The Potential for Energy Savings in a School with Outsourced FM

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ABSTRACT

Purpose / Theory: Modern school buildings are complex and interactions between users, equipment, and the building change over time, with energy use often creeping up as equipment is added. Within a contractual structure in which the different roles needed to run a school are outsourced to several agencies, responsibility and accountability for energy use are sometimes mismatched. There is one energy bill but many legal entities and many different groups of people causing it. This paper draws lessons from a case study in a relatively new school in the UK. It examines the effects of the contractual structure, and equipment and building use, on the efforts of the parties involved to bring down high electricity use.
Design/methodology/approach: The case study was run over several months and involved several meetings with representatives from the FM, contractual management, and Information Technology (IT) companies, along with the school manager. Meter data was analysed and group and individual interviews were conducted. Systems thinking was used to better understand the dynamics at play between the building, agencies, and energy consumption.
Findings: The paper illustrates the need for flexibility in FM contracting, the perception of fairness in paying for energy bills (matching accountability with responsibility), and explores the potential for more effective energy saving campaigns in a modern school building.
Originality/value: This paper takes a fresh look at energy management within a school where FM and other services are outsourced. It finds that even when people want to do the right thing their actions and decision making are restricted by contractual arrangements, the availability of information, and operational needs.

Keywords

Facilities Management, Outsourcing, Energy Management, Systems Thinking.

1 INTRODUCTION

There is a need to reduce energy consumption in non-residential buildings to both tackle climate change and make organisations more cost-efficient. The £55bln UK government programme Building Schools for the Future rebuilt over 180 secondary schools between 2005 and 2011[1], and it might be expected that so many new and more efficient buildings would have improved that

[1] FM World Magazine, 6/7/2010

sector's energy performance, yet a review by (Godoy-shimizu et al. 2011) of Display Energy Certificates[2] revealed that average carbon emissions in secondary schools rose by 8% between 1995 and 2007. There are many possible reasons for this: modern schools host a wide diversity of uses, contain more electronic equipment, more mechanical ventilation and more cooling, and they are being used more during out of school hours for community purposes (Carbon Trust 2010). As (Prodromou et al. 2009) found, classrooms are environmentally complex, with high transient heat loads as students come and go, lighting requirements that change with the teaching methods used, and generally full or near-full occupancy levels. Part of the problem lies in everyday energy and building management practices: Building Management Systems (BMSs) may be programmed incorrectly, equipment and lights may be left on when not needed, and unplanned-for amounts of plug-load equipment may be brought into the building.

Post-occupancy evaluations have shown that actual energy consumption in buildings can be much higher than planned for at design stage. For example, CarbonBuzz, an online database of performance data for buildings in the UK, shows average actual performance for UK schools of 56.9 kg $CO_{2e}/m^2/yr$[3] versus an average of 29.4 kg $CO_{2e}/m^2/yr$ for design performance[4]. Similarly, (Prodromou et al. 2009) state that post-occupancy building performance for new schools can be up to 45% higher than predicted at design stage. (Demanuele et al. 2010) found that the most successful management of new school buildings occurs when occupants are well-informed and/or there are experienced facilities managers available to deal with operational issues, plus data management to track energy targets.

The management of a school building by Facilities Management (FM) inevitably includes responsibility for the management of energy consumption. This role has been traditionally assigned to FM staff because of their role in maintaining the building services that consume energy - in other words, Energy Management (EM) has been seen as a part of providing building services along with making them reliable and safe. However, due to the amount and variety of energy-using equipment in modern schools it's no longer true that a staff focused on providing those services can control the majority of carbon emissions from a building. This paper relates this story of ever-increasing technologisation in schools and the resulting difficulty in doing EM, through a case study done at a school in the UK. It uses concepts from the field of systems thinking to better understand the case study and identify ways of achieving higher levels of energy savings.

2 BACKGROUND

FM and Energy Management in Buildings

In general, there is a research gap concerning energy management in non-residential sectors. (Payne 2006) found that *'the energy policy field has not done a thorough job of describing energy consumption in the commercial sector';* there is a lack of empirical evidence, with discussion of consumption in the commercial sector *'driven primarily by theory, with very little*

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[2] Display Energy Certificates provide an A-G rating for non-residential buildings based on actual energy use. DECs are required for buildings occupied by the public sector over 1000m^2.

[3] The terms "GHG emissions", "carbon", "CO_2" and "CO_2e" are commonly used interchangeably in industry to mean carbon dioxide gas or equivalent amounts of other greenhouse gases emitted either directly from the fuel combustion process or indirectly via electricity from the grid.

[4] Carbon Buzz (www.carbonbuzz.org) is an online database of building energy consumption data, created to highlight the performance gap between design figures and actual readings.

field data collected on the way commercial sector decision-makers describe their own options, choices, and reasons for taking action.'(ibid.) A review of research on energy efficiency barriers in non-residential sectors by the UK government's Department for Energy and Climate Change found that *'research was particularly clustered in the industrial and commercial office sectors, leaving most of the other sectors under-researched by comparison. In particular, there was very little specific research on the following sectors: retail, schools, government estate, sports, public offices, heritage and entertainment, healthcare, transport and communications. This distribution of research is unrelated to the relative carbon emissions of each sector.'* (DECC et al. 2012)

However, several authors have written specifically about FM's role in energy management.

- A review of building evaluation practice by (Leaman et al. 2010) identifies the institutional barriers to good energy management, such as the fact that it is difficult to *'set aside capital budgets to include aftercare, tune-up and feedback'* of equipment and buildings once the building is occupied. When new buildings are built through a Private Finance Initiative (PFI) contracting package – which combines the finance, design, build, and operation of buildings for clients in one contract – it could be expected that link-up of installation with maintenance and performance would be easier, but instead *'inside the package responsibilities can be even more tightly divided up than ever, e.g. with the project being sold on after it has been built; and if feedback is obtained, it tends not to be shared.'* (ibid.)
- (Duffy 2000) discusses the practice of the outsourcing of FM functions in the UK's public sector, which has had the effect of reducing the contact between facilities managers, senior management, and end users, despite one of the original goals of FM being that of becoming *'a strategic discipline with a strong voice in the boardroom'*. FM's *'customary technical and service role'* means they are *'almost entirely reactive: in effect, a part of the supply chain, but embedded, more or less by accident, in client organisations'* (ibid.) Duffy finds that this reactive role disempowers facilities managers, despite them having to manage what are often quite complex building services such as BMSs, commercial kitchens, fire and security systems, and air conditioning and ventilation systems.
- A study by (Aune et al. 2009) in Norway revealed the hidden roles performed by FM staff that go beyond the FM handbook. The authors identified *'four important, yet often neglected daily activities of building operators (which we call teaching, housekeeping, managing and juggling)'*. The paper found that facilities managers need to have broad knowledge and sufficient technical training to support these different roles, and that because FM staff carry out these roles they have *'an underestimated potential of contributing to energy efficient buildings'*; because facilities managers *'are able to "see" both users and energy, they were in a unique position to improve the interplay between technology and use and to contribute to more energy efficiency.'* (ibid.) Whether this potential is helped or hindered by outsourcing is not examined in the paper, but making use of this potential would require acknowledgment by all building users that the FM role goes beyond maintaining building services systems.

To summarise, there is a lack of understanding of reasons for high discrepancies between design and actual building performance, FM staff are crucial in implementation in any efforts to save energy, and changing the role of FM to be outsourced building managers, rather than embedded within the organisation, has made this more difficult.

Energy Management

The need for end-use services (e.g. computing, lighting, heating) to meet organisational needs leads to purchase and use of energy-using equipment (e.g. computers, light fixtures, heating systems), which lead to energy being consumed (electricity or gas). The annual energy consumption of a piece of equipment in kWh can be calculated as the number of hours it is turned on per year multiplied by its kW rating, times the percentage of time equipment is actually running while turned on (100% for lighting but only around 50% for servers) and the actual efficiency with which it runs. If there are n pieces of equipment in a building then total energy use is the sum of energy use per piece of equipment from 1 to n, with the four variables having unique values, as shown in Equation [1].

$$Total\ Annual\ kWh\ in\ Building = \sum_1^n (annual\ operating\ hours\ (h) * power\ rating (kW) * \%\ of\ time\ running * 1 efficiency\ \%) \quad [1]$$

Energy savings can be achieved by affecting the values of these five variables through several types of interventions, shown in Table 1.

Table 1: Variables Influencing Energy Use and Ways to Reduce Them

Variable	Interventions
N	Reduce total amount of equipment through consolidation of devices and/or reduction in service levels (e.g. fewer lights per room)
operating hours	End-user behavioural change programmes to get users to switch off equipment when not in use, automated controls, improved programming of building management services software that controls central building services
power rating	Reduce power rating by purchasing higher efficiency equipment or down-rating equipment
efficiency and % time running	Improve efficiency by maintaining equipment regularly, use of specialist control software, and ensuring correct operating environment

Systems Thinking

The term "systems thinking" broadly refers to an approach to working with the world that recognizes the complexity and interconnectedness of things within both engineering and people systems. The International Council on Systems Engineering describes systems thinking as '*a way of thinking used to address complex and uncertain real world problems. It recognizes that the world is a set of highly interconnected technical and social entities which are hierarchically organized producing emergent behaviour.'* (INCOSEUK 2010) The field of systems thinking covers a wide range of analytical and simulation methodologies, including problem structuring methods that provide ways to systemically approach a complex system, and System Dynamics (SD) which uses computer simulation to model real-world systems so that they can be diagnosed and solutions to problems can be found.

The SD methodology involves several stages: conceptualization (problem definition and system conceptualisation); formulation (positing a detailed structure and selecting the parameter values); testing (model behaviour and model evaluation); and implementation (policy analysis and use) (adapted from (Luna-Reyes & Andersen 2003)). One tool commonly used for problem definition is Causal Loop Diagramming. Causal Loop Diagrams (CLD)s are '*visual representations of the dynamic influences and inter-relationships that exist among a collection of* *variables'* (Spector et al. 2001). CLDs can help by: (i) quickly capturing hypotheses about the causes of system dynamics; (ii) eliciting and capturing the mental models of individuals or teams about the system; (iii) communicating important feedbacks believed to be responsible for a problem (adapted from (J. D. Sterman 2001)). CLDs cannot be parameterised or simulated, and they don't communicate levels of change in stocks and flows of equipment, information and people; however, they are a good way to represent key system elements, the causation between them, and important feedback loops; they can form the basis of a full SD model.

One of the key concepts in SD is the understanding of structure and its relation to system behaviour. In fact (J. Sterman 2000) says that the behaviour of a system *arises* from its structure. So if behaviour arises from structure, how much agency do individuals have to change things? (Richardson 2011) explores this question by asking: *'Who are the actors in the dynamics of a complex system and how do their perceptions, pressures and policies interact? Are we parts of the problem, or parts of the solution, or merely bystanders watching difficult dynamics play out over time?'* According to (Lane 2000) it is not either-or; the SD approach involves *'a feedback model of the relationship between agency and structure'.* Thus, a SD model will always include both structure and agent decision-making and the dynamical behaviour between them.

In this paper we use causal loop diagrams to represent our dynamic hypothesis about the causation of levels of energy consumption at the case study school – the conceptualisation stage of SD modelling. We use the concepts of structure, behaviour and feedback to interpret evidence from the case study, and to identify potential types of actions that could be implemented to reduce energy use. Future work is expected to build initial CLDs into a full SD model, which would enable model simulation and scenario testing of possible interventions.

3 CASE STUDY

The case study was done at a secondary school built in 2007 in the UK under a Private Finance Initiative (PFI) contract. There are five agencies involved in its running: the PFI company owns the building and leases it to the school; the FM company maintain central building services and ensure health and safety and security; and there are subcontractors for the provision of Information and Communications Technology (ICT) and catering. The school pays a lease fee to the PFI which covers FM. Gas use is low against national benchmarks, but electricity use is high. Contractually, energy management is the responsibility of FM. Each year a consumption target is set for the coming year's energy consumption based on an expected reduction in the previous year's consumption, usually around 5%. If at the end of the year energy use is different to the target by up to plus or minus 10% then FM get or pay the difference. If savings are greater than 10% then they share the savings with the school. Thus, if savings are made each year the target will gradually fall. This arrangement often has the somewhat perverse result of discouraging facilities managers from achieving all the savings they can in one year, as that result will make savings much harder the following year.

Figure i shows the basic types of equipment within the school building, who is responsible for procurement and maintenance, and who uses them.

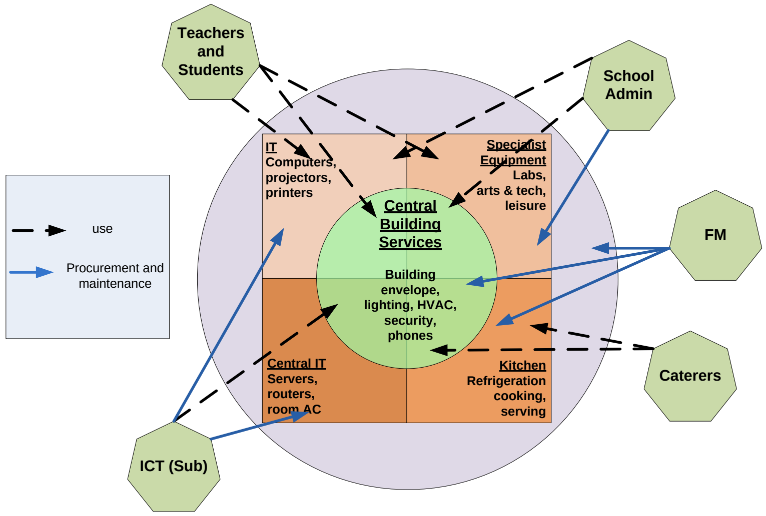

Figure i: Types of Equipment in Use at Case Study School, Which Agencies Procure and Maintain them, and Which Agencies Use Them

For the first three years of occupancy, an error made in the original governing agreement for the contract meant that the school did not pay for its electricity. Once this error was rectified, there was suddenly an awareness of how much they were using and efforts were put into place to reduce consumption. Actions included the following shown in Table 2.

Table 2: Initial Actions Taken by School

Action	Effects on Values in Equation [1]
a switch-off campaign aimed at end users (school staff and students)	reduced operating hours
a policy that gave FM staff permission to turn off any equipment left on at the end of the day such as printers, projectors, etc.	reduced operating hours
a programme of consolidation and upgrading of central ICT service equipment such as switches and routers	reduced total amount of equipment (n) and improved efficiency and power rating
changes to scheduling of central building services equipment such as heating, cooling, lighting and air handling (reducing operating hours).	reduced operating hours

After some initial success in reducing consumption, savings reached a plateau and all concerned had run out of ideas for further actions. At this point, the researcher was invited to come into the school to help find further opportunities for savings, and a trial was run from March to September 2012. The trial involved several group meetings, analysis of meter and submeter data, walkthroughs of the building, an equipment audit, and semi-structured interviews. At the end of the trial, a suite of recommended actions was presented to the group by the researcher; however most of these were not taken up.

Figure ii shows the past two years of consumption history. The high data points are school days and the low data points are weekends or school holidays. Significant savings were achieved during the 2012 summer holidays, due to the site manager's actions in turning off a range of equipment not previously turned off during holidays, resulting in a rather dark and stuffy school building for the small number of staff working there over the holidays.

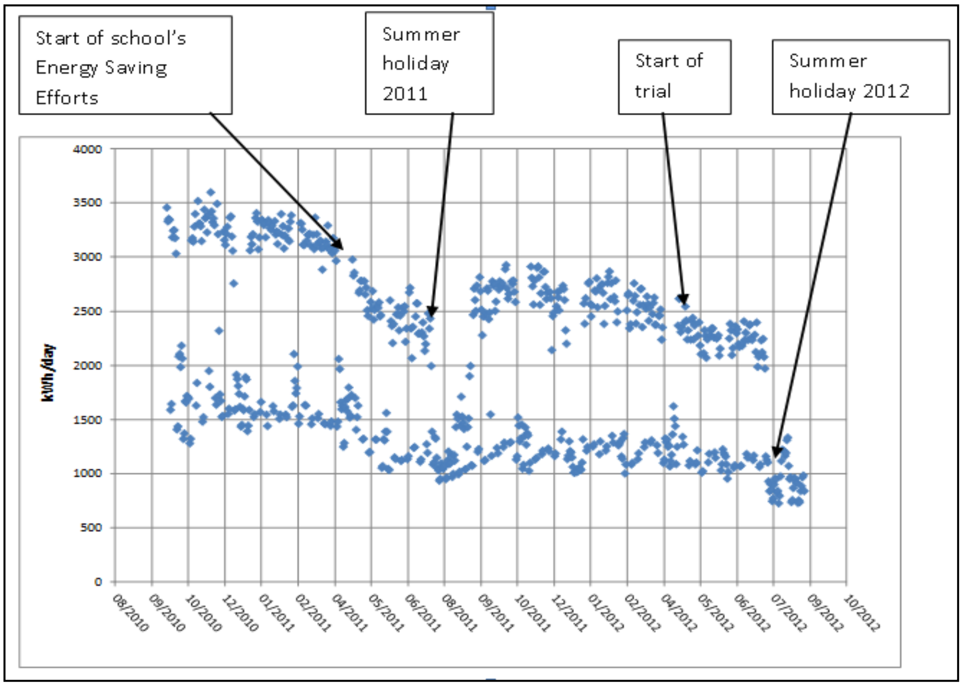

Figure ii: History of Energy Use at Case Study School in kWh/day

4 UNDERSTANDING CAUSATION

The causal loop diagrams presented in this section were created to communicate our hypothesis about the factors influencing energy use in the school and the causation between them including feedback loops. This is an interpretation (a mental model) of the real world created by the authors, intended to be useful solely for the purpose of understanding energy use. Figure iii shows the hypothesis about the primary positive feedback loop influencing consumption before the school started receiving energy bills.

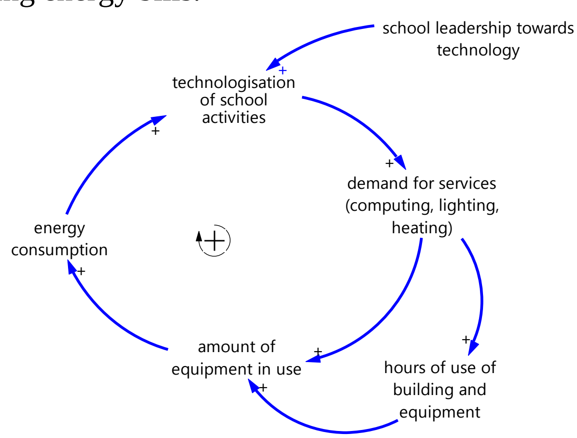

Figure iii: Positive Feedback Leading to Increasing Energy Consumption

Once the school started to receive bills they realized that consumption was much higher than other comparable schools and the financial penalties for this, so started to take action to reduce it. The CLD in Figure iv shows the addition of a balancing loop that decreases energy use over time, which is driven by awareness of energy use through receiving energy bills, which leads to actions to reduce energy use. A secondary feedback loop feeds into the main balancing loop, when willingness to act increases the likelihood of actions to reduce energy use, which leads to savings for the agencies involved, which leads to more willingness to act.

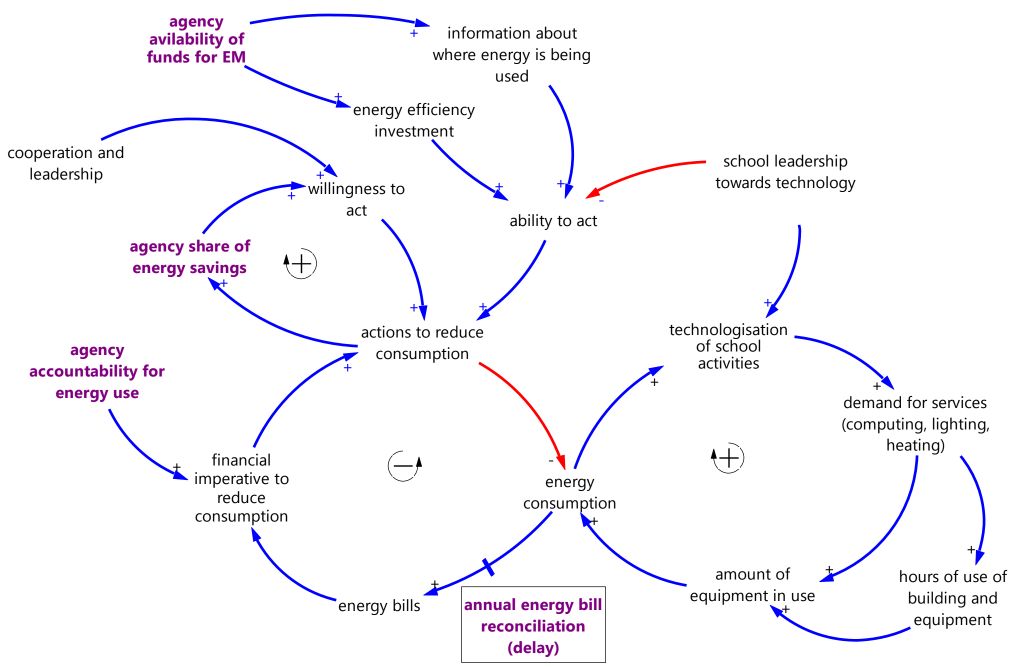

Figure iv: Positive Feedback Leading to Increasing Energy Consumption

What enables action to reduce energy use is information about how much and where energy is being used and the ability to act (behavioural changes or upgrading equipment). The school has a strong technology focus and prioritises access to ICT and other technologies such as photography and graphics for students, and this impedes the balancing loop somewhat, as the total amount of equipment continues to slowly grow.

Four influences on the balancing loop arise from the PFI contracting (shown in purple):

1. **Agency share of energy savings**: FM takes the hit on differences less than 10% above or below target, and the school gets a share of savings over 10%. If energy use is within the target range, FM does not have a large incentive to make further savings; however, this is where the school would see the benefits. If the school make effort to reduce consumption but savings are less than 10% then they get nothing back.
2. **Availability of funds for energy management:** FM will invest if they can see that it will bring additional income or avoid a fine for over consumption, but investments must meet their internal payback rules. The school have no budget for energy efficiency, presumably because this is supposed to be covered under their PFI lease payment.

3. **Agency accountability for energy management:** Accountability is not directly related to responsibility (i.e. cause) of energy use; the school are responsible for a large part of energy use (estimates of up to 50%) through end-use equipment and yet FM take the majority of the accountability.
4. **Annual energy bill reconciliation:** There is a delay in the energy-reducing balancing loop which weakens it, because energy bill reconciliation is only done once per year, and the negotiations are complicated and not fully understood by all of the parties. Additionally, the school does not currently see the effects of utility tariff increases.

5 UNDERSTANDING POTENTIAL

To help understand where the potential for energy savings is, we can use the concepts of structure (things that accumulate over time and change very slowly) and behaviour (e.g. habits of end users and everyday decision making) from SD. Changing behavioural factors is quicker, but because behaviour happens partly a result of structure, deeper and more lasting changes cannot be made without addressing structural influences – which are more difficult to change. Table 3 analyses the nature of the main driving variables in the CLD in Figure iv.

Table 3: Structural and Behavioural Factors Influencing Energy Use, and Potential for Change

Factor	Category	Observed Effects	Potential for Change
agency accountability for energy use	structural	Although accountability was partially shared between school and FM, its assignment was felt to be unfair by many. When the trial started, FM felt they had done all they could to reduce central building services energy use, but were still being pressured to reduce more – even though they suspected that high use was because of school management decisions and staff behaviours.	Change the contracting to make all the subcontractors and the school management accountable for the portion of the energy bill they are directly responsible for. So, caterers would pay for the energy they use for catering, and similarly for ICT and the school. This would need detailed submetering available in real time, which would enable the agencies to manage energy use and be billed correctly.
agency availability of funds for EM	Structural	There were no funds for EM from any of the agencies, except FM had installed some lighting controls that were expected to pay back quickly. This factor ties in with accountability.	A change in contracting would probably lead to agencies making more funds available. However, a formal agreement that requires all agencies to put aside a small amount purely for EM could prove cost-effective in the long term.
agency share of energy savings	Structural	This is the carrot factor, and it motivated the school who were seeking to get funds to supplement a very tight school budget. However, this did not motivate FM as much because higher levels of savings don't benefit them.	This would be solved by the change in contracting described above. The only problem would be where there is fuzziness about use and responsibility for equipment and what is reasonable to request from the FM.
information about where energy is being used	Structural and behavioural	This problem was stalling progress at the start of the trial. There was a lack of knowledge of what equipment is in the building (i.e. the "n" from equation [1] is not known) and how much each type of equipment was consuming. Information about the submeters had been lost and there was no central equipment inventory,	Putting automatic meter reading on submeters is essential to allow more active management of energy by department and by agency. In addition, putting meters on individual pieces of equipment would reveal more useful information. Finding information on the "hidden" equipment that's always running in the background would

		but separate ones in each agency.	explain the “mysterious” baseline use that confounded everyone.
cooperation and leadership	Behavioural	The school business manager’s leadership helped to kick-start the energy saving campaign and there was genuine desire to meet goals. However, cooperation was often lacking in the correct use of equipment by staff. It’s not uncommon for teachers to put on the AC full blast and open the windows!	Better communication between agencies on choice and use of equipment would enable more savings. There are many urban myths about how equipment should be used that are incorrect. Setting up two-way communication channels between all the agencies would enable this.
amount of equipment in use	Structural (fixed equip) and behavioural (new equip)	The building is sophisticated and there is a minimum amount of equipment running all the time to serve security and H&S needs. Complicated controls are needed to deal with the wide variety of equipment. New equipment is continually being added to support school activities, although some is also taken away when it reaches end of life.	An overarching equipment management policy that monitors and sets targets for the amount of equipment in use could prevent an ever increasing inventory. Whole-life costing of new equipment that takes into account running costs would encourage more efficient products being procured. The value of services should be evaluated against the cost of energy needed to run them.
school leadership towards technology and technologisation of school activities	structural	This affects the amount of equipment used in everyday school activities. Most classrooms have projectors, and there is approximately one computer per student (1200) as well as 7 photocopiers, 53 printers, 18 fridges, 15 laminators, and a wide range of other specialist equipment such as graphics and photography.	This is dependent on the ideas of what constitutes good teaching practice. Because the school is focused on teaching technology this is probably not going to be changeable. There are some schools that have taken on the sustainability agenda and have achieved a low-carbon and successful school, but these all had leadership from the school principal.
hours of use of building and equipment	Behavioural	This was the first place to start and actions have helped to reduce energy waste that was occurring because of people leaving equipment on when not needed and not managing the building well to keep in heat or coolth.	More can always be done to reduce energy wastage, such as smarter controls and programming of the BMS. However, the amount of savings is limited because equipment will always have to be switched on during those hours when it is needed.
demand for services (computing, lighting, heating	Behavioural and structural (school culture)	Subcontractors are contractually obliged to meet the needs of school staff and students; they cannot refuse a request for, e.g., more AC. There is rarely push back from the support services or the school admin when teachers request equipment and longer opening hours, while budget allows.	The demand for services depends on curriculum needs, perceptions of comfort and convenience, and the range of subjects offered to students. Some of these demands are changeable in terms of staff accepting lower levels of service, and some are not. It may be possible to get teachers to question their need for services.

6 CONCLUSIONS

The technical complexity of modern school buildings, and the amount and diversity of equipment in use, pose challenges for energy management in schools. Complex contractual arrangements on responsibility for maintaining equipment and on accountability for energy use in a PFI structure can further contribute to energy management being a problem. Splitting the benefits of energy savings between parties can weaken the incentive to act, and not knowing which agency within a multi-agency structure is causing which parts of the total bill can create resentment between parties when they are continually being asked to reduce consumption.

This paper has taken a look at this problem through examination of a case study school with the use of concepts from systems thinking and System Dynamics. The authors first identified a positive feedback loop that was leading to ever increasing amounts of energy use, partly due to the use of technology in teaching, and then a rather weaker balancing loop to reduce consumption was identified, influenced by incentives such as high energy bills and income from energy savings. The structure of contractual arrangements led to part of the difficulties, with little money available for energy efficiency investments and agencies only being held accountable once per year at reconciliation time. The main sticking point was lack of information about what equipment was running in the building and causing the energy use, partly due to the lack of real-time submetering and partly due to there not being a central register of equipment.

The main factors influencing energy consumption were analysed for their interactive effects, and identified as structural or behavioural, leading to proposals for actions to change the current dynamics, principally: rewriting contracts so that accountability and responsibility are better matched; making budgets available for energy efficiency; maintaining knowledge about what equipment is in use and how much energy it's using; and, proactive energy management by all those with the power to make decisions that ultimately lead to energy use. These actions would allow the school to be run with lower carbon emissions while supporting the prime objective of the system – to provide an education specialised in technology to secondary school students.

ACKNOWLEDGMENTS

This work was supported by the Systems Centre at the University of Bristol, UK; the EPSRC funded Industrial Doctorate Centre in Systems (Grant EP/G037353/1); and Sustain Limited, Bristol, UK. The authors wish to warmly thank the participants in the trial at the school for their friendliness, time, and cooperation with the research.

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