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UK Energy Lab:
Feasibility Study Final Report

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Annex G – Non-domestic settings

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1. Summary

Throughout the consultations conducted during the UK Energy Lab Feasibility Study it has been universally recognised across both government and academia that understanding energy consumption in non-domestic settings was important, but design and surveying methods for socio-technical analysis in this area are much less developed than for domestic settings, and that the logistics involved in trying to construct a National scale survey of non-domestic settings outweigh the potential benefits at present.

It is therefore recommended that non-domestic buildings not be included in the UK Energy Lab study at this stage. It is recommended that this is kept under review, and that if the challenges around identifying appropriate units of analysis and sampling frames can be overcome, that consideration be given to introducing a non-domestic buildings component to the UK Energy Lab survey focused on particular sub-sectors of the stock where data on such sub-sectors would clearly be complementary to the analysis of energy consumption in homes.

This report provides no specific recommendations on which sub-sectors these may be, as despite considerable discussion no clear rationale for inclusion of any subsectors could be identified. Additionally, we also considered that for the foreseeable future the focus of national scale non-domestic settings energy surveys should be on addressing the primary methodological issues of identifying suitable units of analysis and sampling frames.

Of the emerging units of analysis that may potentially be applicable to national scale surveys of the non-domestic building stock, the concept of the "Self-Contained Unit" (SCU) was regarded as the most promising. Work in this area is still developing and requires further time before it could realistically be deployed as a unit of analysis at the national scale. However, in view of the proposed time frame for UK Energy Lab, the SCU method is likely to be ready, for England and Wales, by the start of UK Energy Lab. In this context it was also noted that the Building Energy Efficiency Survey (BEES) had recently been commissioned and would provide additional data in this regard in the short term.

2. Aim

This work-package assesses the value of different research designs for the non-domestic building stock with a particular emphasis on stratification, sampling within strata, and the role of clustering to deliver specific policy outcomes of interest such as feasibility of heat networks in urban areas. The linking of non-domestic and domestic components of the survey will also be addressed.

3. Work undertaken

The Work Package was undertaken through a mixture of internal workshops and literature reviews and by drawing on the existing expertise of the team. Input was also taken from Work Package 1 on the Benefit Case form the policymaker and academic workshops. Considerable discussions were undertaken on which elements of the non-domestic building stock could prove most useful for joint analysis with domestic building data.

- A number of meetings have been held to discuss issues of challenges and opportunities of including non-domestic buildings within the UK Energy Lab.
- A presentation and CEE internal workshop was given to raise understanding and provide a forum for discussion of non-domestic stock data issues across the UK Energy Lab teams.
- Two background papers have been produced. The first, a brief gap analysis of important data currently missing from our non-domestic stock knowledge and modelling. This highlighted areas of potential application of a longitudinal panel survey of non-domestic buildings. The second, a more substantial background paper on the issues regarding surveying the non-domestic stock and potential sample frames. Both of these are summarized into this Annex.

4. Background

a. International best practice in non-domestic building stock surveying

Internationally, the only established survey of the non-domestic building stock is the Commercial Buildings Energy Consumption Survey (CBECS) run by the US Energy Information Administration[1]. This survey differs in important respects to that proposed in the UK Energy Lab. The three most significant of these are that the CBECS is an incomplete representation of the non-domestic building stock, in that it does not include energy consumed in industrial or agricultural buildings; that CBECS is repeat cross-sectional rather than longitudinal; and that the CBECS uses buildings as its unit of analysis. This last point is significant, as buildings make more sense as a unit of analysis in the US than they do in the UK. The US non-domestic building stock is significantly less diverse in terms of age, construction type, and contiguity (the extent to which buildings are physically abutting each other) than the UK stock. The UK's older, more diverse and more conjoined stock makes use of buildings as a unit of analysis more problematic. Additionally, as discussed below under sampling, buildings are not a particularly useful unit on which to enact policies and programmes, as the scope for enacting measures in the non-domestic stock lies more at the premises or hereditament level where operational control over energy consumption decision making lies.

[1] See: http://www.eia.gov/consumption/commercial/

It is also noteworthy that the US Energy Information Administration chooses to conduct its surveys of the domestic stock (RECS) and the non-domestic stock (CBECS), independently, as they are methodologically distinct and independent pieces of research.

Unlike in the UK, where we have the Valuation Office Agency non-domestic premises database, in the US there is currently no existing comprehensive central database of US commercial buildings. In order to construct a sample frame the EIA identifies what it classes as statistically representative geographic areas. EIA staff then survey all buildings within these representative areas. This technique is called multi-stage area probability sampling. This is then augmented through the inclusion of a number of different non-domestic sampling frames[2].

Methodologically, the CBECS sample frame is constructed through conducting physical surveys of "representative" contiguous geographic areas of the non-domestic stock. This is followed by telephone or face-to-face interviews to get data on vectors and quantities of energy consumed directly from building occupiers, where these data are available. Where these data are not available, an Energy Supplier Survey is conducted directly with the energy providers for that building to gather data on the quantity and vectors of energy provided.

The statistical methods used to conduct the CBECS survey are currently being revised in accordance with guidelines from the US National Academies' February 2012 study on Effective Tracking of Building Energy Use: Improving the Commercial Buildings and Residential Energy Consumption Surveys[3].

In summary, while the statistical methods underlying the CBECS represent best practice in constructing a nationally representative sample of non-domestic buildings, they do not address the issues arising from the conflicts between the varying potential units of analysis for surveying the non-domestic stock, particularly in the UK. There is also currently no linkage between the CBECS and RECS surveys conducted by the US Energy Information Administration.

b. Costs of surveys

The first ever campaign of surveys of energy use in UK non-domestic buildings was carried out in the 1990s by teams at the Open University (OU) and Sheffield Hallam University (SHU)[4]. These surveys sampled (although rather unevenly) the entire non-domestic stock, other than military and agricultural buildings. The SHU team made site audits of some 1000 premises, and obtained complete data sets including annual energy consumption figures for around 700 premises. These audits involved visiting every room in each premises and recording the numbers and types of every piece of energy-using equipment, with its power rating and an estimate of the hours of use.

[2] The process is detailed and moderately complicated and is described in detail here: http://www.eia.gov/consumption/commercial/2012-cbecs-building-sampling.cfm

[3] See: http://www.nap.edu/catalog.php?record_id=13360

[4] See: http://www.environment-and-planning.com/epb/fulltext/b27/b2573.pdf

The surveyors were trained building scientists. Small, simple premises might be surveyed in a day, but large premises could take several days. In addition there was preparatory work making contacts and appointments, and time spent processing and analysing the data afterwards. The survey programme stretched over a decade, and cost several million pounds. Additional data on built form, construction materials, structural systems, glazing, building age and so on were collected by the OU team.

c. Overlaps with other survey work

Last year DECC initiated a new project to update the 'evidence base' on non-domestic buildings, with a pilot survey of premises in the food retail sector. And this year, the programme is being extended to the remainder of the stock, in DECC's Building Energy Efficiency Survey (BEES) project[5]. The costs of the work are again in the millions, but the programme will still not match the numbers of audits carried out by SHU in the 1990s. A sample of some 10,000 hereditaments[6]/premises has been drawn from the Valuation Office Agency Rating List[7] and other databases. The initial plan, in order to limit costs, was to subject the majority of these to telephone interviews, with follow-up questionnaires administered online or by post. Only some 250 site audits were planned. Even in the planning stages, questions had been raised about the quality and extent of information that might be gained just from telephone interviews, and these doubts seem to have been borne out raising questions about the efficacy of this survey mode in the non-domestic stock.

[5] See: https://www.gov.uk/government/collections/non-domestic-buildings-energy-use-project
[6] A 'hereditament' is the term used by the UK Valuation Office Agency as the base unit of valuation, it is broadly comparable to the more widely used term 'premises'.
[7] See: http://www.2010.voa.gov.uk/rli/static/HelpPages/English/help/help153-central_rating_list.html

5. Discussion of potential non-domestic sub-sectors for surveying

The following areas were considered as potential specific aspects, or sub-sectors, of the non-domestic stock to include within the UK Energy Lab survey.

Current benchmarking systems do not make an appropriate distinction between energy used for the performance of activities (appliance energy use) and energy used by heating, ventilation and air-conditioning systems to manage the internal environment that enables the effective performance of activities. For example, the use of computers in an office activity environment is not part of the operation of the building in which the office activity takes place. In effect, the use of computers is no different from the use of electric welding equipment in a factory and is thus a component of energy used for the activity, or process, carried out in the premises/building. Building simulations generally include a great deal of detail about building dimensions, fabric and other building demographic factors, but usually rely upon default values for internal gains resulting from activities inside the building. It is, however, the appliances that are used to perform activities (and may thus be considered to be the activity) that change most frequently. This means that more information on equipment used for activities is required and suitable time series data collection would enable the analysis of how and why change occurs. The collection of energy use data for the individuals/organisations and premises/buildings over the same period should then allow analyses to identify how changes in energy-using equipment impact overall energy use for each unit of analysis, be it the individual/organisation or premises/building. In turn, this information may be used to inform the building simulation models and help close the gap in building energy performance. Such information would also prove valuable in the operation of the Simplified Building Energy Model (SBEM) upon which Energy Performance Certificates (EPCs) and Building Regulations Part L2 are based.

While surveying appliance use energy would fill a useful gap in the knowledge with respect to end uses of energy within the non-domestic building stock, it would only be of use in the context of a more comprehensive knowledge of energy consumed within the stock as a whole. Making use of this information would require being able to map this appliance energy consumption data into existing models of the non-domestic building stock. As the gathering of better data on appliance energy use would be in line with DECC's recently acquired responsibilities for appliance energy use data gathering, it was felt that this would be best addressed through an independent survey mechanism, as there was no clear synergy with the gathering of data on the domestic building stock.

In an industrial setting, the energy use of process equipment has particular relevance to the potential capture of waste heat for use in other activities. Understanding where, how and when usable waste heat is produced would be of interest with regard to the development/operation of heat networks and the potential reduction of costs for businesses and households.

While there is a synergy between the production of waste heat in industrial settings and the inclusion of that waste heat within heat networks for domestic buildings, the practicalities of doing this are heavily dependent upon the geographic location of the industrial heat source and the residential heat demand. Mapping this resource onto this demand is something that would be best achieved within a Geographic Information System (GIS) framework that covered sources of heat and demands for heat across the UK. This is an entirely separate framework to the stratified clustered random sample of households proposed for the UK Energy Lab. This work would be better conducted through lower super output area[8] (LSOA) level GIS modelling of heat sources and demands across the UK. However, NEED has the potential to identify sources of heat, and areas of demand, at granularities finer than LSOA level, in England and Wales.

In addition, there is no easy way to construct a sampling frame for heat producing industrial processes and buildings in order to get a reasonably national representative picture of the level of the resource available. For these reasons it was felt that, while this information would be of benefit for those looking at the construction of the networks, that this work could be conducted effectively independently of the UK Energy Lab project and its inclusion would adversely affect the research design for the project.

Little is known of temperatures in non-domestic buildings/premises beyond offices, schools and, to a lesser extent retail. For energy models, there is a general reliance on the assumption that the occupants of buildings maintain their environments in accordance with design guidance. However, evidence from comparisons of Energy Performance Certificates (EPCs) and actual operational energy use indicate that an EPC is not a reliable indication of energy use in offices. Here it should be considered that historically offices have been the subject of the bulk of energy performance research, but account for less than 16% of the total floor area of the non-domestic building stock. Very little is known about two premises types that respectively account for 28% and 31% of the floorspace of the stock, namely factories and warehouses.

It was felt that monitoring temperatures in factories and warehouses may provide interesting and useful information about the provision of thermally suitable workspaces for employees, but that the law in this area was ambiguous in terms of the areas required to satisfy employee comfort. In addition, recording temperatures without recording other information about the buildings, such as whether the heat was provided from waste heat processes, and details on the physical form and fabric of the spaces being heated, would be difficult to interpret. For these reasons, along with the difficulties of identifying suitable sampling frames, it was decided that gathering these data alone would not add sufficient significant value. But, gathering these data, together with other salient information, would likely provide useful

[8] See: http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/super-output-areas--soas-/index.html

inputs to energy scenario models and policy decisions, especially those relevant to a shift from fossil fuel-based heating systems to electric systems.

A longitudinal study of operating temperatures within non-domestic buildings would enable us to better understand how businesses manage their energy use and how, in particular, they react to changes in the weather, in terms of maintenance of working conditions that are acceptable to those businesses. Even a year's data would be valuable, but longer term data would provide a better evidence base for modelling how the energy performance of businesses might change over time, due to changes in the focus of their activities (which would affect equipment) and changes in weather patterns. This evidence base could then inform both technical aspects and the policy of interventions, especially with regard to heat networks and suchlike. At the same time as the installation of temperature sensors, a brief survey of the physical characteristics of the premises/building and energy-using equipment, could be achieved. Subsequent visits to maintain sensors could also include a follow-up survey of changes to the building, the equipment it contains and changes to operating behaviour.

Similarly to above, a longitudinal study of operating temperatures within the non-domestic building stock was regarded as valuable, but in the absence of reasonably comprehensive data about other aspects of the stock it was felt not to add sufficient value given the expense and complexity of gathering this data.

Consideration was given to the inclusion of sub-sectors of the non-domestic building stock such as high-street shops with dwellings above. While gathering data on such premises would potentially provide information about heat flows between the dwellings and the shops, the benefit of this information was considered limited as the temperature differentials between them were thought unlikely to be significantly greater between vertically contiguous dwellings such as flats. While it was considered that some small business owners may live directly above the premises, and thus some information would be gathered about people's relationship between their place of residence in their place of work, this was likely to be in a very small minority of cases and the data would be difficult to interpret in the absence of other data about the relationship between people's dwelling and people's workplace. In the absence of a stronger rationale for the inclusion of this non-domestic sub-sector it was considered that its inclusion could not be justified.

a. Risks and challenges of sampling in the non-domestic building stock

The non-domestic building stock is recognised as posing major challenges for the construct and conduct of any form of representative sample. The authors have long experience in this field and have identified a range of key issues that make attempting a national survey of non-domestic buildings at this time premature. These are summarised below.

b. Sampling Options

Options for sampling include: premises or hereditaments; activities; self-contained units (SCUs) and occupants, i.e. institutions and businesses.

Premises or hereditaments
The more straightforward of these options is to sample hereditaments. A sample can be drawn from the VOA's Rating List, which covers all 1.8 million rated hereditaments in England and Wales. The majority (~90%) of these are also in the VOA's Summary Valuation (SMV) database. A sample of hereditaments for the panel survey would make it possible to follow building-related changes affecting energy consumption: extensions and demolitions, refurbishments, changes of use, improvements to fabric and systems, changes of fuels used etc.

Activities
The VOA has a complex but useful system of classification that can allow a sample to be drawn on the basis of activities. The SMV contains floor area data that would allow such a sample to be stratified (for the most part) by size of hereditament. Data on non-rated types could be assembled from a variety of other sources. This would not, however, constitute a sample of 'buildings'.

Self-contained units (SCUs)
A group at the UCL Energy Institute is currently working on a new model of the non-domestic stock, that will put hereditaments together into 'self-contained units', which are well-defined spatial units that are largely something like (but not exactly the same as) 'buildings'. These will have data attached on geometry (volume, surface area, plan depth) and on age, materials and construction. Activities defined at the hereditament level will be broken down by floor level and by sub-activities (office work, sales area, kitchen, storage, plant rooms etc.) The methods are being piloted on the London Borough of Camden. When this model is extended to England and Wales, then a sample of self-contained units could be drawn, on multiple criteria. But it may be some time before that is possible, though it may be achieved within a year or so.

Occupants
Sampling occupants would, in principle, be appropriate for following changes in business and institutional practices, behavioural changes, management issues, and the use of movable power-consuming equipment. Sampling based on occupants, however, presents significant challenges, as it is not clear how such a sample could be drawn. A hereditament sample would not be (or would only be weakly) appropriate in this context. There are commercial databases of businesses in the UK, such as those produced by Experian or the German company Faust. But these would appear to be seriously incomplete, and/or badly organised. Perhaps data on businesses from the Office of National Statistics might be used, although these too would not be comprehensive and would not cover non-commercial organisations and institutions. Beyond this, there is the question of how to get from organisations/businesses to the premises they occupy. This is not at all straightforward.

The Experian database links businesses to 'sites', but the Experian data are far from comprehensive, and we are not aware of any systematic attempt to test the reliability of these links. In any case, 'sites' would not necessarily equate to either premises or 'buildings'. DECC have tried to match Experian data to the VOA Rating List and SMV, but with very limited success. Even were it possible to match a sample of hereditaments to occupiers, by addresses, at the start of a panel survey, there would remain the problem of following the occupiers as they moved. In the retail, office and industrial sectors there can be rapid rates of turnover. Companies can expand, contract or amalgamate; and they may move premises regularly in order to do so. It is not straightforward to follow such changes as the survey evolves. It would be necessary to find a company's new premises at every stage, and make surveys of them.

c. Sampling limitations and sizes

The VOA data are geographically constrained to cover England and Wales only. Commercial rating is handled separately in Scotland and Northern Ireland. For this reason all models of energy use in the British non-domestic stock constructed to date have covered only England and Wales, or been pro-rated on population to include Scotland.

There is no possibility at present of sampling by characteristics such as age, construction system, building fabric, servicing systems etc.

On account of the heterogeneity of the stock, a representative sample needs to be very large to cover a range of sizes of premises for every type of activity. Should a sample be somehow stratified on the basis of further characteristics it would have to be yet larger. Arguably the SHU sample of 1000 was too small to be representative, especially in the industrial sectors. The main report for the feasibility study of the UK Energy Lab arrived at a minimum sample size of 10,000 on the basis of statistical arguments about representativeness, given the need for various breaks across different types of homes and so on. Thus the sample for non-domestic is likely to be large, even though the number of premises is somewhat smaller than the number of homes in the UK.

d. Additional challenges for non-domestic surveying

Responsibility for, and control of, non-domestic premises is complicated by the fact that in many cases the manager or owner or director will not be found at the property in question. While they frequently are in certain institutions like schools, small businesses and independent shops, it is not the case for larger businesses, shop chains, or major public sector organisations, these responsibilities may not lie with any individual on site, and surveyors will instead have first to make contact with and seek information from head offices, or from national bodies like the National Health Service, Ministry of Defence or the Civil Service. It may be that only the head office keeps records of energy consumption or equipment installed; and in any case, permission to make surveys will need to be sought at high levels in these hierarchies.

However, the BEES project indicates that these data access constraints can often be overcome.