Smart energy management for non-domestic buildings: Case studies of two local authorities in the UK

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Abstract

The use of smart meters has increased since the beginning of the 21st century. The UK government, for example, has recently initiated a programme of rolling out 53 million smart electricity and gas meters for homes and small businesses by 2020 with the expectation that €20 billion will be saved on energy bills over the coming 15 years.

The UK's mass deployment of smart meters has resulted in Local Authorities experiencing additional costs from their installation in their non-domestic buildings, including the costs of new data collection and reporting systems. As a consequence, energy managers are increasingly being forced to consider the ideal frequency for collecting and reporting energy data, appropriate methods for processing that data and the need to rely on 'real-time' energy data when there are several other ways in which energy data can be accessed (bills, direct readings, etc.). Finally, what are the realistic expectations about the financial savings attributable to the installation of smart meters?

This paper seeks to address these questions through two case studies which examine the effects of the smart meter roll-out programme on two separate UK Local Authorities, Northamptonshire County Council and Leicester City Council.

Introduction

Policy makers face an up-hill challenge to reduce energy consumption as part of their effort to meet challenging carbon reduction targets. The Climate Change Act commits the UK to decrease its carbon emissions by at least 80 % in 2050 from the levels of 1990. The energy consumption of buildings is estimated at 30–40 % of world consumption, and-in the EU- the emissions of buildings accounts for 36 % of the total emissions; in consequence, reducing their energy consumption will play an important role in meeting the carbon reduction targets (Ferreira & Fleming, 2014). Smart meters are at the forefront of the UK Government's energy strategy to facilitate a step change in how consumers engage with energy.

Metering the energy consumption in end users' properties, including non-domestic customers who are the focus of this paper, witnessed a step change by moving from traditional meters to automatic meter reading devices in the late 1970s (ETHW, 2015) and then to smart meters over the last decade. For a traditional meter, a site visit is necessary to collect the readings to calculate energy consumption whereas advanced and smart meters supply these data to both the energy supplier and to the building user automatically. The only difference is that a smart meter enables a two-way communication unlike the advanced meter which is a one-way communication device. A smart meter can receive different types of information from the energy supplier such as instantaneous energy prices and communications to the building users for example to turn off appliances when it is expensive to use them at a specific time of the day. Both smart meters and advanced meters can provide data to a visual display or to an application that can make meter readings visible to the buildings managers or users. This advance in energy metering has been informed by different drivers, the most important of which were to be able to balance the load on the electricity transmission grids, especially after the introduction of electricity generation from renewable sources, and to manage peak loads through Demand Side Management (DSM). This is considered to be a cheaper solution than capital investment to increase generation capacity and handle the high electricity demand at specific times of the day.

DSM is defined as the combination of programs which "consist of the planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage" (EIA, 2002, p. 2). It relies on the deployment of smart meters for different reasons (BEIS, 2016); firstly, smart meters enable a two-way communication between the network operators and its customers. The goal behind this kind of communication is to balance production and the consumption by encouraging users to either decrease or increase their use of electricity in response to incentives such as lower tariffs. This is expected to lead to more efficient electricity markets (Pepermans, 2014, p. 280). Second, it is expected to provide the network managers with a real-time view of the status of the grid to prevent any problems and to optimise primary energy production and energy delivery. While the majority of analysis has focused on residential properties this paper will explore what benefits and challenges the UK's smart meter roll-out programme and smart metering in general might bring to non-domestic consumers.

METHODOLOGY AND STRUCTURE OF THE PAPER

The aim of this paper is to investigate the roll-out of smart meters in non-domestic buildings through a comparative study. Two case studies have been undertaken in UK Local Authorities (LAs). Both case studies are action based, and therefore subject to standard questions over objectivity which were in part addressed by discussions and reflections of other participants. However, the data collected for this paper was to clarify the stories of the roll-out of smart meters, to locate the energy data and related processes within those stories and to compare the two to identify key lessons. It is important to recognise that while this paper has compared two on-going cases with a similar focus, the impact of smart meters on the energy management of local authority buildings, this was not the intention of either study and as such the methodologies employed and activities undertaken by the two action researcher/practitioners are significantly different. The thematic analysis of each case from multiple sources; the analysis of documents (e.g. contracts), from energy data (e.g. derived from the initial analysis of the smart meter roll-out in LCC) and from on-going communication with key personnel in both Local Authorities (LAs) (e.g. energy managers) has supported the generation of more abstract concepts that lend themselves to comparison and are reflected in the following text.

The lead author has been employed for two years in the Energy and Carbon Management Team at Northamptonshire County Council (NCC). His job is focused on the negotiation of the energy contracts and implementation of energy efficiency measures in buildings and assets owned by the County Council; this requires access to the metering contracts and to the smart metering programme. For the purpose of this paper and in addition to the materials he has from his daily activities the author had meetings with three energy managers in NCC to elicit the process for collecting energy data for NCC buildings, the motivation behind it, the types of data collected and how it is used.

The second researcher has worked in various capacities with Leicester City Council's (LCC) energy data systems (i.e. collecting the energy data and analysing it) over ten years. He has also worked on the adoption and use of advanced metering in Local Authority buildings on a number of European Projects for which LCC was a major partner. For this paper the researcher had a further meeting with two energy managers from the authority to establish which types of data exist, the chronology of LCC's energy activity and to check that the narrative of this paper is accurate. The researcher also used data from earlier work (Bull 2015; Stuart, 2011; Ferreira, 2007, 2014) to build the LCC case study.

The paper will initially present the UK Government's smart meter roll-out programme; it will then review the technical literature related to advanced and smart metering, followed by an evaluation of the implications for local authorities. In the second part of the paper the authors will explain the approaches followed by the two local authorities, summarise the key findings and lessons from the comparative study and make some recommendations about the adoption of smart meters in non-domestic buildings.

The United Kingdom's Smart Meter roll-out Programme

Many countries have set targets to increase the use of smart meters for electricity and gas in residential and commercial properties. For example, in Italy and Sweden, the use of smart meters is the norm, while Spain has introduced a programme to change all meters into smart ones by 2018; France is also in the process of finalising a smart meter deployment programme (Kavanagh, 2014). These countries had different reasons for the introduction of smart meters; "Italy introduced them to reduce fraud, Sweden for accurate billing and California to manage demand from air conditioners" (Richens, 2011, p. 35) and countries belonging to the European Union have been encouraged by different pieces of legislation. For example, Directives 2006/32/EC and 2012/27/EU recommend the use of advanced/improved/electronic/smart metering -meters which automatically supply meter reads to the energy provider- to induce energy efficiency in buildings. Directive 2009/72/EC states that by 2020, and where the roll-out of smart meter is assessed positively, at least 80 % of consumers should have intelligent metering systems.

In the United Kingdom by 2020, "more than 50 million new 'smart meters' are being rolled out to 30 million homes and smaller non-domestic sites in Britain. These smart meters, which will include an offer of a free in-home-display for households and are for the electricity and gas supply, are intended to allow consumers to see, and adjust, in real time what energy they are using" (Richards, Fell, & White, 2014, p. 1). One benefit of this programme, according to market regulator Ofgem, is that it will deliver €8 bn in savings over the twenty years from 2011 to the users of these smart meters, energy and network companies (Richards, Fell, & White, 2014, p. 1).

COST, BENEFITS AND ECONOMIC IMPACT OF ROLL-OUT THE SMART METER PROGRAMME IN THE UK

According to the Impact Assessment (2013) study prepared by the Department of Energy & Climate Change (DECC) about the "Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB)", the programme's value is €13,5 bn. These costs will be covered by energy suppliers, network providers and the Data Communication Company (DCC); this is the company which establishes and manages the systems linking the smart meters to the network providers and the energy suppliers.

The net present value (NPV) of the benefits of this programme up to 2030 is estimated at €18,5 bn and will be achieved through (DECC, 2013):

- Customers' consumption savings by providing real time data; users of the smart meters can control their consumption via the efficient use of energy.
- Peak load shifting with savings achieved through better decisions on generation capacity investments.
- Savings in operational costs for the energy providers through more accurate billing and the avoidance of energy theft or site visits to record the energy consumption.
- Better management of the energy debts of the consumers.
- Network savings through the avoidance of network failures, electricity outage and better management of the network.

A report published by the Department for Business, Energy & Industrial Strategy (BEIS) in August 2016 updated these values with the NPV of the projects being €6,75 bn, the cost €12,8 bn, and a benefit of €19,6 bn.

The deployment of smart meters seems promising particularly for energy providers and the network managers who can make savings by optimising the way they collect meter readings and manage their production of energy. It is true that these operators will also incur some costs although, as will be explained in the following case studies, these are often transferred to the customers during the deployment phase. The DECC Impact Assessment (2013) also argues that energy suppliers are responsible for purchasing the smart meters and the In-Home Displays, installing them in their customers' premises, operating and maintaining them. The Data Communications Company (DCC) will provide communication hubs, whereas the energy providers will maintain them once installed in their customers' premises. Finally, the network providers are responsible for upgrading the network or the electricity grid to support the transfer of the information between the smart meters, DCC and the energy providers for all types of consumers. Figure 1 summarises the meter roll-out to end users and the roles of the main stakeholders of the programme.

How can smart meters be used?

TARGETING AND MONITORING

Advanced and smart meters can play a significant role in promoting energy efficiency in buildings through targeting and monitoring energy use and can produce detailed data sets to profile the energy consumption of a selected building. This short term time series can be half or quarter hourly and can enable businesses to identify potential energy costs and carbon savings by providing detailed information about the way in which they use their energy (Carbon Trust, 2007). Nonethe-

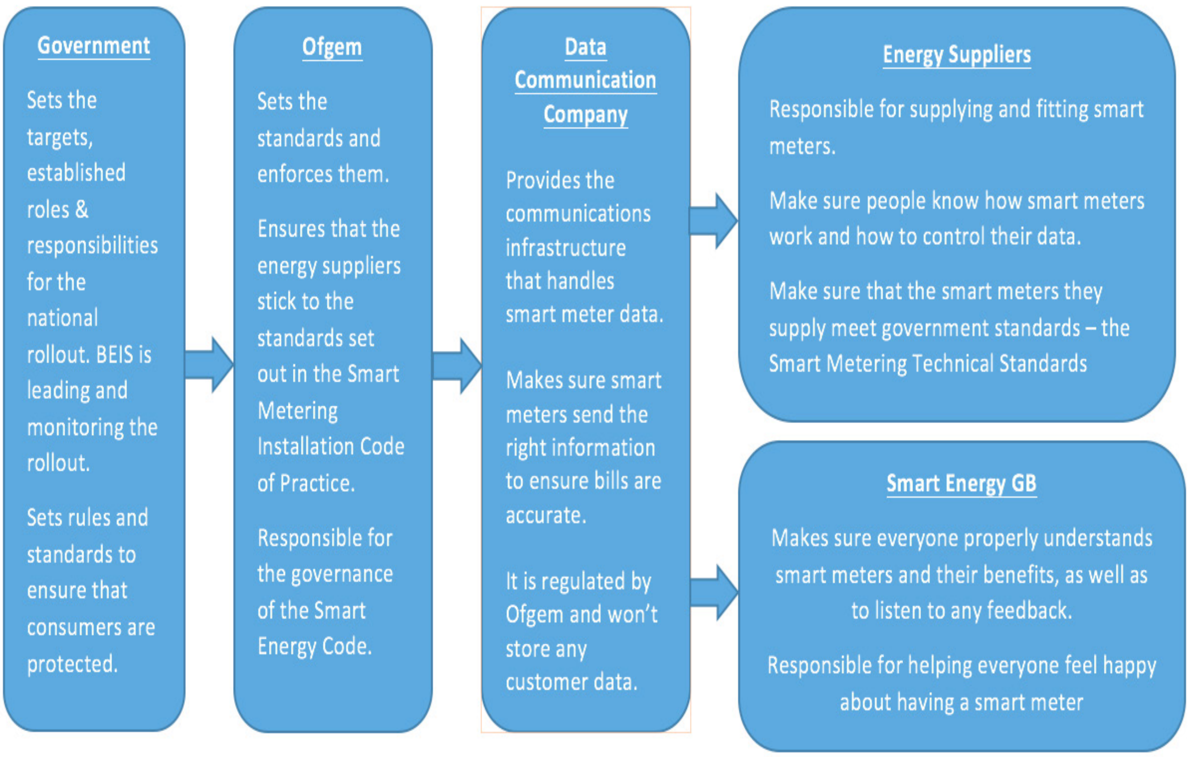

Figure 1. UK Smart Meter Roll-out Programme (Smart Energy GB, n.d.).

less, how can the availability of these data-sets help in actually achieving energy savings?

A two year trial carried by the Carbon Trust between 2004 and 2006 where 582 advanced meters were installed in small business premises to demonstrate the potential of this technology yielded results showing that an average of €1,100 per site has been saved through reduced consumption. Advanced metering also helped in identifying 12 % of carbon savings of which 5 % has been implemented. Finally, the trial showed that smart metering has a better payback period for multi-site projects when compared with a single site.

Data collected from smart meters can be used to create energy profiles and identify opportunities for energy savings and better energy management. The first step towards decreasing the energy consumption of any building/process is to understand how it uses that energy. The savings can be achieved in three ways (Carbon Trust, 2007); firstly, by studying the base load and removing any unnecessary constant use of energy; second, by analysing the energy profile and defining the technologies/processes which are energy intensive and trying to optimise their running cycles and thirdly, by determining the causes of peak load through the analysis of frequencies, timings, activities and technologies used on site. Advanced metering can also help to benchmark the energy profile of a specific building/process so that it can be compared with similar building profiles and potential similar savings interventions (Fernández et al., 2016).

ANALYSING DATA COLLECTED FROM SMART METERS

Significant amounts of data can be collected through smart meters and the analysis of this can be time consuming if appropriate tools or methods are not used. The two case studies in this paper suggest different ways of analysing the data however the tools to support this should help energy managers to rapidly detect uncommon energy consumption patterns. Ferreira and Fleming (2014) state that techniques to analyse half hourly time series for energy data are still in their infancy unlike those for monthly or annual periods which are well established. They suggest an automated primary approach for analysing half hourly meter reads and assessing energy saving opportunities. This technique entails using the half hourly meter reads to profile the energy consumption of a building and then grouping them based on the load demand shape indicators, created by the researchers, and the activities performed in these buildings in order to create profile indicators. This will help in calculating a twelve-month average electricity load demand profile and enable the benchmarking of energy consumption against a typical profile for buildings with similar activity.

CONSUMPTION AWARENESS

One of the benefits of smart meters is the ability to link the meter with a visual display or other feedback devices that can present the consumption to building users or managers. Over recent years there has been much research into these new 'feedback' mechanisms that provide the building user with information or 'feedback' on the consumption within a particular building type (Westskog et al., 2015; Anderson & White, 2009). Smart meters enable more dynamic, regular, and in many cases real-time, feedback. Through the installation of either simple wireless transmitters on the electrical cable coming in the building, or through more sophisticated 'smart' meters, live usage data can be sent to a display unit in a range of formats. The feedback of energy consumption through software or a display (i.e. the visualisation of the consumption) can result in energy savings ranging between 5 and 15 % and there is a greater tendency to respond to this feedback among high, rather than low energy users (Darby, 2006).

Recent research has explored the use of visualisation tools in the non-domestic or workplace setting; Bull et al (2015) reviewed the use of energy dashboard tools in the public sector and argued the need to move 'beyond feedback' towards user engagement. This is not to say that savings cannot be made through visualisation tools, or that they cannot be useful tools for more effective management of energy within organisations. For example, a recent review of the literature and evaluation of an energy savings intervention in a commercial office space by Mulville et al. (2014) achieved savings of 18 % over the intervention period. However, in a comprehensive review of over twenty energy and behaviour change interventions in the workplace Staddon et al. (2016) note, in common with Bull et.al. (2015), that the most successful initiatives involved a combination of technological automation and 'enablement'. This suggested opportunities for building users to move beyond education and training towards users' engagement in saving energy.

Implications of smart metering for local authorities

As has been mentioned earlier, the installation of smart meters and home displays is free of charge for homes and smaller non-domestic sites, meaning that medium to large commercial sites will be paying for the cost of installation. Although this consumer subset already pays, through their energy bills, for the cost of their meters and their maintenance, this arrangement is due to remain after the installation of smart meters (DECC, n.d.). In the UK, electricity is billed via a load profile, or profile class billing scheme, except for half hourly (HH) sites where the billing depends on the actual consumption/meter readings. Prior to October 2016, eight non-mandatory HH profile classes existed in addition to one mandatory HH profile class (00) with a base load above 100 kW. These profile classes have been designed in such a way that they group large populations of different consumers (Elexon, 2013). During the last years, more profiles have been added to the HH settlement. This shift means that businesses will incur the cost of the contract which includes the price of the smart meter, its maintenance and the necessary telecommunication service to send the collected data as part of the Meter Operator Agreement (MOP). Moreover, there is an additional Settlement Cost which is part of the energy bill and includes the cost for retrieving the data, validating it and data collection and aggregation (DA/DC) costs.

Comparative case studies

In the following section, the deployment and use of smart meters will be compared in two UK local authorities.

NORTHAMPTONSHIRE COUNTY COUNCIL

Northamptonshire is one of the counties in the East Midlands region of England and Northamptonshire County Council (NCC) has a portfolio of around 100 buildings. This portfolio has been significantly reduced recently due to cost optimisation. The Council also helps at least 350 schools in the County in their energy management duties i.e. energy purchasing and billing, advanced and smart metering, energy efficiency schemes, etc.

History of smart meters' adoption in NCC

The first smart meters were introduced for electricity metering by the Council in the five heaviest electricity consuming buildings in May 2007. In 2011, under the Smart Energy Metering Roll-out Programme launched by central government, the electricity supplier of the County Council made an offer to install smart meters in 529 of their properties and schools. The Council was motivated to accept this offer due to their positive experiences with previously installed smart meters. One of the perceived benefits was the ease of access to the electricity data of the buildings. In the past, such information was received on cards with the meter readings of every property and one staff member had to upload this onto the system with associated problems of human error.

Prior to May 2015, 54 meters had been withdrawn from the programme for two main reasons: the site no longer existed either because it was sold or demolished, or the site was in a location with a poor signal and data transmission problems. These buildings could return to the programme once a landline option becomes available. In 2013, the Council independently also decided to install smart meters for gas in their 27 main consumption sites; the reasons behind this decision were to:

- Avoid site visits to read the meters, and
- Improve the consumption data quality and consistency needed for management and invoice checking purposes.

Additionally, the Council will work with the gas supplier to roll-out smart meters in their portfolio of buildings and maintained schools in 2017. However, the main reason behind focusing on first installing electricity smart meters rather than gas is that it was more difficult to detect problems. For example, if there is over consumption of gas, the buildings will overheat and will be felt by the user, or if there was a gas leak it will be easily noticed unlike for electricity.

Cost of the smart meters

NCC originally had five buildings under mandatory half hourly supply but with the introduction of P272, this number increased to 16 buildings. For this category, there are two costs: the first one is the cost of the settlement contract which is around €230/meter/year (between €165 and €350, depending on the type of the supply and the communication lines). The second cost is for having access to the half hourly meter readings, priced at €330/meter/year.

Under the non-mandatory half hourly supply, the Council manages a stock of 122 buildings of which most have Advanced Meter Reading (AMR) devices. Prior to October 2016, this cost €105/meter/year, but under the new contract the price dropped to €50/meter/year. The Council pays also this cost for 220 school's meters. This tariff is cheaper than the compulsory half hourly supply for two main reasons; compulsory data needs to be verified by the supplier to ensure there are no missing readings. Secondly, the supplier already has access to the meters reads, since they are constantly sent by the AMRs, and is offering it to the customers at a lower price to motivate them to purchase the HH data. However, the conditions under the two agreements are different since the first one has to comply with a set of regulations related to HH settlement.

NCC has access to cheaper electricity through a public buying group which purchases energy in bulk and sells it to public organisations at a preferential tariff. This means that NCC could make an offer to schools to buy their energy, and under the same deal, it offers them access to half hourly meter readings to help them manage their energy budgets and buildings' consumption.

Overall the cost of smart metering for both categories for the financial year 2016/17 is around €25,000 excluding the salaries of the staff for managing the programme and analysing the data. It is important to note that even if it was the duty of the energy supplier to manage the smart meter installation programme, NCC were required to recruit a full-time employee to supervise, coordinate and drive forward the project; and without the efforts of this employee, the project would not have proceeded. Also, it is necessary to note that the roll-out programme cost at least €20,000 to NCC even though the energy supplier's offer included free installation. This additional cost was generated by the problems faced while installing the meters. For example, the old cables were too large to fit with the new meters and needed to be changed. Also, some buildings had a supply at 400 amps and the meters needed additional protection. For some buildings, especially schools, managers refused to pay these costs because they were considered too high and the benefits of the smart meters were not valued.

For the gas supply, and under the contract signed in 2013, the price paid for having access to half hourly meter reads was €110/meter/year.

Use of smart meters and energy savings

The smart meters are used by NCC for two main reasons: firstly due to the size of the team dealing with the energy management of the authority's property portfolio, targeting and monitoring using smart meters is undertaken monthly and sometimes in a reactive manner as explained below. At the end of every month, the data collected through the smart meters is used to verify the energy bills and see if they are correct. In addition, each month the consumption is monitored to see if it exceeded predictions. If it does, then the team uses the half hourly profile data to detect any anomalies in the consumption. As an example, in December 2016, the team was notified that the thermostat of one of the boilers of a major building had broken and was 'over'-working. By using the gas smart meter and its generated profile data, the team was able to monitor the consumption during the day to ensure that the targeted gas consumption is met and a comfortable working environment is guaranteed by manually turning the boilers on and off while waiting for the thermostat to be fixed or replaced. The estimated savings from the use of the smart meter during this event was about €1,000. The team now has a target to use the profile data to monitor the larger buildings at least weekly and the technology has significantly decreased the manpower and the number of site visits needed to take meter readings. Although, it is the responsibility of the supplier to take regular, but not monthly, meter readings, the team also performed this exercise to decrease the number of estimated bills and to ensure that the supplier had monthly readings for billing purposes.

The second role for smart meters is when there is a need to upgrade lighting or boilers or to install energy saving schemes in buildings. The profile data plays an important role in understanding how the building is used during the day (i.e. working hours, base load, etc.) to quantify the prospective savings and thus the payback period for each solution. As an example, there has been a high reliance on profile data to analyse the PV potential for different buildings. Unfortunately, at this stage, it is very difficult to quantify the savings achieved through smart meters, but their users anecdotally affirm that they have helped greatly in managing energy use in buildings and detecting anomalies in energy consumption. A more systematic engagement with users will be necessary to understand this more fully.

LEICESTER CITY COUNCIL

Leicester is a city and unitary authority in the East Midlands region of England. It is the 17th largest district of England by population, with a population of just under 350,000. Leicester City Council (LCC) manages around 300 buildings, nearly all of which have had half-hourly metered electricity and gas/heat and water consumption data available for over a decade via a proprietary automated meter reading system. LCC believes this system has paid for itself many times over.

Prior to deregulation of the UK energy market the energy management team at LCC were successfully running a system tracking monthly billing data based on manual meter readings. Consumption data from bills were entered into a proprietary software system and used to track consumption patterns. Simple degree day analysis and data visualisation helped to identify issues which needed further investigation and to verify and quantify savings due to interventions.

Manually collected, monthly meter readings are fairly sensitive to quality issues such as recording the timing of a manual reading accurately and recording the meter reading correctly. Human error is a significant factor and monthly data often need a manual process of cleaning before they can be used for analysis. In LCC's experience the data were regularly provided by energy suppliers and were of relatively good quality. However, with the deregulation of the industry, data quality became an issue. In addition to the standard data quality issues estimated readings where suppliers were not able to take regular readings became an increasing problem.

Smart meters adoption in LCC

Leicester City Council were early adopters of an early version of 'smart metering' with their first experimental systems being installed in 2002. The earliest systems included sub-metering installed in council owned buildings in order to recharge tenants for their energy and water usage. Pilot systems were installed covering electricity, gas and water consumption in ten of their larger buildings. The data produced immediately helped to identify wastage in areas that were previously invisible; in particular, electrical equipment (e.g. ICT) running overnight, heating left on manual control overnight, faulty urinal controls and water leaks due to broken pipes. In the early days of the system the energy team would review the data, identify issues and compile reports for buildings. These reports were then communicated to building managers via email and a dialogue was started. In the decade since the pilot, LCC has expanded the system in a phased roll-out across their entire building stock. The system is now installed in between 250 and 270 sites across the city, typically covering the main utilities (electricity, gas/heat and water).

Leicester City Council have been involved in many FP7 (EU) projects over the last 15 years which have helped them to explore the potential of smart systems and get the best value possible out of them. In part this has led to innovation with software providers developing new reports and tools. For example, building managers now have the option to access their data directly via a proprietary web interface to the analysis software. Rather than the energy management team pushing information to the sites when problems are identified, building managers can now access information on demand and run their own analyses. This decentralisation of the analysis not only increases the number of people looking at the data but also puts the right data in front of the right people with the specific on-site knowledge necessary to diagnose problems. Another example is a simple baseline analysis report showing the ratio of consumption between occupied periods (i.e. daytime) and unoccupied periods (i.e. overnight) allowing for a simple league table to be produced. Running this report on a daily basis helps to pinpoint which buildings should be looked at in more detail and optimises the process of identifying faults and issues that need to be addressed. Improving the processes by which the data can be analysed has been extremely successful and enabled LCC to extract the maximum benefit from the available data whilst minimising the time spent analysing data.

Costs and savings of the smart meter programme in LCC

Ferreira et al. (2007) showed that the cost, for LCC, of setting up the consumption monitoring (electricity, gas/heat and water) which comprises hardware, connectivity/communications and labour costs, was approximately €3,750–€4,500 per building (a total cost of €1,155,000 over 280 buildings). The annual cost of running the system (maintaining/replacing hardware, data communications, software) was less than €200 per building (totalling around €53,250 per year at the time) and the estimated value of energy and water savings was €225,000 per year. This gives an annual net saving of around €171,750, enough to pay back the initial investment in less than seven years. Since this time, the annual savings have continued to increase by ensuring that when energy and water wastage occur they are detected quickly and appropriate action is taken. The LCC energy team has a full-time member of staff whose main role is to look at the data and trigger further investigation.

Discussion, outcomes and recommendations

Table 1 summarises the comparison between the two case studies. For a number of reasons the UK smart meter roll-out programme has been designed in a way which does not help commercial customers make direct or automatic financial savings. Firstly the customers may not have been appropriately trained to use the advanced and smart meters and to analyse their energy consumption and detect opportunities for energy savings. Where success has been found in the implementation of smart metering at the Local Authority level, it has not necessarily been as a consequence of the roll-out programme itself. For instance, the financial savings attributed to LCC's metering project have been achieved as a result of investment in energy management software which is connected to the meters and to the real time monitoring of energy consumption and understanding of consumption patterns for specific times of the day and for different types of building. Additionally, the monitoring and savings are achieved thanks to the expertise of energy managers employed by both Councils. The trial carried by the Carbon Trust between 2004 and 2006 further confirms this point; the savings for this were achieved in lage pat because of the expertise of the project team leading the trial (Carbon Trust, 2007).

The important savings achieved by LCC are mainly due to their motivation to monitor their energy usage with the smart meters unlike NCC which still did not explore the full potential of this technology and benefit from minimal savings. It could be argued that NCC failed in achieving big savings mainly because it found itself caught in the UK's smart meter roll-out programme and had to deploy smart meters in its properties. The achieved savings from this technology are to minimise the effects of its cost. In other words, NCC's roll-out programme was reactive since it came as a response to the legislation requirements. On the other hand, LCC's programme was proactive since it was implemented to save energy.

Secondly, as evidenced by NCC's metering programme, the roll-out did not take into account the costs borne by commercial customers when installing the meters. Indeed, the cost forecasts presented in the Impact Assessment study are those which affect central government only. Thirdly, and again as in the case of NCC, the programme had to be managed by the client to ensure the successful installation of meters in all the buildings targeted by the contract. Fourth, the programme did not take into consideration advanced and smart metering measures already taken up by organisations. For instance, LCC had already implemented a metering programme before the start of the UK roll-out programme and HH settlement. Hence, for some buildings which fall under mandatory HH profiles, the authority has a double cost: one for the maintenance of the existing system and one for the costs related to mandatory HH settlement. Therefore, clients may save on costs if there is an option to communicate the meter readings produced by existing systems to the energy providers. Fifth, the type of savings published in different government reports of the smart meter roll-out programme are directly linked to one commodity, electricity, although the programme targets both electricity and gas.

In addition, the UK smart meter roll-out programme did not include water metering; an omission that is often questioned by experts. Water consumption is often neglected for a number of reasons by commercial consumers in the UK whose main business activity is not water intensive: water is a cheap commodity; there is a distinct lack of metering data available and, the virtual monopoly of the water supply in England and its regulatory policy is not as advanced as in the case of electricity and gas (Azennoud et al., 2017). As an example, there is no

Table 1. Smart meter roll-out comparison in the two cases.

	NCC	LCC
Motivation	Trial of electricity advanced meters in 5 buildings in 2007 and gas advanced meters in 2013 in 27 buildings Offer from the electricity supplier to roll-out smart meter in the whole NCC portfolio	A pilot system to detect any wastage in electricity, gas and water consumption
Funding	The trial has been funded from a departmental budget that can be seen as a direct cost to NCC. The supplier's roll-out programme was a free offer however the energy team had to pay for any additional costs.	It was funded as part of an invest to save programme
Process of data collection, analysis and use	HH Meter reads are only collected for electricity for majority of buildings and gas for 27 buildings. The data is analysed at the end of each month to verify the accuracy of the energy bills. The data is also used to monitor sites when an energy wastage is identified	HH meter reads are collected for electricity, gas, water and district heating. The data is monitored and analysed daily to detect any energy wastage
Energy monitoring and analysis technology	NCC is getting the HH meter reads from the suppliers. They are automatically uploaded to the Council's energy management system	LCC are getting HH meter reads uploaded directly from their meters to their energy management system. LCC is also getting HH meter reads for their HH mandatory and P272 sites, but these stand as a duplicate for the existing system
Savings	Savings are minimal and are only perceived once an energy wastage is detected which might be weeks after it started.	Savings are important, the daily monitoring of the HH meter reads helped the system pay for itself
Way forward	The energy managers in NCC appreciate that thy have not explored the full potential of the smart meters and are willing to start monitoring the HH data at least weekly. NCC is also going to finish the roll-out of gas smart meters during 2017.	Smart meters are already rolled out through the LCC's properties. However, the energy managers are willing to explore areas for improvement.

obligation to water suppliers to install smart meters for new supplies unlike for gas or electricity. In fact, NCC does not have a single smart water meter installed in their property portfolio whereas LCC has installed them in an attempt to reduce water consumption. In other words, NCC did not roll-out smart water meters because there has been no legislative requirement to do so while LCC's motivation was basically to minimise not only energy wastage but also water wastage through the use of these technologies. The deregulation of the water market in 2017 is however expected to prompt changes in authorities' water policy.

Smart metering can be effective and help in achieving both energy and financial savings if the customer is willing to invest money and time to install all the required systems and analyse the data using real-time monitoring. The success achieved in the LCC's smart meter roll-out had an element of serendipity after the authority decided to invest money and time to save energy and water, but the authority recognised the potential and decided to build on it. Moreover, smart sub-meters need to be used to ensure that a holistic view of the flow of energy within a building is captured. As an example, NCC is responsible for managing several large buildings and is aware of the existence of energy wastage within its buildings; however it is difficult to trace. Conversely, LCC uses many sub-meters and they have proved their usefulness in locating energy wastage in short periods of time. Without sub-meters energy wastage in a big building will be very difficult to locate since all the wiring, pipes, devices and processes need to be checked to locate the source of that waste. Finally as can be seen from the case studies, data collected from advanced and smart meters can be used for different purposes such as: defining the best technologies to be installed in a site and helping to prepare a business case to prove its viability; helping to define the exact energy consumption of buildings for procurement purposes and decreasing the number of estimated bills received. However, their main contribution is when they are used for real time energy targeting and monitoring. The approach will, of course, differ from one case to another depending on the data collected and the number, and type, of buildings to be examined.

A number of recommendations and lessons can be inferred from the preceding case analysis. First, for better energy savings, real time targeting and monitoring should be adopted and the gathered data should be analysed and used to make energy management decisions. The analysed data gives a better insight of the energy consumption. There should also be a willingness to invest time and money on systems and the training of selected staff to achieve energy savings. Non-domestic consumers should acknowledge that they might end up with too much data but with the right analysis techniques developed by energy managers, these data can quickly help in detecting energy, and financial, saving opportunities. Second, it should be clear from the beginning what the purpose of gathering HH meter readings is since smart metering can be used for a range of purposes: monitoring, complying with legislation, etc. Third, using sub-meters will make the monitoring process easier and faster once a problem has been spotted and more in-depth data is needed. Fourthly energy or building managers or premises officers should be trained on how to use the smart meters and how to analyse the collected data. Energy suppliers should also clearly explain to their commercial customers any costs that they will face during the installation process. Finally, it may be helpful if the government explains in detail how the savings will be achieved from each commodity and update their cost guidelines to include those met by the energy suppliers and the customers.

Conclusion

The primary focus of the UK smart meter roll-out programme was to make Demand Side Management (DSM) tasks easier and more effective. Indeed, the ability to implement an effective DSM strategy has been enhanced through access to real time meter readings at a wider scale than ever before and this is helping with an instantaneous view of energy consumption. Furthermore, it is believed that DSM will only become more effective as energy suppliers hone communications with their consumers via the smart meters to transmit information related to the cheapest times to use energy and when they can intervene and control consumption and decrease peak demand. It is also logical for the programme to focus more on domestic users and offer free installation of smart meters since domestic energy consumption constitutes a significant share of national energy consumption. However, the programme must recognise that it can achieve important savings by helping non-domestic customers with the costs and training related to smart meters.

This paper recognises that the roll out of smart meters has to an extent failed in achieving important but not small savings for one local authority, Northamptonshire County Council, when they deployed the meters in response to policy requirements. Another LA, Leicester City Council, which chose to deploy smart meters as part of a solution for effective monitoring of energy consumption, was however able to locate and reduce energy wastage. The government, as the owner of the UK's Smart Meter Programme, must recognise the need to tailor a smart metering programme to relevant energy stakeholders, especially with regards to those non-domestic consumers who are paying for a system that can achieve financial savings but do not know how to realise this potential. As an example, the Government can ask the smart meters suppliers to train their customers on how to use them to achieve energy savings. Central to this process will be the requirement to undertake more systematic research into how Demand Side Management processes might be integrated into the culture of an organisation. The paper also recognises the limitations of the data but does suggest a number of key lessons that also require more systematic attention. Last, this study has drawn upon the practical engagement of researchers in roll-out; it has not undertaken the more qualitative exploration necessary to understand the behaviour change that might be required from utility and buildings managers and non-domestic building users (Bull et al., 2015). This needs to be undertaken alongside the policy, management and technical changes that have formed the focus for the above discussion.

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