SERIES 18

CPD fundamentals

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

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MARK THROWER MANAGING EDITOR

energy institute

Energy metering and monitoring

by Chris Burgess, trainer and technical adviser, Energy Institute

Energy monitoring and targeting (M&T) is one of the fundamental techniques that an energy manager can use for the long-term management of energy consumption and to highlight potential improvements in the efficiency of energy use.

Monitoring is essentially aimed at establishing the existing pattern of energy consumption, whereas targeting is the identification of a level of energy consumption which can be set as a goal for the energy management strategy.

Monitoring and targeting should form an essential part of the energy strategy for any size or type of organisation, whether industrial, commercial or public sector. The primary objective of M&T is to gain a better understanding of how energy is used. When correctly applied M&T helps identify signs of avoidable energy waste and other opportunities to reduce energy consumption, but energy savings are achieved only if appropriate actions are taken based on the correct interpretation of the M&T results.

The output from a well-designed M&T scheme will enable the energy manager to:

• detect avoidable energy waste that might otherwise remain hidden;
• identify areas for investigation and action prompted by unexpected patterns of energy consumption;
• quantify the savings achieved by energy-saving projects in a manner that accounts for factors such as variations in external temperature or levels of production output;
• improve energy or carbon budget setting;
• improve the collection of data required for performance standards such as ISO50001 and organisational carbon footprints compiled in compliance with ISO14064; and
• provide visible feedback to support staff awareness campaigns.

Smart meters may benefit domestic energy consumers by increasing the visibility of energy costs and their consumption profile. In the non-domestic sector devices with communication capability together with analysis software are now commonplace, enabling systems to be configured to automatically measure, analyse and report energy consumption.

Checking fiscal energy meters and utility bills as a cost control measure might once have been considered a basic form of monitoring but now automatic M&T has evolved into a mature area of business with a wide range of products and services from different suppliers.

Four parts of an aM&T scheme

There are four parts making up an automatic M&T scheme starting with the meter - typically, electricity, natural gas, water or heat meters with a digital interface, commonly a simple pulsed output. Then an automatic meter reading (AMR) system which reads the metered consumption (typically over 30-minute periods) and stores the data ready to be analysed. Meters can be hard wired to the meter reader, but wireless technology is often more practical and cost effective.

Third, there are sensors or other data input facilities to record the parameter that "drives" energy consumption, such as external temperature or production throughput in a manufacturing environment.

The final part is analysis software - there is a variety of software available with different levels of sophistication in terms of the depth of analysis and facilities such as energy dashboards using real-time data displays, cost and carbon reporting and databases to record energy reduction projects. Often the software sits in the cloud and is accessible via the web which means the user only requires an internet-enabled PC.

In a manufacturing setting, where processes and site services are often controlled using a SCADA system, it is worth investigating the possibility of integrating metering into the existing control system - additional energy analysis software may be required.

The fundamental step in the M&T analysis is carried out to establish the relationship between the dependent variable (i.e. energy consumption) and the independent variable (i.e. variables that influence energy consumption - sometimes referred to as the energy driving factor). A standard statistical technique called regression can be used to establish the relationship if there is a single independent variable for each consumption stream to be monitored.

Any measurable independent variable can be used provided there is a genuine relationship between it and energy consumption. Typical energy driving factors are production output for energy-intensive manufacturing processes, degree days for space heating or mileage for a vehicle fleet.

To illustrate the analysis, data can be shown graphically. Generally, when energy consumption is plotted against an appropriate driving factor, a straight-line relationship normally exists. This can be represented by an equation of the form: $y = m x + c$ where 'm' is the gradient of the line and 'c' is the intercept with the y-axis.

The values of 'm' and 'c' are significant as can be seen by using space heating as an example. Gas consumption for space heating will normally exhibit a straight-line relationship with heating degree days. The gas consumption and degree day data can be plotted as a graph. Each point on the graph is gas consumption during the monitoring period (i.e. day, week or month) shown on the vertical (y) axis and the number of degree days for the identical period shown on the horizontal (x) axis.

The mathematical functions within spread sheet software include a statistical analysis tool called 'least squares linear regression' and this can be used to calculate the formula for the 'best fit' line to represent the relationship between gas consumption and degree days. The best fit line is often referred to as the characteristic line.

The value where the line intercepts the vertical axis, is the value 'c' in the equation, and represents the fixed demand or base load consumption i.e. gas used at zero-degree days when the space heating load should be zero.

The base load consumption could be the result of boiler standing losses or other loads which are included in the metering data, but which are not dependent upon external temperature such as gas used for domestic hot water heating or catering. The slope of the characteristic line (the value of 'm' in the equation) indicates the increase in gas consumption for each degree day.

The formula for the characteristic line represents the heating energy performance over a historical time period that is analysed and can be used to calculate an estimate of the expected consumption for any future period using the relevant degree day value.

So once established, the characteristic line can be used as a 'performance target' for the future operation of the heating system by comparing the predicted value with the actual metered consumption to determine whether an over or under consumption has occurred. Any significant deviation in fuel consumption should be investigated and prompt corrective action taken as necessary to maintain the performance of the system.

The same type of calculation can be performed to establish an annual budget for space heating energy, by using the number of degree days for an average datum year in the formula. Or to establish an annual budget for process energy consumption by using the annual production output figure in the formula.

Correlation coefficient

Regression analysis is typically evaluated using a correlation coefficient (R2) which is a measure of the degree scatter of the energy data points from the line of best fit and is calculated by the spreadsheet software. The range is 0 to 1, with 0 representing no relationship and 1 meaning an exact fit (the model explains all the variability). For energy analysis an R2 above 0.8 is generally regarded as evidence of a reasonable relationship.

A wide scatter of points can be due to poor quality or inconsistent data but could be due to inadequacy or malfunction of the heating system controls. The correlation may also be

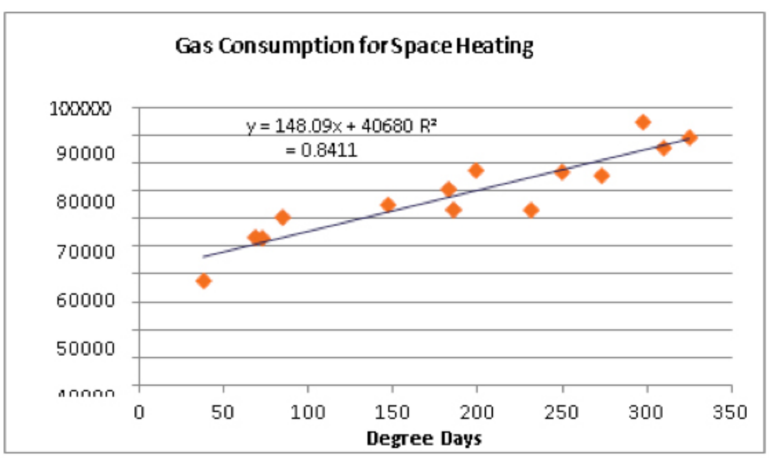

Figure 1: shows an example set of energy consumption and degree day data and the graphical results of the linear regression analysis.

Month	Degree day	Gas kWh
Apr	199	77,558
May	147	64,663
Jun	69	53,222
Jul	73	53,034
Aug	38	37,701
Sep	85	60,443
Oct	183	70,551
Nov	250	76,352
Dec	325	89,394
Jan	298	94,679
Feb	310	85,368
Mar	274	81,874
Apr	232	75,502
May	186	63,155

poor if heating accounts for only a small proportion of the fuel demand. A reasonable characteristic line can, however, usually be produced but this does not mean that the heating system is operating efficiently, merely that its performance is consistent with the analysis period.

To monitor trends in performance a simple bar chart can help to make comparisons against the previous year's consumption patterns, although this does not account for different weather between the two years if looking at space heating or different production outputs if looking at a production process. A better method to represent the data to show energy consumption trends more clearly is to use what is known as CUSUM analysis. CUSUM is the usual abbreviation for the CUmulative SUM deviation analysis. CUSUM analysis can also be used to calculate energy targets and savings for energy projects which are normalised for factors such as different weather or production figures. There are several references available which explain in detail CUSUM so this is not covered here.

Numerous energy suppliers provide online energy monitoring and reporting tools. Using these can offer a cost-effective first step to identify potential savings to justify further investment in a larger M&T programme.

What are degree days and how do you calculate them?

Degree days can be described as the summation of temperature differences over time and a reflection of the duration and extremity of outdoor temperatures.

The temperature difference used is that between a fixed reference temperature and the varying outdoor air temperature. This reference temperature is known as the base temperature which, for buildings, is the balance point temperature i.e. the outdoor temperature at which the heating (or cooling) systems do not need to run in order to maintain comfort conditions.

Published degree day figures are calculated from daily maximum and minimum air temperatures, using the daily difference between the mean and base temperatures. The daily temperature deficits (for heating) or excess (for cooling) are aggregated over each day, week or month to give a total for the period. The formulae are adjusted to allow for days when the outside air temperature falls either side of the base temperature.

Start with spreadsheet

For small single sites or buildings, those responsible for energy could start with their own spreadsheet analysis using electricity supplier half-hourly data or even manual meter readings. If proprietary M&T software or an integrated system is preferred it is important to select software that suits the level of analysis and features needed; unnecessary sophistication means additional complexity and cost for the user.

The initial challenge for an energy manager wishing to implement wide scope M&T is to evaluate the availability of data and to develop a metering strategy. Energy data for a site or organisation might be held in a variety of different locations, systems and formats - spreadsheets, building management systems, internet connected devices or even paper invoices.

The most basic metering strategy would be to obtain data from the fiscal meters. However, the granularity of this data only provides insights at a site-wide level. For smaller premises or sites this might be as deep as M&T needs to go but there are advantages to be gained in automating the M&T process and collecting data from additional sub-meters to improve coverage and data granularity down to individual services to give a clearer picture of how energy is consumed.

In this case the sub-metering strategy needs to be developed to account for areas of significant consumption particularly where a clear 'driving factor' can be established. For example:

• buildings: sub-metering boilers, lighting, HVAC and across individual floor consumption;
• industry/manufacturing: sub-metering of hot water and steam boilers, condensate return, compressed air, ventilation, chilling as well as process lines; and
• multi-site portfolios: monitoring building services across sites.

A typical building energy management system will incorporate some form of monitoring function with customisable dashboard and graphical interface alongside the real time monitoring and control of building services plant. This could offer a cost-effective M&T solution but the ability to perform analytical functions such as regression should be confirmed.

Within industry and manufacturing environments, where processes and site services are often controlled using a SCADA system, it is worth investigating the possibility of integrating metering into the existing SCADA system although additional energy analysis software is likely to be required.

As noted above for simple situations it is feasible to develop M&T software in-house, using the type of basic spread-sheet analysis discussed above.

However, since proprietary software is readily available it may not be considered cost effective to develop bespoke in-house systems. The number of metering points and the way information is collected does, however, need to be carefully considered to avoid the system being under-utilised, especially if it requires excessive amounts of data when a few important indicators would suffice. Over-detailed reporting can cause staff to miss or ignore vital information.

The ability to respond quickly is an important factor in the success of any M&T system. Data collection and input should be as near real-time as feasible and practical. Exception reports indicating excessive consumption should be generated speedily to allow early action and it is necessary for the energy manager to establish how the organisation will respond to whatever the M&T process highlights.

Although there are many proprietary M&T software packages available, not all of them are designed to provide full M&T analysis. Some software supplied with automatic meter reading hardware may do little more than display demand-profile charts and other energy accounting software may lack the analytical and target-setting functions discussed above.

Turnkey solutions on offer

Some M&T companies offer turn-key solutions to supply and install all the aM&T components whilst others provide single components and the end-user assembles the complete system. This can require a degree of metering and IT expertise to piece it all together and there are obvious installation risks and cost implications to consider. To ensure continued meter data integrity the system must be maintained. This is typically done through a service contract often with additional costs for important software updates.

An alternative is to outsource the entire or part of the M&T activity to a bureau or energy management specialist company. These providers offer a range of additional services beyond energy M&T and carbon reporting such as invoice validation, tenant billing and energy procurement.

Monitoring and targeting provides mechanisms for the long-term management of energy and if correctly applied can help save energy and cut costs. However, it is important to adopt the appropriate level of M&T whether the choice is bespoke in-house M&T, a turnkey system or a bureau service.

The effective application of M&T provides the cornerstone of any energy management strategy by allowing the energy manager to:

• monitor energy consumption and detect avoidable energy waste;
• identify unexpected energy use and to enable responsive and effective remedial action;
• help quantify the resulting savings;
• identify further productive lines of investigation;
• provide feedback for staff awareness;
• improve target and budget setting; and
• undertake meaningful benchmarking.

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CPD SERIES 18 | MODULE 06 | JANUARY 2021
ENTRY FORM

METERING & MONITORING

Please mark your answers below by placing a cross in the box. Don't forget that some questions might have more than one correct answer. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet, return it to the address below. Photocopies are acceptable.

QUESTIONS

1) What step in the M&T process achieves energy savings?
- ☐ Collection energy consumption data
- ☐ Reporting the consumption data
- ☐ Taking action based on the output results from M&T
- ☐ Analysing the data to determine results.

2) Output from the M&T process will help the energy manager in several ways. Which of the following is not one of the most direct benefits?
- ☐ Detecting avoidable energy waste that might otherwise remain hidden.
- ☐ Prompting action by identifying unexpected patterns of consumption.
- ☐ Improving energy budget setting
- ☐ Developing the energy policy

3) Which of the following is not one of the four basic stages in the M&T process?
- ☐ Data collection
- ☐ Data analysis
- ☐ Calculating an energy benchmark
- ☐ Communicating results

4) What is aM&T?
- ☐ Automatic collection of data
- ☐ Automatic setting of targets
- ☐ Automatic analysis of data
- ☐ Automatic collection and analysis of data.

5) What does AMR stand for?
- ☐ Automatic monthly reading
- ☐ Automatic metering reading
- ☐ Automatic metering ratio
- ☐ Accredited meter register

6) Which of the following is a fundamental requirement of any M&T scheme?
- ☐ To interface with fiscal meters only
- ☐ To monitor every energy stream
- ☐ To produce complicated reports that no-one reads
- ☐ To estimate expected consumption vs actual consumption to identify over or under consumption.

7) Which of the following is not a key component of aM&T?
- ☐ Energy meters
- ☐ Automatic meter reading systems
- ☐ Data analysis and reporting software
- ☐ Hardwired connection between each meter and the PC running the software

8) Which of the following is not likely to be the most important driving factor for linear regression analysis?
- ☐ Number of staff employed in a plastic extrusion plant.
- ☐ Production output in tonnes per day for an aluminium production facility
- ☐ Number of heating degree days for a space heating boiler
- ☐ Hours of darkness for a large external lighting scheme.

9) In the formula describing the characteristic line what does the constant 'c' represent?
- ☐ Increase in consumption per unit increase in the driving factor
- ☐ Energy base load
- ☐ Number of degree days
- ☐ Monthly energy consumption.

10) What is the significance of factors such as production volume or number of degree days for activity-based M&T?
- ☐ They introduce noise into the data which impedes analysis
- ☐ Raw consumption data must be adjusted to eliminate their distorting effect
- ☐ They are normally the factor driving energy consumption
- ☐ They can usually be ignored.

PLEASE COMPLETE YOUR DETAILS BELOW IN BLOCK CAPITALS

Name .... (Mr. Mrs, Ms) ....

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COMPLETED ANSWERS SHOULD BE MAILED TO:

The Education Department, Energy in Buildings & Industry, P.O. Box 825, GUILDFORD, GU4 8WQ. Or scan and e-mail to editor@eibi.co.uk. All modules will then be supplied to the Energy Institute for marking

CPD fundamentals

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

How to obtain a CPD accreditation from the Energy Institute

Energy in Buildings and Industry and the **Energy Institute** are delighted to have teamed up to bring you this **Continuing Professional Development** initiative.

This is the sixth module in the eighteenth series and focuses on **Metering & Monitoring**. It is accompanied by a set of multiple-choice questions.

To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to EiBI for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course and notification by the Energy Institute, **free of charge** for both Energy Institute members and non-members.

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