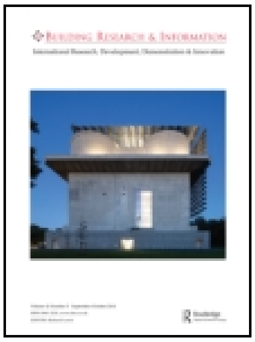


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INFORMATION PAPER

# Heat metering: socio-technical challenges in district-heated social housing

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**Individual heat metering and charging (IMC) are seen as promising methods to reduce domestic heating and hot water use through the provision of financial incentives. The heat consumption measured by meters is influenced by both the dwelling characteristics and the behaviour of the occupant, but heating charges would ideally relate to occupant behaviour only. This dilemma can be especially relevant under two circumstances: if the thermal performance of the dwelling is poor and/or if heating costs represent a substantial part of the occupants' income, *i.e.* in social housing. The case of a district-heated council block in London is presented where the installation of individual heat meters was planned in 2010 but had to be suspended due to concerns about implications for occupant heating costs in light of the thermal performance of the building. It illustrates a technically and socially complex environment where fairness in allocating heating costs is an important concern. The case also shows how lack of funding or other issues on the infrastructure side can hinder behaviour-orientated measures such as IMC. A holistic energy conservation strategy addressing both physical building properties and occupant behaviour is therefore essential and should be supported by policy.**

**Keywords:** district heating, energy demand, energy management, fairness, housing, metering, mixed tenure, social housing



## Introduction

Individual metering, energy displays and informative billing are seen as promising methods to reduce energy consumption in homes by informing more sustainable user behaviours (Darby, 2006; Fischer, 2008). Consequently, the European Union has recommended individual meters reflecting the final customer's actual consumption of electricity, natural gas, district heating and/or cooling, and domestic hot water since 2006 (Energy Services Directive, Article 13). In the UK, energy meters have been part of the governmental strategy to reduce greenhouse gas emissions since 2007 (DTI, 2007, p. 63).

Heat meters are needed primarily in district-heated dwellings, while the heating use of homes with individual gas or oil boilers can easily be charged based on fuel consumption. Currently, only 2% of the UK's total heat demand is provided through district heating, while the Department of Energy and Climate Change (DECC) expects that up to 20% of the domestic sector might be served by heat networks in 2030 (DECC, 2013). Most of the existing 210 000 district-heated dwellings are apartment blocks owned by registered social landlords (DECC, 2013; DEFRA, 2007; Russell, 1993) and only a fraction of them have heat meters in place. A slightly dated DEFRA survey from 2007 indicates that less than one-quarter of local authority or housing association dwellings on district heating were heat-metered at the time of the survey. In the rest, residents are charged flat rates for their heating, which are independent of consumption and based only on floor area.

Although the energy efficiency of the UK social housing sector has improved substantially during the last decade (DCLG, 2012), many buildings originate from the 1950s or 1960s and require retrofitting in order to perform to present-day standards. Ideally, the introduction of heat meters and improvements to thermal building performance would be done together, but financial constraints on social landlords can complicate the retrofit process and may lead to the possibility of heat metering in thermally underperforming buildings. This can be problematic because the heating consumption measured by meters is influenced by both the dwelling characteristics and the behaviour of the occupant, while heating charges would ideally relate to occupant behaviour only.

A review of the literature on heat metering shows that little attention has so far been paid to the social challenges of heating cost allocation through meters. This paper aims to contribute to this knowledge gap by presenting the case of a district-heated apartment block in London. In 2010, the London Borough of Camden, the social landlord of the block's residential section, planned to install individual heat meters in all flats. But a group of occupants voiced concerns about the thermal performance of the heritage-protected building in connection with the proposed change in heating cost payment mode after meter introduction. In response, Camden postponed the decision about the heat meter installation in the block in 2011 until both technical and social challenges could be understood more thoroughly. The University College London (UCL) Energy Institute was asked to help by some residents and this request was approved by Camden. This paper presents the results of this investigation.

The paper has three main sections. It begins by illustrating the issues of heat metering based on a review of related literature. The case study and the research methods used are then introduced before findings are presented and discussed. Apart from illustrating a range of challenges to heat metering, the presented case is especially interesting because it also illustrates difficulties for communication and decision-making in situations in which little reliable consumption or physical performance data are available.

## Context

### Literature on heat metering

In 1978, Socolow's Twin Rivers study showed for the first time that dwelling energy consumption is influenced not only by the physical characteristics of the dwelling but also by the behaviour of the occupants (Socolow, 1978). Since then, much research has looked at the role of occupants in household energy consumption (Gill, Tierney, Pegg, & Allan, 2011; Hiller, 2012; Steemers & Yun, 2009) and occupants have become a prime target of conservation efforts (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Allcott, 2011). As for heating use, there is consistent evidence that metering in combination with consumption-dependent charging can act as an incentive for more sustainable heating behaviours in district-heated dwellings:[1]

- Goettling and Zaworski (1984, p. 134) reviewed studies in the US and found that 'consumption measuring devices for determining allocation of heating costs have lowered consumption by 15–30% when compared with flat rate charging'.
- A study published in the periodical of the Danish Board of District Heating (Gullev & Poulsen, 2006, p. 20) reports consumption reductions of up to 30%, but points out that the variation between individual households is significant and 15–17% reductions are more likely to be realistic on average.
- DEFRA (2007, p. 30) quotes a presentation 'Utilising Community Heating and CHP' given at a district heating seminar in 2006. It is no longer available as a primary source, but reports, according to DEFRA, savings between 15% and 30% achieved in studies across Europe (Germany, Denmark and the UK).

Apart from energy and carbon savings, the use of meters to allocate heating costs promises further benefits to building owners and policy-makers such as a green image or the possibility to emphasize the end-user's responsibility in reducing consumption (DECC, 2012a; DEFRA, 2007). It has also been part of the political rhetoric that heat meters can contribute to fighting fuel poverty by reducing overall expenses for heating and hot water (White, 2010).

From the occupant point of view, however, there are difficulties. With the most commonly used flow meters as well as with evaporation meters, heat loss towards unoccupied adjacent flats or local deficiencies of the building envelope potentially increase the occupants' heating costs, but they cannot benefit from the delivered heat. If temperature rather than heat meters is used, external sources of heat (*e.g.* solar gains) increase the primary heating cost (Babus'Haq, Overgaard, & Probert, 1996). The fact that heat meters may be seen to attribute costs to actual heating use inappropriately can result in a lack of acceptance of the technology among occupants (Siggelsten & Olander, 2010). It can be expected that this might be more significant in poorly performing buildings as the following case will illustrate.

### A heat metering feasibility framework

The intrinsic link between dwelling, heating system and occupants in the consumption of heating energy is a fundamental challenge to the allocation of heating costs through meters in district-heated housing. In low-income social housing, the technical difficulties of accurately determining occupant-induced energy consumption and attributing expenses accordingly are especially important. Firstly, energy costs often represent a substantial part of the residents' income. Secondly, flats are assigned to council tenants and they do not chose thermally unfavourable flats such as top-floor flats for other benefits such as the view.[2]

The following section develops a simple analytical framework to illustrate groups of variables relating to the allocation of heating costs through heat metering (Figure 1). Heating costs in district-heated systems can fundamentally be allocated in two different ways: consumption-independent (heat consumption and heating costs are decoupled) or as a function of the actual heat demand. In the latter case, the heat consumed in a dwelling has to be measured somehow.

Flat-rate charging, for instance based on floor area, is an apparent example of decoupling where occupants have no influence on their heating costs and consequently no incentive to exercise control over their flat temperature other than for reasons of comfort. In contrast, heat meters establish a relation between actual consumption and costs, thereby encouraging lower living temperatures, thoughtful ventilation practices and more careful use of hot water through financial stimuli.

The heat consumption of a dwelling, however, is influenced by two groups of variables: physical building properties and occupant behaviour. Physical building properties include among others the heat loss coefficients of the building fabric, the air tightness of the construction but also the efficiency of the heating system. In addition, flat configuration-dependent factors such as solar gains or heat losses through exposed walls influence the demand for heat provided by the primary heating system (Hens, 2012). On the other hand, occupant behaviours (*i.e.* the temperature preferences of the dwelling occupants, their heating and ventilation practices including how much time they spend at home and their use of hot water) also drive heat consumption (Gram-Hanssen, 2009).

With respect to providing incentives for low heat demand through unit charging, a dilemma can arise from the fact that the first group of variables is

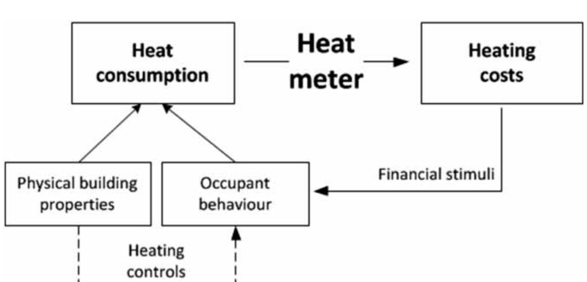


**Figure 1** Socio-technical context of heat metering in tenanted housing

outside occupant control in tenanted housing. In owner-occupied housing, high heating costs might prompt building-side energy efficiency measures as well as sustainable heat behaviours. In contrast, building-side measures are the landlord's responsibility in tenanted housing while fuel bills are paid by the occupants – a classical split-incentive situation (Bird & Hernàndez, 2012, p. 507). This means, however, that any financial stimuli through heating costs can only affect the immediately occupant induced part of heat consumption, but not the part determined by building physics.

This split can be very relevant in poorly performing district-heated dwellings: although occupants were found to be more influential in terms of absolute heating consumption in older, leakier buildings as opposed to the newer housing stock (van Dam, 2013, p. 69), bills nevertheless remain higher there due to fabric and distribution heat losses. Additionally, heat demand will depend strongly on the individual configuration of each flat in dwellings with high fabric heat losses. The influence of occupant behaviour on heat consumption is also mediated by the physical building properties, especially by the design and the functionality of *heating controls*. In their paper on issues with heat metering in China, Liu, Fu, Jiang, and Guo (2011) point out that poor temperature control in flats due to lack, dysfunction or poor design of control devices can make heat metering unfeasible.

## Research objectives and methods

The objectives of this research project were:

- To identify challenges to the introduction of heat meters *in the light of physical building properties*: to what extent does a building's thermal performance impact on heating cost allocation through individual heat meters?
- To understand challenges to heat meter introduction from *the social context of low-income public housing*.

This paper explores these issues using an in-depth single-case study in order to gain a thorough understanding of a complex and so far little-researched matter and its context (Flyvbjerg, 2006). Due to the socio-technical nature of the research questions, an interdisciplinary approach gathering both social and physical data is chosen. Table 1 lists the applied data collection techniques; they are further illustrated in the following section detailing the case. While the social data are mainly qualitative, the technical data include both qualitative and quantitative elements.

## The case study

This project looks at a heritage-protected council estate in the London Borough of Camden, which is served by a gas-fired district heating system. In 2006, Camden Council (the local authority) initiated a heat metering pilot project on one of its other estates, introducing individual heat meters for all flats and changing the billing system from floor area-based flat-rate charges to consumption-dependent prepayment (White, 2010). As a result, the total fuel consumption of the 146-household estate is reported to have dropped by 30% and – hugely important in low-income housing – every household made financial savings. Encouraged by the success of the heat metering pilot, Camden applied for and was awarded a grant to install flat-level heat meters in 2800 properties within 11 district-heated estates throughout the borough in April 2010. The subsequent developments on one such estate, housing 378 flats and distinct due to its heritage-protected status, are investigated in this study.

The estate in question is composed of a single mixed-use building with a dominant residential section completed in the early 1970s. Three main groups of stakeholders are involved in the potential installation of heat meters there: the social landlord, the social housing tenants and the owner-occupiers. The social landlord of the case study building's residential section is the London Borough of Camden. Camden is the initiator of the heat metering project and the actor who, covering most of the costs, ultimately decides about the installation of heat meters. Secondly, there are two types of tenure in the case study building: council tenants and owner-occupiers as some residents exercised their 'Right to Buy'[3] in the past. Interestingly, the difference in tenure also implies different ways in which heating costs are charged for as explained subsequently.

Social housing tenants comprise 310 out of a total of 378 flats. Their heating and hot water costs are currently based on the consumption of all Camden-let buildings within the so-called *heating pool*. The heating pool is an organizational structure of tenant heating charges implying that the amount paid by the residents of all Camden blocks together covers the heating costs of all blocks. Residents in above average-performing blocks consequently subsidize residents in blocks with poor thermal performance. Owner-occupiers inhabit 68 flats in the case study building. They currently pay a proportion (subject to flat size) of the real cost arising to heat the case study building. They therefore have no connection to the heating pool.

During the first steps of the this investigation, secondary data were collected to support a better understanding of the case context: estate consumption data from the only existing meter, historic and current heating charges, minutes from Heat Metering meetings held on the estate in September and October 2011 involving the social landlord and several residents, as well as information on the Camden heat metering pilot and the heating pool in general. Based on this information, interviews with residents of the case study building were planned using a semi-structured format, thereby maintaining the flexibility to uncover new themes. To meet time and resource constraints of the project, the number of interviews was restricted to four. Although results from these interviews cannot be generalized to other occupants in the building, the study as a whole nevertheless highlights the complex issues that confront individual heat metering and charging (IMC) in

**Table 1** Data collection methods for case analysis (in chronological order as applied in the study)

| Date | Social data collection methods | Physical data collection methods |
|---|---|---|
| February 2012 | Repeated meetings with the social landlord and building service engineers to support a better understanding of the case context | |
| | Attendance of the case study building's 'Tenants and Residents Association' meetings | |
| March/April 2012 | Semi-structured interviews with four residents to understand the occupants' perception of heat metering | Monitoring of temperature and humidity in nine flats to compare with occupant statements and obtain further insights into phenomena of heat loss and internal or solar gains |
| | | Thermal imaging to identify main sources of heat loss |
| May/June 2012 | | Analysis of whole block energy cost and consumption data from a bulk meter to benchmark thermal building performance |
| | | Modelling of different apartments types to estimate flat level energy consumption |

the context of district heating. It is important that these issues be further investigated and addressed, especially in the light of the proposed expansion of heat networks in the UK and elsewhere (DECC, 2013).

Interviewees were primarily recruited through attendance at meetings of the case study building's Tenants and Residents Association, aiming for differences in tenancy, type of flat occupied, gender and profession (Table 2). Some further contacts were made through referral by existing contacts. The scope of the interviews was intentionally broad because both the analysis of preliminary case data and the literature on (smart) metering suggested that residents' attitudes towards heat metering were influenced by a range of factors:

- heating use and heating controls
- cost of heating and hot water
- occupant perception and experiences of thermal inefficiencies of the building and problems with the heating system
- expectations for heat meter installation and their effect on heating costs

The interviews were tape-recorded, transcribed and then analysed by using an analytic inductive approach (Silvermann, 2011) to explore the above listed topics.

Physical data were also collected during March–April 2012. Data consist of frequent temperature and relative humidity measurements (ten-minute intervals) to compare against occupant statements and obtain added insights into phenomena of heat loss, internal and solar gains as well as particularities in occupant behaviour causing temperature variation between and within flats. Nine flats were monitored in total, of which three were those inhabited by the interviewees. (One interviewee did not consent to temperature monitoring in their flat.) 'HoBo' temperature sensors were installed in flats selected to guarantee a variety in flat size, orientation, block, tenure and number of occupants. The selection of flats, however, likewise the recruiting of interviewees, was subject to accessibility issues since both concern people and their homes. In each of the flats, sensors were placed in the (main) bedroom and between lounge and kitchenette, aiming to replicate the exact location (Figure 2). Further, sensors were placed in different locations of interest, such as in the conservatory area and in or close to the airing cupboard. Two sensors recorded the outdoor temperature during the monitoring period; the collected temperatures were later averaged.

**Table 2** Interviewee characteristics in key categories

| Interviewee | Tenancy | Type of flat inhabited | Gender |
|---|---|---|---|
| A | Tenant | Two bedroom | Male |
| B | Leaseholder | Two bedroom | Male |
| C | Tenant | Two bedroom | Female |
| D | Leaseholder | One-bedroom maisonette (split-level flat) | Female |

## Main findings

### Case study building characteristics

The case study building is poorly insulated as it was built in times when energy was not yet an issue but construction techniques were advanced enough to allow for thin walls. The flats have large integral conservatories (14 m$^2$ of glazing in a living room of 22 m$^2$ floor area), which are mostly single-glazed and often referred to by occupants as 'big greenhouses'. While they make the flats light and pleasant, problems with overheating in summer are frequent and the heat loss in winter through the conservatories is substantial. In addition, the primary district heating circuit (connecting the flats to the boiler room in the basement) is operated at 120°C flow temperature, while the heating mains of the distribution system are partly conducted externally. There is plenty of anecdotal evidence of elevated temperatures next to the rubbish chutes, where the risers are situated. A thermal imaging survey conducted for this project confirmed considerable temperature differences

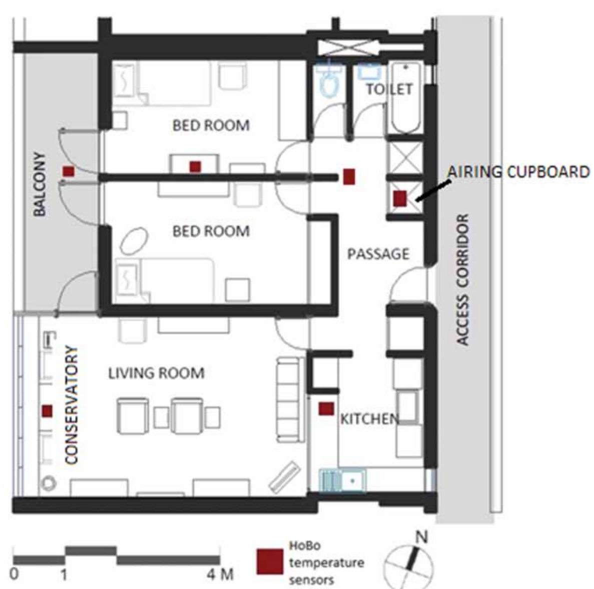


**Figure 2** Location of 'HoBo' sensors in a two-bedroom flat
*Source*: P. Chaudhari, modified by authors

across conservatory windows and external distribution pipes indicating heat loss.

All in all, the case study building may be classified as an apartment block with poor thermal performance. But demand-reduction measures such as the installation of external wall insulation or a replacement of the single-glazed windows are hindered by the building's heritage status. Camden Council, the social landlord of the block's residential section, is hence in a difficult situation with respect to achieving its ambitious carbon reduction targets (27% for total estate and operations by March 2017). Therefore, motivating sustainable occupant behaviour seems desirable. The feasibility of heat meters in a building with poor thermal performance, however, needs to be considered, and this will be reviewed in the discussion section.

The heat-metering feasibility framework (Figure 1) also suggests that effective heating controls are a prerequisite for IMC. In the case study building, every flat is equipped with a programmable thermostat. During both interviews and monitoring visits, occupants generally express satisfaction with their means to control flat temperatures during winter. The heating system of the case study building (heat generated by eight 500 kW gas boilers) seems to be powerful enough to achieve comfortable conditions by simply turning the heating on when needed. However, the knowledge of the interviewed occupants about the installed thermostats appears rather limited. The interviewed tenants do not know that their thermostats were programmable. Although one of the owner-occupiers admitted to knowing, he never bothered exploring this function further.

While occupant control over their heating system is sufficient in the case study building, residents currently have no means to influence their heating costs as the following quote from one of the interviews illustrates vividly:

> It just seems a lot because I'm here on my own most of the time, and I don't have it particularly hot, I don't [ . . . ] so it seems quite a lot of money to me. [ . . . ] And you know, yes I can turn my heating down to a reasonable level, but apart from that we really don't have very much control.
>
> (occupant D)

All interviewees agree upon the fact that the decoupling of actual consumption and costs is undesirable, wishing they could somehow influence their heating costs. This appears to resonate with the literature on smart meters, where the motivation to save money was found crucial in prompting behaviour change (DECC, 2012b, p. 21). This finding suggests that metering may be beneficial from an occupant perspective if problematic issues in the case study building as presented subsequently were resolved.

### Heat meter introduction in the light of physical building properties

Occupant interviews and informal conversations both during temperature sensor installation and alongside meetings of the tenant and resident association revealed that the poor thermal performance of the case study building seems to be common knowledge among residents – for some, backed by a technical understanding of the above issues, for others based on rumours and hearsay. Moreover, many have learnt from statements originally ascribable to Camden Council that their heating costs are subsidized through the heating pool. This means tenants do not pay what it costs to actually heat the building, but less – and the same as all Camden council tenants – while the gap is filled by subsidies from thermally better-performing buildings in the pool. Against this background, tenants are concerned that with the introduction of individual heat meters, subsidies for their block would be lost and heating costs could rise. This concern was severe enough to prompt a series of discussions about and spark this investigation into the introduction of heat meters in the case study building and points towards the importance of cost issues in social housing.

Figure 3 confronts the total costs to heat the case study building (including gas purchase, operational electricity costs as well as gas and electricity overheads) with the total amount paid by all building residents (including owner-occupiers) for their heating and hot water. The overall increase in costs can be attributed to rising gas prices as well as to a steep increase in fuel consumption (from approximately 7500 to over 10 000 MWh/year) after a replacement of the previous hot air heating system by a more powerful wet system with radiators in 2010. For the first two heating seasons shown, the heating pool subsidies for the case study building are indeed substantial, but Camden closed this gap through an adjustment in both tenant and owner-occupier charges in 2010/11. In 2011/12, the subsidies from the pool only amount to 5% of the case study building's heating total.

This suggests that the tenants' concerns about potentially being disadvantaged through individual heat meters for living in a thermally poor building might be exaggerated in relation to the heating pool. Interviewee responses highlight at the same time that the removal of heating pool subsidies is indeed perceived as a main threat to heating costs following meter introduction. Poor building performance, however, raises a different issue for heat metering. In the case study building, a strong dependence of actual heating demand on flat configuration could be

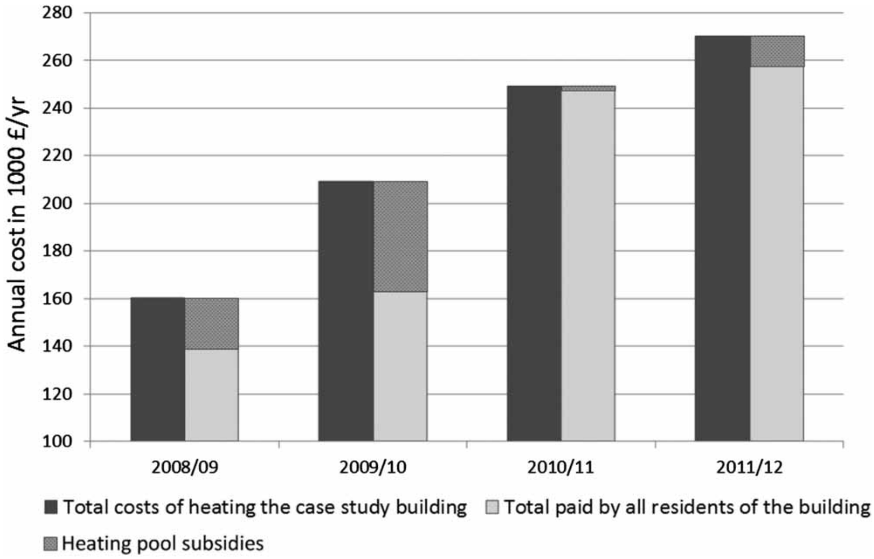


**Figure 3** Historical data of case study building heating costs and cumulative resident heating charges



shown. Implications of this will be investigated in the discussion section. The following section provides evidence from monitoring data, thermal modelling and interviews as well as causes for the link between heat demand and flat configuration.

In the case study building, a strong influence of flat configuration on heat consumption is evident for three reasons: different exposure of walls to the outside for mid- versus top-floor flats, heat transfer between flats due to different internal temperatures, and differences in solar gains due to flat orientation. Other causes of location-dependent divergence from average space heating demand such as increased heat loss through higher wind velocities in flats on higher levels (Kenworthy, 1978) or local deficiencies of the building envelope (Liu et al., 2011) could not be analysed due to lack of data.

Compared with mid-floor flats sandwiched between other flats, top-floor flats lose a significant amount of heat through the uninsulated roof. A Standard Assessment Procedure (SAP)[4] model of both flat types based on the floor plan shown in Figure 2 and validated through measurements of night-time cooling in monitored flats indicate that the heat loss coefficient of a two-bedroom top-floor flat is 1.5 times bigger than that of an otherwise equal mid-floor flat. Also, while people in mid-floor flats perceived the front door, the open vents in the bathrooms and the uninsulated party walls as the main sources of heat loss, the interviewee living on the top floor reported:

> But it cools down quite quickly, because [ . . . ] I don't know whether that's because we are on the top floor and we don't have a flat above [ . . . ].
>
> (occupant A)

The other interviewees as well as some of the occupants hosting 'HoBo' sensors likewise mentioned that their flats cool down quickly, but while they stated times between two and three hours for the flat to go from 'Comfortable' to 'Too cool', the interviewee on the top floor gave an estimate of one hour.

Another phenomenon frequently noticed by residents is heat coming into their flats from the flats surrounding them. All interviewees report this, but for one of them it was especially evident:

> For some reason, since they have put in the radiators, you don't even have to have them on. I think it's [ . . . ] because I'm mainly surrounded, most of the time I don't need to put my heating on.
>
> (occupant C)

In this case, the heat transfer through the uninsulated party walls of the case study building is not only noticeable to the occupant but also reduces their demand for heat supplied by the district heating system. This has no implications for the fuel bill of either neighbour with flat rate charging. But if heating costs are allocated based on actual use, internal heat losses and gains may well become relevant.

Solar gains also vary across the case study building where two flat orientations exist: north-east facing door/south-west facing conservatory and south-west facing door/north-east facing conservatory. Solar gains for the first flat configuration can be expected to be a lot bigger, especially given the large size of the glazed window areas. This expectation is supported by statements from the interviews. The results of temperature monitoring are less conclusive with regard to solar gains in a first analysis. While it is evident that solar gains lead to increased temperatures in all conservatories (Figure 4), no significant difference ($p = 0.26$) between east- and west-facing conservatories is found. If there is a difference, it sometimes appears as if east-facing flats were benefitting from higher solar gains. There are several potential reasons for this inconclusive result:

- no weather station exists on site to record the diurnal sunshine course
- heating behaviour is not accounted for and in-flat temperature differences are attributed exclusively to solar gains
- between-flat variation in sensor location is due to *in-situ* monitoring
- the conservatory–living room temperature ratio is subject to the absolute value of both

The SAP models of the case study building developed for this project indicate that orientation can make a 12% difference in annual fuel consumption between east- and west-facing flats (other parameters unchanged). These values have to be regarded with caution due to the nature of SAP as a basic static model and some uncertainty in the inputs for the case study building due to limited primary sources of information, but they indicate nevertheless that differences could be considerable.

### Social aspects surrounding heat meter introduction

As is typical in English social housing, the case study building is inhabited by both council tenants and owner-occupiers in a mixed-tenure situation. It seems to be performing well socially and all four interviewees stated that one of the major advantages of living in the case study building was the sense of community there. People know each other to a certain degree and some even share the goal of improving the living quality in the block. With regard to heating use, however, all interviews suggest that residents suspect differing heating practises occur throughout the estate. Generally, interviewees have come to form impressions of others' use of their heating systems through direct interaction with their neighbours and conversations about mutual problems such as malfunctions of the heating system, flat overheating or a constant and uncontrollable heat flow from their airing cupboard.[5] As for the latter, one of the interviewees described this as heat 'bursting' from the cupboard.

Two interviewees also noticed the practice of having windows open continuously at low outdoor temperatures. They concluded that the heating would be switched on at the same time because of the cold

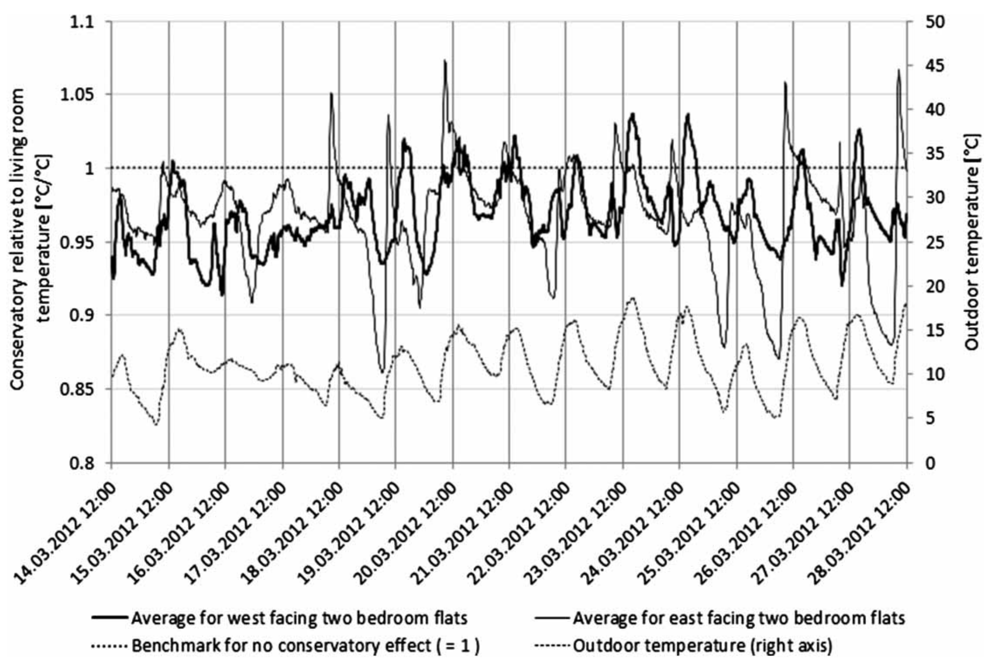


**Figure 4** Relative conservatory temperatures indicating heat losses and solar gains

weather. One interviewee, who described himself as environmentally aware, commented on this practice:

> I try not to waste hot water and heat. [ . . . ] By not having the heating on when the window is open. Which lots of people here very often do.
> (occupant B)

Both interviewees inferred from their observations that their own heating use must be lower than those of others who let heat escape out of the windows.

During three of the four interviews, differences in heating use were raised by interviewees in the context of heat meter installation. For two interviewees, who both perceived their heating use to be lower than that of their neighbours, this fostered an interest in exploring heat meter installation. One of them reflected on incentives for low heat use:

> The total amount which is spent on heating is affected by the temperature which everybody in the building has his heating at. There is no incentive for anybody to turn their heating off or down.
> (occupant D)

The range of temperatures in the monitored flats also suggested that there are high and low heating users within the case study building: The daytime temperatures (06.00–23.00 hours) averaged for the monitoring period ranged between 21.8°C and 24.7°C in different flats. Meters could consequently bring savings to people with low temperature preferences and conscious ventilation routines on their heating bills without any behaviour change as they might currently be paying more than their use justifies. But without meters it is impossible to determine how much individual residents contribute to the overall heat consumption and the resulting heating costs.

With regard to the heat metering contemplated for the case study building, the question of who would pay for meter installation is different for tenants and owner-occupiers. For tenants, the installation cost would initially be covered by Camden, while owner-occupiers would directly pay for the total cost of the installation themselves. Tenants may then suspect that Camden will pass the installation costs on to them gradually by increasing rent or heating costs. Owner-occupiers, in contrast, are sure to immediately face an expenditure that might use up savings from sustainable heating behaviours for years to come. One of the owner-occupiers wondered:

> The costs that they have quoted us for doing it mean that it would take ten years or even twenty years to recoup the cost of the heat meter with saved heat. So what is the point?
> (occupant B)

There is consequently a range of social aspects at work driving or suspending the interest that individuals take in the introduction of heat meters in the case study building, including the spread of information and misinformation alluded to in the myth of the generous heating pool. The following section will take a closer look at resulting options for different stakeholders.

## Discussion

In the case study building, poor thermal performance issues and a combination of social factors put a halt to the current ambition of Camden to install heat meters in each flat. This study investigated the socio-technical context and challenges to IMC there more closely in order to provide a background to negotiations between involved stakeholders on how to proceed. Apart from Camden and the residents of the case study building, both council tenants and owner-occupiers, policy-makers could be understood as an additional, more indirect stakeholder of the investigation given the increasing interest in heat networks as part of a low carbon heating future. This section will discuss implications of IMC and options in the context of the thermal performance of the case study building for each stakeholder group.

### Implications for occupants

The heat metering feasibility framework introduces the fundamental dilemma of heat consumption which is influenced by both physical building properties and occupant behaviour while heating charges would ideally relate to occupant behaviour only. For building occupants in tenanted housing who have no influence on their homes' physical properties according to most UK letting agreements, this can be problematic as the physical building properties have a significant impact on heating consumption. In social housing, this is aggravated by the fact that council flats are allocated on the basis of waiting lists and tenants do not chose properties for non-energy-related benefits such as location or aesthetics.

The resulting problem with IMC for building occupants is one of fairness. The pursuit of fairness, however, is inherent to the concept of social housing which aims to provide and improve the living standards of the disadvantaged. Fairness in general is widely discussed in the philosophical literature and many different aspects of fairness have been investigated within environment and energy research (*e.g.* allocation of carbon emissions, water use, natural resources in general). For this project, the following understanding of fairness seems most relevant:

> People who choose to live at similar temperatures, spend a similar amount of time at home

> and have much the same ventilation routines should have similar heating costs regardless of the configuration of the building and flat they are in.

Based on this understanding, a fair allocation of heating costs is difficult with the currently available metering technologies. In addition, meter introduction brings existing physical underperformance and associated factors such as exposure and the external surface area of individual apartments into focus which had not previously impacted on households. In his seminal review on social aspects of energy use, Lutzenhiser (1993, p. 259) identified that fairness and equity are crucial to achieving consumer acceptance. Similarly, Siggelsten and Olander (2010) concluded from their study on the perception of individual metering and charging systems in Sweden that considerable annoyance among tenants is rooted in the belief that IMC systems are unfair. The interview results in this small study also highlight the importance of fairness when facing the deliberation of payment structures in the social housing context. For example, one interviewee said:

> So in some ways, for some of us, it might be better to have meters but it's got to be fair for everybody, hasn't it?
>
> (occupant C)

At the same time, fairness is always susceptible to point of view. To deliver a comprehensive cost–benefit analysis of heat meter introductions, it is not enough to identify fairness issues when allocating heating costs through meters, but this has to be put in the context of how fair is the allocation of heating costs through the current flat rate charging. Figure 5 schematically illustrates possible fairness issues in heating cost allocation when comparing tenants in different blocks of flats which will differ in their physical building properties and installed heating controls (fairness between blocks), but also when comparing residents in the same block of flats (fairness within blocks).

The presented case can be understood as poorly performing building in which the introduction of metering may create issues with fairness between blocks. For occupants of better performing blocks in the heating pool, however, metering is likely to be perceived to increase fairness in heating cost allocation. Within a block, fairness issues may result from metering for occupants in unfavourable flats, *i.e.* flats requiring more heat to achieve standard temperature levels due to their configuration. At the same time, heat metering could remove issues with fairness for occupants with low relative heating as they may be paying more than their actual heat use justifies through flat rate charges based on the heat consumption of the entire block. Interestingly, their behaviour is ultimately the one the UK and other governments are hoping to motivate in large parts of their population.

The above definition of fairness, however, only encompasses one dimension of how the concept could be understood in the context of heating costs. A second dimension of fairness might want to take account of occupant vulnerability as advanced age and poor health can be major drivers for elevated temperature requirements while often simultaneously reducing income. In contrast, young and healthy residents might work fulltime in heated buildings elsewhere, reducing their heat demand at home substantially. Ideally, a socially just way to shape heat pricing structures would consequently consider both flat configuration-based effects on heat consumption as well as occupant vulnerability. The variety of social and technical drivers for heating use, however, makes the undertaking to design such tariffs extremely complex. Further research is recommended to create heat pricing mechanisms for heat networks that are economically and administratively feasible while respecting these complexities.

In times of ever-rising energy prices, there is a further need to understand how different methods to allocate heating costs might affect occupants in district-heated social housing during price extremes. A thought experiment details how the individual can respond in such times. With flat-rate charging, residents pay a fixed amount for heating and hot water which is determined by the social landlord and independent of actual consumption. This arrangement protects residents against energy price rises in the short-term. Once it becomes inevitable for the social landlord to adjust the rates, however, residents are left without any means to adapt since changes in heat use will not affect their bills. In contrast, residents on heat meters may at some point choose to reduce their heating use to prevent overspending. This is by no means to say that trading expenses against thermal comfort is generally desirable, but an average internal temperature within the case study building of 22.8°C suggests there could be room for some residents to lower their current living temperatures if prompted or required to do so.

### Implications for social landlords and general policy

IMC offers several benefits from the perspective of social landlords and policy-makers such as the provision of incentives for occupants to use heat efficiently and heating controls well or a reduced subsidization of high heating use by low heating users within district-heated apartment blocks. Actual savings from the implementation of IMC, however, are uncertain and may not always financially justify the capital cost of metering equipment. Also, retrofitting meters in existing buildings can at times be difficult and, as in this case study, expensive. Nevertheless, individual meters will seem an attractive option especially in hard-to-

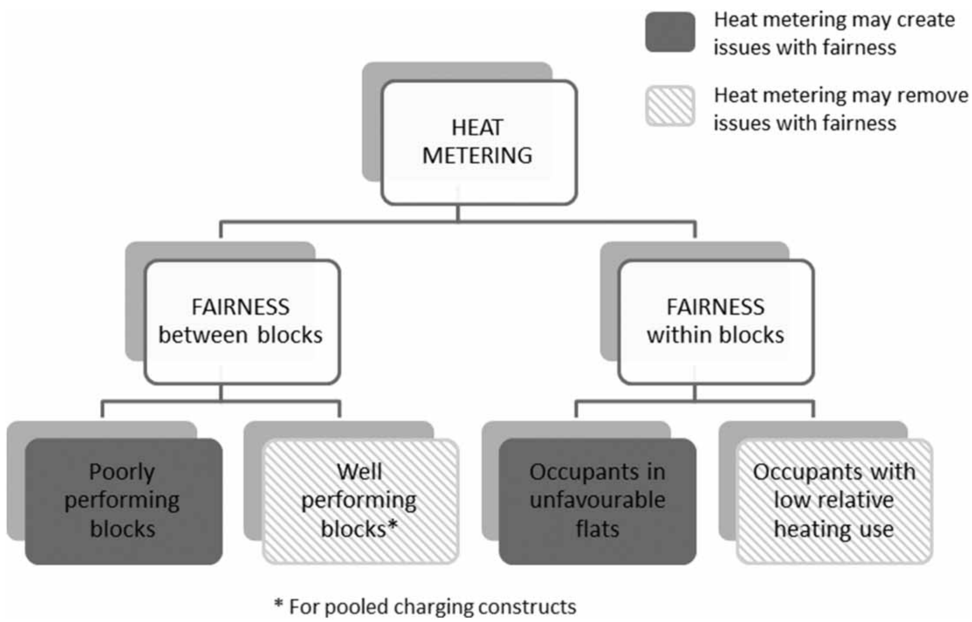


**Figure 5** Fairness issues in heating cost allocation

treat or heritage-protected properties where the means to reduce heating consumption otherwise are limited.

Landlords and policy-makers may, however, not overlook that individual occupants can only be one aspect of any discussion about energy use through domestic district heating. The efficiency of heat generation and distribution are equally important and concepts such as the use of waste heat and/or thermal storage should be explored. Here, meters can increase planning reliability by providing information on actual heat demand and sources of heat loss in buildings.

The present case also illustrates that issues on the infrastructure side may hinder behaviour-orientated measures such as heat metering. A holistic energy conservation strategy addressing both physical building properties and occupant behaviour is therefore essential for social landlords and building owners more generally. Policy could offer support here through relevant funding mechanisms and opportunities for knowledge exchange between local authorities.

This study further suggests areas of interest to social landlords and public policy which would benefit from further investigation in a larger study. Flat-rate charging and the resulting lack of prospect for financial savings from energy efficiency improvements might reduce occupant tolerance to building works. Some retrofit work done in the case study building between 2002 and 2007 (replacement of heating system and windows, restoration of concrete structure, painting of the outer facade) promised higher comfort and an improved appearance of the building but no financial benefits for residents. And although the residents generally seem highly pleased with the outcome, three of the four interviewees report to have suffered considerably from the disruption by the building works. The prospect of tenants' direct financial savings from building works that reduce energy demand – made visible through IMC – could potentially increase occupant resilience and ease the process for the work initiator.

Individual metering and charging might also enhance the use of available means for temperature control to reduce heating costs, commonly claimed to be one of IMC's advantages. In the case study building, use and knowledge of the installed thermostats and their programmable functions currently appear low, suggesting scope for improvement. Several recent studies show, however, that existence and even use of thermostats do not automatically result in lower heating consumption (Peffer, Pritoni, Meier, Aragon, & Perry, 2011; Shipworth et al., 2010). The pecuniary incentive to reduce heating bills through control use offered by IMC might therefore be insufficient to conserve energy in the case study building. Therefore, it is recommended to combine potential financial motivation following the introduction of meters with advice provision and information campaigns (*e.g.* on effective use of thermostat settings at night). Certainly, the social cohesion observed among the building occupants could be made use of for this purpose. With suitable facilitation, the existing personal connections of residents might be helpful in demystifying the heating pool and promote learning on energy issues. If residents were encouraged to think about the temperatures inside their flats, and understood how their controls could be used appropriately, savings might be possible regardless of the outcome of the heat meter installation debate (Gram-Hanssen, 2014).

## Conclusions

This study illustrates that both the installation of heat meters and the allocation of heating costs in district-heated social housing in general can be less straightforward than it may appear. Over the last decade, numerous schemes have been proposed and implemented in the UK and internationally to reduce heating demand in socially owned buildings, many with a strong technical focus. At the same time, there is growing pressure on governments to address fuel poverty issues. The presented case suggests that both agendas need careful balance, appreciating social alongside with technical and economic challenges. An integrated management and communication strategy is needed in energy terms, equilibrating the efforts in those areas. Such approaches would certainly be beneficial in social housing – particularly if frequent political and personal changes occur that result in a lack of overall strategies for building refurbishment and improvement.

The presented analysis of factors in heat metering is also relevant to the general debate of individual versus master metering in district-heated apartment buildings. In social housing, a context that acknowledges and attempts to counteract social inequalities, fairness appears to be an important issue in allocating heating costs. Individually metering, although considered modern and well aligned with energy conservation efforts, may conflict with the fuel poverty agenda, especially in buildings with poor thermal performance. To ensure that meters can be useful in helping occupants to save energy, occupants need to be empowered through necessary dialogue, clear communication, advice and support to understand and use them as a form of feedback.

Complications for demand reduction can arise from the heritage status of dwellings – not only hindering building-related measures but also indirectly influencing behaviour-orientated measures such as heat metering. The value of heritage in times of climate pressures meanwhile remains a complex matter for further discussion.

In addition, English council estates represent a complicated social context for change and change management because of the socio-economic diversity of their residents. This study suggests that owner-occupiers may form strong allies and even spokesmen for heat metering projects if they were relieved from the burden of initial installation costs, *e.g.* through monthly instalments. At the same time, the need to protect all residents' interests leaves local authorities and housing associations in a dilemma between choosing economically and environmentally profitable projects, on the one hand, and social responsibilities, on the other hand.

Based on the improved understanding of these socio-technical challenges, this study has developed several recommendations to support further decision-making on the installation of heat meters in the case study building. They include a more detailed assessment of thermal building performance to implement suitable retrofitting measures before or alongside with meter installation as well as some considerations on managing the transition. However, further research is needed to clarify, for example, the following questions: Is a heat pricing mechanism conceivable that protects people in unfavourable flat configurations without reducing the general incentive to reduce heating use? Could some of the social challenges be mitigated by lower installation costs for heat meters through a stronger supply chain?

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## Endnotes

[1]It should be noted, however, that the sole provision of feedback, *i.e.* without alterations in charging mechanisms, was generally shown to achieve somehow more mixed results in both current and earlier (post-1970s' energy crisis) feedback studies.

[2]Compared with mid-floor flats, top-floor flats lose additional heat through the roof. It should be noted, however, that in dwellings that have been metered for a while, variations in the likely cost of heating would be better understood by landlords. Such information could be shared with potential tenants to ensure that at least they were as fully informed as possible before taking on the tenancy.

[3]The legal 'Right to Buy' is a UK policy allowing tenants of councils (as well as of some housing associations) to buy the home in which they are living at a discount of currently up to £100 000 (Wilson, 2014). The policy was introduced through the 1980 Housing Act and it is estimated that about 1.5 million homes have been sold since.

[4]The Standard Assessment Procedure (SAP) is the UK government's method to assess and compare the energy performance of dwellings delivering a defined level of comfort and services. The assessment is based on estimates of annual energy consumption for the provision of space heating, domestic hot water, lighting and ventilation making standardized assumptions for occupancy and behaviour.

[5]These provide the interface to the heat distribution system in the apartment blocks, and a hot water storage cylinder.