directly with (unadjusted) sub-meters. The results on this page will be identical to the main results if there are no energy source systems and no adjustments other than allowance for valid process energy.

6 *Option A: Simple building energy assessment*

Sheet tab name: Stage1

Status: Shown when main option A is selected.

Description: This screen allows all the required data for a simple building assessment to be entered. On completion of this screen the procedure takes you to screen 7 'Results of overall assessment'.

7 *Building types and size*

Sheet tab name: S2Type

Status: Shown when main options B or C are selected.

Description: This screen allows the entry of data on the building type and extent for up to four building zones.

8 Energy use

Sheet tab name: S2Energy

Status: Shown when main options B or C are selected.

Description: This screen allows the entry of data on metered energy supplies and their properties for up to five energy sources. Buttons are included to access the 'Change Specials' screen or the 'Change Adjustments' screen, see the descriptions below.

9 On-site combined heat and power, renewables, and process energy uses

Sheet tab name: CRS

Status: Optional when main options B or C are selected. Shown if the 'Specials' button is clicked from the 'Energy Uses' screen.

Description: Allows entry of energy generation or consumption data for on-site CHP, renewables (such as photovoltaics and wind), or special (process) energy uses which are approved, to be outside the benchmarked building energy use such as a large national server floor in an office. Energy data are generally expected to be metered and estimates are not acceptable.

Entering energy supply values here for on-site CHP and renewables does not affect the main rating (option B) because the main rating already has the benefit of these supplies: the site metered energy consumptions (on which the main rating is based) are lower than they would have been without these supplies. So to investigate the retrospective effect of installing, say, photovoltaics, their expected contribution would be entered on this page and then the entered value for the metered electricity to the site would need to be reduced by the same amount on the 'Energy Use' page. For the systems energy use analysis (option C), the system energies are added together and then reduced by these supplies to obtain the site metered energy.

10 Adjustments

Sheet tab name: AdjInput

Status: Optional when main options B or C are selected. Shown if the 'Change Adjustments' button is clicked from the 'Energy Uses' screen.

Description: This screen allows the building's actual conditions of weather, occupancy and systems to be allowed for.

11 Adjustment calculations

Sheet tab name: Adj_Calc

Status: Background calculation sheet. The sheet is not viewed from main options A, B or C.

Description: Calculates the magnitude of adjustments using data in the 'Adjustments' (AdjInput) sheet. These adjustments are applied to the system energy use in the next sheet 'Adjustment Summary' (Adj_Summ).

Adjustments are obtained by calculating the actual building value in relation to the reference benchmark value according to the following principles:

Weather dependence of heating: heating energy use is taken to be proportional to heating degree days allowing for a weather dependence fraction set in this version at 90%. There is no adjustment for exposure, although a mechanism for adjustment is included based on an exposure factor (set in this version at a constant 100%).

Weather dependence of cooling: cooling energy use is not adjusted for climate, although a procedure for adjustment is included in which cooling energy use is taken to be proportional to a climate factor (set in this version at a constant value) allowing for a weather dependence fraction.

Occupancy dependence of non-heating energy use: non-heating energy use is taken to be proportional to full load plant hours per week calculated as follows:

- A background factor allows for the minimum energy use when plant is off (set at 25% in this version).
- Weekday full load hours are core hours plus wing hours (start-up time), plus any extra (non-core) occupancy hours reduced* according to associated occupancy percent.
- Saturday full load hours are Saturday occupancy hours and ‘wing’ hours combined, and reduced* according to Saturday occupancy percent.
- Sunday is as Saturday: Sunday full load hours are Sunday occupancy hours and wing hours combined, and reduced* according to Sunday occupancy percent.

Occupancy dependence of heating energy use: heating energy use is taken to be 100% during the full load operating hours periods (as calculated above allowing for extended occupancy). For the remaining hours the heating energy is reduced by a thermal weight factor which varies between 0.20 for heavyweight and 0.60 for lightweight; a general value (0.4) is set in this version.

IT-intensity dependence: IT energy is taken to be proportional to the average operating power of IT per m² of floor area calculated from the average operating watts per workstation and the occupancy density as m² floor area per workstation. The average watts per workstation is calculated from default data for cathode ray tube (CRT) workstation (150 W) and flat panel workstations (40 W), and the proportion of workstations of each type: the default value is 40% TFT.

Effect of changing to electric space heating: the effect of changing to electric heating is taken to be to scale energy use by a simple ratio which in this version is 0.45 as specified in the benchmark page.

Effect of changing to electric water heating: the effect of changing to electric heating is taken to be to scale energy use by a simple ratio which in this version is 0.45 as specified in the benchmark page.

Effect of changing to absorption cooling: the effect of changing from electric compressor to fossil-fired absorption chilling is taken to be to scale energy use by a

*The reduction in plant hours for occupancy percentage (for weekday non-core, Saturday and Sunday) is calculated by taking a linear increase in plant use from zero plant use at zero occupancy up to 50% plant use at 10% occupancy, and then a linear increase up to 100% plant use at 100% occupancy; this is achieved using the ‘fnPLant’ function described in Appendix 6.

simple ratio which in this version is 0.45 as specified in the benchmark page.

Effect of changing to fossil-fired humidification: the effect of changing from electric humidification is taken to be to scale energy use by a simple ratio which in this version is 0.45 as specified in the benchmark page. In addition the effect of changing the extent of humidification measured as percent of floor area humidified has been included.

12 Adjustment summary

Sheet tab name: Adj_Summ

Status: Background calculation sheet. The sheet is not viewed from any of the main options A, B or C.

Description: This sheet tabulates the energy consumption for all systems, for all four zones (and overall for the zones combined), for both the actual energy used (based on metered energy) and the two levels of benchmark energy use ('good practice' and 'typical'). The effect of adjustments and allowances (as derived from the 'Adjustment' calculation sheet above) is applied to the metered energy from the top of the page downwards and to the benchmark energy from the bottom of the page upwards, and the actual and benchmark energy can be compared at any level, in principle. This comparison is shown at all levels using the AGT function (see Glossary) which compares actual with good practice and typical.

13 Calculations for overall assessment

Sheet tab name: S2_Calc

Status: Background calculation sheet. The sheet is not viewed from any of the main options A, B or C.

Description: This sheet carries out the calculations for the overall assessment for options A or B and for the first part of option C. It makes use of the adjustments and special energy use described above.

14 System assessment summary

Sheet tab name: SysResults

Status: Shown when main option C is selected.

Description: This is the results page of the systems assessment. Provides a comparison of sets of systems data with benchmarks in tabled and chart form, all from the 'Systems Assessment' (SysMain) sheet. Menu options allow the selection of one or two source datasets and the building area or size metric and the carbon metric (Carbon or CO₂).

15 Systems assessment

Sheet tab name: SysMain

Status: Shown when main option C is selected, after the overall assessment.

Description: This sheet collects together up to four sets of 'actual' system energy use data and allows any two to be compared with good practice and typical benchmarks. The sets are:

- Design-stage or calculated system energy use: from the 'Design Assessment' (SysDesign) sheet.

- Metered energy use: from the ‘Metered Data’ (SysMetered) sheet.
- Estimated system energy use: from the ‘Plant Analysis’ (Plant) sheet.
- Direct entry data: for ‘what if?’ investigations.

The first three sets are obtained from separate data entry sheets accessed from buttons on this sheet.

Any two sets can be compared with the benchmarks; menus allow selection of which two sets are compared.

When a set is selected for comparison, there is also an option to ‘auto-complete’ the data: this refers to an optional capability of the software which can be useful when not all system energies are known — the unknown systems are automatically given energy use values so that they all have the same performance level in relation to the benchmarks (i.e. the remaining systems all have the same AGT value) while ensuring the total of the systems (and any CHP and renewables) matches the building metered energy use.

16 *Design assessment*

Sheet tab name: SysDesign

Status: Optionally shown when main option C is selected, after clicking the ‘Change Design Data’ button from the ‘System Assessment’ (SysMain) sheet.

Description: Allows calculated system energies to be entered for comparison within the ‘System Assessment’ (SysMain) sheet.

17 *Metered data input*

Sheet tab name: SysMetered

Status: Optionally shown when main option C is selected, after clicking the ‘Change Metered Data’ button from the ‘System Assessment’ (SysMain) sheet.

Description: Allows metered system energies to be entered for comparison within the ‘System Assessment’ (SysMain) sheet.

18 *Plant analysis*

Sheet tab name: SysPlant

Status: Optionally shown when main option C is selected, after clicking the ‘Change Plant Data’ button from the ‘System Assessment’ (SysMain) sheet.

Description: Allows estimated system energies to be used for comparison within the ‘System Assessment’ (SysMain) sheet. The sheet allows system energies to be calculated by entering details of each item of plant and equipment, its connected power, its usage and which system it is associated with. A group of similar items (such as general office lighting lamps) can be entered as a single item.

The effect of changes or energy saving measures can be assessed by optionally revealing the second (purple) columns and entering only the changed data in these — this changed data is for information and is not used in the comparison sheets.

19 *End of procedure*

Sheet tab name: Finish

Status: Shown at the completion of all main options A, B or C.

Description: Indicates completion of the assessment with the option selected. Allows printing of the sheets viewed and return to the main menu to revise assessment data or to change the main option selected, e.g. to carry out a system assessment once a main assessment has been completed.

20 *Benchmark data by building type*

Sheet tab name: Benchmarks

Status: Background source data sheet. The sheet is not viewed from any of the main options A, B or C.

Description: This sheet contains the source benchmark data for each sub-type of building.

21 *Procedure map*

Sheet tab name: Map

Status: Optionally viewed from the main menu.

Description: A block-diagram of the TM22 procedure.

22 *Release notes*

Sheet tab name: ReleaseNotes

Status: Optionally viewed from the main menu.

Description: These form an integral part of the software and manual, and provide a summary of:

- comments on the current status of compatibility of the TM22 procedure with relevant legislation including the Energy Performance of Buildings Directive⁽¹⁾
- changes implemented in the current software version, and implications for the printed manual
- other known issues with the current version of the software and the printed manual.

23 *Menu page*

Sheet tab name: Code_Menus

Status: Background sheet.

Description: Programmer's sheet for storing the lists of menu options.

24 *Progress sheet*

Sheet tab name: Code_Progress

Status: Background sheet

Description: Programmer's sheet for recording progress and sheet navigation details.

25 *Text page for help boxes and alerts*

Sheet tab name: Code_Helptext

Status: Background sheet

Description: Programmer's sheet for storing help text.

Appendix A6: Special functions used in calculations

The following user functions are defined for the TM22 calculation procedures. These custom-defined functions are the only significant calculations carried out in macros (VBA code) and they are used to greatly simplify the spreadsheet formulae. Other VBA coding (not described here) is used for procedural purposes such as navigation and formatting.

Each function name is followed by a list of input values (arguments) which it requires (in a similar way to normal Excel functions) and then a brief description and the calculation procedures that define the function.

Function: **fnAGT (ActualValue, GoodPractice, Typical)**

Calculates the AGT of ActualValue in relation to GoodPractice and Typical.

If ActualValue > Typical, then $\text{fnAGT} = \text{ActualValue}/\text{Typical}$

If GoodPractice < ActualValue ≤ Typical, then $\text{fnAGT} = (\text{ActualValue} - \text{GoodPractice}) / (\text{Typical} - \text{GoodPractice})$

If ActualValue ≤ GoodPractice, then $\text{fnAGT} = (\text{GoodPractice} - \text{ActualValue}) / \text{GoodPractice}$

Function: **fnAGTblank (ActualValue, GoodPractice, Typical)**

As fnAGT above but gives a blank if ActualValue is zero; this is useful for tables of results.

Function: **fnPlant (ActualValue, Fifty%Value)**

A simple approximation to a general response curve returning a value between 0 and 1. Used when calculating plant full load hours for the occupancy adjustment.

If ActualValue ≤ Fifty%Value, then $\text{fnPlant} = 0.5 * \text{ActualValue} / \text{Fifty\%Value}$

If ActualValue > Fifty%Value, then $\text{fnPlant} = 0.5 + 0.5 * (\text{ActualValue} - \text{Fifty\%Value}) / (1 - \text{Fifty\%Value})$

Function **ElecValue2 (ElecValue1, NonelecValue1, %Elec1, %Elec2, ElecToNonelecRatio)**

Used in the 'Adjustment Summary' sheets. Calculates the electricity consumption (ElecValue2) after a change of energy source (i.e. a change in percent electricity), based on a simple ratio of energy use for the two energy sources. Given data is a starting electricity energy use and a starting non-electricity energy use, and the ratio of electricity to non-electricity energy for the same system load.

An intermediate result (ElecResidual) is first calculated to simplify the subsequent algorithms.

```

If %Elec1 <> 1 Then
  ElecResidual = ElecValue1 - NonelecValue1 * ElecToNonelecRatio * %Elec1 / (1 - %Elec1)
  If ElecResidual < 0 Then ElecResidual = 0
Else
  ElecResidual = 0
End If
If %Elec1 = 1 Then
  ElecValue2 = ElecValue1 * %Elec2
ElseIf %Elec1 = 0 Then
  ElecValue2 = NonelecValue1 * ElecToNonelecRatio * %Elec2 + ElecResidual
Else
  ElecValue2 = (ElecValue1 - ElecResidual) * %Elec2 / %Elec1 + ElecResidual
End If

```

Function: NonelecValue2(ElecValue1, NonelecValue1, %Elec1, %Elec2, ElecToNonelecRatio)

This is the same as function ElecValue2 above, except that it calculates the Non-electricity energy use after the change in percent electricity. Uses the same data as the Function ElecValue2.

An intermediate result (NonelecResidual) is first calculated.

```

If %Elec1 <> 0 Then
  NonelecResidual = NonelecValue1-ElecValue1*(1-%Elec1)/(ElecToNonelecRatio*%Elec1)
  If NonelecResidual < 0 Then NonelecResidual = 0
Else
  NonelecResidual = 0
End If
If %Elec1 = 0 Then
  NonelecValue2 = NonelecValue1*(1-%Elec2)
  ElseIf %Elec1 = 1 Then
  NonelecValue2 = ElecValue1*(1-%Elec2)/ElecToNonelecRatio+NonelecResidual
Else
  NonelecValue2 = (NonelecValue1-NonelecResidual)*(1-%Elec2)/(1-%Elec1)+NonelecResidual
End If

```

Appendix A7: Sector data and benchmarks

The main benchmark data table can be viewed in the software package using an option button from the main menu.

For each sector the summary lists the benchmark source references, the building types used for the benchmarks, building size measurements available in the procedure for the sector, and the system/energy headings in the benchmarks.

Examples are also given of system/energy headings which are excluded from the benchmarks. Only metered (or otherwise approved) energy use under an excluded energy heading may form a claim for special/process energy use allowance in the TM22 procedure.

A7.1 Offices sector

Benchmark sources:

- Energy Consumption Guide ECG019: *Energy efficiency in offices*⁽⁸⁾
- CIBSE Guide F: *Energy efficiency in buildings*⁽²⁾.

Building types:

- cellular naturally ventilated
- open plan naturally ventilated
- standard air conditioned
- prestige air conditioned.

Building size measurement:

- gross internal floor area
- treated floor area
- net lettable floor area.

System/energy headings in benchmarks:

- heating and hot water
- cooling

- fans, pumps and controls
- humidification
- lighting
- office equipment and associated local servers
- catering
- other normal electricity use: lifts, vending
- excluded:
 - regional or national server room or computer suite
 - employee catering and dining
 - trading or dealing floors.

A7.2 Hotels sector

Benchmark sources:

- Energy Consumption Guide ECG036: *Energy efficiency in hotels*⁽⁹⁾
- CIBSE Guide F: *Energy efficiency in buildings*⁽²⁾.

Building types:

- luxury hotel
- business or holiday hotel
- smaller hotel
- options:
 - air conditioning
 - pool.

Building size measurement:

- gross internal floor area
- treated floor area
- number of bedrooms.

System/energy headings in benchmarks:

- heating
- hot water
- lighting
- catering
- ventilation fans, pumps
- cooling
- office equipment
- pool, sauna
- other normal electricity use.

A7.3 High street banks and agencies

Benchmark sources:

- *Introduction to energy efficiency in post offices, building societies and agencies*⁽¹⁰⁾
- CIBSE Guide F: *Energy efficiency in buildings*⁽²⁾.

Building types:

- bank branch

- agency branch
- options:
 - gas heated or all electric
 - cooling
- building size measurement:
 - gross internal floor area
 - treated floor area
 - sales (public) floor area
- system/energy headings in benchmarks:
 - heating and hot water
 - lighting
 - fans, pumps and controls
 - cooling
 - office equipment and associated local servers
 - other normal electricity use
 - excluded: regional or national server room or computer suite.

A7.4 Mixed use industrial buildings

Benchmark sources:

- Energy Consumption Guide ECG018: *Energy use in industrial buildings and sites*⁽¹¹⁾
- *Introduction to energy efficiency in factories and warehouses*⁽¹²⁾
- CIBSE Guide F: *Energy efficiency in buildings*⁽²⁾

Building types:

- cellular naturally ventilated office
- open plan naturally ventilated office
- standard air conditioned office
- prestige air conditioned office
- distribution and storage
- light manufacturing
- factory office
- general manufacturing.

Building size measurement:

- gross internal floor area
- treated floor area
- gross internal volume.

System/energy headings in benchmarks:

- heating and hot water
- cooling
- fans, pumps and controls
- lighting
- office equipment and associated local servers
- catering
- other normal electricity use — lifts, vending
- excluded: industrial process energy use.

Appendix A8: Energy Tree Diagram assessment

The energy performance of an occupied building can be understood and explained in terms of the performance of its various systems, such as lighting and ventilation. An approach has been developed to achieve this understanding within reasonable time and cost.

The approach helps improve the quality of design and management of buildings by the use of performance benchmarks, and can allow high quality internal environments to be achieved with less operating cost and less environmental impact.

This appendix describes briefly how this can be achieved and how the approach can be used to

- understand system performance
- develop targets for the building and its systems
- identify likely wastage
- suggest remedial energy saving measures
- support the development of customised energy consumption indices.

At the heart the method is the analysis represented by the tree diagram shown in Figure 3. Data for all of the boxes in this diagram can be obtained for an existing building, or projected for a new building. The m^2 denominator measures building size, normally as treated or gross floor area depending on the benchmarks used, or as a sector-specific measure such as sales floor area for retail buildings.

At the top level, box A is calculated from the building’s annual energy consumption which can be obtained from (or reconciled with) actual energy bills and provides an overall energy consumption index for comparison with published yardsticks. Box A is the sum of all the boxes of type B, although if more than one fuel is used, each fuel should be assessed separately or combined in terms of a meaningful measure such as total cost or CO_2 emissions.

Box B is an energy consumption index for each system, which can be compared with published benchmarks. Box B is obtained by multiplying the contents of boxes C and D and dividing by 1000 to scale for kilowatt hours.

Box C is an index of installed power per m^2 which provides a simple but powerful check on energy efficiency of installed plant and equipment. It can be used directly or combined to form a whole building index. Box C is obtained by multiplying the contents of boxes E and F (and, in the case of lighting, dividing by the scaling factor of 100 due to the units used for lighting efficiency).

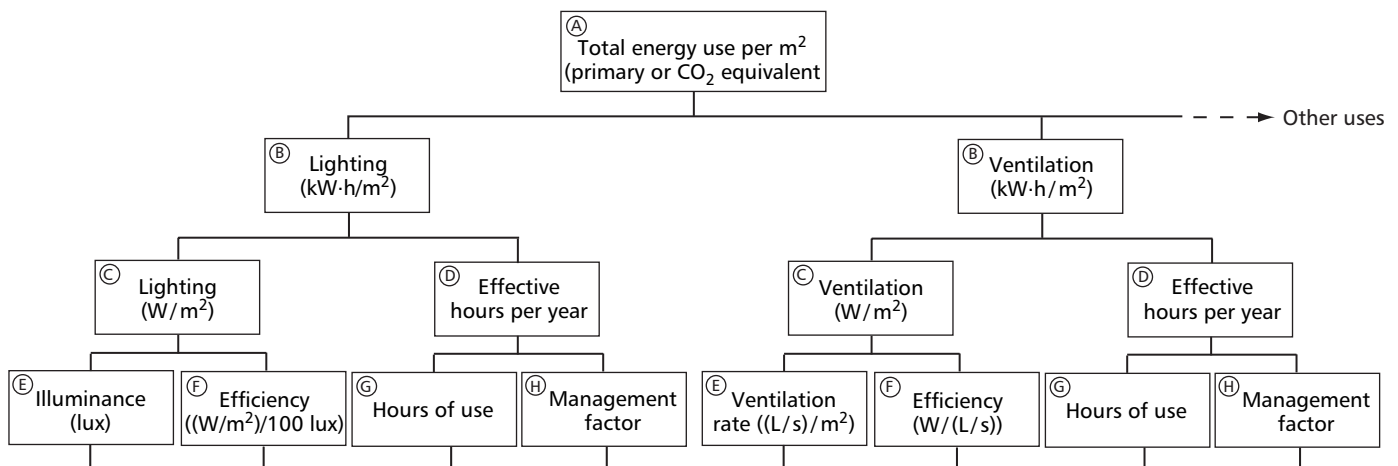


Figure 3 Analysis of building energy consumption and service provision; each box can be considered as a benchmark

Box D is the effective hours at nominal full load for each system, which can be compared with typical values. Box D is obtained by multiplying the contents of boxes G and H.

Boxes E to H provide more detail for boxes C and D:

- box E is the level of service provided (e.g. the amount of light or ventilation) and can be related to published guidelines, such as those provided in CIBSE Guides
- box F is a measure of the efficiency of the equipment for which published benchmarks are available
- box G is the number of hours per year that the service is required for each system
- box H is a management factor which indicates the fraction of the time enabled the systems are working (for part load operation the hours are effectively reduced pro-rata).

To obtain these data for new building designs, the installed power densities (box C) and expected occupation hours (box G) are known, and management/control factors (box H) can be estimated from experience or published benchmarks. Equivalent full load operating hours can therefore either be calculated or estimated directly from published values.

For occupied buildings, the installed power densities (box C) can be assessed on-site without excessive effort, and operating hours (box G) and control factors (box H) can be assessed by consideration of control schedules, observation and discussion with operators and occupants. This is the approach used in the 'Plant' module of TM22 Option C.