"Low hanging fruits" or cost-effective energy and water savings using intelligent metering and monitoring systems?

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Abstract
The paper presents Leicester's approach to identifying energy and water savings in local authority buildings (schools, libraries, leisure centres, swimming pools, administration offices, warden assisted accommodation, maintenance depots). Traditionally Leicester City Council collected and analysed monthly and quarterly utility billing data to identify energy and water saving opportunities. More recently, it has been gathering electricity, gas and water consumption data on a half hourly basis using a proprietary system which combines information technology and a proprietary software package. Energy and water consumption for nearly 300 local authority buildings is metered and monitored continuously. Electricity, gas and water meter readings are taken at half hourly intervals, and after being collected in a central workstation data is automatically checked for errors. The data is then analysed by the energy manager using the software's built-in analysis techniques, leading to the detection of potential energy and water savings. The initial savings are usually caused by incorrect operational management and maintenance procedures – sometimes described as "low hanging fruits". Once these operational issues have been solved, the analysis helps maintain effective energy and water management of the buildings. This paper presents the actual costs and savings produced, and examples of the "low hanging fruits" picked up by the new metering and monitoring system.

Introduction
In recent years there have been great advances in technology to measure, acquire and store large quantities of short- time series (usually in half-hourly and quarter-hourly intervals) energy and water consumption data. Technology is becoming less expensive and the need for more accurate billing in the new liberalised energy markets is driving the increasing availability of such 'smart' metering. The short-time series data for a large number of buildings and sites is available to be analysed using different data analysis software techniques to manage energy and water consumption in buildings.

The recently approved Directive on End-Use Efficiency and Energy Services will be another important driver for the development of new metering and monitoring practices for improved energy efficiency in the European Union. Article 13 of the Directive requires Member States to ensure that meters and systems measure the actual energy consumption, both accurately and frequently. Energy users should have access to good quality and frequent billing information. This is expected to have an impact in delivering energy savings. However, there are other potential applications for intelligent metering, particular for grid management and demand side management. Continuous monitoring and performance assessment can quantify and verify energy and water usage following corrective actions or the implementation of efficiency measures. This can be accurately carried out using short time series data together with effective analysis techniques. Analysis on the use of short-time series electricity data and innovative analysis techniques have already been tested and documented for UK office buildings (Ferreira et al. 2003) and UK secondary schools (Stuart et al. 2007). It has also been suggested in (Ferreira et al. 2006) that

the use of intelligent metering and monitoring can be used to increase the cost-effectiveness of conventional energy audits. The experience of the Leicester energy agency suggests that occasional or even regular energy performance assessments or energy audits are not the only tool for municipal building energy management. They employ a first resource approach for the identification of savings and evaluation of energy and water efficiency and renewable energy projects: the collection and analysis of half hourly electricity, gas and water data, using an intelligent energy and water metering and monitoring system in their municipal buildings.

Leicester intelligent metering and monitoring system

Leicester City Council collects utility data using a proprietary system which combines information technology and a proprietary software package, which is commercially available under the label "Automatic Monitoring and Targeting (aM&T) system. The aspect of aM&T, which differentiates it from more traditional M&T is the capacity to profile energy and water use and automatically highlight variances from set patterns or expected outputs. The half-hour analysis is critical to enable variances to be acted upon immediately.

In Leicester's intelligent metering and monitoring electricity, gas and water meter readings are taken at half hourly intervals and recorded onto a data logger locally. Data is also collected from district heating heat meters and from automatic weather stations. Each day the 48 daily readings from each (electricity, water and gas) meter are transmitted by low power radio to one of seven main receivers, similarly to the system presented in (DETR 1996). The main receivers then forward the data on to a central receiver located in the energy office where it is stored and analysed. It is possible to test the relationship between energy use and weather and/or occupancy. The proprietary software is used to plot it as charts at various resolutions; it also provides regression analysis and generates alarms when consumption falls outside predetermined levels. In summary the proprietary software's main features are:

- Graphical display of data (including profiling with target setting);
- Regression analysis with degree-days (assess weather related consumption);
- Cumulative sum of the differences from an existing pattern of consumption;
- Year on year comparison;
- Reporting functions, including exception reporting.

Currently the Leicester City Council system collects and performs analysis on gas, electricity and water data for about 280 buildings, including:

- Schools;
- Libraries;
- Leisure centres/Swimming pools;
- Administration offices;
- Elderly persons homes;
- Warden assisted accommodation;
- Maintenance depots.

COSTS AND SAVINGS

The cost to set up the energy and water metering and monitoring system is of the order of 3,750 Euro to 4,500 Euro per building. In the current contractual arrangement with the aM&T technology providers, about 60 % of the cost to set up metering and monitoring is for the hardware (new metering equipment), about 25 % is for connecting the new and existing meters to the monitoring system and 15 % is the labour costs of the installation.

Leicester intelligent metering and monitoring system started to be installed in 2002, when a pilot demonstration of aM&T of 10 buildings was implemented. Until now the total investment in the system, which includes the 280 buildings was about 1,155,000 Euro (approximately over the last 5 years). The annual maintenance costs, which include all the cost of keeping the system running, from software updates to replacement of batteries in data loggers is about 52,500 Euro per year. Data transmission from the seven main receivers to the central computer, performed on a daily basis, costs about 750 Euro per year.

So far, estimated savings on energy and water, the so called "low hanging fruits", are in the order of 225,000 Euro per year (2006 figures), and this figure is increasing rapidly as more buildings are being added to the a M&T system. When no more of new buildings are added to the system, and after all the low hanging fruits picked up, the annual savings produced by the system are expected to be reduced. The system will be exclusively performing monitoring and targeting, i.e. detecting uncommon consumption patterns.

TYPICAL "LOW HANGING FRUITS" IDENTIFIED

The intelligent metering system assists in the building operational management, but it also can help in diagnosing consumption patterns that might be indicative of excessive energy and water consumption. It allows potential savings to be accurately quantified. Frequently, energy and water cost savings can be attained by simple no-cost, and low cost corrective measures, these are what can be labelled as "low hanging fruits". These savings would probably be undetected if it was not for the continuous metering and monitoring system, and they even could pass unnoticed in a short walk around survey to the building, or at least would not be fully explored. Most of these savings were not physically visible, as they were not noticed by the building manager and building occupants. These were only detected because of the analysis of high resolution data, which pinpointed unusual patterns that were then proved to be caused by water or energy wastage. Leicester Energy Agency (Leicester City Council) provides, remotely, technical and analytical support to the building managers along the entire process of detecting and quantifying savings.

The first, most common and important low hanging fruit ready to be picked by the energy manager in charge of the metering system are water savings. So far water monitoring is yielding the best results in terms of cost savings and when comparing with electricity and gas. In Leicester buildings, water

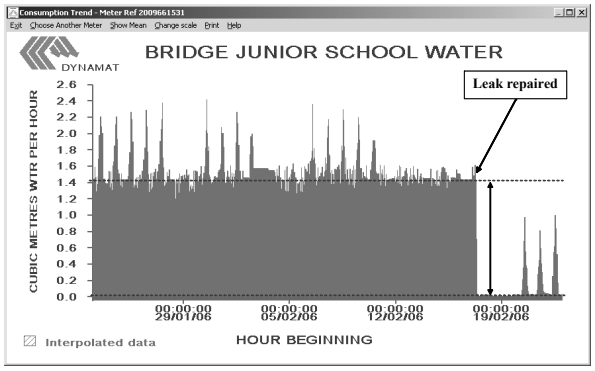

Figure 1. Detection and elimination of water leak

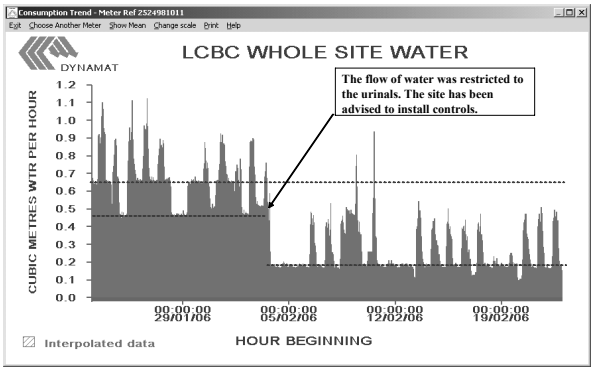

Figure 2. Detection and partial elimination of water flushing control in urinals

savings represent about 60 % of the total savings. This is due to the relative straightforward identification and elimination of water wastage. After wastage is identified by the energy manager, there are only a few areas to eventually investigate further on site in order to complete the wastage diagnosis and correction. Typical savings are usually achieved by repairing water leaks in valves, toilets, kitchens, tanks and in plant rooms.

The second most important low hanging fruit that would remain undetected if it were not for the half hourly metering and monitoring concern gas wastage representing 25 % of the total savings identified. The energy manager in Leicester Energy Efficiency Centre conducts the analysis to the half-hourly gas data comparing consumption in the occupied to the out-of-hours periods, and calculating the building energy degree-day signature (Harris 1992), i.e. the regression analysis between gas consumption and degree-days. This relationship is then used as a target to compare against the actual consumption. Overnight gas consumption and heating control problems are the typical anomalies identified and easily corrected. Poor maintenance of the boilers and heating systems are also detected with the metering and monitoring system. The system is also used for benchmarking purposes.

Electricity wastage is far more difficult to identify. Although the intelligent metering and monitoring system enables the analysing of high detailed data in half-hourly periods, in most of the building there is only one electricity meter installed and therefore the energy manager does not have the possibility to analyse the performance of individual equipment. Therefore when an unusual electricity consumption pattern is detected, the identification of the cause is not straightforward, and in some cases requires an on site comprehensive inspection. Nevertheless there have been simple no-cost, and low cost corrective measures implemented in Leicester municipal buildings to eliminate electricity wastage, which represents about 15 % of the total cost savings implemented.

Although Leicester's intelligent metering and monitoring system is running smoothly, needs has been identified to improve the methodology for energy and water saving detection, particularly for electricity. The process is still very resource intensive in terms of time the energy manager spends in data cleaning and data analysis. A more automated system is required, leaving more time for the energy manager to detect energy savings and to report on them, as well as to promote action by engaging building managers and occupants and provide technical support to the implementation of energy and water efficiency measures.

EXAMPLES

In Bridge Junior school it was possible to detect and eliminate a water leak leading to the saving 9,638 cubic metres and 23,130 Euro per year. This water leak was found in buried pipe between the meter and the main valve of the building. Water had been leaking to the soil for an undetermined period of time and it would be unnoticed if it was not for the installation of the aM&T system that detected an unusual base load consumption, as presented in the figure 1.

In Leicester Creative Business Centre, a recently refurbished building, the intelligent metering system helped the energy manager detect 4,467 cubic metres and 10,722 Euro per year of potential water saving. The waste was being caused by the lack of urinals controls, and therefore the water tank would fill in and flush the water into the urinals continuously. None of the building occupants had detected this situation. The immediate solution was to reduce the flow of water in the restricting valve. This no-cost action reduced 2,715 cubic metres and 6,516 Euro per year, as presented in figure 2. In the meantime urinal controls will be installed in the building, and the resisting base load water use will be eliminated.

In Braunstone Neighbourhood Centre the heating controls failed in the on position, and this caused the heating to be on 24 hours 7 days a week. However the building is only occupied about 10 hours from Monday to Friday. The energy manager

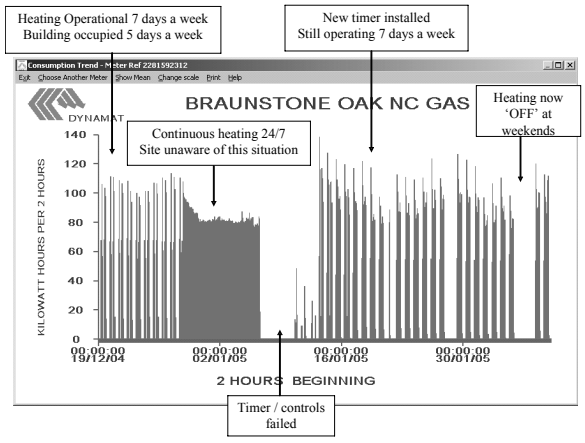

Figure 3. Diagnosing and elimination of space heating timer control problems.

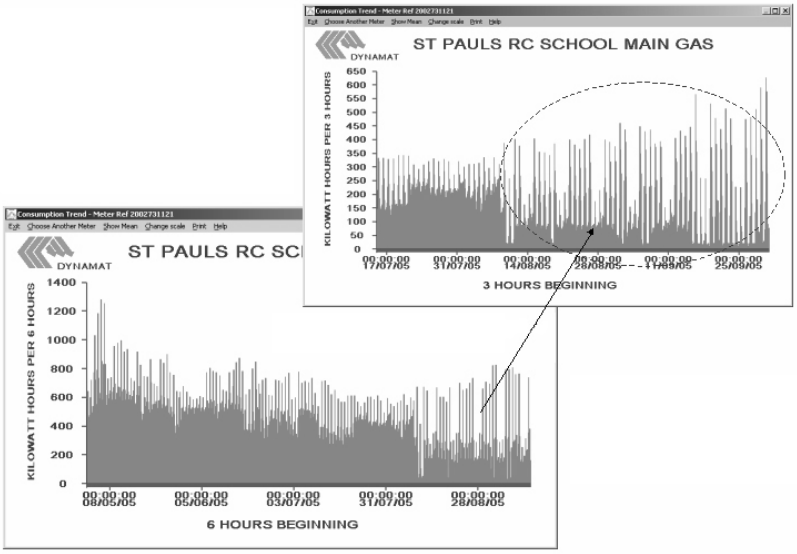

Figure 4. Detection and elimination of gas wastage; change in control set point saved 740,000 kWh and 22,200 Euros per year.

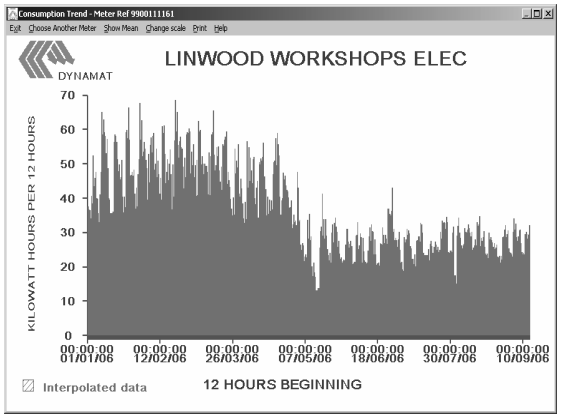

Figure 5. Measurement of electricity savings through the installation of occupancy lighting controls in corridors and bathrooms.

contacted the building occupants to communicate the problem. However before they have the chance to investigate in detail what was happening the the timer controls failed completely and the building had no heating for several days. After these events, a new timer was installed, initially heating was still on 7 days a week, but then it was reset to shut the heating over weekends. Figure 3 present an overview of the events using the aM&T system.

In St Pauls School gas consumption was reduced by 740,000 kWh per year, by resetting the control set point temperature. This originated about 22,200 Euros of gas savings per year. In figure 4 it is clearly to see the high and variable consumption that was indicative of potential energy wastage. This caught the attention of energy manager who then visit the building and reset the control set point temperature.

In figure 5 presents documents the saving achieved by installing occupancy lighting controls in corridors and bathrooms at Linwood Workshops in Leicester.

Conclusions

The intelligent metering and monitoring system is cost-effective (including investment and running costs) even when most of the energy and water savings achieved though simple no-cost or low cost measures – "low hanging fruits". Once these "low hanging fruits" have been picked, the effective (annual) savings might be reduced. However the ongoing monitoring of the buildings will ensure buildings are continuously operating efficiently, it will help to quantify the savings from any energy efficiency improvement measure and to identify further energy saving opportunities.

Intelligent metering and monitoring systems based on short time series metered data and adequate energy analysis techniques can clearly contribute to the implementation of Directive on End-Use Efficiency and Energy Services, and for Member States energy efficiency and carbon emission reduction targets. The results of the study of Leicester's municipal building intelligent metering and monitoring systems indicates that there is probably a significant potential for replication in other European municipalities.

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