Insights from inside the school walls: Contextual data crowdsourcing and feedback mechanisms for UK school stock modelling

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Abstract

The auto-generation of UK school building stock models could facilitate non-domestic carbon emissions tracking. However, contextual fabric and building service data are required to differentiate between asset or operational performance, and these may only be available in situ from building users. Engaging such groups through proposed data crowdsourcing would require robust feedback and data gathering mechanisms to be developed to overcome motivational and informational barriers.

This paper describes five stakeholder sessions and a crowdsourcing survey of 139 responses from London schools to better understand these two mechanisms. Aesthetics and budgetary drivers were found to be persistent amongst participants, with a diversity of views on achieving these in practice. This research should inform future data gathering and develop more updated and robust stock refurbishment datasets.

Keywords School buildings, stock modelling, crowdsourcing.

1.0 Introduction

1.1 The case for contextualisation in UK school stock modelling

Legislation to reduce net carbon emissions to zero in the UK by 2050 (1) has been enacted due to concerns about anthropogenic climate change (2). This legislation has driven an increased focus in identifying energy demand reduction by modelling the UK non-domestic building stock, responsible for around 18% of the UK's total annual emissions of 560 Mt CO_2 (3). The school sector, while accounting for only 3% of the total premises (4), comprises 10% of the non-domestic stock by floorspace, leading to greater impact of individual buildings within the stock. This, coupled with a greater proportion of publicly owned and controlled buildings (5) and greater standardisation of building design (6) and working environment (7) than other non-domestic sectors makes the school sector a suitable starting point for investigating energy models used to test reduction policies.

Until recently, models of the UK school stock were largely defined as either top-down (8) or bottom-up (9), providing respectively population level energy demand coverage and physics based modelling of individual systems separately. However the possibility of combining both to provide understanding of performance of individual building systems at a national scale has been developed through the SimStock method of autogenerating building physics models (10) at a sector or district level. SimStock utilises a Python library coupled with high performance computation to autogenerate thousands of input data files (idfs) for the EnergyPlus building simulation software by combining comprehensive national datasets of geometry from Ordnance Survey (11) with building age and condition data from the Department for Education's (DfE) Condition Data Collection (CDC) (12).

In order for SimStock to be capable of addressing individual root causes for underperformance, additional contextual fabric and building service datasets are necessary (13) within models, critical for differentiating between inefficient and high energy requirement buildings (14). Post occupancy evaluation (15,16), where coupled with sub-metered energy demand can provide contextual explanations for deviations from expected performance for a handful of buildings. However, the following difficulties in gathering and utilising such detailed individualised data across a larger sample of schools have been acknowledged:

a) To carry out a survey of 22,000 school buildings (12) is a formidable task, requiring a significant investment of capital (£36 million (17) for CDC).
b) In the 5 years taken to conduct the survey, the stock may have been upgraded or demolished for a significant proportion of schools.
c) In lieu of data on individual schools, the National Calculation Methodology (NCM) (18) provides a generic description of occupancy and building service schedules and setpoints. However applying these constraints uniformly across the stock provides no individual granularity on how these systems are operated in reality.

1.2 A proposed application of crowdsourcing for UK school stock models

The above limitations demonstrate a need to investigate alternative methods for gathering such contextual datasets. However, as operational rather than design phase datasets these may not be trivial to obtain since they lie outside the knowledge domain of the engineers and architects, responsible for initial building design. Hence, it falls to occupants of the buildings themselves to articulate these datasets, and in many cases occupants may lack knowledge of scope of modelling work and motivation to effectively contribute.

Data crowdsourcing (19) has been proposed as a potential means of bridging this knowledge gap (20), by providing contributors with access to co-created datasets. Within models of the built environment, data crowdsourcing has previously been utilised in applications of expert collaboration on building design (21), retro-fitting budget and task allocation (22), with applications in the operational phase to self-reporting measurements from non-expert residents on thermostat usage (23). While a similar approach has previously been used for contextual dataset gathering via the CarbonBuzz platform (24), this application was for skilled building professionals to collectively quantify the performance gap in their non-domestic projects. The application of un-skilled building users providing operational data for stock modelling requires a new framework to be developed.

Two key characteristics required to define a crowdsourcing framework (25) are what the crowd gets in return for volunteering (feedback) for what it has to provide (the contextual data). Specifically, this research addresses these two aspects of a proposed crowdsourcing method targeting school building users, through the following two research objectives:

a) Feedback – Determine drivers, questions, and data requirement for school building users to engage with energy performance at individual level.
b) Contextual data – Test overall efficacy of crowdsourced built form and fabric data contributed to by building users.

Geographically, London schools have been selected for this project, due to a pilot of the stock modelling approach SimStock (10) being targeted within the Greater London Authority.

2.0 Methodology

2.1 Methodology for feedback interviews

Semi-structured qualitative sessions on building energy performance have previously facilitated free-flowing discursive content from industry actors rather than directed dialogue (26), while maintaining a set of broad themes for analytic comparison between sessions. Case study research which actively pursues atypical cases rather than generalised cases has been utilised to ensure as diverse a set of viewpoints can be found (27) given the need to study a small sample in great detail. Hence 30-60 minute interviews covering a diverse rather than typical set of schools was proposed with audio recorded with head teachers and business managers at participating schools between November 2018 and November 2019.

The elements of Motivation, Opportunity and Ability Theory (28) were used to frame the following broad themes of how participants could engage with feedback information.

- Motivational factors - What are the priorities of stakeholder(s) who are interested in improving performance of the schools buildings for which they are responsible?
- Decision making opportunity - How would the stakeholder(s) use information from modelling to make decisions?
- Information requirements - What informational format(s) are most relevant to stakeholder(s) for assimilating into their own decision making processes?

Through bulk emailing within the London Borough of Camden and personal contacts in other London Boroughs, a set of 5 schools was curated representing a mix of different size, age groups, responsible bodies and building eras as shown in Table 1. Administration staff at the schools were responsible for recruiting interviewees, referred to collectively using the names Schools A-E although they represent individuals within those schools.

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School	Local authority	Age group	Responsible body	Building era	Capacity (students)
A	Camden	Primary	Local authority	1970s	210
B	Camden	Primary	Church of England	2012	236
C	Ealing	Primary	Local authority	2017	415
D	Ealing	Secondary	Independent Islamic	1984	620
E	Wandsworth	Secondary	Academy (Church of England)	2003	903

Table 1 – Summary of schools interviewed

The recordings of these questionnaires were transcribed and coded in the NVivo qualitative data analysis software, organised the above three elemental themes as well as accounting for discursive content.

2.2 Methodology for crowdsourcing questionnaire

The crowdsourcing questionnaire was laid out to form a progressively more detailed top-down narrative from buildings to sub-systems, but also with consideration for the types of analysis required to be carried out on the individual data categories to address the second research objective. Figure 1 gives a diagrammatic representation of these linkages between questionnaire layout and analysis type. In this report, commentary has been provided on each of the five highlighted aspects of the crowdsourced dataset in turn - the representativeness of the data provided, verification of the base geometry and fabric used in modelling, development of archetypes, validity of NCM assumptions and a summary of qualitative feedback received on usefulness of the form.

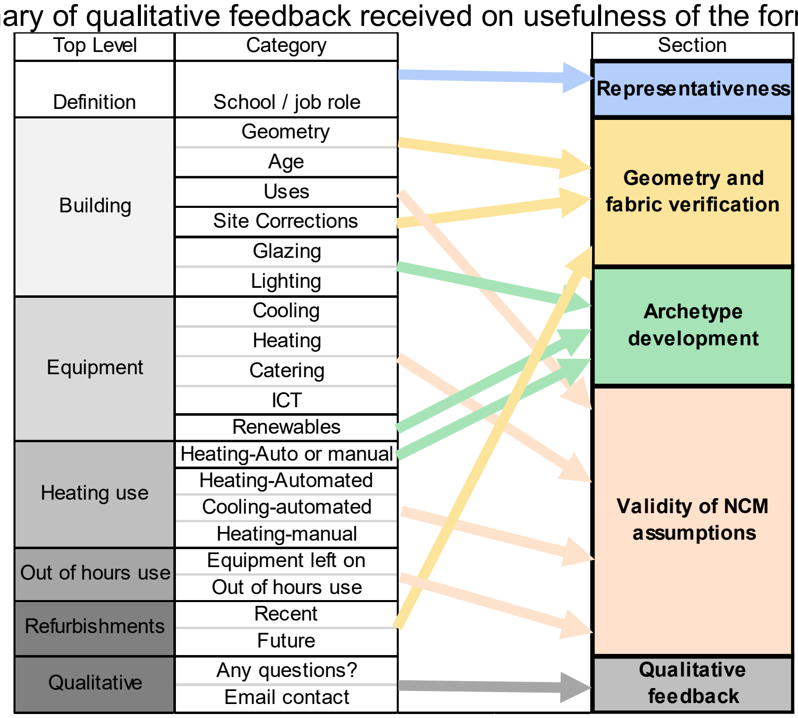


Figure 1 – Connectivity between questionnaire layout and analysis

In order to allow participants to refer to existing known infrastructure, it was intended, where possible, that individualised questionnaires could be provided with a diagram of the school site for reference to facilitate individual building descriptions for each school site. Individualisation is largely beneficial to the process of crowdsourcing since it allows an iterative picture of the school site to be developed, rather than the researcher just blindly asking for assistance. The SimStock methodology (10) had already been used to generate input data files for the EnergyPlus building simulation software for 1630 London school buildings. Subsequently, .jpeg images were successfully created by using the Ruby programming language to manipulate projections of these files created using the OpenStudio plug-in within the SketchUp building software. On individual inspection and comparison with Google Maps depictions of the school sites, it was found that 1244 of the schools had images which were representative. Therefore individualised questionnaires were constructed of those schools with numbered building layouts within the questionnaire as shown in Figure 2.

For creation and distribution, Google Forms was the most appropriate platform for the questionnaire based on the functionality of creating individualised questionnaires using Google Scripts to add images. Bulk emails were sent out inviting participants using the Getting information about schools database (https://get-information-schools.service.gov.uk/) to provide email contacts. These were sent in two batches, in July 2020 and March 2021, to account for unavailability of schools during different periods due to the Covid-19 pandemic and the time taken to process images used in the individualised questionnaires. Schools which had already responded or indicated that they were not able to respond in the first batch were excluded from the second batch.

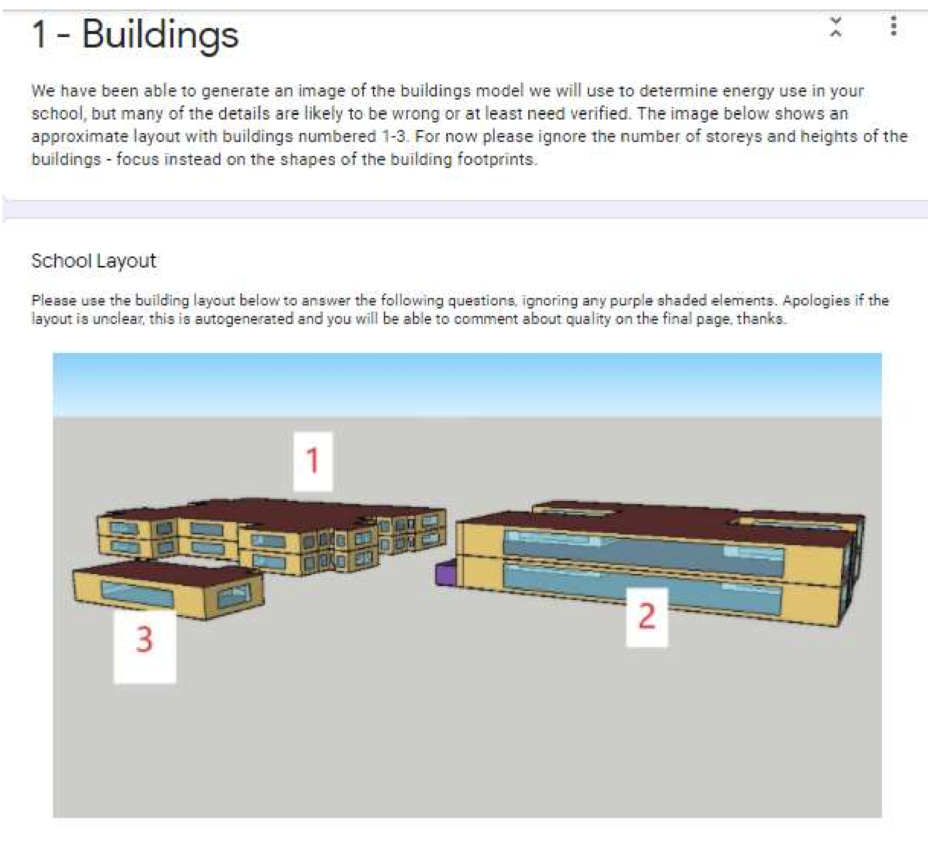


Figure 2 – Example of individualised questionnaire layout

Summary of the response rate by individual campaign is given below in Table 2, differing from overall rate from both campaigns which was 139 responses from 3213 schools (4.5%), after consolidating 3 sets of duplicates and 1 deliberately erroneous entry. However records were retained where different personnel had completed the same form (3 responses) or where the form had been completed months apart (1 response). It can be seen that there was a relatively low response rate in the first batch for the individualised questionnaires of close to 1% relative to the overall average of 2% per campaign. However this was compensated by an above average response rate of closer to 3% in from the larger set of individualised questionnaires included in the second batch.

Delivery date	Status	Generic	Individualised	Total
15th July 2020	Sent	2513	700	3213
	Received	58	8	66
	Response rate (%)	2.3%	1.1%	2.1%
16th March 2021	Sent	1907	1217	3124
	Received	41	32	73
	Response rate (%)	2.2%	2.6%	2.3%

Table 2 – Summary of crowdsourcing questionnaire distribution and responses

3.0 Results

3.1 Feedback mechanisms

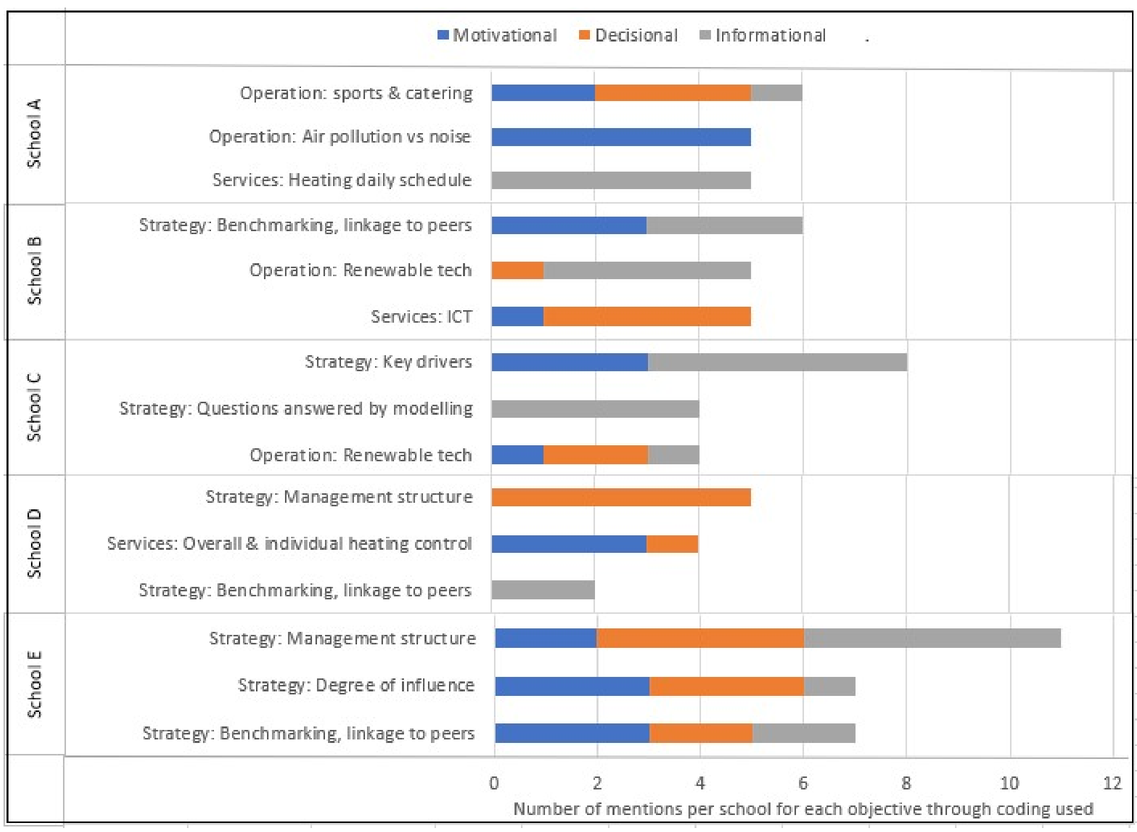


Figure 3 - Top 3 codes used by each school, colour coded by element

The coding analysis of the five interviews, as shown in Figure 3, revealed a couple of differences in the prevalence of motivational, decision or information requirements between schools:

- While the three primary schools' personnel (Schools A-C) spent most time talking about individual problematic bottom-up service and operational elements within their buildings, the secondary Schools D and E, operating with a degree of independence as independent and academy schools respectively, devoted more commentary to overarching top-down strategy.
- Schools with the older buildings (Schools A and D) were tilted more to future motivation and decision aspirations rather than current informational requirements of existing systems.

The rest of this section considers the case study schools together, moving from motivational requirements of feedback, through to current decisions being carried out and information needs. Since much of the discussion is budgetary, it is useful to briefly introduce the current complex network of UK school funding bodies and autonomy arrangements impacting interviewees:

- Refurbishment funding models:
  - Salix funding (29) is an arms length body set up by the DfE and other UK governmental bodies in 2004 to ensure public sector bodies have access to low interest loans for energy efficiency measures.
  - The Priority School Building Programme (PSBP) (30) has provided funding from DfE since 2014 for schools identified in need of urgent repair based on condition only.
- Pupil premium funding (31) was enacted as a means of lowering the attainment gap in areas of higher deprivation by providing direct additional funding to schools based on pupil numbers, free school meal requirements and status of parents in addition to core funding.
- Academies and Free Schools Programme (32) has established a programme of funding schools directly from Department for Education through academy trusts, independent of local authority control, to drive up standards. As of January 2018, 35% of the 21,538 state-funded schools in England were academies (33).

3.1.1 Motivational factors

Unsurprisingly, economic drivers were the primary focus of all five schools, with Schools A and C expressing trying to *"reduce expenditure"* from *"electricity budgets which are so tight"* to *"be able to spend money more… towards teaching and learning".* All schools reported issues with excessive utility bills (Schools A, B and C) and onerous maintenance contracts (Schools B, D and E). However in terms of secondary motivational factors on how to achieve this improved spending on curriculum, schools were split.

Based on social factors, School D, while further behind in intended renovations than other schools, spoke consistently of an *"utterly false dichotomy"* between economic and environmental factors and the need to be more ecologically sensitive. In contrast, School C's recently completed renovations had been motivated by the need for *"a slightly bigger space for pupils"* and School E mused that although it was *"slightly more efficient to have more pupils"* due to per pupil premiums increasing over fixed costs there is a loss of *"the culture and the ethos of the school… as you get bigger"*.

Consequently much of the schools' motivation on building performance is on aesthetics of the school site, improving attractiveness amongst prospective parents to optimise the use of the school site. Amongst interviewees, it was hoped that this, together with the drive to reduce operating costs mentioned in the previous paragraph, would positively correlate with externality improvements in comfort factors and energy efficiency which could also drive the attractiveness of the school.

3.1.2 Decision making opportunities

When asked about feedback required for making decisions, the primary school (A-C) interviewees devoted a considerable amount of time to control systems and identifying economic wastage, since large scale refurbishment decisions are delegated to the local authority or diocese. In school A, where the heating system was caretaker operated, the required feedback consisted of *"how much money would we save if it was turned off when the kids left than, say, 7 o'clock?".* School C, which had a dashboard for sub-metered data was keen to identify high usage individuals and *"getting them to switch stuff off!".* Both schools were keen to quantify energy use out of hours due to various groups using their facilities. Comfort was also of concern, with both Schools A and B reporting overheating issues and decisions about proactive (air conditioning in School B) or reactive (individual fans in School A) measures.

Moving towards larger-scale design of new technology, School B reported a worry about increased costs with their new ground source heat pumps since compared to boilers, it *"costs more money because we have to get it serviced"*. The Secondary School E also raised concerns about *"Trend air handling and heating"* systems *"way more complex than any school caretaker can understand".*

Strategically, as more independently run bodies, the secondary schools (D and E) expressed frustration at being limited to small projects through having to justify larger works to their respective budget holders. Extenuating factors preventing effective decision making identified by School E included budget uncertainty, overly broad executive roles for head teachers and current focus on energy efficiency and replacing rundown buildings. Their combined effects is leading to a lack of life cycle analysis in fixing rather than effectively maintaining items such as ageing boilers, not covered by PSBP (replacing rundown buildings) or Salix funding (energy efficiency measures).

3.1.3 Information requirements

Utility bills are the main source of information for all five schools currently with respect to individual energy performance, although this notably excludes comparison with peers within their responsible bodies which all five schools regarded as useful. Although there is some awareness of display energy certificates (DECs), all three primary schools had recent changes in terms of solar panels and new heat pumps and buildings which had led to some confusion on what was the current appropriate rating. The local authority model was touted by all 5 schools as a useful model for managing groups of 8-20 schools to retain knowledge and share performance metrics even to the extent that the individual academies Schools D and E are keen to recreate a similar model in order to best allocate resources for monitoring and analysing performance.

3.2 Analysis of crowdsourced datasets

As discussed in the methodology, this section has been split into five consecutive sections, providing examples of each type of analysis in turn.

3.2.1 Representativeness of data recorded

A breakdown of the 139 questionnaire responses for primary, secondary and other schools by local authority area in Figure 4 reveals that responses were received from all local authorities, varying from a 1.5-2% rate in Barking and Dagenham, Ealing, Wandsworth and Westminster to 7.5-10% in Barnet, Hammersmith and Fulham, Hounslow and Islington. The geographical distributions and relative disparity does not reveal any particular trends regarding likelihood of schools to respond, with primary and secondary school responses also generally well dispersed across local authorities.

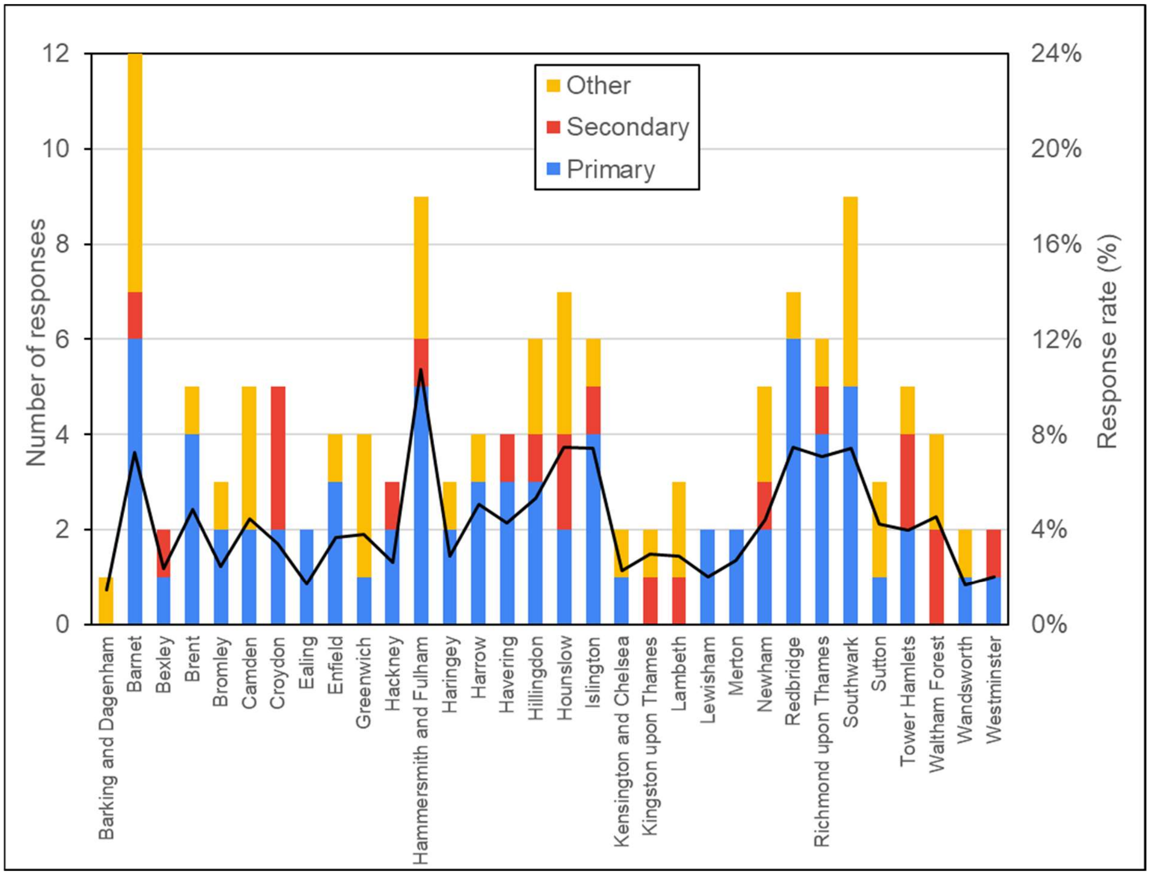


Figure 4 - Response rate by Local Authority area and phase

Respondents by personnel and the school types (based on the Getting information about schools database) are shown below in Figure 5. Of particular interest is that responses from head teachers (37%) and business managers (35%) are considerably more prevalent than facilities managers (16%). While the former two disciplines are likely to have an overarching responsibility of the school site, it was expected that with more of a direct responsibility, that facilities managers would have more of the cumulative knowledge regarding built form and building services required for this exercise. This may indicate a challenge in directly making contact with such personnel through a larger scale exercise or possibly a delegation of energy matters to the business and academic managers of the school. The response by school type indicates a fairly uniform response rate across the four main mainstream groupings of community (or local authority), academy, voluntary (typically diocese run) and independent. 9 out of the 38 pupil referral units in London represents an abnormally high response rate of 23.7% for which there is no obvious explanation.

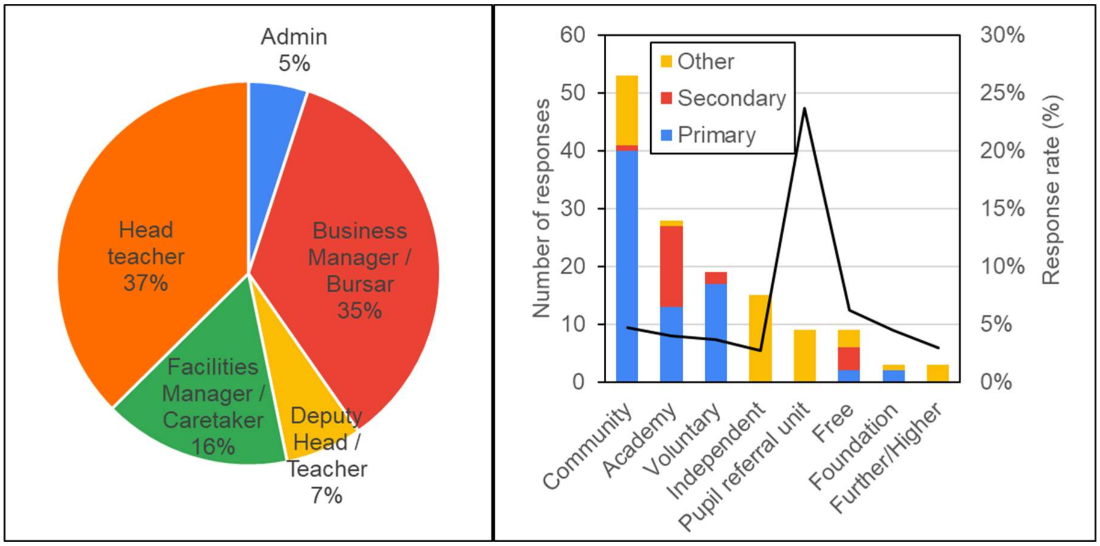


Figure 5 - Breakdown of respondents by job title and school type

3.2.2 Geometry and fabric verification

In order to evaluate how up-to-date recent data captured by the Condition Data Collection is likely to be, all questionnaires provided the opportunity for building users to describe recent (previous 5 years) as well as future (following 5 years) refurbishments. In addition the 39 responses provided for buildings where models have been constructed allowed users to feedback their own evaluations of diagrammatic school layout, geometry and fabric age provided for various buildings.

Refurbishments within the questionnaire have been categorised as follows:

- Large scale - construction of a new building, extension or upgrade
- Medium scale – upgrade/improvement in insulation/glazing/renewables
- Small scale – upgrade in existing services – boiler, lighting, ITC, ovens

Table 3 - Percentage of schools with recent and planned refurbishments

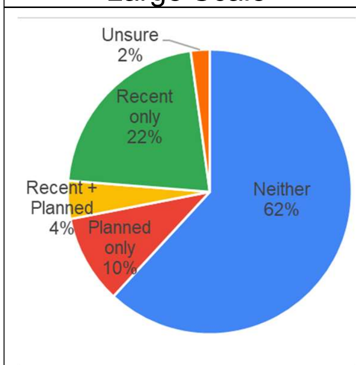
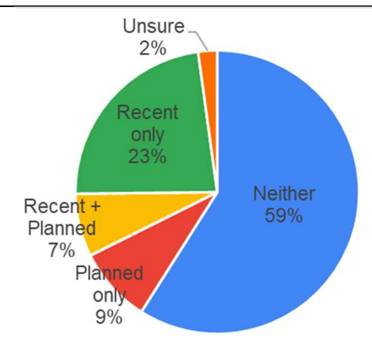
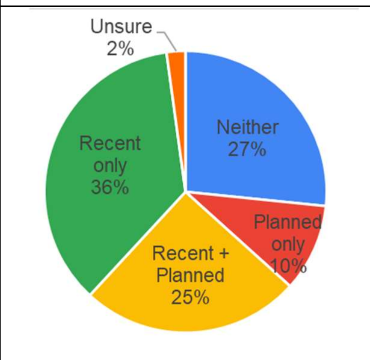
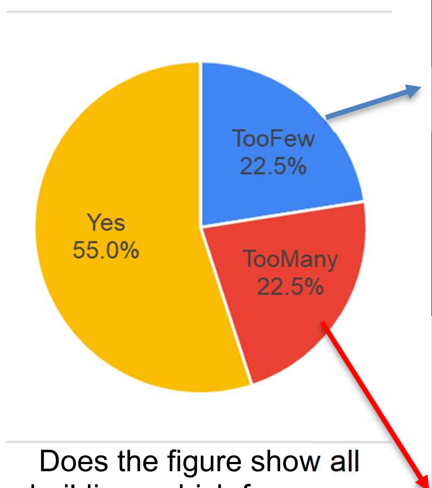
Large Scale	Medium scale	Small scale
		
Examples: New building – 46.4% Refurbishment of existing building – 31.9% Extension – 21.8%	Examples: Double glazing – 45.0% Roof insulation – 22.5% Solar panels – 16.2% Heat pump – 9.9% Wall cavity – 6.3%	Examples: LED installation – 23.6% ITC upgrade – 20.2% Radiator upgrade – 12.3% Heating upgrade – 10.0% Catering upgrade – 9.8% Other – 24.0%

Table 3 gives the percentage of schools which have indicated such works have been or will be completed recently or in the near future, together with some examples. At least one third of schools will have completed works within a decade which update significantly the built form of schools (large scale refurbishment) and 40% will update fabric (medium scale). More than two thirds will make changes which although smaller scale could significantly update assumptions on heating or electric load of the building in operation.

Table 4 - User commentary on school layout in individualised questionnaires

<table>
<tr><th rowspan="5">

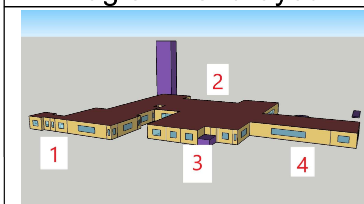
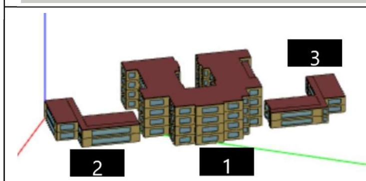
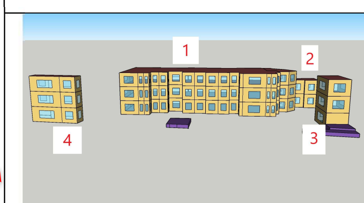
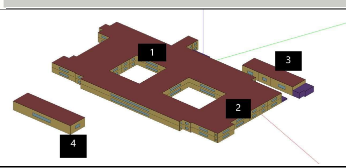
Does the figure show all buildings which form your school's campus?</th><th>Diagrammatic layout</th><th>Response</th></tr>
<tr><td>
</td><td>"Separate external building (prefab) – 1 floor, teaching/other, 40 m^2 erected approx. 2010 To the right of building 4 - across the playground"</td></tr>
<tr><td>
</td><td>"Building 4, 3 floors, 20-40%, 1919-1945, 1200m^2, Teaching, Catering East of building 1 i.e. in front of building 1 in the given diagram"</td></tr>
<tr><td>
</td><td>"2 - Premises manager house. 4 -Outside storage. 3 - Outside building not in use"</td></tr>
<tr><td>
</td><td>"Building 3 was demolished in 2015. Building 1 & 2 are the same building"</td></tr>
</table>

Table 4 shows that from the 40 individualised responses, 9 reported additional buildings were shown in the model representation of their school campus generated by SimStock and another 9 reported buildings which no longer formed part of the campus. As can be seen from both sets of sample responses, this commentary mostly reflected changes in the past decade, inclusion of nearby buildings or exclusion of auxiliary buildings such as accommodation on site. However it demonstrates that in many cases, building users could be influential in correcting site layouts derived from national level datasets to improve model accuracy.

3.2.3 Archetype development

It has been previously possible to develop archetypes of the school stock by building age by collating sets of constructions with representative heat transfer and capacity characteristics (34), indicative of an era. However in order to better understand whether it is possible to expand existing archetypes to integrate additional features, it is necessary to dig into era at building level (361 total records from 139 schools) to find where relationships exist with other parameters in the dataset such as geometry, glazing, lighting, renewables and heating controls.

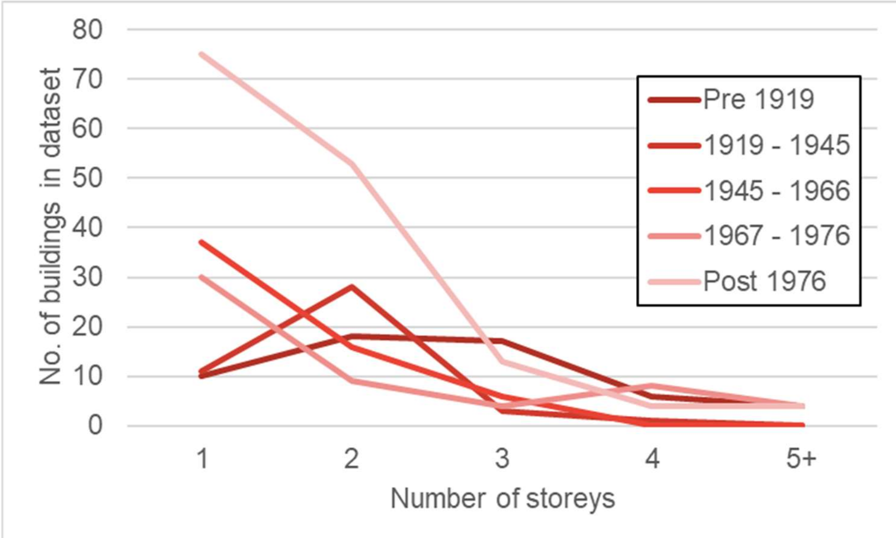


Figure 6 - Number of storeys for different era buildings

Figure 6 demonstrates that within the crowdsourced data, the oldest Pre-1919 buildings are most likely to be 2-3 storey, the majority of inter war buildings are 2 storey with over half of post-war buildings consisting of 1 storey. This could form the future basis of further adjustments to existing archetypes used in stock modelling or the creation of new archetypes to include features such as glazing and heating controls, which appear to have no correlation with current archetypes limited to building era.

3.2.4 Validity of NCM Assumptions

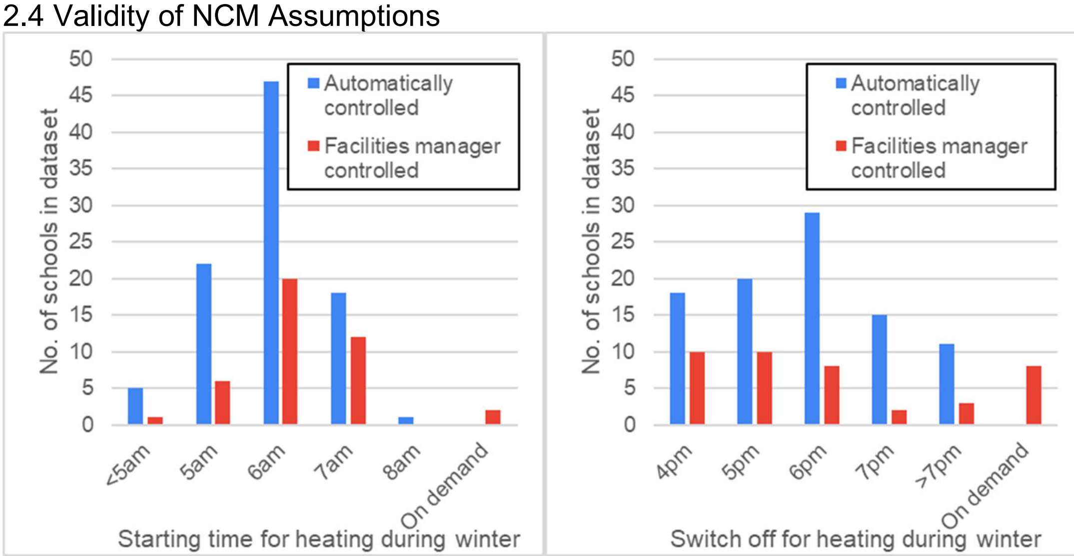


Figure 7 - Winter heating on and off times

Currently, NCM assumptions provide operations of building services within stock modelling. However the degree of variation in perceived building operation have been demonstrated through the questionnaire results. Figure 7 demonstrates one such variation from the 5am-6pm heating pattern heating availability in the NCM, with schools with a more pronounced morning peak in switch on time of heating around 6am than in the evening. Differences between automated and caretaker operated controls may also need consideration in future iterations of SimStock as different switching off patterns may exist in reality.

3.2.5 Qualitative feedback from participants

Building users had the opportunity to submit general energy use/refurbishment concerns (38 responses) and suggested improvements to the form (11 responses). The vast majority (>80%) of refurbishment concerns related to resource constraints preventing replacement or refurbishment of aging fabric and systems which the form did not ask for. Suggested improvements to the form involved three main themes:

- 6 responses on the distinction between planned works (asked for) and required improvements (omitted)
  - *"DFE should ask what needs to be improved rather than what is planned."*
  - *"Schools just don't have the money to install heat pumps"*
- 3 responses on adding "I don't know" for thermostat settings
  - *"It would be almost impossible for a bursar to answer some of the technical details and equally impossible for the site manager to answer others… you should look at splitting the form into two - one aimed at Head/Bursar and one at Site Manager."*
- 2 responses on the need to be able to enter multiple answers for refurbishments – in order to allow these to refer to individual buildings rather than generally, this functionality had been lost within the form.
  - *"Some of the medium and smaller works cannot be ticked as the question allows only 1 answer ie. double glazing and roof cavity insulation"*

A couple of schools contacted the researcher by email regarding the appropriateness of the existing form for describing their school site:

- A mixed Community Special School in West London reported that since they share 2 sites with a mainstream academy and do not control those buildings, it is challenging to differentiate individual uses of infrastructure and building services.
- The Head of Safety, Energy and Compliance at a large independent boarding school responded with an explanation that the school estate consisted of *"boarding houses, academic buildings, ancillary buildings, residential and sports facilities*" meaning that it was "*not possible to complete* (the form*) in its current form as our estate differs significantly* (to the format of the form)".

These comments raise the question about different arrangements for overall responsibility and control for prioritising and improving energy demand for shared or independently operated sites. While these school sites are likely to be the exception rather than the rule, with therapeutic treatments (for SEN schools) and larger sites (for independent school) they may be more substantial when the stock is defined by energy demand and floorspace.

3.3 Discussion

3.3.1 Implications for feedback mechanisms

The coding for the five interview sessions demonstrated that smaller primary schools (A-C) delegating larger refurbishments to local authorities or diocese are likely to view building services in a segmented, bottom-up manner. By contrast, larger, more independent secondaries (D-E) having a top-down approach of evaluating refurbishment needs for which they have greater control. Schools B,C and E, which were further ahead with refurbishment works, were able to express specific data requirements around modelling, since billing and DECs currently provide insufficient insight for schools to justify, after identifying, improvements. Subsequently, a number of opportunities to provide feedback through modelling have been identified:

- Lifecycle costs of replacing ageing equipment, justifying maintenance spend.
- The need for proactive or reactive measures to tackle overheating
- Out of hours energy billing of third parties using school premises
- Identifying wastage through global and individual heating controls .

3.3.2 Implications for contextual data gathering mechanisms

In terms of representativeness, it is clear that a wide variety of school and employee types have been reached via the questionnaire across all London Boroughs. However it is unclear whether the responding schools are representative in terms of their energy activism and may represent sampling bias, in wishing to respond to queries ostensibly about energy demand and climate change. Future analysis could include more sophisticated categorisation of the stock through Ofsted rating, or a similar metric which could be indicative of how efficiently the school is operated.

The questionnaire indicated a need to upgrade of fabric within models from large and medium scale changes affecting around a third of schools every decade. More importantly, many of the 40 responses to the individualised questionnaires have demonstrated that building users can articulate corrections to premises diagrams generated by such models directly. The smaller scale changes in building services affecting around 70% of schools could globally affect the NCM assumptions within the model over time due to frequency of turnover.

Improvements to modelling could entail the expansion of existing archetypes; although the variation of number of storeys across different eras has been demonstrated, other features such as glazing or lighting systems do not appear to correlate with existing archetypes. However there are preliminary indications from comparison with NCM assumptions that automated and manually operated control systems could require distinct archetypal approaches for hours of heating.

In terms of the crowdsourcing format, qualitative feedback has emphasised the need to capture required as well as recent and planned improvements denoting potential in addition to current performance of stock. In addition a need to delineate clearly where head teachers or site managers would be expected to contribute different data streams and site issues with SEN and independent school have been identified.

3.3.3 Future work

The involvement of responsible bodies such as local authorities, diocese groups and academy trusts is critical to the success of future gathering efforts, as evidenced by primary schools delegating responsibilities to these groups. Such efforts could increase flexibility for users to articulate desired as well as planned changes in fabric and wider range of refurbishment options, although outputs must also account for the inclusion of outputs within a stock modelling template.

The next step of this work is the analysis of building service data provided within the crowdsourcing responses against the validity of NCM assumptions. This analysis could be used to improve the identification of operational rather than asset underperformance within individual buildings or sectors of the stock.

4.0 Conclusions

This research has demonstrated that future UK school crowdsourcing exercises could supplement geometry and metered datasets with individual contextual datasets, leading to improved predictability of stock models, assuming feedback and data gathering mechanisms are designed appropriately.

The feedback mechanisms derived from the five stakeholder sessions indicate that while attractiveness of the school site is a key driver to boosting curriculum spend, schools are motivated to track comfort and energy wastage externalities as improvements are made. Decisions being made are largely around the lifecycle analysis of degrading but not broken heating systems and fabric, constrained by existing funding, with suitable informational feedback providing the justification for maintenance and investment. Changes in these constraints are likely due to increasing concerns regarding overheating and air quality, hence should be viewed as dynamic dependent on funding mechanisms for maintenance and energy management.

The 139 crowdsourcing responses have demonstrated that it has been possible to gather representative data from around 5% of schools across London, including getting respondents to correct errors in SimStock inputs for individualised questionnaires. While there is a need to update fabric datasets due to one third of schools reporting significant scale of works within 5 years, the need for other planned but unfunded works needs to be captured. Potential augmentations to current archetypes to include number of storeys have been proposed including a need to track technological changes in overheating prevention and comfort issues which may affect future iterations of the NCM. Future improvements to the form to better account for job role, required rather than planned improvements and SEN schools and independents which may have complex site issues to resolve.

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