Evaluation of water and energy metering and monitoring practices in European local authorities

Vasco Ferreira
Research Group on Energy and Sustainable Development - IDMEC
Instituto Superior Técnico – Technical University of Lisbon
Portugal
vferreira@ist.utl.pt

Paul Fleming
Institute of Energy and Sustainable Development
De Montfort University
United Kingdom
pfleming@dmu.ac.uk

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Abstract

Metering and monitoring building water and energy consumption is becoming an increasingly important activity in European municipalities as a tool to improve building energy efficiency. This paper presents the results of a survey to European local authorities carried out to investigate metering, monitoring and energy management practices in European municipal buildings. The respondents were informed about the survey through different European networks of cities and municipalities active in sustainability, climate change and energy issues, such as Energie-Cites, ICLEI-Europe and CEMR. The survey had a total of 76 respondents from 19 European countries, responsible for managing energy and/or water consumption in over 63,000 municipal buildings. It was found that nearly all the European local authorities represented in the study are collecting data on building water, electricity and gas consumption. This data is collected both manually and automatically and is being used to identify and quantify energy savings. However, energy managers are using relatively simple analytical and visualisation techniques to analyse the data. The survey showed that there is a demand for more automated, accurate and flexible metering, and for easy-to-use water and energy consumption monitoring tools and techniques.

Survey planning, preparation and delivery

Short time series (hourly and sub-hourly frequencies) metering hardware 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. Short-time series data for a large number of buildings and sites is now available and can 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 is also an 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 also other potential applications for intelligent metering, in particular for grid management and demand side management. Continuous monitoring and performance assessment can quantify and verify energy savings following corrective actions or the implementation of energy efficiency measures.

More than 300 buildings owned by Leicester City Council are being monitored using an automatic metering and monitoring system. This system has been the basis for research and development of new energy analysis techniques (Ferreira et. al 2006 and 2007). EC Intelligent Energy Programme, supported two projects on metering and monitoring municipal building energy use: Intelligent Metering (Webber et. al, 2007) and ENERinTOWN (Ferreira et. al, 2007) projects. Both projects assessed the technical and non-technical barriers of deploying metering and monitoring system in complex institutions

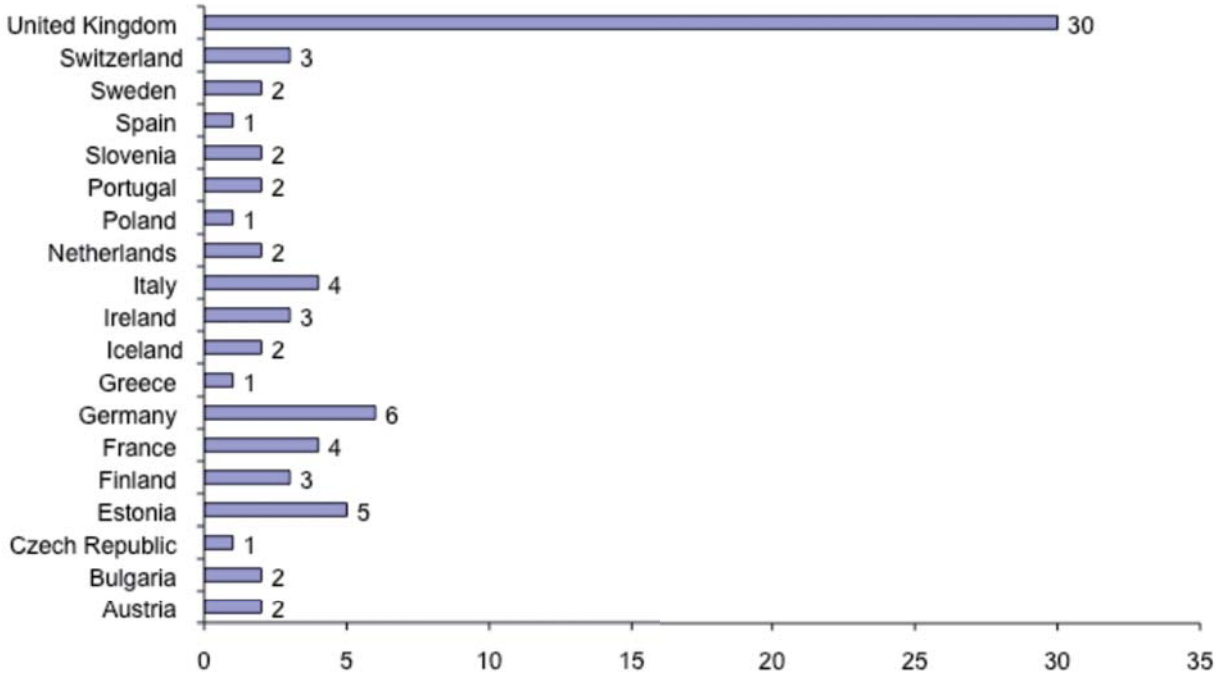

Figure 1. Number of respondents per country

such as local authorities. These projects involved more than 30 municipalities in Europe for about 11 different countries, which demonstrates the increasing interest of local authorities to manage their energy costs by installing automatic metering and monitoring systems.

This paper describes a survey of European Municipalities to assess their metering and monitoring practices. It was based on an exploratory survey, aimed at investigating how metering and monitoring in municipal buildings is currently being carried out in European local authorities. It also assessed the energy managers' needs in terms of data technology hardware and software.

The survey was conducted through an online questionnaire distributed to European energy managers. This was the considered the most appropriate and feasible way to collect information on building energy and water metering and monitoring practices. The survey questions were devised and analysed based on previous survey research. (Converse et. al., 1986) and (Reeves et al., 1981) state that in an exploratory qualitative study error margins are not the key issue, and that sample size only needed to be large enough to ensure a wide variety of answers from different countries. Therefore 20 to 30 replies might be enough to get qualitative information on the metering and monitoring practices in European local authorities. All the answers were from voluntary respondents who were informed about the survey through different European networks of cities and municipalities active in sustainability, climate change and energy issues, such as Energie-Cites (www.energie-cites.org), the European office of ICLEI - Local Governments for Sustainability (www.iclei-europe.org) and CEMR, the Council of European Municipalities and Regions (www.ccre.org). Therefore the local authorities that responded to this survey can be considered very active in energy management, when compared to other European local authorities. Consequently the results presented here are biased, and may be considered to be amongst the best practice in Europe.

The survey questionnaire was devised and then piloted in late August until early October 2006. Three local authorities (from UK, Germany and Spain) and Energie-Cités took part in the pilot exercise and the survey was amended to take into account the views of the pilot respondents. The main online questionnaire was available at: http://www.iesd.dmu.ac.uk/survey/emb/. The survey started on the 13th November 2006 and was closed on the 31st January 2008. During this period several emails were sent to energy managers, directly by the authors and by the networks: Energie-Cités, ICLEI-Europe and CEMR.

The survey had 76 respondents in total, from 19 European countries, as presented in Figure 1. About 39% of the respondents were from the UK, this because the questionnaire was only available in English and not in other languages. In total, the respondents said to be responsible for managing energy and/or water consumption in nearly 63 thousand municipal buildings.

Data collection practices by local authorities

It was found that most (nearly all municipalities in the study) European municipalities are collecting data in municipal buildings related to the use of water, electricity and gas consumption. As expected, electricity consumption data is collected in most of the municipalities (71 out of the 76 municipalities), followed by water consumption data (65 out of the 76 municipalities) and gas consumption data (62 out of the 76 municipalities).

Data on oil use, for space heating systems, is collected in more than 50% of the local authorities that replied to the survey, and heat use is collected in 1/3 of the municipalities that participated in the study. Additionally, 30% of the municipalities are collecting outside temperature data. Biomass, solar thermal

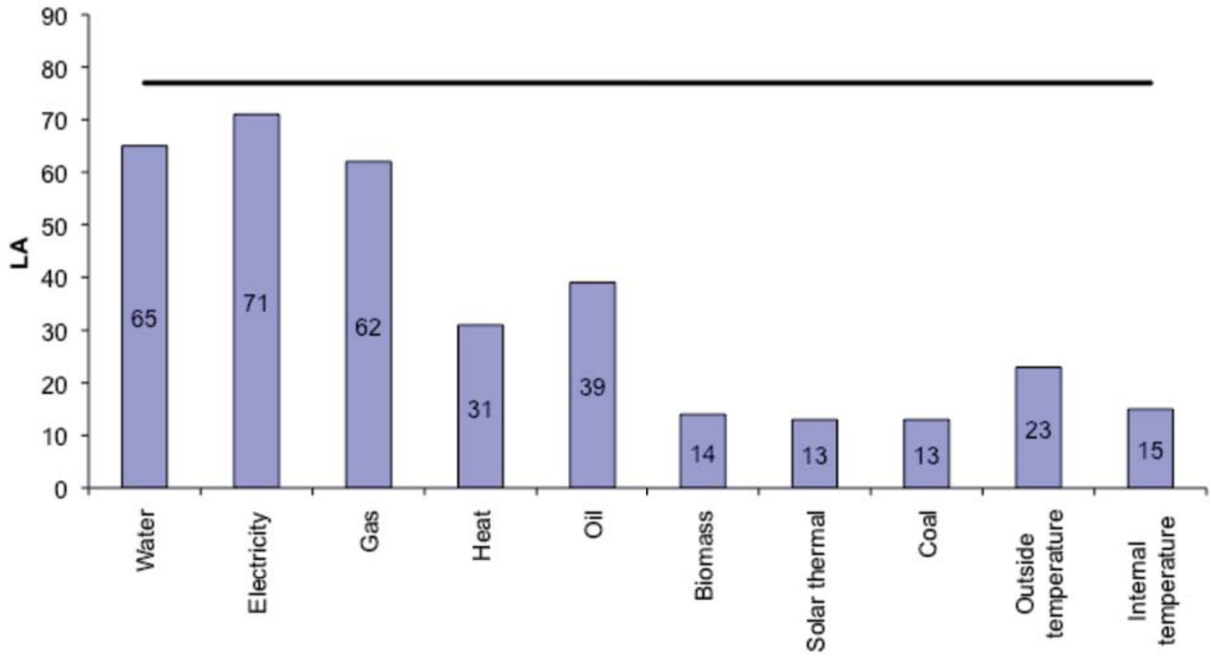

Figure 2. Number of European local authorities collecting water and energy data being

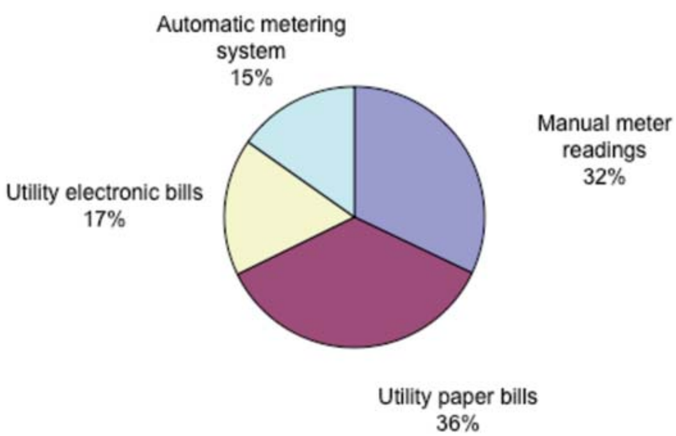

Figure 3. Data collection procedures used by local authorities

and coal consumption data are only collected in a few municipalities, since they are not very common energy sources in European municipal buildings. Building internal temperature data is collected in very few local authorities, mostly in large buildings with building energy management systems (BEMS).

From Figure 3 it is possible to see that only a relatively small proportion of municipalities collect building data automatically through electronic bills, and even less with automatic metering systems.

About 32% of the energy and water data is being collected through manual meter readings, and about 36%, through utility paper bills. European municipalities are still using manual and very little sophisticated procedures to collect energy and water data. Electronic bills provided by utilities are only responsible for about 17% of the data collected, and automatic metering reading system represent just 15% of the data collected.

Figure 4 presents a breakdown of data collection procedures per type of utility: water, electricity, gas, etc. Automatic metering systems are responsible for collecting water, electricity and gas in 10%, 13% and 7% of the cases, respectively. However, automatic systems are being used to monitor the new and renewable energy use: 21% for heat and 47% for solar thermal. Temperature data is also being collected automatically: 63% outside temperature and 53% for inside temperature. There is no additional information on utilities referred to on the 'Other' category. Nevertheless and from the results in other questions these replies are probably referring to degree-day information collection.

It was found that monthly data collection frequency is used for about 35% of the cases. Data collected in periods larger than the month (in which we included intermittently collected data)

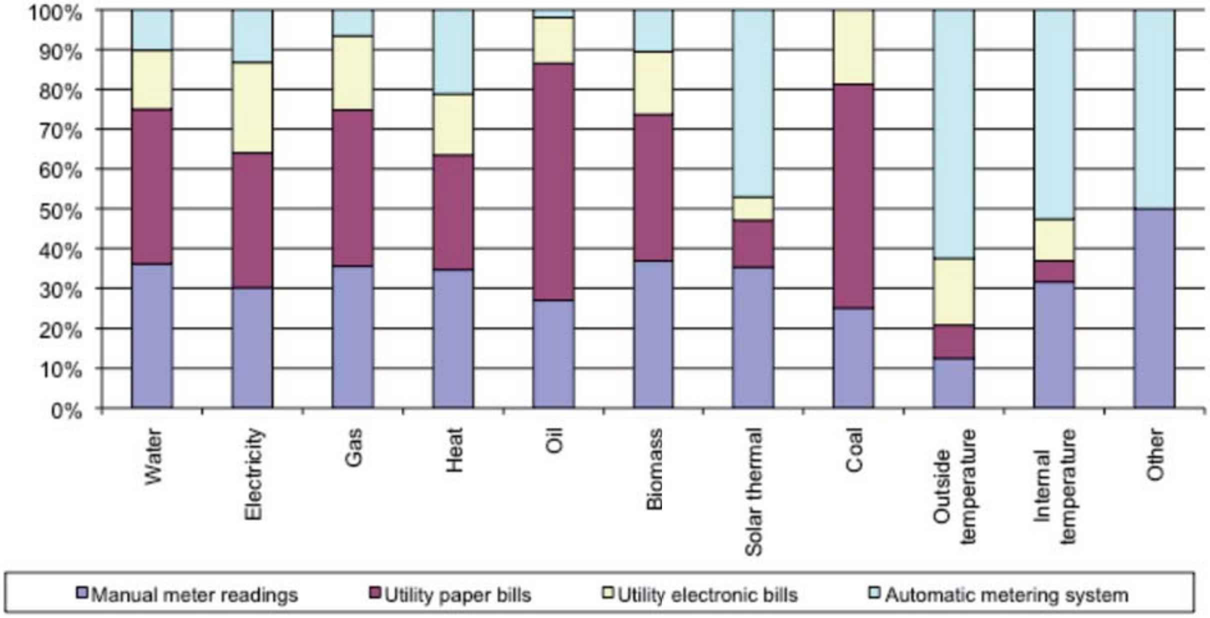

Figure 4. Type of water and energy data collection procedure per utility

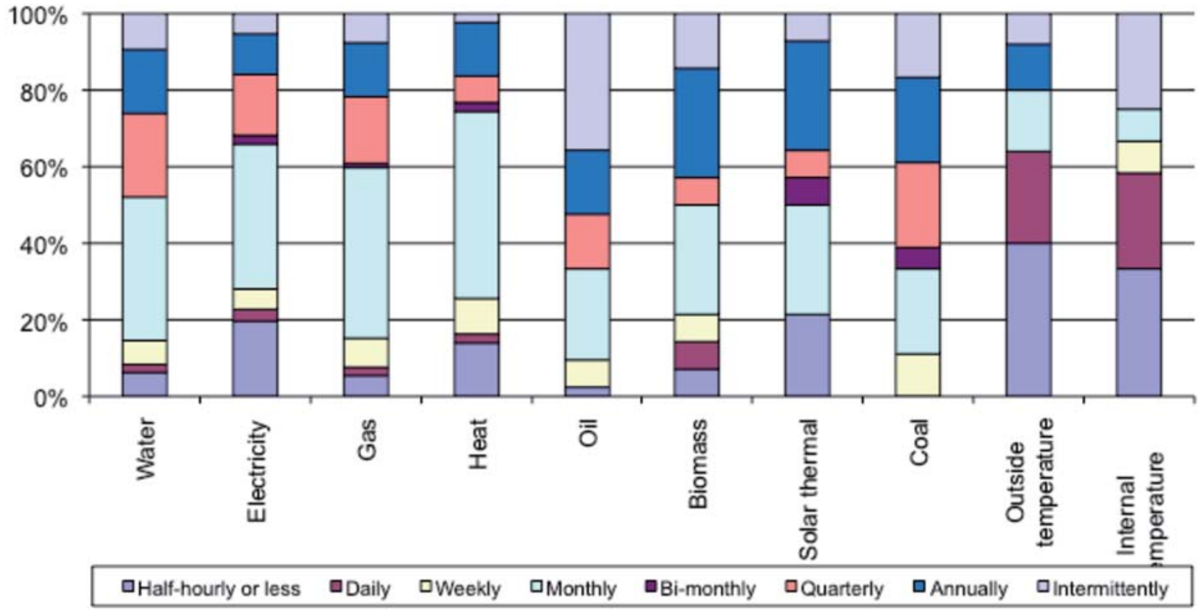

Figure 5. Frequency of water and energy data collection systems per building utility

represent 41% of all data. Only about 12% of the data is collected in sub-daily periods, i.e. in half-hourly (or less) intervals.

Figure 5 presents the frequency of data collection for each utility. From half-hourly or less, daily, weekly, monthly to data being collected intermittently.

Figure 5 shows also that data collected in short time series (half-hourly or less) periods is less than 20% for water and energy utilities, except for solar thermal energy production and temperature data (inside and outside). Half-hourly electricity data collection is more frequent than half-hourly water and gas data. For the most important utilities (water, electricity and gas), monthly data collection is the most common metering/monitoring frequency, however, quarterly and annually collected data are also very common.

Figure 6 presents the contrast between the number of municipalities that are collecting data for each utility, with the number of municipalities that are storing data in digital format. Nearly all the local authorities store their building's water and energy consumption data in computer databases, with most of this data is coming from non-electronic format in typically monthly or larger reading periods. This probably requires a resource intensive activity for inputting the water and energy data collected onto a computer database for management or other purposes.

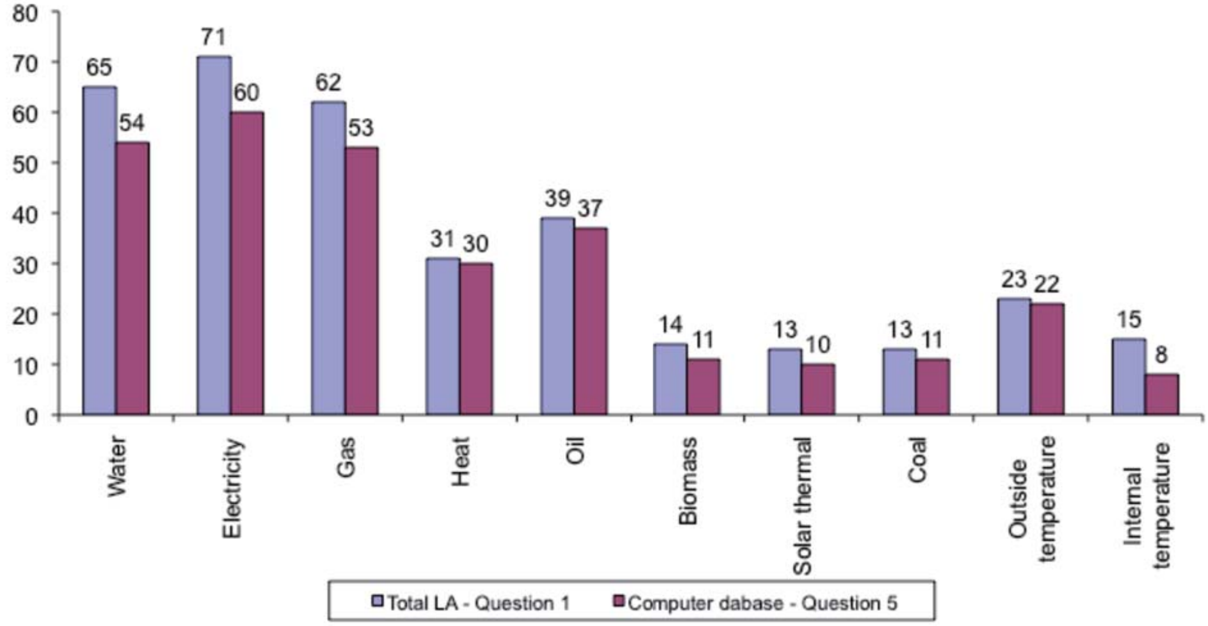

Figure 6. Digital storage of building water and energy data

Applications of collected data

The survey showed that applications of collected data are quite varied. The survey, which allowed Energy managers to select multiple answers from a set of prepared applications and to include additional applications and comments, resulted in a ranking of selected applications as can be seen below (the number of answers on each of the items is in brackets):

- To identify excessively high levels of consumption in normal use (61);
- To verify utility billing data (59)
- To monitor unusually high or low consumption to identify energy wastage (58);
- To measure and verify energy/water savings measures (55);
- To communicate with buildings occupants in order to change behaviour (51);
- To perform benchmarking analysis with similar buildings (47);
- To negotiate with utilities (e.g. in calls for tender for energy supply) (41);
- To measure municipal buildings greenhouse gas emissions (40);
- To communicate with general public, by displaying building performance (36);
- To check for faults affecting consumption permanently (35);
- To prepare dossiers for performance contracting in municipal property (23);
- To ensure that consumption is within the utility contract and avoid penalties (20);
- Not effectively used (11).

Additionally, respondent's comments suggested that data is used to calculate water and energy costs, and several references to calculation of indicators were made: carbon emissions, environmental management, DISPLAY® Campaign (Shilken 2005) and Normalised Performance Indicators (NPI) usually expressed in kWh/m^2 per year. Building certification under the European Directive on energy performance in buildings was also referenced.

The most important application of water and energy use data is to monitor consumption, identify high levels of consumption, identify wastage and measure and verify water and energy savings measures. In addition water and energy data is also used to communicate and to promote behaviour change of building occupants. Benchmarking with similar building types is also an important application. The verification of billing information is another important use of water and energy data.

Finally, about 14% (11 out of 76 municipalities) of the local authorities that participated in this survey responded that the water and energy data collected is "Not effectively used". Understanding the reasons why some local do not effectively use building water and energy data in their management is out of the scope of this survey. However, based on discussion with some municipalities, it is likely to be that there are insufficient staff resources to analyse collected water and energy data.

Characterisation of current energy analysis practices

The survey also included open question, aimed at getting more information on the analysis techniques used by energy managers. No new or different techniques from those commonly used were cited. The respondents stated several techniques, the most cited are listed below, the number of citations is in brackets:

- Simple year on year, trend analysis and historical comparisons (5);
- Invoice validation and billing simulation (3);

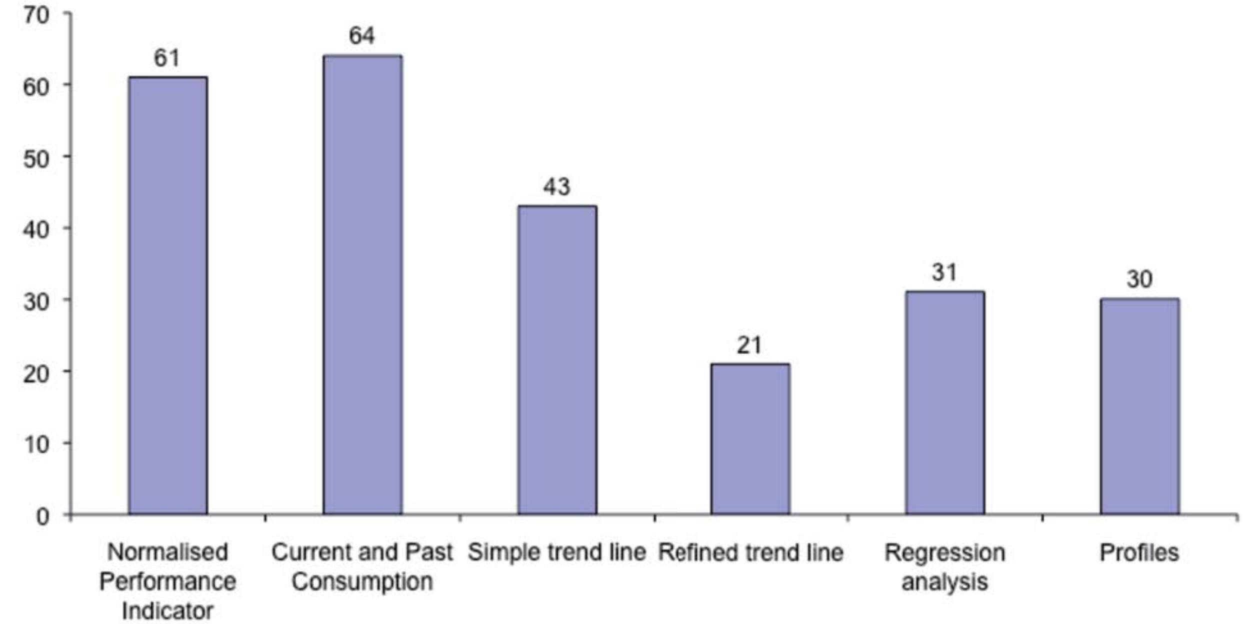

Figure 7. Energy analysis techniques used to analyse water and energy data

- Monthly league tables, compare monthly consumptions year on year - current and past (4);
- Analysis using Excel charts (9);
- Graphs showing energy profiles against time (6) - example: Half hourly data for analysis of use profiles for the larger electricity supplies;
- Baseload Analysis (1) - out of hours usage/wastage;
- Regression Analysis with degree days and CUSUM (event detection technique used in energy monitoring and targeting) (5);
- Target based on the pattern/shape of usage - weather dependent, signatures, simple bar charts against historic targets (3);
- Exception reports - examples: variances between the actual usage and the target and would also include calendars and an alarm band width (4);
- Normalised performance indicators (NPI) and performance indicators (PI) – a wide range of indicators was cited, from EMAS performance indicators related to energy and water consumption, to CO_2 emissions from energy calculated using UK's Department for Environment, Food and Rural Affairs (DEFRA) standard methodology, and the conventional consumption per unit floor area (or cost) consumption against local benchmark, MWh/m³ in month/year (6);
- Benchmarking – once again a wide range of indicators used for benchmarking were cited: internal benchmarks for group of owned buildings, comparison with UK' Department for Education and Skills (DfES) benchmarks for schools, comparisons with similar building types, league table with highest consumers in order, statutory benchmarking, Heat Energy Rating Software, Performance Indicators, Year-on-year comparison using old BVPi 180 indicator for UK's local authority buildings (8);
- DISPLAY® Campaign tool - poster year on year comparison, before and after energy efficiency measures (9);
- Analysis capacities and reports generated by commercially available software packages - such as STARK, TEAM, Energy Controlling System, Erbis, Systems Link Energy Manager, Declic, Energy Monitoring & Controlling Solution, Signum and Enercompta (7).

The survey showed that energy managers use benchmarks (published and internal to the local authority), based on NPI (in kWh/m_2 per year), mostly on an annual basis. Simple visualisation techniques, comparisons between past and current consumption, mostly on a monthly basis, are also used. There are a few references to the use of degree-days, regression and fewer references to CUSUM, a statistical technique used in quality control, also applied in building energy management (Harris 1992). There is only one reference made to the use of half hourly electricity data in the analysis, and this concerned the use of profiles.

There is specific reference to some proprietary software packages used in water and energy monitoring. Microsoft Excel is also used in several local authorities, referred in 9 cases. The DISPLAY® tool was also referred to by 9 respondents.

In the survey, the respondents were asked to select from a list of commonly used energy analysis techniques. The results are presented in Figure 7.

The Current and Past Consumption and Normalised Performance Indicator are the most used techniques, followed by the Simple trend line (energy against time). The comparison of current consumption with past consumption is one of the simplest methods of analysing data. However, it does not take into account weather variations, and other variable that changed during the period. Normalised Performance Indicators (NPI), normally expressed in annual energy consumption per building floor area are usually corrected for weather variations. NPI is one of the most common ways of benchmarking building energy performance. More sophisticated techniques such as regression analysis of energy against outside temperature, time series profiles, and refined trend lines are used in less that half of the respondent local authorities. All these techniques have been reviewed in several energy analysis publications, including (Ferreira, 2002) and (Ferreira et. al., 2003).

Most local authorities use a standard rating system or benchmark to assess their building's performance. Of the 19 European countries represented in the survey 11 have a national standard rating or published benchmarking system that can be applied to assess performance in municipal buildings, these countries are: Germany, United Kingdom, Netherlands, Czech Republic, France, Austria, Bulgaria, Sweden, Switzerland, Finland and Estonia.

The analysis of data using software packages

The survey showed that 54%, (41 out of 76) local authorities, use a software tool for analysing the collected building water and energy consumption. This percentage is higher in the UK, (81%) compared with the rest of Europe (46%).

The most important input variables for analysis software are electricity, water and gas use data followed by oil, outside temperature and heat consumption. Local authority software tools are also used to analyse coal, biomass, solar thermal and inside temperature. Other input variables indicated by respondents were degree-days, solar photovoltaic and building area.

From the combined analysis of replies to question 10 and question 11 it is possible to conclude that electricity is the most common input variable (98% of local authorities that have software systems) with gas and water both at 88% of local authorities. Therefore most local authorities that invest resources in the development or acquisition of analysis software tools aim to analyse building electricity, gas and water consumption.

The most used municipal building energy management tools are from in-house development, including MS Excel spreadsheets and software packages such as TEAM, System Link Energy Manager, STARK and the DISPLAY® tool. Most of these software packages were developed and are sold exclusively in the UK. The DISPLAY® tool is available for European local authorities.

European energy managers needs

The final open question was aimed at acquiring information about the needs and expectations of energy managers in terms of hardware and software to manage water and energy consumption in municipal building in Europe.

Concerning metering systems the main requirements requested by energy managers were the following:

- Automatic metering, constant monitoring and real time data;
- Accurate data (not estimated);
- Data management and secure databases;
- System with flexible data import facilities: manual, invoice, electronic data from utilities and automatic metering.

Concerning the water and energy data analysis, including analysis techniques, energy managers stated that they need the following techniques and features:

- Normalised Performance Indicators;
- Building classification according to the European Building Directive;
- Benchmarking for costs, energy, water and carbon emissions (local and standard);
- Historical comparisons, current and past consumption;
- Weather adjustment and building energy signature (energy against outside temperature or degree days);
- Constant and weather dependant targets;
- Tariff analysis;
- Billing verification;
- Visualisation of data;
- Electrical parameter reports (low power factor, maximum demand, capacity etc.);
- Exceptions reports, targeting, alarm, warnings, tolerance alarm / error report;
- Budget forecasting.

There were some additional features for monitoring systems that were indicated:

- More automated analysis;
- Easy to use software with user-friendly interface.

The main reporting features suggested by energy managers were the following:

- Suitable report templates and custom reporting;
- Report in units that people understand (money, amount of light bulbs, etc.).

In summary, energy managers requested a more automated, accurate, robust, flexible metering of water and energy consumption data to be used in non-domestic municipal buildings. There is a need for a clear methodology for the overall assessment of building performance, identification of savings/ wastages, and benchmarking (internal to the local authority and using approved standards). It was frequently suggested that metering and monitoring could help the implementation of EU Directive on energy performance in buildings.

Conclusions

This was the first comprehensive survey of municipal energy mangers, focused on the collection and analysis of data. It provided information about data collected, the tools, the analysis techniques used, the difficulties and the real needs of municipal energy managers.

It was found that data is being collected typically in monthly periods from paper bills and manual meter readings. However data is being inserted in to digital format and stored in computer databases and about 54% of the respondents use some kind of software tool to analyse data. It is probably more cost-effective to automatically collect data (using electronic bills or automatic metering reading).

Short time series data, in hourly or sub-hourly periods is not yet very frequently used, only about 15% of the municipalities in the study are using this technology. However, the trend is for an increase in the availability of sub-hourly data, and energy managers are calling for near to 'real time' data.

From the survey results, one can say that the most important applications of monitoring systems are the identification of high levels of consumption and wastage and measurement, the verification of savings measures, verification of utility billing data and benchmarking with similar building types. Water and energy data is also used to promote behaviour change of building occupants.

Techniques used by energy managers (including the ones featured in commercial software packages) are not sophisticated enough for dealing with large volumes of data. Energy managers use annual benchmarks (PI and NPI), and simple visualisation techniques, including past and present analysis on a monthly basis. There are a few references to the use of more advanced techniques and weather correction;

Energy managers need an easy to use, straightforward, and as much as possible automatic software tool to analyse building energy data. This is even more relevant when it is expected and increasing penetration of automated metering systems and sub-hourly data in the EU.

In conclusion, there has been very little research on the improvement of energy analysis techniques and software tools in response to energy managers needs. Further research is needed on automating metered data analysis, support for data analysis interpretation and to improve building performance assessment, as part of a certification scheme and energy-auditing programme. New benchmarks using sub-hourly energy and water data can be useful in automating analysis and identifying potential energy saving opportunities. This would contribute to reduce the energy related greenhouse gas emissions in non-domestic buildings across and help the EU move towards meeting its international climate change targets.

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