Easy-to-adopt lessons for organisers of large scale energy consumption studies in households

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Abstract

Most authorities need to establish the types of data that can only be produced from household studies but are put off from commissioning them due to their anticipated cost and complexity. This paper demystifies these complexities and demonstrates a successful management structure that can be confidently adopted by any authority planning to commission such studies in future.

A study monitoring some consumer behaviour and the electricity consumption of all the domestic appliances in 250 households was completed in England in 2012. The results of the initial analyses and, uniquely, the entire 8 Gb database have already been made publically available. Although this presentation will pick some headlines from the findings, its main theme is to identify the key features of the design and management processes that enabled this huge and complex research programme to be completed as specified, on time and on budget.

Introduction

There have been many small scale studies of energy consumption in households but few have been attempted on a national basis. Whilst the 250 households study reported here may seem large by comparison it is still small when compared to the 26 million total of households in the UK. (Note that the households monitored in this Study were all in England.)

The Study was commissioned by the authorities responsible for energy consumption and climate change policy in the UK. It was focussed on the consumption of electricity as additionally monitoring the consumption of gas and water would have more than doubled the cost of the planned programme.

There were two main needs that the study had to satisfy; one was identify what electrical products made the main contributions to consumption during the peak energy demand periods which, for the UK, occur during the coldest days of the winter. The other was to more reliably establish the average consumption for each of the major energy consuming products in domestic households. This data was needed for consumption projection modelling which, in the absence of any better data, would otherwise need to be based on assumptions about consumption patterns or on consumption data established in trials comprising just a few households. And, since the data from this study typically showed variations between the lowest and highest consuming households of some 500 % for many of the different product types, it is clear that small scale household trials can yield very unreliable data due to the huge variation of household size, affluence and living patterns.

The purpose of this paper is not to discuss or share some of the findings of the study, remarkable though they were. Links to the reports of the findings are given at the end of this document. The purpose is to provide details of how this study was managed, what skills were needed to deliver it and what lessons were learnt that can be passed onto those undertaking their own large scale trials in the future.

The essentials

BUDGET

Undertaking a study to provide robust findings of national significance is likely to be a substantial undertaking. This study had a budget of €1 million and an earlier, larger (400 households) study in Sweden is believed to have cost substantially more.

This UK Study was completed with an underspend of 5 %.

TEAM MAKE-UP

The following roles each played an essential part in the delivery of the Study. All, except those making up the Governing Body, were contractors.

Governing body

The Governing Body comprised of representatives of the commissioning Government departments. They initially drew up the specification of the Study and, following a competitive tendering exercise, appointed a consortium of contractors. All the bidders for the contract were consortia, this being a recognition that the variety of skills and experience required to deliver this Study do not normally exist within a single company.

The specification required the successful contractor to be responsible for all features of delivery i.e. the Government staff who commissioned the study would be left free to concentrate on its overall stewardship and so not be responsible for ensuring that specific parts of the programme were being delivered. All day-to-day management, all organisation, all problem solving etc. occurring within the Study being the responsibility of the contractors.

Once commissioned, the role of the Governing Body was to act as a Steering Group which met with the Managing Contractor (described below) every 3–4 months in order to monitor progress and to provide advice as needed. Over time, the Steering Group grew with additional members joining from the Government Departments that originally commissioned the Study. The diversity of steering group members represented a wide range of policy interests and this ensured the Study delivered data that could be used by several Government departments.

Managing contractor

This Study required the delivery of a variety of technical solutions e.g. market research, installation of measuring equipment, data analysis etc. Put simply, it was the managing contractor's job to ensure the smooth and successful integration of all these technical activities. The importance of this role should not be underestimated. There is a myriad of things that can (and do) go wrong in a study of this size and complexity. So there is a continuous need to develop and implement contingency plans and have problem solving expertise to hand. Importantly, the Managing Contractor for the Study was not responsible for providing any of the technical solutions, so was able to focus entirely on the overall management of the study without being distracted by the responsibilities of having to deliver one of the technical solutions too.

The Managing contractor thus developed and then monitored progress on the complex timing and activity plans to ensure each of the 250 households was recruited, interviewed, had instrumentation installed and later removed, maintained their activity diaries etc. This process worked very efficiently as the Managing Contractor assigned one person to manage the whole project. This ensured good project continuity but it did place that individual under considerable pressure at times.

This Study was completed on time.

Technical team member (1) – market researcher

It was known that locating suitable households was a task that organisers of studies often underestimate. In the case of this Study, the demographic profile of the householder sample needed to be a good match to the overall population in England in terms of:

- *Social grade* using a classification system enabling a household and all of its members to be classified according to the occupation of the Chief Income Earner.
- *Number of people living in a household.*
- *Life-stage.*
- *Working status.*
- *Property age.*
- *Geographical region.*

Thus a challenging task best undertaken by a professional market research company that already has this type of statistical data available and who has the recruiting capacity to locate not just 250 suitable households but also enough additional ones to act as a reserve in case some households drop out after volunteering. In the case of this Study, the drop-out rate was close to 30 % – a strong indication of how challenging this aspect of the Study was.

Employing the skills of a professional market research company meant that attitudinal interviews could be undertaken at each household in the study. And, whilst there, the interviewer was able to conduct an initial audit survey to establish what electrical appliances were available for use in each household.

The interview ensured that data about social grade, household size, etc. was collected. The attitudinal survey covered pro-environmental behaviours segmentation, views towards climate change and energy saving. The appliance audit revealed that the average household had 41 appliances; the minimum found was 15, the maximum 85.

Technical team member (2) – measuring instrumentation supplier

The supplier (contractor) for the Study provided all the measuring instrumentation, data capture processes and data analysis. Having a single contractor to provide all the instrumentation, data capture and storage was attractive because it meant just one entity was responsible for a key part of the process which involved the interplay of several technologies. In the case of this Study, that contractor was also responsible for data analysis. This brought certain benefits but also some drawbacks – these elements are discussed in a later section of this paper.

One of the choices that needed to be made at the time of commissioning the Study was what measurement technologies were to be employed. Each of the consortia that tendered for the Study were required to make their own proposals and most

chose to submit just one option rather than a choice. The options submitted varied. There were 3 main variations:

- Serial wattmeters for plug loads, combined with clamp-on meters used for individual circuits at the consumer unit – all measuring devices having some form of integrated data storage. The data being manually downloaded by a technician when visiting that household.
- Serial wattmeters for plug loads, combined with clamp-on meters used for individual circuits at the consumer unit – all measuring devices having some form of integrated data storage. The data being automatically downloaded and transmitted using ZigBee type technology.
- Plug load data capture using Radio-Frequency Identification (RFID) technology. The data being automatically downloaded and transmitted utilising the household's Wi-Fi router.

The choice made for the Study was to employ serial wattmeters for plug loads, combined with clamp-on meters used for individual circuits at the consumer unit with data being manually downloaded by a technician when visiting that household. The reason for making this choice was that it was based on well-proven technology of known reliability. The newer, higher technology options, though attractive as some were physically less intrusive for householders, did not have such a well-established reputation for reliability. Although remote monitoring meant that data streams could be checked in real time, the cost of dispatching a technician to make the necessary repairs could become very high.

One other important choice about the instrumentation was whether to purchase it or rent it. Rental was much less costly than purchase but it meant that the client departments would not have the instrumentation available for further studies once this Study had been completed. In this case, the equipment was rented.

Details of the instrumentation used for the Study are provided in the literature referenced at the end of this paper.

Technical team member (3) – measuring instrumentation fitter

All households needed to be visited by a technician to fit the measuring instrumentation and again sometime later to remove it. During their return visit, these technicians also downloaded the captured data onto laptop computers for subsequent onward transmission for storage in the database and eventual analysis.

For the tasks they had to do, the technicians needed two key attributes. One was that they needed to be qualified electricians as minor dismantling of household electrical supplies was occasionally necessary in order to fit the measuring devices. Clearly, any such task had to be undertaken in a completely safe manner and in accordance with wiring regulations, so only certified electricians were employed for this task. The other attribute was not a technical one, for it required inter-personal skills. These were necessary as the electricians were, apart for the market researcher who made the initial recruitment visit to each household, the only person to person contact that the householders had with those running the Study. These electricians were also going to spend as much as one day in the household fitting the instrumentation and, because this meant them visiting every room in the house, could be rather intrusive at a personal level. Therefore, it was particularly important that these electricians had very good "client management" skills i.e. were very polite, prepared to spend time with the householder to explain what they were doing, worked very tidily and were even attentive to small considerations such as removing their shoes when entering people's homes.

This consideration might seem unnecessary but these "ambassadors" received excellent feedback from householders and on a few occasions were able to identify pre-existing safety faults in household wiring systems that they were able draw to the attention of the householder.

Prior to commencing their role in the Study the electricians (two small teams of electricians covered the whole of England) were provided with substantial training by the instrument suppliers.

Technical team member (4) – data analyser

Studies like this generate a huge amount of data (220 million lines of data in this Study) and those who commission them may not understand this aspect well – so can find themselves being offered advice about the provisioning of databases and analytical solutions that they do not fully understand the implications of. Some of this impacted this Study. The solution offered by the measuring instrument supplier, which was for them to also store the data in their preferred data base solution complete with their in-house analytical tools, was very convenient and produced elegant outputs in accordance with the wishes of the Steering Group.

In the short term, this provided a very satisfactory solution – the solution only being limited by the Steering Group themselves as they were required to produce a list of requested analyses. But this solution can impose limitations in the longer term as other parties begin to ask for analyses for which no solution can be provided other than through the inflexible and added-cost route of needing to request and pay the data base custodian (the Measuring instrument Supplier) to provide the required analyses.

The solution that was developed for this Study was to migrate all of the data into a MySQL database. MySQL was chosen as it is widely used open source software, so available to all would-be users. Such databases provide storage facilities only so need some additional features to enable users to access the data in suitable formats for their intended use. The following were developed for this Study:

- WAMP database solution package with pre-defined queries (WAMP is a pre-packed set of programs that enable web based queries to be made of the MySQL database). This solution being designed to enable non-database base experts to run their own queries on the database.
- The MySQL database was given a Microsoft *Access* front end to allow users to design their own queries (users can use the core MySQL database and add their own front end). This solution being designed to suit those with some familiarity with databases, particularly the most common one MS *Access*.0
- Or, for database experts, they would be able to export data files directly from the MySQL database.

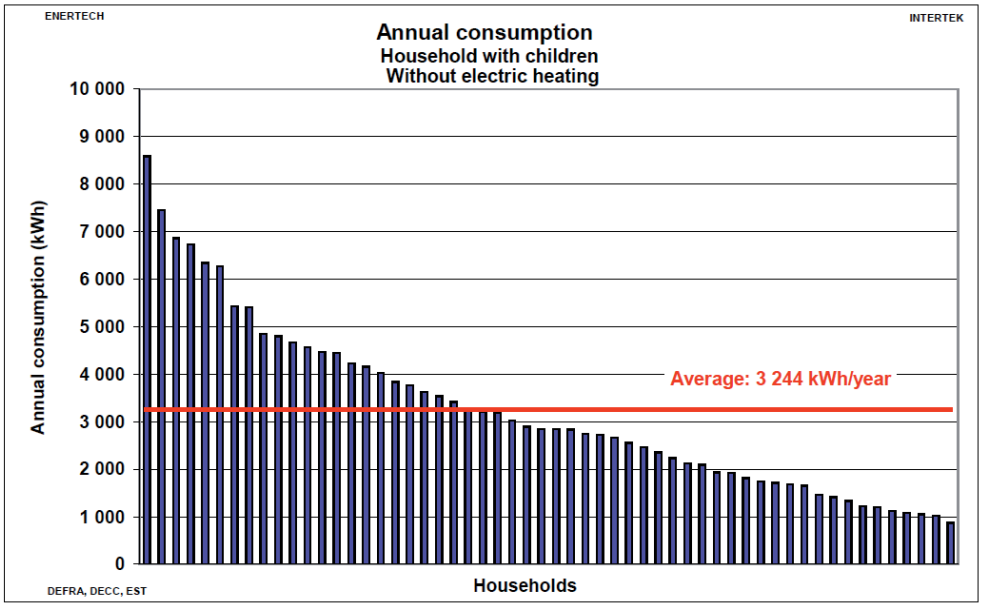

Figure 1. Annual energy consumption.

SOME OTHER FACTORS

- All of the households in the Study were owner-occupied. It was not possible to recruit households from the social housing sector and rented sectors as the wiring needed to be modified to fit some of the measuring instruments and landlords were not expected to readily give permission for this.
- The most difficult household population to recruit was younger single occupiers. These were important to include as 29 % of UK households are single person dwellings.
- Ownership of the intellectual property rights to the analytical tools required to analyse the database needs to be established at the outset.
- The detailed analyses that were required should be determined well in advance of completion of the study.
- Downloading of data during intensive (peak) periods could be intrusive for householders and should be done remotely where possible.
- Owning rather than renting the instrumentation may encourage the development of lower cost studies that can be used to refresh the data in future years.
- Only the data analyser could check the data as the project progressed and as much of this was done at the end it meant that problems with missing or corrupted date were not always spotted as early as they could have been.
- Appliances that are built into kitchen units in such a way that their power input plugs are inaccessible can be particularly difficult to monitor.
- Households that use portable electric heating to supplement a non-electrical main heating source need particularly close attention to ensure these extra heating sources are included in the monitoring programme.
- Studies such as this only provide a snapshot in time; so will eventually need to be repeated.

Some eye-catching findings

- The study found the total average annual electricity demand for all dwellings monitored in the survey (excluding electrically heated homes) to be >3,200 KWh.
- This average annual electricity consumption in the Study's households was 10 % higher than the UK national average.
- Single person households were found to use as much, and sometimes more, energy than typical families. This is particularly true of cooking and laundry activities.
- TV viewing is close to 6 hours in a typical day; the typical household having 2 TV sets.
- Although peak domestic electricity demand occurs at breakfast time and again in the evening, there remains a seemingly high baseline demand of 175–200 watts throughout the 01.00–05.00 hours period.
- Excluding electric heating, the largest contributor to the average annual household demand is the combination of consumer electronics and ICT (20.5 %), followed by cold appliances (16.2 %) and lighting (15.4 %). Cooking and wet appliances consume similar levels of energy at 13.8 % and 13.6 % respectively.
- UK households use much more energy to dry clothes (annual average 394 kWh), than to wash them (166 kWh) and they use more energy to wash dishes (294 kWh) than to wash clothes.
- Incandescent lamps accounted for the majority of lighting with close to 40 % of all installed light bulbs. Halogens come next with 31 %, demonstrating that CFL and LED technolo-

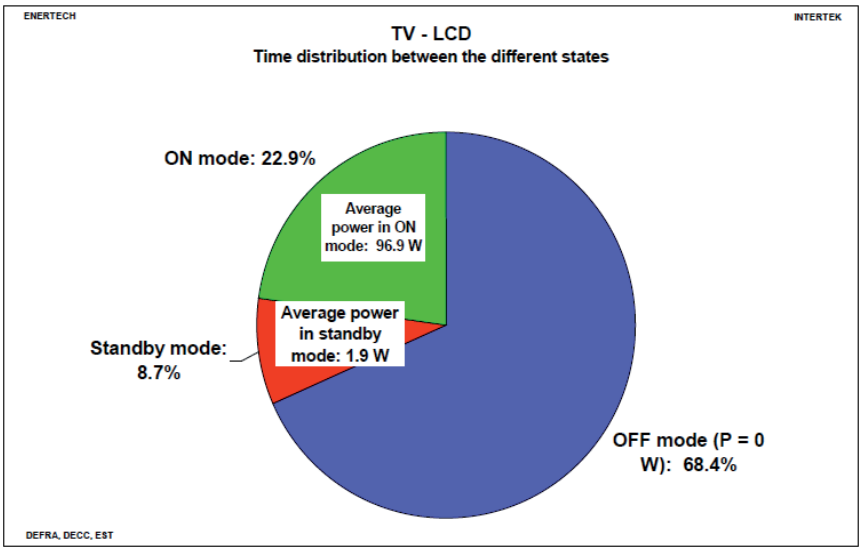

Figure 2. Time distribution between different TV modes.

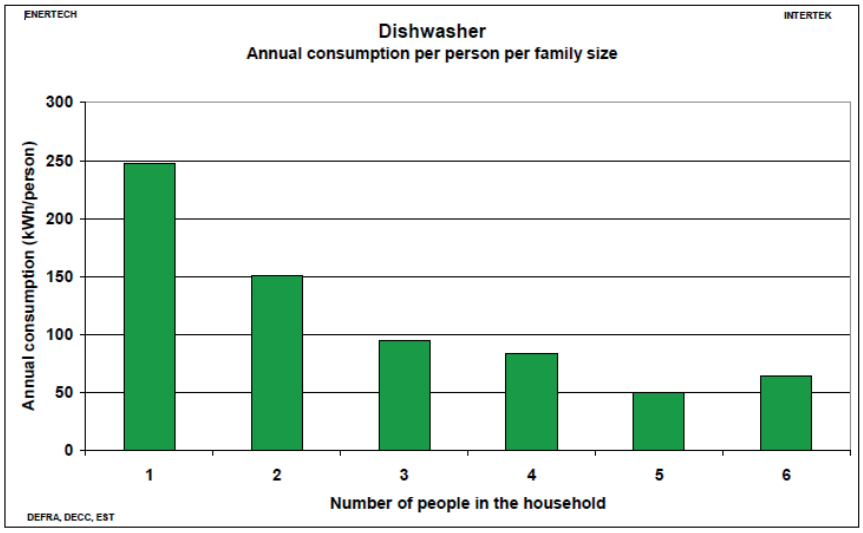

Figure 3. Annual energy consumption from use of dishwashers.

gies still have a huge market to penetrate and huge savings to potentially be made.

References and further reading

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