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UK Energy Lab:
A feasibility study for a longitudinal, nationally representative sociotechnical survey of energy use

Final Report

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SYNTHESIS REPORT

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Disclaimer

The views presented in this report are the authors' own. Nothing in the report represents a commitment to funding or a statement of policy by those public bodies involved or mentioned, including the UK government Department of Energy and Climate Change.

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ANNEXES

These are provided in separate documents.

1. Background and aim of study

This feasibility study into establishing a nationally representative longitudinal panel of energy use in the UK was commissioned jointly between the UK government Department of Energy and Climate Change (DECC) and the UCL Centre for Energy Epidemiology (UCL CEE) at the UCL Energy Institute (UCL EI) with the UCL Department of Science, Technology, Engineering and Public Policy (UCL STEaPP), working in partnership with the NatCen Social Research (NatCen). The study came about following the publication of 'Developing DECC's Evidence Base'[1] in January 2014, which identified the need for better data about people, technologies and buildings to inform energy policy.

The aim of the study was to explore the feasibility of setting up a process of long-term, nationally representative data collection that could meet this need. The details of the scope of this process are set out below. Here we set out the background reasoning for why exploring the feasibility of large-scale data collection is an important step in the process of exploring how to get better data into energy policy.

a. What this report covers

The report synthesises across all the project workstreams set out below (see subsection c, page 8). Each area (apart from finance) has an annexed standalone report available alongside this main synthesis report. This report is structured into 6 further sections:

Scope
Covering the details of the different elements under consideration and the limits on these, from where data will be collected from, to data types, frequency and spatial density of collection.

Nature of the opportunity
This covers the 'gap' in the data, policy and research landscape for energy that a potential large-scale data collection in this area would fill. Here we identify the range of benefits such a project would provide. It includes a review of both what kinds of data policy organisations need to make more effective policy in this space, and what the research and innovation sectors need. This also includes a look across planned data collection proposals in relation to a range of recent initiatives, e.g. Catapult projects, as well as understanding the role and impact of smart metering as roll out takes root.

Assessing the design and methods options
The number of possible approaches for gathering data in this space is immense. To make sense of these possibilities, we have identified what we are calling a 'proposed approach'. This is seen as the best starting point for

[1] See: https://www.gov.uk/government/publications/developing-deccs-evidence-base

considering data collection in this space and for balancing costs, pragmatics, ethics, security and other factors. The approach identifies the fundamental choices for data collection design, sampling and strategies, and identifies an approach that balances practical and cost issues against the benefits delivered. Variations on this approach can then be considered in an easier and more systematic way. The approach set out is deemed to be the most deliverable, and best balance of costs vs benefits given the evidence we have available for this report.

Assessing the costs
Here the design options are operationalized into a cost-calculator tool (see **Annex C**, Appendix B) with the underlying assumptions and approach set out. This tool enables the exploration of different approaches to rolling out the survey giving an estimate of costs incurred for different models.

Financing, governing and managing
Here different financing scenarios are explored in relation to possible governance arrangements for the data collection. A proposed financing model is established and, using the scenarios for costings estimated in the previous section, cost burdens on different institutions will be identified, with a focus on DECC. *Note that assumptions have been made about the financing model that involve participation of other bodies, such as RCUK and other public bodies with a direct interest in the sort of data this project might provide. We have not contacted any of these bodies directly about the likelihood of their participation. This analysis is produced purely for illustrative purposes, based on potential scenario for DECC and in no way indicates likely participation from these organisations in any future project based on the analysis here*. Finally we briefly explore the management approach likely to be required and the cost implications.

What next
This section covers the potential next steps after this feasibility project should stakeholders agree that the proposed development programme of data collection is to be pursued.

Below we give further background on the reasons for a feasibility study in this area and the approach the project has taken.

b. Reasons why a feasibility study in this area is needed

The context of national policy making for this feasibility study places very specific emphasis of certain elements of design for data collection. These are set out below:

- National policy requires understanding what is happening nationally. This means that data collection must provide data that can be used to derive policies that are tailored to the different social and regional contexts at the national scale.

- The design and development of national energy infrastructure, involving the Transmission Network Operator, Distribution Network Operators and suppliers – as well as other parts of the energy supply chain – depends on understanding the trends and drivers of energy consumption at the consumer level. The industry's need for greater detail and more timely energy consumption data increases, as more distributed and intermittent generation is added to the grid, and as existing infrastructure reaches capacity.
- National policy making is a continuous process that takes place over years. This means that data collection needs to continue over time if it is to remain relevant to policy-making.
- The factors driving end use energy demand are changing rapidly, driven by technology developments, social trends and regulatory requirements. Policy and programme making must both take into account, and respond proactively to, this rapidly changing landscape. Timely knowledge of both how and why end use energy demand is changing is therefore important for research and policy making.
- Energy policy requires understanding how technical, physical components interact with social, human components. This is because energy consumption is mediated both by the technologies that distribute and consume energy, and the people that use them to achieve particular goals.

These four elements mean that certain kinds of designs for the data collection are essential. For each aspect identified above, the following design elements fulfil the needs of policy:

- A sample large enough to capture the right level of variation across the population under consideration. This means having a minimum sample size that allows for statements to be made about the scale of issues affecting energy demand across the geographic or other areas of interests. The total sample size will therefore be driven by the key analysis sub-groups (such as geographic areas or type of housing) and their natural prevalence in the population, or whether the sample design incorporates boosting.
- Some kind of repeat-wave or continuous data collection design is necessary. In large scale surveys of the sort implicated by the point above, this will normally mean a design that is either **repeat cross-sectional** (a completely new sample selected for each new wave of data collection) or **longitudinal** (the same sample is subject to repeat waves of data collection) or some combination of the two.
- Data collection that considers what the nature of the physical stock (buildings), the technologies in the stock (e.g. heating systems, electricity-powered appliances) and what people are doing with them and why is essential to ensure that i) the full range of options for

effective policy-making are identified and risks to effective policy delivery are better-managed; ii) that emerging trends, risks and opportunities and the reasons for them are spotted and dealt with sooner and more effectively.

These design elements are explored in more detail below, including a deeper description of the scope. Fundamentally, this feasibility study is therefore set to explore the following:

How feasible is it to set up and run for several years a large scale, nationally representative, repeat-wave survey of energy use and its drivers in both homes and workplaces?

A 'UK Energy Lab'?
For the sake of brevity, and to reflect the combined technical and social nature of the proposed data collection, we chose a simple name for the survey as 'UK Energy Lab' (UKEL). This is solely for the purposes of this feasibility study. We use this name as a shorthand for the longer descriptive title implied in the question above.

c. The approach and structure of the project

The feasibility project was established to explore this question using eight different workstreams. These are set out below. Each stream was established to explore a different but linked element of the work.

Workstreams

A. *The Case for a 'UK Energy Lab'*. This reviews what policy and research stakeholders in the energy sector think about the proposed UK Energy Lab and whether investment in such a facility would fill important, strategic gaps in the energy research landscape. The full report from this stream is available at **Annex A.**

B. *Available data and relevant surveys*. This reviews what current or past data is available in the energy sector that has a bearing on the kinds of data envisaged for a 'UK Energy Lab'. This is part of understanding what the nature of the data gap is and what opportunity there is to build on current data collected in other surveys of relevance. The full report from this stream is available at **Annex B.**

C. *Design and methods options*. This is the central part of the study which explores the core options for executing a survey which would meet the basic requirements set out above, enabling an estimation of the range of costs involved in setting up and running a 'UK Energy Lab'-style facility. The full report from this stream is available at **Annex C.**

D. *Ethics and data security*. This identifies and explores responses to the potential ethical and data security issues raised by the generation of data on the scale envisaged for a 'UK Energy lab' ensuring that there are not likely to be any fundamental legal or ethical barriers to setting up such a facility. The full report from this stream is available at **Annex D.**

E. *Governance*. This explores the options for governing a 'UK Energy Lab' under a given set of financing scenarios. This section learns from the approaches used in other UK surveys, especially where there are joint funding arrangements between research councils and government and where there are longitudinal designs. The full report from this stream is available at **Annex E.**

F. *Finance*. This is where the cost ranges of the survey are estimated with some consideration for the benefits accrued and therefore where the weight of interest might lie in terms of institutional funding.

G. *Pragmatics and piloting.* This is where the considerations for the next phases are set out, and more detailed consideration for many of the practical issues for undertaking the development and execution of a 'UK Energy Lab' style survey. The full report from this stream is available at **Annex F.**

H. *Non-domestic settings*. This is where specific consideration is given to surveying in non-domestic settings. Here a range of complications are already known and therefore the design and surveying methods for this area are much less developed than for domestic settings. The full report from this stream is available at **Annex G.**

2. Scope

This section sets out the scope of the possible data collection in a number of ways. This covers *where*, *when* and *what* such a new survey should cover at a relatively high level. Detailed consideration of actual survey questions or monitoring elements is outside the scope of this study and is something that would be addressed should there be agreement to progress development further.

a. The where

Sites of data collection under consideration
This feasibility study is primarily giving consideration to data collection in the **home**, since this is the currently the most feasible given the infrastructure and methods available. Secondary consideration is being given to data collection in workplaces, but the inherent complexity of a systematic study of these at a national scale (see **Annex G** for a detailed report on these issues) means we will only consider initial tactics for how some non-domestic data could be collected on the back of a domestic-focused study.

Geographic coverage
The initial assumption is that the data collected would cover the whole of the **United Kingdom**. However, this is dependent on partners from the relevant jurisdictions being willing and able to participate in the roll out of the study. This is in part because the distinct housing and energy supply types that exist in both Scotland and Northern Ireland mean that data collection in these areas would most benefit policy makers and researchers interested in those areas.

Spatial resolutions
Here we consider what is the smallest geographic unit of analysis for which reliable statistics could be provided. We recognise that optimal spatial resolution trades-off increasing specificity of geographical context against increasing survey expense, so a balance needs to be struck. Potential spatial resolutions range from countries (4 in the UK) to principal authorities (433 in UK). Existing analytical frameworks, such as the Standard Assessment Procedure[2] define climatic regions that sit, in scale, between these (21 in UK of which 12 are in England and 9 in Scotland), and are broadly comparable in scale to the ONS Regions and electricity and gas distribution regions England (although substantially different in Scotland). The initial intention is to adopt a spatial resolution at the ONS Regional level (12 regions in total of which 9 are in England and one each in Scotland, Wales and Northern Ireland). The ONS Regions provide a suitable spatial scale for analysis of variation in a) energy distribution; b) regional administration; c) climate in England. Spatial

[2] See SAP 2012: STP11/WD01. Available at: http://www.bre.co.uk/filelibrary/SAP/2012/STP11-WD01_Wind_Data.pdf Accessed 20 Aug 2014

resolutions above this scale have too great an impact on survey cost at the levels of precision desired, as can be seen in sections 5 and 6 below.

b. The when

Term of data collection
Our starting assumption is that data collection will be carried out for over a period of five years – this is the proposed approach that is described in the following sections. This period is sufficient for additional benefits from investment to be returned by having long-term data, but not indefinite, taking account of limitations on the ability of potential funders to commit funding in advance.

Frequency of data collection
The frequency of data collection will differ for different types of data collected – see below for a more detailed exploration of this. For the our proposed approach we are assuming the following three classes with these approximate data collection frequencies:

- **Social/Human factors**[3] survey: annual collection baseline socio-demographic and other social/human data (e.g. self-reported occupant psychological data; subsampling of small numbers for shorter periods of behavioural and physiological monitoring at higher frequencies using 'quantified self'[4] technologies).
- **Building survey:** An initial survey of the property will be undertaken with partial repeat surveys undertaken of equipment (e.g. boilers or windows) determined by their life-cycle or when triggered by event
- **Energy and environmental monitoring**: The frequency of monitoring will vary and in some circumstances will be driven by how rapidly the measurand itself changes. Energy monitoring will be at the limits of home area network (HAN) resolution (approximately every 10 seconds for electricity and half-hourly for gas)

c. The what

The aim of a UK Energy Lab is to provide high-resolution descriptive statistics on disaggregate energy demand in homes, along with data that allows us to understand the drivers of energy demand in homes and how these change over the time. This aim dictates the classes of variables that need to be collected within the UK Energy Lab. The dependent variable for the study is disaggregate energy demand in homes. This determines the 'energy' class of variables, covering electricity, gas, and alternative fuel vectors such as oil,

[3] We recognise that social/human data can be collected and inferred from other data sources (e.g. identifying practices by patterns of energy consumption broken down by technology source). However, here we use 'social/human' data to refer to data drawn directly from people either via written or verbal response or using monitors that exclusively measure human or social attributes.
[4] This includes life-logging and personal monitoring using technology. For more see: quantifiedself.com

coke, coal, and other solid fuels (collectively called '**energy data'**). It also determines the need to be able to break these down into socially meaningful end uses such as energy used for heating, cooling, cooking, hot water, lights and appliances. In order to explain these as 'dependent variables' three additional classes of data are required (independent or explanatory variable classes).

Data on the physical form, fabric, and technologies of the home (collectively called '**building data'**) is needed in order to determine the efficiency with which different forms of socially useful energy such as heat and light are delivered to the home, and how efficiently the home utilises that energy. Data on the household is needed, including economic, socio-demographic and broader sociological, psychological and physiological data (collectively called **'social/human data'**) is needed in order to determine the underlying social/human drivers of energy use. Data on the external environment is needed in order to determine the rate of heat loss and heat gain from the building, and data on the internal environment is needed in order to determine the physical conditions associated with occupant comfort, health, and activity (collectively called '**environmental data'**).

Collectively, these classes of variables will allow for the construction of detailed disaggregate descriptive statistics and powerful explanatory models of energy demand for different social purposes, what drives this demand, and how it changes over time. Section 4 of this report on expands on this and on how these classes of variables will be collected at different levels of detail for different parts of the sample.

3. Nature of the opportunity

a. Energy policy and energy research landscape arguments

At the energy policy and energy research landscape level, the case for investing in a new nationally representative, longitudinal, socio-technical survey of energy use in homes rests on four main arguments. In addition there are a range of high priority policy areas to which a UK Energy Lab would provide unique and fundamental input. In Boxes A-D we explore the benefits to these different policy priority areas.

i. There is limited data in the UK that allows us to **manage the rapid transition to a largely decarbonised housing stock** over the next 25 years, as legislated through the Government's Carbon Plans. This transition will require unprecedented rates of change how we supply and use energy in homes (approximately 30% of final energy demand). However, we currently have no mechanism to monitor, understand, or manage such changes in home energy demand over time. This determines the need for a substantial longitudinal component to this survey, which in turn will allow us to build powerful explanatory models of how and why energy use changes.

ii. There is a similar lack of data on how to **correctly design whole energy systems retrofit programmes** to be most efficient, taking into account the interaction effects between the physical, technical and social aspects of home energy use, and the required sequencing of these interventions. If these interaction and sequencing effects are not understood at the national scale in a way that supports developing socio-technical consumer segments, then the financial and political risks of failure in the UK's decarbonisation programme are high. This again necessitates longitudinal data and socio-technical data.

iii. The very large range of recent energy research initiatives, ranging from the Energy Technology Institutes' (ETI) Smart Systems and Heat programme[5], through the Technology Strategy Board's (TSB) Energy Systems Catapult[6], and the Engineering and Physical Sciences Research Council/TSB/DECC Energy Catalyst[7] are not intending to systematically gather national scale, representative, socio-technical data on energy consumption in homes. And yet all these programmes require such data in order to **contextualise and interpret the findings from their own programmes** of research. Data from a UK Energy Lab would help identify socially and technically acceptable intervention opportunities at national scale. This necessitates understanding, at the national scale, how households, dwellings, and their

[5] See: http://www.eti.co.uk/programme/smart-systems/

[6] See: https://www.catapult.org.uk/two-new-catapults;jsessionid=88EB4FED8EB2AF967319B0D4F9529F62.2

[7] See: http://www.epsrc.ac.uk/newsevents/news/energycatalystfund/

energy systems interact to create demand in homes, and hence determines the need for a socio-technical design to this survey.

iv. There is a common need across government, industry and academia for high-quality, disaggregate, energy demand data from UK homes of known accuracy and precision. This is needed to **support strategic oversight of the energy demand landscape for policy formation**, and to provide a statistical backcloth for the contextualisation of other smaller energy demand studies. This necessitates understanding the level of disaggregation achievable for a given degree of accuracy across household, dwelling, technology and geographic sectors, and hence determines the need for a hierarchical structure the survey. Each of these four main arguments at the energy policy and research landscape level are expanded on in **Annex A**

A crucial point to bear in relation to the four points above is that there **are** datasets available which play an important role in supporting energy policy in the UK. These include the NEED Data framework[8] and the English Housing Survey[9]. These are significant investments in personnel and data infrastructure resources. However, the full value of these data sources is limited by the absence of any data source that can relate a wide range of technical, environmental and social/human factors to changes in patterns of energy demand of homes at different temporal and spatial scales over time. We believe that the addition of such data would be complementary to, and significantly enhance, the value of these existing datasets.

Box A: Benefits to fuel poverty policy

A UK Energy Lab could help to address policy and academic research on Fuel Poverty in three main ways. Firstly, it would provide new empirical data on both the incidence and prevalence of fuel poverty at the national scale, adding real value to modelling efforts in this area that often rely on assumptions. Assessment of the incidence of fuel poverty would be supported by the longitudinal nature of the UK Energy Lab, enabling policymakers to understand the conditions that lead households to move in and out of fuel poverty. Assessment of prevalence of fuel poverty would be supported by the national scale of the UK Energy Lab, and this, in conjunction with the collection of data on energy consumption, internal temperatures in homes, and data on the building form, fabric, and technologies, and socio-demographic data on households income-band and benefits, would allow governments to assess the efficacy of fuel poverty programs through contrasting measured data from the UK Energy Lab, with modelled estimates from other sources. Secondly, UK Energy Lab would allow for the understanding of the wider, non-energy, costs and benefits of different approaches to Fuel Poverty alleviation through gathering

[8] See: https://www.gov.uk/government/collections/national-energy-efficiency-data-need-framework
[9] See: https://www.gov.uk/government/collections/english-housing-survey

data that will allow the impacts of Fuel Poverty programs to be assessed across other government departments such as Health and Work and Pensions. Thirdly, it will allow academics and policymakers to develop more accurate segmentation models for predicting Fuel Poverty using widely available, anonymised and administrative data. This will support better targeting of Fuel Poverty interventions to those that need them most.

b. Key stakeholder functions

In addressing the points i-iv above, a UK Energy Lab could deliver the following key functions to different stakeholders.

The policy community

- A **strategic oversight** of how energy used across all major household and dwelling combinations resulting in a significantly better understanding of energy use and drivers than at present, and greatly enhanced empirical, disaggregate, end use energy demand trend data.
- An '**observatory' capacity**, highlighting emerging trends in energy demand that will enable more rapid identification of emerging opportunities and risks associated with energy demand from this key sector.

Box B: Benefits to smart metering policy
The UK Energy Lab could both support, and be supported by, the smart metering program. UK Energy Lab would use smart meters to gather high-quality, high temporal resolution, gas and electricity data from the participants' homes. The disaggregate temporal and end-use resolution of this data would vary across the three levels of the Energy Lab hierarchical research design. The UK Energy Lab could support the smart metering programme through developing both sensor-based methods, and statistical inference methods for disaggregating the end uses of electricity and gas within the home. This will allow assessment of how savings from smart metering are being realised within different kinds of home. Through the longitudinal analysis of time of use tariffs, the UK Energy Lab could support development of better customer segmentation models for identifying which type of customers respond most positively to time of use tariffs, and assessment of where such tariffs may cause negative health or economic consequences to recipients.

- A **policy evaluation** capacity, to assess how national and regional energy demand reduction policies and programmes are working on the ground. Providing earlier, more disaggregate, and more comprehensive information on whether policies are working as intended. This would reduce the need to commission policy-specific evaluations in many instances.

- An **omnibus survey** capacity, to add specific, policy related questions in individual or a short series of survey waves. This would both reduce the costs of doing independent surveys, and will add enormous value through leveraging the existing knowledge about participants in the Energy Lab.
- An '**innovation lab' capacity**, to allowing direct testing of policies and technologies in a linked by quarantined representative sample of homes (see Box E). This would remove the need to commission many small detailed technical studies independently as is currently the case. Such studies can be added into the Energy Lab sample as required though this omnibus capacity. This would result in much better pre-intervention data, much better data on the performance of the technologies in-situ, and much easier and quicker deployment into the field testing environment, keeping it relevant to policy timescales.
- Providing an **authoritative reference source** of data for adjudicating disputes on the major issues and opportunities affecting UK energy demand in homes, and an authoritative source of evidence for convincing stakeholders of the need for specific policies.
- Understanding the **wider, non-energy, costs and benefits** of different approaches to distributed energy generation and energy efficiency, for example on physical and mental health, workplace productivity, education outcomes, and others. This would support contextualising residential energy policy within wider policy priorities understanding where synergies could lie between the goals of policies in different spheres. For example, identifying, understanding and tracking the fuel poor in order to understand the wider implications of fuel poverty that may fall across the remit of other government departments.

Box C: Benefits to understanding off gas grid consumers
UK Energy Lab could easily boost the sampling of homes in off gas grid areas. The combination of the socio-technical and longitudinal elements of UK Energy Lab could provide high-quality data on how these customers consume energy, how this is changing over time, and how these customers previous experience of heating technologies is likely to impact on their acceptance and use of alternative gas or electric heating technologies. In conjunction with detailed information on the physical form, fabric, and technologies currently used to provide heating within off gas grid communities, this would provide the basis for a much better assessment of both the technical and social acceptability of alternative heating technologies. This would support DECC's ability to plan the infrastructure necessary to move these communities to less carbon intensive modes of heating, and to structure the carbon benefits of doing this into their carbon pathway plans.

The research community:

- a '**statistical backcloth'** - providing national data for contextualising other studies;
- **benchmark methods** - establishing harmonised methods of measurement;
- **uncertainty quantification** - determining uncertainty as a function of measurement method and providing measurement models for use by the academic and professional communities;
- an **omnibus capacity**, to add specific, research questions in individual or a short series of survey waves;
- a **catalytic capacity**, by providing a focal point for the end use energy demand in homes community through engaging in the governance processes of, inputting into the design of new instruments for, and participating in the analysis of the findings from, the Energy-Lab;
- providing the opportunity to exploit learning from **natural experiments** (energy price rises, extreme weather events, international energy events, etc.) and deliberative experiments (through the innovation lab capacity, at sufficient scale, and with sufficient understanding of the uncertainties, to differentiate between the impact of such events and noise in the data.

c. Value added

The Energy Lab will add value nationally through:

- allowing energy fieldwork and trials funded through Research Councils UK (RCUK), the Office for Gas and Electricity Markets (Ofgem), TSB, ETI, Carbon Trust and others to use **rigorously developed and tested standardised methods**, to harmonise with UK Energy Lab, to quantify uncertainty, and to contextualise their findings against national data;
- **improving our socio-technical understanding of energy use** in homes, with the consequence that other, more targeted studies can be executed to higher standards through drawing on better instruments, and contextualising against better data, in order to deliver more robust findings for policy, industry and academia;
- **reducing trial costs** through providing an 'innovation lab' facility with homes of known National representativeness from known socio-technical market segments;
- **reducing energy surveying costs** through provision of an omnibus survey leveraging all the data collected from UKEL participants;
- **increasing business development and growth** advantages through identifying technology spaces into which they can innovate;
- **reducing the cost of policies** and programmes through better targeting of energy efficiency expenditure;
- **increasing the efficacy of retrofit** through providing the construction industry with anonymised data on the efficacy of fabric and technology interventions in a diverse range of homes;

- **increasing the efficacy of Local Authorities renewable and low carbon energy planning** through development of socio-technical segmentation models for domestic premises;
- **supporting national energy infrastructure planning** by providing greater and more timely detail on the evolution of the underlying drivers of change in home energy demand.

Box D: Benefits to energy technology innovation

The UK Energy Lab could support innovation in two main ways. Firstly, via an "innovation lab" capacity (see Box E, p. 41 for more detail) – a linked ring-fenced component of the sample in which intervention field trials can be conducted – it could allow organisations from DECC, through TSB and ETI, to Ofgem and others to access a pre-recruited pool of participants about which high-quality baseline energy, environmental, social, and building data already exists, to test their innovations. This will dramatically improve the quality, and reduce the cost, of field trials of innovations from low carbon technologies through to social marketing messaging.

Secondly, UK Energy Lab could drive innovation in the academic research community through supporting the development of new, home deployable, 'Internet of Things' wireless sensing technologies using the enabling technology platform of smart metering to improve our capacity to describe and explain the drivers of energy use in homes. This could also drive innovation in ‘big-data’ thorough developing methods to handle, integrate, and analyse large quantities of socio-technical data on homes from occupant physiology through to building physics.

The Energy Lab will add value internationally through:

- **demonstrating how Advanced Metering can be used** enhance data on energy use in homes with applicability across the EU through the Energy Efficiency Directive;
- **developing new methods of measurement and analysis** of energy use in homes with applicability across government and industry globally;
- being done in **accordance with the new EU Energy Statistics Regulations**[10] providing learning benefits across EU in the implementation of these;
- **developing and disseminating best practice** in energy demand measurement, analysis and reporting.

[10] See: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008R1099&from=EN

d. Questions a UK Energy Lab could add value to

A UK Energy Lab would allow us to answer key questions in the following areas. For a full list of identified research questions see **Annex A**.

Energy landscape questions:

- How do people use energy in their homes?
- How and why is home energy use changing over time?
- Are we making progress in reducing energy demand and if so how much is due to planned events and how much is beyond our control?

Deep explanatory questions:

- How do households and dwellings influence each other to determine energy demand?
- We can only explain half the observed variance in home energy consumption, what factors do we need to explain the other half?
- What educational/life-historical factors lead to lower energy use in homes?

Policy relevant questions:

- Which households will respond positively to Time of Use energy tariffs and why?
- Are building regulations delivering the expected energy savings?
- How does energy use change as people move in and out of fuel poverty?

Energy and environmental health questions:

- Does how we heat homes effect occupants' metabolism?
- Does the pattern or level of heating impact on physical and mental health?
- What effect does invalidity and/or disability have on home energy use?

Energy futures questions:

- How do generations, or cohorts differ in the their energy consumption pathways over time? Will tomorrow's retirees differ in their consumption from todays?
- What is the extent and impact on energy use in homes from social trends like the collaborative economy or working from home?
- How far into the future can we predict demand based on current trends?

In conclusion, the size, structure, and content of the proposed UK Energy Lab is driven out of addressing needs that are not satisfied by existing data sources. This has led to the proposal of a new UK energy survey that is:

- focused on homes;

- national in scale;
- primarily longitudinal;
- intrinsically socio-technical;
- covers social/human, building, environmental and energy data types;
- able to resolve effects to within a few per cent between policy- and academically-relevant segments of the population.

We believe that this structure will allow us to create powerful market-segmentation models, addressing interaction and sequencing effects, revealing how to target interventions that are both socially relevant and technically efficient.

e. Sector's perspective and needs

There is a surprising degree of consensus that, despite recent increased funding for collection of data, there remains a need for high quality, national scale, primary data collection on energy use and its drivers in buildings. The findings from the review of relevant energy landscape policy documents, the stakeholder meeting with DECC representatives (mainly from the Energy Efficiency Deployment Office), presentation to the Low Carbon Innovation and Co-ordination Group (LCICG), and interviews with relevant academic experts have drawn out the following key characteristics of the current UK end use energy demand in buildings landscape.

- There are **no repeat-measure, national-scale surveys** of energy use in UK homes, either cross-sectional or longitudinal. The nearest survey is the Energy Follow-Up Study to the English Housing Survey (EFUS)[11]. This, however, is cross-sectional in design, and extremely infrequent (2 'waves' over 15 years – though the 1996 and 2011 studies are not entirely comparable). It is primarily focused on the physical and technical drivers of energy demand capturing limited data on the energy demands arising from occupants.
- There remains a **lack of deeply integrated socio-technical data** on how building physical form and fabric, heating technologies and their controls, and building occupants and their needs, wants, behaviours, practices and social contexts interact to shape energy demand spatially and temporally.
- The primary need within DECC is for **high quality, timely, comprehensive data** on energy use in buildings and its drivers for strategic planning purposes. This is, in the first instance, more important than specific policy evaluation or innovation test-bed capacities, though there remains strong recognition for the need to improve both these capacities. Ideally data frequency of reporting would range from between quarterly and yearly (depending on variables) and would use smart meter energy data.
- Lack of measured data on energy use in occupied buildings and the performance gap between as designed and as built performance is a

[11] See: https://www.gov.uk/government/publications/energy-follow-up-survey-efus-2011

"…**major barrier to market confidence** in the achievement of energy reduction in buildings."[12]. Both the LCICG's Technology Innovation Needs Assessments (TINAs) for Domestic Buildings[13] and Non-Domestic Buildings[14] identified improved data on energy use in operational buildings as being the primary case for UK public sector intervention.

- That there is a need for **research that exceeds the normal planning and funding cycles** of government and the research councils in order to "…enable long-term investments in infrastructure, surveys, trials and experiments to be exploited fully." And that research investment strategies should "…take account of long-term energy policy goals and associated uncertainties."[15]. Specific examples cited for such treatment in the RCUK prospectus include cohort studies and the evaluation of the impacts of policy interventions.
- **Virtually all empirical studies** currently being funded by bodies like the Low Carbon Networks Fund (LCNF); Research Councils UK (RCUK) Transforming Energy Demand through Digital Innovation (TEDDI), BuildTEDDI, and End Use Energy Demand (EUED) programmes; the Energy Technologies Institute (ETI); the Technology Strategy Board (TSB); and DECC **are case studies targeting specific geographic regions or specific market segments**. Significant value would be added to these studies through provision of a benchmark study at national scale using publically available reference methods of measurement with quantified uncertainties through which they could contextualize their samples to the national scale.

f. Current data and surveys

Figure 1 summarises the analysis carried out about the relevant current available datasets that undertake or have undertaken data collection similar to that envisaged for a UK Energy Lab. Here the main relevant surveys in England are plotted in framework of sample size and regularity of data collection. The points marking the surveys position on the chart also indicate if the survey is longitudinal (L), cross-sectional (X) or mixed (M). The colour of the letter indicates if the survey has a lot of relevant data (green), some (amber) or little (red). The principle message from this assessment is that there is no current

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[12] See the LCICG Strategic Framework 2014: http://www.lowcarboninnovation.co.uk/working_together/strategic_framework/overview/

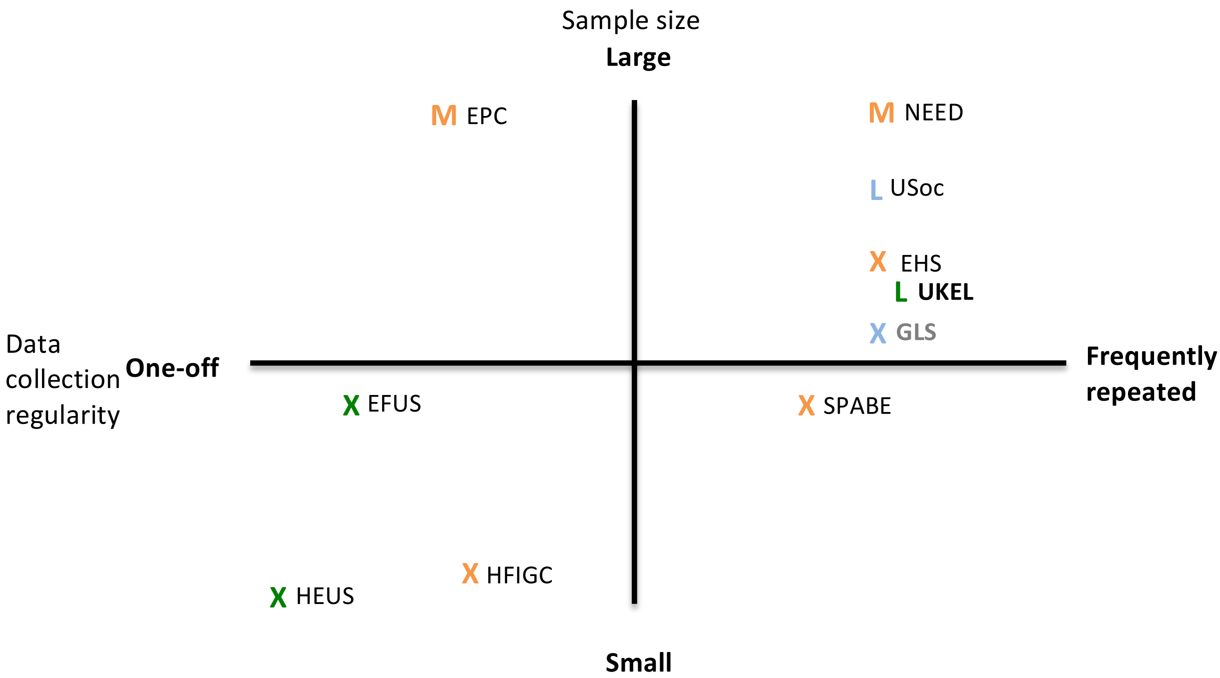
[13] See: http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/domestic_buildings/

[14] See: http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/nondomestic_buildings/

[15] See page v of Skea, J., Hannan, M.& Rhodes, A. (2013) 'Investing in a Brighter Energy Future: Energy Research and Training Prospectus'. Accessed 20 Aug 2013: http://www3.imperial.ac.uk/rcukenergystrategy/prospectus/documents/energyresearchandtrainingprospectusreports

nationally representative, regular data collection of energy use and its drivers in the UK. As remarked on above, there are clearly datasets that approach this:

- The **National Energy Efficiency Data Framework** (NEED) assembles administrative data related to physical energy efficiency interventions (from the household energy efficiency database, HEED), energy consumption, and some property and householder characteristics by address. While the consumption data is effectively longitudinal, it is longitudinal to the energy supply point or address, not the householder. Data collection for HEED and Energy Performance Certificates (EPCs) is continuous but event-driven.
- **English Housing Survey** collects representative data on housing which incorporates some energy factors. This is repeat cross-sectional, and has limited energy data within it.



Key: L – longitudinal data; X – cross-sectional data; M – mixed design; blue letter – minimal range of data compared to that for UK Energy Lab**;** amber letter – partial range of data compared to that for UK Energy Lab; **green** letter – strong range of data compared to that for UK Energy Lab. EPC – Energy Performance Certificate; NEED – National Energy Efficiency Data Framework; USoc – Understanding Society; EHS – English Housing Survey; GLS – General Lifestyle Survey (now closed); SPABE - Survey of Public Attitudes and Behaviours toward the Environment; EFUS – Energy Follow-up Study; HEUS – Household Electricity Study; HFICG – Human Factors in Domestic Gas Consumption in South-East England; UKEL – UK energy lab suggested position.

Figure 1: All the relevant data sources plotted according to their sample size, data collection regularity, data type (cross-sectional, longitudinal or mixed) and the degree to which the data they generate is close to that envisaged for the UK Energy Lab (from green: similar, to red: different)

As noted above, both NEED and the EHS are fundamental elements in the landscape of data collection and collation for energy and buildings. We believe that both studies would be enhanced significantly by a data source that is able to link buildings with energy technologies and the practices, lifestyles and behaviours of people over time. A deeper and more comprehensive review of the energy data landscape is given at **Annex B.**

Building from a current survey

In creating a UK Energy Lab, one approach could be to build off a current survey. We assessed the viability of doing this with a survey that is the nearest match to the UKEL - the English Housing Survey (EHS). However, there are such strong limitations (explored in **Annex B**, section A) that the strong recommendation is **not** to do this for a future UK Energy Lab.

4. Assessing design and methods options

This section covers the basic design choices that enable an energy survey of the UK to be made feasible. The major components of the design of a UK Energy Lab comprise the overall survey design (longitudinal vs. cross-sectional) and sampling. Both of these components play a major role in the kinds of data that can be delivered and the overall costs. A detailed report on the design and methods is available at **Annex C**.

Key benefits to be delivered
There are three key benefits that we focus on delivering via the design considerations:

1. **Nationally representative estimates**. We need to provide estimates that can be scaled up validly to the national level. Policy consultations helped identify the preferred *minimum* level of precision at a 95% confidence level[16] with intervals of ±4%, with a desire for ±2-3% on major sub-sample areas. This specification sets the minimum overall sample size required to achieve this.
2. **Large-sample collection of technical data**. We need to design a way of ensuring more complex, costly technical measurements of buildings, energy and environment can also become nationally representative. This includes challenges of pragmatics as well as methodological challenges around integrating technical data with social data.
3. **Being able to identify important changes (and reasons for them) in the population**. This is especially useful for evaluation of policy as well as identifying spontaneous drivers of change that could be accelerated by policy interventions.

a. High level survey design options

The high level options for the survey design comprise whether the survey is longitudinal, cross-sectional or a mixed design. We consider each of these below.

Pure longitudinal
This is a design where all the participants in each wave are contacted for repeat data collection. In practice, due to survey attrition, a regular 'top up' sample is normally required to ensure the overall sample size remains the same. Since each top-up sample will be new each wave of collection, they will be cross-sectional. This means that a 'pure longitudinal' will actually comprise around 80% longitudinal and up to 20% cross-sectional across the whole sample for any one year.

[16] This is the minimum general level of statistical reliability used in almost all sciences. That said, what is acceptable can vary by context and there is no absolute level here nor is it always true that a higher confidence level is necessarily better.

Pure (repeat) cross sectional
This is where no attempt is made to re-contact the same participating households each wave of collection. For the different types of data collection, some may still remain longitudinal (e.g. energy use data) but perhaps for a shorter period (e.g. 3-12 months) compared with the pure longitudinal (where the period of data collection may go over 2 or 3 years).

Mixed cross-sectional & longitudinal
This is where part of the sample (e.g. around 50%) is recruited to be part of the longitudinal panel, and the remainder is set up as a cross-sectional study. This has the advantage of reducing the impact of panel conditioning across the whole wave of data, but does reduce the power of both the longitudinal and cross-sectional if the overall sample size is kept the same in relation to the two 'pure' design options set out above.

Consideration
The benefits set out above would most clearly benefit from a **longitudinal design**. This is for the following reasons:

- This is the design that can best detect change. This is since change at the individual level *and* at the total sample (i.e. population level) can be detected. It is also much better suited to understanding the impact of energy use on wider factors and the consequence of wider changes (e.g. on health or employment) on energy use.
- Where there are different temporal patterns of change – energy use change can occur over minutes or hours, but dwelling materials change much more slowly – it is possible to take advantage of the slower rates of change to get greater power from the data. This is because buildings survey data collected in one wave will remain largely valid for many subsequent waves, as long as the home remains in the sample.
- Monitoring kit that is installed in one year can remain there for subsequent years. In a cross-sectional design, there would be a constant pressure to do buildings surveys and install and retrieve monitoring devices that is significantly reduced in a longitudinal design.
- Crucially, although panel conditioning effects (the systematic effect on responses of being in a panel) can be a problem for longitudinal designs, they can be assessed by collecting data from a smaller fresh sample each year, which can be matched back to the main sample. This is explored further in **Annex C**.

b. Sample size and strategy

It is assumed that as a large-scale government survey that may potentially be used to generate national statistics, a probability-based sampling approach will be used. This approaches produces data that is least prone to bias and challenges to external validity, and therefore produces better indicators of what is happening in the energy consumption system.

Minimum sample size
To meet the requirement of being able to generate nationally representative estimates, with the level of precision set out above, and with the preferred requirements around specific sub-groups, a minimum sample size can easily be identified. For a precision on national-level estimates of with a margin of error around ±2-3% for sub-groups such as different building types, (e.g. purpose-built flats) we need to ensure there are approximately 1500-2000 cases in the main sample. For this to happen as a consequence of the normal occurrence of such building types we would need an **overall sample size of around 10,000**. This sample size would also give better precision for more common building types (e.g. terraces: ±2.0%) and worse for less common (e.g. flat conversions: ±4.9%). This is the target **minimum** sample size we recommend, though we also consider the cost and design consequences of doubling this to 20,000.

A note on the margins of error presented here
Calculation of margins of error in a longitudinal and three level hierarchical designs such as this is determined by more than simply the standard sampling error. The margins of error present in this report derive mostly from random-probability assembled cross-section social survey methods. These are used here in part because they are widely understood and can capture a significant part of the data. Margins of error, however, depend upon a range of factors. These factors include the observed variance in the dependent variable, the size of the treatment effect that needs to be observed (in this context a 3-4% difference between groups), the weighting factors applied to sub-sectors of the population, the nature of clustering a used in the design, and the imprecision of instruments used to measure independent variables.

Also, margins of error calculated in this report and in **Annex C** are calculated assuming a degree of geographic boosting. In addition, the margins of error calculated in this report do not take into account any potential impact of clustering of the sample as this is difficult to estimate that at this juncture. The margins of error arising from a study implemented using this design are therefore likely to be larger than shown in this report (perhaps by around a third, so a margin of error of ±3% would more likely be around ±4%). Of course this may be offset by the fact that they have been calculated based on an observed survey measure of 50% and margins of error around other observed percentages will be smaller. Further refinement of the estimated margins of error should be undertaken in any subsequent phases of development, following the recommendations of this report.

Addressing panel attrition and conditioning: a cross-sectional element
Two major risks face longitudinal panel data's external validity[17]:

- *panel attrition* where the panel loses its representativeness over time as drop-outs leave only those with more interest in energy in the panel;
- *panel conditioning* where those in the panel spend more time considering their energy use, thus start to act differently from the wider population they are supposed to represent.

Estimates suggest that, for the first few waves at least, 20% attrition may be expected, though this may drop after wave 3. To address this **we propose that a target of 8,000 longitudinal panel members is maintained alongside a 2,000 cross-sectional sample drawn afresh each year**. This creates a total in-wave sample of 10,000. This is the minimum sample size in order to provide sufficient power within the longitudinal panel for the levels of precision preferred, and enables the panel to be systematically topped-up from the cross-sectional element. In addition, the fresh cross-sectional element is sufficiently large to enable the degree of panel conditioning to be assessed on many measures, helping to correct for that when producing estimates.

Sampling approaches: clustered vs. variants
Most government surveys are based on clustered sampling design. Unclustered samples result in slightly higher levels of precision but significant additional costs. It is assumed that **a clustered approach will be required**. The precise degree of clustering and its impact on the margins of error for key measures is something that would be incorporated into the more detailed design and development phase of the survey. We also only consider **random-probability sampling** (as opposed to quota sampling, for instance) with stratification as this method gives the most valid sample distribution that enables strong analysis.

Stratification and boosts
The feasibility of boosting will depend on whether the particular groups can be identified at the sampling stage – for example off-gas-grid homes. The decision of whether to boost such homes in the sample will also depend in part on the prevalence in the population.

c. Variable classes and data collection levels

Variable classes
Following a review of the available data in this area (see **Annex B**), and given the requirement to understand energy use, we have identified 4 classes of variables that a UKEL should collect as a minimum in order to deliver the benefits of socio-technical monitoring:

[17] 'External validity' refers to the extent to which the data you collect in the study truly represents the actual reality outside the conditions of survey. This underpins the degree to which (in this context) the findings are generalizable to the wider population.

1. **Social/human data**: this includes standard demographics including household income (important for fuel poverty analysis) as well as other sociological (e.g. status, practices, lifestyle), psychological (e.g. attitudes, intentions, expectations, beliefs, subjective comfort) and physiological (e.g. weight, energy expenditure, activity).
2. **Building data**: this includes standard measures of the building form, fabric and technology.
3. **Energy monitoring**: this includes electricity and gas at the meter point, preferably (and ultimately for the entire panel) by smart meter but may also include a range of direct appliance use monitors, collection of better data for non-metered fuels.
4. **Environment monitoring**: this includes measure of environmental conditions at different temporal and spatial resolutions, including air temperature, humidity and so on.

Data collection

The challenge
The four classes of data above create a practical and scientific challenge if data from every class is to be collected in sufficient numbers of homes as to provide estimates that have a margin of error of no more than ±3%. While there is little difficulty in getting interviewer-derived data at this scale, the practical challenge is how to get the number of sensors required to gather direct measurement data from the number of homes required.

The scientific challenge is how to know which sensors are most important to understand what most affects demand for energy. At one end of the extreme we might consider 100 different possible monitoring devices installed in 8,000 homes. This is clearly impractical even if it were affordable and ethical.

The proposed solution
However each of these factors count against that. In addition, we do not start from ground zero when considering what might be more important factors to monitor and so it is possible to narrow down the monitoring to what established knowledge indicates to be the most useful variables. That said, significant uncertainties remain about whether these measures are the best ones and what else – not previously measured or considered might play a role. As such, for the technical monitoring we propose to collect data at two levels of intensity:

- Light touch monitoring: installation of around 5 devices[18] across all 4 classes (e.g. comfort parameters; boiler activity; occupant activity; and a smart meter consumer access data logging device)

[18] By 'device' we mean an individual instrument. Such a device might collect 3 or 4 different types of data (e.g. temperature, humidity), and there may be 3 or 4 of the same type of device installed in the same home.

- Detailed monitoring: installation of around 20-30 devices across all 4 classes (e.g. covering the above but extended to include additional environmental variables such as CO_2 and VOCs; additional behavioural monitoring such as window and door sensing; additional physiological variables such as heart rate and activity; and additional building variables such as accurate envelope measurement and pressure testing.)

These two levels of intensity complement the more standard social survey/interviewer-acquired data to create **3 levels of data collection**.

Level 1 Interviewer collects data from household via one visit. No monitoring is undertaken. Smart metering is accessed when available.

Level 2 Surveyor also attends to undertake survey of building, install around 5 monitoring devices. High-resolution smart metering data is accessed.

Level 3 Monitoring technician also attends to fit around 20-30 devices around the home for the household.

Sampling for each of these levels

In order to maximise the benefits of each of these levels of data collection, while mitigating risks we propose the following design, based on the target 10,000 total sample per wave.

	Depth of data collection		
Variable class	**Level 1**	**Level 2**	**Level 3**
Social/human	Socio-demographics, reported behaviour, practices	Various possibilities: self-completion, diary, wearable device	Physiological measurement, wearable devices
Building	EHS-like building demographics, some direct measurement and data-linking (e.g. EPC)	More detailed building measurement by surveyor, infra-red measure	Detailed building measurement, blower test, laser scanning property
Energy	View of bill, meter reading, NEED meter point data, non-metered energy data	High resolution smart meter, plus other measurement	Disaggregation of gas demand and monitoring of devices for electricity
Environment	Householder report, one-off measurement	Temperature and relative humidity	Detailed spatio-temporal monitoring of a range of possible factors

Table 1: Showing the 4 variable classes and three levels of data collection proposed for the UK Energy Lab

Level 1 data collection
For level 1, this is the easiest and lowest risk data collection level. This can easily be collected from every home, every wave.

Level 2 data collection
For level 2, practical constraints suggest a more modest approach within any one year, with a target of the entire longitudinal panel element achieved over a reasonably short timescale, e.g. 3 years. This equates to around 2750 homes per year. Each home would stay measured for as long as practicable (potentially up to 5 years), but with a proportion of revisits anticipated for various practical and scientific reasons. Since this is targeted at the longitudinal panel it makes sense only to commence after wave 1 for those homes where successful re-contact is made. For those receiving level 2 data collection, they will receive a visit from an interviewer to obtain level 1 data, and a surveyor to collect level 2 data and install monitoring equipment.

Level 3 data collection
For level 3, this would be targeted at specific homes and measurement that will most benefit understanding the wider data from the UKEL. The scale of the sample will need to be very small (around 100 homes) and last at most for 1 year (with some elements, such as human measures, lasting much less). This level of data collection comes with specific risks – not least the number and novelty of the monitoring equipment – which demands specific piloting and testing prior to fieldwork commencing. We therefore propose that no level 3 data collection takes place for at least the first if not also the second wave of UKEL. For those receiving level 3 data collection, they will receive 3 visitors: an interviewer for level 1 data, a surveyor for buildings survey at level 2, and an engineer to fit monitoring equipment that covers levels 2 and 3 of data collection. The engineer will return at the end of data collection to de-install equipment.

The number of homes sampled at level 3 does not need to be nationally representative; indeed the costs of deploying the level of monitoring anticipated at level 3 at the national scale would be prohibitive. The sampling strategy at level 3 is one of sampling across the space of different combinations of households, dwellings, and heating technologies in order to capture the variability observed in the sample at larger scales. The exact numbers of homes in each of the combinations of these categories will depend on the specific type of measurement error that the sensing strategy is designed to minimise. This will vary from wave to wave and will be determined through undertaking global sensitivity analysis of models constructed from the UK Energy Lab data. This iterative process is intended to progressively reduce both imprecision in accuracy in the measurement methods and measurement models developed and deployed during the Energy Lab project. The exact size of the level 3 sample we therefore anticipate being set year on year based on what error needs to be assessed as the level 2 data emerge, and via possible EPSRC-funded projects being set up to refine this approach. Table 1 sets out what might be measured at each level for each variable class. More detail is available in **Annex C**.

Note: for simplicity, we propose that all 4 variable classes within a level are always collected together from the same homes.

d. Proposed survey design summary

The proposed approach comprises the following, and is illustrated graphically at Figure 2:

- A total 10,000 sample for each wave of data collection
- 8,000 of that sample to be longitudinal
- 2,000 of the sample to be cross-sectional, with around half recruited to the panel for the next wave, acting as a top-up
- All the sample to receive level 1 data collection on every wave
- Wave 1 data collection comprises **only** level 1 data
- Level 2 data collection occurs in batches, to cover the entire longitudinal panel over 3 years (ca. 2750 homes per year) from wave 2 onwards
- Level 3 data occurs from wave 2 at the earliest, and lasts for 1 year (ca. 100 homes per year)

Annex C, appendix A shows a more detailed graphical representation of this design.

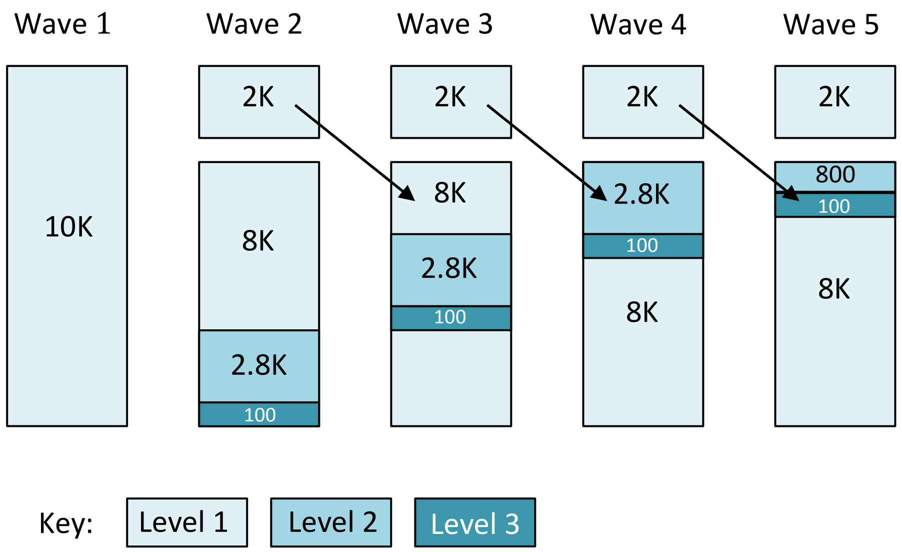


Figure 2: Showing the sampling approach for the proposed approach, with target sample sizes for each level of data collection per wave. Note that since the sample is longitudinal the level 1 sample below level 3 in waves 3-5 still return level 2 data on account of building data acquired and monitoring

equipment installed the wave before. This means that by wave 5 the achieved sample of homes returning level 2 data is close to 8,000.

e. How the proposed approach maximises statistical confidence

UK Energy Lab proposed approach employs a series of tactics to try to increase the statistical confidence in the findings. These include analysis of the longitudinal component of the data in order to eliminate between subject variability, through to the development of measurement models to increase the precision of estimates of the independent variables via the proposed different levels/intensities of data collection (see p. 29).

The proposed longitudinal nature of the data in UK Energy Lab supports different forms of analysis compared to cross-sectional data. In cross-sectional data the analysis of the impact of the programme depends on identifying differences in the relevant dependent variable **between groups**. This constitutes a "between-subjects" design and allows little room for the elimination of variance in the dependent variable. This is since there is naturally-occurring random variation between people which increases the variance in the estimates, and constitutes a source of noise when comparing two estimates over time, or between two groups at the same time. Where you are following the individual panel members through time, looking for differences in energy consumption coincident with certain natural experiments, such as the rollout of a given policy or programme, then a lot of the variance is removed. This is in large part because the natural variation that exists between people is removed by comparing changes within people. Through the application of panel methods, alternative forms of statistical inference can be conducted which takes into account the elimination of the between subject variance This enables more powerful analyses and allows for detecting smaller changes arising from the intervention.

The hierarchical nature of the data in the UK Energy Lab allows for the construction of inference models between the levels of the hierarchy. Models constructed at level 3 can be used to infer more accurate and precise estimates of the independent variables mentioned at level 2. These can in turn be used to make inferences about the independent variables measured at level 1. This construction of measurement models is entirely new to research in this field (although it is common in other fields such as physics). In addition to the construction of measurement models, considerable effort will be invested in the design and development of new, benchmark, instruments for the measurement of the dependent and independent variables.

Collectively, these approaches to the minimisation of variability will allow for significant improvements in the margins of error expressed here. The margins expressed here are conservative estimates based on existing, simpler, approaches.

f. Design risks and how they can be managed

There are several risks that UK EL needs to manage for it to be successful in delivering the benefits set out in Section 3. The design set out above is a direct attempt to manage these risks, but there are other risks around piloting and testing that need to be taken into account. These comprise:

- **Recruiting sufficient sample at level 2 and 3.** The scale of sampling here is unprecedented so there is little way of knowing how the range of homeowners required will react. Wave 2, where level 2 data starts being rolled out may need to be executed with specific care and interviewer reporting to enable adaptive management of the roll out.
- **Monitoring equipment success**. This covers a range of issues including factoring in failure-rates, accounting for particular issues in homes, and the remote transmission and access of data. The three wave roll out of level 2 data helps to mitigate this, especially if the first wave is seen in part as a live pilot. Subsequent waves can be adjusted to take account of success of the equipment, though at the potential cost of increased numbers of installations in later waves to account for earlier failures.
- **Data security lapses and ethical issues**. **Annex D** addresses ethics and security. Good governance and management here (see Section 6 below) are critical to ensure secure data and reduce the chances of a loss of credibility with the panel members. There is sufficient expertise in the UK to handle this via the medical cohorts, so the risk while high impact is low probability if sensible measures are taken.
- **Data complexity/accessibility**. Longitudinal data is normally more complex. UKEL also proposes greater complexity via the generation of complex socio-technical datasets that will require new forms of analysis to integrate and understand them. It will be important to invest in programmes of research to ensure these modes of analysis are developed to maximise the use of the data. Likewise, ensuring the management team is sufficiently resourced to enable stakeholder-accessible interfaces to the data, and programmes of training for analysts will be critical to maximise impact. In addition, collecting the right data to support other studies will require effective engagement prior to fieldwork to avoid the risk of data not being fully utilised.
- **Responding to funding pressures**. Over the years, different levels of funding may be available, depending on the funding model (see Section 6 below). **Annex C** outlines how the design proposed is modular, enabling relatively significant stripping back without necessarily endangering the overall survival of the panel. For instance, the amount of level 2 monitoring can be reduced, slowed down or paused. The cross-sectional element can be paused, level 3 data collection can be halted for several years (or funded via different routes), and so on. Additionally, the ability of the study to enable better technical innovation development and testing suggests that alternative sources of funding may be available, improving the resilience of the study to general changes in funding levels.

5. Assessing the costs

In this section we estimate the likely cost envelope of the proposed approach and compare that to the costs of main alternative designs. The costs here are generated via a cost calculator tool that was developed by NatCen under conditions of commercial confidentiality for DECC. The figures in this section of the Synthesis report are abstracted from Appendix C – Methods and Design, which were in turn based on Appendix B to Annex C, the cost calculator tool. As the cost calculator tool is based on NatCen's commercially sensitive cost estimating methods and data this tool will not be made public.

a. Survey costs calculator

The costs in this section are generated based on a range of assumptions:

- **Achieved response rate**: longitudinal response rate is assumed to be around 80% or higher year on year, lower for the cross-sectional element (around 58%).
- The **cost of monitoring equipment**: this is difficult to judge as it depends on exactly which piece of equipment is being purchased and any consequent discounts, future price changes, fail rates and so on. We use an estimate of £100 per piece of monitoring equipment as a conservative estimate. Some pieces will be more expensive and others much cheaper. This figure also takes into account some uncertainties regarding failure rates, testing costs and so on.
- The **costs of surveyors and interviewers** and associated training costs. This is difficult to estimate in total, but the core element is likely to be within current costs for these as deployed in a range of surveys including the EHS.

The cost calculator presents estimates for the different components of the survey design.

Estimated cost for the proposed approach

Below we present 5 year cost estimates based on the proposed approach (see section 4d for a summary). This comprises:

- A total 10,000 sample for each wave of data collection
- 8,000 of that sample to be longitudinal
- 2,000 of the sample to be cross-sectional, with around half recruited to the panel for the next wave, acting as a top-up
- All the sample to receive level 1 data collection on every wave
- Wave 1 data collection comprises **only** level 1 data
- Level 2 data collection occurs in batches, to cover the entire longitudinal panel over 3 years (ca. 2750 homes per year) from wave 2 onwards
- Level 3 data occurs from wave 2 at the earliest, and lasts for 1 year (ca. 100 homes per year)

For the purposes of the generating the cost estimate we assume a wave 1 survey length of 60 minutes with subsequent interviews being shorter at 40 minutes. In reality the actual average survey length has an extremely small marginal impact on the overall cost of delivering a UKEL with the proposed approach.

Based on the cost calculator we estimate that the minimum cost of setting up and running UKEL is around **£5-7M per year**, with a **5 year cost** of around **£27.8M,** including management and analysis overheads in today's prices.

Basic assumptions - summary
The sample would be a nationally representative and based on a random probability design. The sample frame would be the Post Office Address File (in common with most other major government surveys). We recommend the target unit of analysis to be the home: a combination of the household (people), the building, the technologies and the environment. In practice, certain types of accommodation or energy customer could be boosted. Any boosting could potentially increase cost depending on the prevalence of the boost sample and the method of boosting. No boosting is assumed.

It is assumed that interviewers would have assignments of around 25 addresses and these would be clustered within postcode sectors (or other areas of a similar size). This is a standard approach to sampling on social surveys, though some - notably the English Housing Survey - use less clustered (more spread out) sample designs. A less clustered design would be more expensive than assumed for the cost calculator.

Household interviews would be conducted in responding households' homes, using Computer-Assisted Personal Interviewing (CAPI).

Response rates and incentives
A household response rate of 58% for fresh sample cases is assumed for costing purposes. This is in line with other similar government surveys. A lower assumed response rate would increase costs since it would mean interviewers spending more time to achieve fewer interviews. A budget for some incentives is included, though the precise means of allocating the budget – such as whether they are conditional or unconditional on participation or even varied for different types of cases - would be a decision that would be decided as part of the final design process and may even be reviewed as the survey develops.

For the longitudinal cases, a response rate at the second year of 80% is assumed, in line with similar surveys. It is also assumed that attempt would be made to trace those cases who have moved from one year to the next and additionally, that for those who have moved, attempts would be made to interview the new residents of the old address. This could enable some potentially powerful analysis of the impact on energy behaviour on differing households at the same physical address (though there are some potentially significant ethical considerations here).

Costs in the cost calculator
The cost calculator works on the basis of the following costs in Table 2 for the different levels of data collection.

Level of data collection	Fixed costs	Marginal costs		
		Labour	Materials	Incentive
Level 1	1.0M	110	20	0
Level 2	0.8M	260	500	150
Level 3	0.5M	2400	7500	250

Table 2: Approximate costs (in £s) per level of data collection broken down by fixed and marginal costs based on a survey of 10,000 homes.

These costs are constructed on the basis of the following assumptions.

Level 1
The fixed costs here comprise both the management overhead for doing a survey per se plus the specific costs of running a longitudinal panel. Materials here represent any specific devices we may want the interviewer to carry (such as temperature monitor).

Level 2
The fixed costs here comprise mainly the costs of managing the buildings survey tool and surveyors. We anticipate smart meter installation being standard for those participating – at no additional cost to the survey. The marginal costs comprise the cost of a visit from a building surveyor who undertakes an EHS-style survey of the building and installs around 5 devices that are simple to install. Retrieval of instruments will be done on a follow up visit by an interviewer so have no additional cost implications. Budget for materials we estimate at £500 per home – this is sufficient to purchase approximately 5 or more devices that are straightforward for the surveyor to install. This a conservative estimate based on the upper end of the cost spectrum since many individual items may cost more like £30 per unit. Some of the homes may require a short revisit, so we budget for £60 per unit based on the notion of most not requiring any visit, some requiring a short revisit and a few requiring a full revisit. An incentive of £150 per home is budgeted for given the level of intrusion required to install and retain equipment in the home.

Level 3
Fixed costs here cover a team of 5 to manage the monitoring equipment both for this level and level 2 and undertake management and analysis of the data. Marginal costs comprise two main visits from an electrical engineer to install and remove devices, plus budget for a follow up visit for fixing issues. The budget for equipment to install here is £7500 per home, which is sufficient to

purchase and generate and test 20-30 different devices to install in homes. We estimate this cost is sufficient to cover most needs on most waves and is based on the experience with the 30 homes study undertaken as part of the ETI Smart Systems and Heat project (see **Annex F**). Rather than attempting to specify in advance what this might actually comprise, given the uncertainties around equipment costs and any specific use of this level in any one year, we think it makes most sense to simply set a sensible budget. This has the added benefit of being scalable.

Costs per wave

These unit costs can now be scaled up to estimate the 'per wave' costs of the proposed approach and can be used to consider alternatives.

Table 3 gives the proposed approach sample sizes per wave.

Wave	Level 1	Level 2	Level 3
1	10,000	0	0
2	10,000	2750	100
3	10,000	2750	100
4	10,000	2750	100
5	10,000	800	100

Table 3: Proposed sample sizes per wave of data collection for the proposed approach. Note that the sample sizes are not additive across levels as each level above level 1 implies collection of data at the level below.

Using the costs above this gives a 'per wave' cost as in Table 4.

Wave	Level 1	Level 2	Level 3	Total
1	1.7	0.0	0.0	1.8
2	2.1	3.9	1.2	7.3
3	2.2	4.0	1.3	7.5
4	2.2	4.2	1.3	7.7
5	2.3	2.5	1.4	6.1
Total	**10.5**	**14.6**	**5.2**	**30.3**

Table 4: Cost (£M) per wave per level of data collection, based on the proposed approach. Management and analysis fixed costs are built in, and inflation is applied at 3% p.a. including on wave 1 (i.e. costs are assumed to be incurred a year from now).

c. Alternative designs – illustrative costs

To understand the value for money achieved by using this design we will compare the effects of **changing the sample size** (doubling all elements of the fieldwork except level 3 data to a total of 20,000, with a 16,000 longitudinal panel and 5500 per level 2 for waves 2-4) and **changing the fundamental**

design by going entirely **cross-sectional**, but maintaining the same structure as for the proposed approach based on waves 2-4 (total sample 10,000, 2,750 level 2 data, 100 level 3 data).

Larger sample
The main benefit of doubling the sample size is increasing the precision of the estimates achieved and having a larger number of cases in any given period to follow for natural experiments (such as house moves). There is also the benefit of having deeper cross-breaks enabling comparisons across housing type, household type and energy pattern use in a way that a smaller sample would not be able to handle with adequate precision. The effects on the margins of error are explored in detail in **Annex C**.

The costs of this approach are set out below in Table 5. Other issues that would need to be borne in mind are the practical difficulties of rolling out over 5000 level 2 visits per year. This may be possible, but it is a much greater risk than that facing the proposed approach.

Wave	Cost (£M)
1	3.3
2	11.4
3	11.7
4	12.1
5	8.7
Total	**47.1**

Table 5: Estimated costs of doubling the sample size of the proposed approach to a total of 20,000. Level 2 data is rolled out at a rate of 5500/wave from waves 2-4, with a 1600 top up in wave 5.

Cross-sectional design
If we were to roll out any one of the waves 2-4 as a cross sectional design, where every year a fresh sample was taken, some costs go up and a few go down. The main area where issues arise is in the value of the data, both on account of the power achieved, and the validity where monitors are returned by post (with a lower and likely biased response).

Overall, the management costs would be cheaper as there is no panel to maintain. We have 'guestimated' this as a third cheaper. Sampling costs would go up as response rates for a fresh sample are higher than for longitudinal samples. We have not costed for the return of equipment here which could be a significant factor if done manually by a visit, or as suggested above, would impact on data quality if returned by post by the participants.

For this alternative design then, the figures in Table 6 are based on a per wave total sample of 10,000 all at level 1, with 2750 receiving level 2 data collection and 100 receiving level 3.

Wave	Cost (£M)
1	6.7
2	6.7
3	6.8
4	7.0
5	7.1
Total	**34.3**

Table 6: Estimated costs of running a **cross-sectional survey** on a similar basis to wave 2-4 of the proposed approach (10,000 main sample at level 1, 2750 at level 2, 100 at level 3). Costs for return/retrieval of equipment **not** included, but management and inflation at 3% is included.

Conclusion

The costs presented above show the difference it makes either increasing the sample size or moving to a cross sectional design. The change of design loses significant benefits – including no longitudinal data, and a vastly reduced level 2 achieved sample size by wave 4 – while not reducing the costs significantly. Increasing the sample size reduces the margins of error and makes better use of the fixed costs, but obviously costs significantly (ca. 50%) more. Over the longer term it may make sense to increase the sample size (decreasing it would reduce the precision for most analysis beyond acceptable levels) of the proposed approach, but it makes little sense to undertake the survey as a purely cross-sectional study.

6. Financing, governing and managing

a. Proposed financing models

There are many ways in which a UK Energy Lab could be funded. To navigate these, we have presented the range of possible funding agents below to give consideration about who is most likely to benefit, and review and consequences for the future sustainability of a survey. We explore alternative funding sources in Box E below.

Funding agents

Research Councils UK
These are the leading public research funding agencies in the UK with a remit to "support excellent research, as judged by peer review, that has an impact on the growth, prosperity and wellbeing of the UK" (RCUK[19]). Under the proposed approach it is envisaged that one or more of the research councils (principally, but not exclusively Engineering and Physical Sciences Research Council (EPSRC), the Economic and Social Research Council (ESRC) and possibly the Science and Technology Funding Council (STFC)) would have a deep strategic interest in supporting a UK EL. This is because such a facility would strengthen the UK research base in this area and put the UK in a globally leading position for domestic energy demand research. It would also boost the opportunities and effectiveness of innovations in this space helping to generate growth and jobs in the UK and contribute towards government objectives on energy security and efficiency and climate change.

UK Government departments
The lead department in the UK is clearly DECC, but there is also strong benefits for the Department of Communities and Local Government with their remit on building regulations and housing. Devolved governments like Scotland and Northern Ireland would be likely to have a strong interest for data from their jurisdictions. Effectively the split set out below reflects the likely contribution of devolved governments (approximately 30% of whatever proportion is funded by the English government). The design we set out could either be rolled out across England or UK, with either a top-line sample size of 10,000 after wave 1 for either of those two geographies. Alternatively if a 10,000 sample were required for England, then around 3,000 sample for Scotland, Wales and Northern Ireland would take the total sample to about 13,000. This latter approach is the only way of ensuring an acceptable level of precision at the country level, should any future study end up having UK coverage.

[19] See: http://www.rcuk.ac.uk

Government Agencies and arms-length bodies
It is likely that bodies like Ofgem, National Grid, the ETI and the TSB will all have an interest in some aspects of the data collection or the facility to collect data. They regularly fund different kinds of research activity in this area, but it is likely that their support might be less in terms of direct funding and more in kind (unless it is for access to a possible Innovation Lab – see Box E). This has implications for the composition of a governance structure that would need to keep their interests in mind as the survey is developed. A key element to generating benefits to these groups will be to ensure effective data access and data linkage that enables them to extract value in relation to their needs.

Private sector energy companies
The major energy companies in the UK have a direct interest in the data, principally to enable them to offer more targeted tariff and energy packages. EdF and EoN in particular have a track record of funding more academic research in energy and are partners in many joint funded activities (both bodies have funded Strategic Partnership research programmes with EPSRC funding a range of research activities). However, the main issue with funding from energy companies is the risk to response rates. There is a strong risk that householders will be put off from taking part if they know the energy companies are involved in the study. This leaves open the possibility that National Grid and the Distribution Network Operators – who have a need to understand consumption patterns, and what predicts them, may have a strong interest in the data. This would mainly be for planning rather than commercial advantage so may not suffer the same issues as those identified for the retail market suppliers.

Box E: **Alternative sources of funding**
Are there other ways of funding the UKEL? Below we look at a number of ways of monetising some of the benefits and consider whether they make sense and provide a sufficient source of funding.

a. **Training for researchers using the data or wanting to undertake their own, complementary studies**
This will be an important aspect of the overall enterprise. However, while there is little doubt that such training can attract funding from national and international sources, it is unlikely to make a significant contribution to the costs of survey delivery, since the cost of carrying out the training will need to be covered. Also it will be important to make sure the cost of training is not prohibitively high, preventing the benefit of the training reaching a wider audience.

b. **Selling data packages for commercial firms**
This has some potential, though as yet the market is untested. There is a precedent in this area such as commercial surveys

supporting market research in the TV and radio industry (see BARB[20] for instance). However, it will be imperative to ensure the survey is not funded directly by commercial interests as this will undermine credibility with the panel participants and impact negatively on response rates.

c. **Getting discounts on monitoring equipment**
The large numbers of monitors required for the panel (around 24,000 to 40,000 separate units) will likely result in discounts via bulk purchase. However there is a possibility of utilising the high profile brand of the UKEL by enabling providers of monitors to benefit from being a supplier. In return there is the potential for even lower prices on the unit cost of this equipment. However, we would warn against attempting to exploit that (at least in the first few waves) as that would undermine credibility if there was a sense in which the survey was a vehicle of sponsorship.

d. **Access to an 'Innovation Lab'**
One of the clearest ways in which funding could be developed is via an innovation panel. This is a small panel of homes that have been part of the panel for a few years and have consented to have new technologies installed for at least a year. Access to the panel, its data, and matching to current panel members provides much better data for testing new technologies. This has a much greater chance of providing support for the wider panel. The cost of testing (ie accessing the homes with the standard UKEL monitoring) would be in the region of £0.9M for a 100 home panel (based on level 3 monitoring costs). The price for access could be set higher to account for the value of the wider data set that provides important comparative data.

e. **Question sponsoring**
Similar to the innovation testing, space on the social survey element could be sold at higher than cost rate. However, the market potential for that is less (since there are a number of competing sources of survey data that act as an omnibus) and the costs around this are much lower, meaning the benefit to the survey funding is low.

Potential funding model - rationale
Given the analysis above, and our findings from the review of other studies (see **Annex E**) our starting point for funding a future UK Energy Lab is to focus

[20] The Broadcasting Audience Research Board. See http://www.barb.co.uk

on the research councils (principally EPSRC and ESRC) and key UK government policy leads (principally DECC, but also the Scottish, Welsh and Northern Irish governments). Given the need for outputs to have a strong credibility and focus on quality of data first – a key message from all stakeholders (see **Annex A**) – it makes sense for the research councils to have a majority stake. Given the need for the study to retain policy relevance and impact, it makes sense for government departments to have a significant funding role, such that without their funding the survey would not be able to continue in the basic form. Within government, it makes sense – given this is an *Energy* Lab – for DECC to have the majority funding stake.

Our starting point for discussion is therefore to assume a 60% stake from the research councils and a 40% stake from government departments. This 40% is split 25% DECC and 15% another public sector organisation (e.g. Ofgem, National Grid). *As noted above, we have **not** consulted with these organisations about any contribution so reference to them here is purely illustrative, and does not imply any intention to contribute.*

Proposed approach - Mixed Government & Research Council
The proposed approach for funding and governing a potential UK Energy Lab would be for research councils to be majority funders. This is likely to be the EPSRC together with the ESRC, and possibly the STFC. Then on the government side the lead department would be DECC, together with one or two other public bodies (OPBs), such as other devolved UK governments with energy policy interest or Ofgem. Within the government group of funders, DECC should be in the lead to ensure the clear, strategic focus on energy, but still ensure significant funding from a second or third partners.

This would give a total of 4-6 partners. With a 60-40 split in funding it means the major stability and quality is assured due to research council major funding, but there is substantive contribution from government to make the study unworkable without them. This helps retain the studies relevance without it being caught into specific policy issues which can be the death of a survey over a period of one or two governments (e.g. Citizenship Survey[21]).

This approach would mean the following funding split:

Research councils – 60%
Government – 40% (DECC – 25%; others totalling 15%)

Below we explore what this split means in terms of two different scenarios:
- **Scenario 1**: following the proposed approach as summarised on page 31 (section 4d).

[21] See:
http://webarchive.nationalarchives.gov.uk/20120919132719/www.communities.gov.uk/communities/research/citizenshipsurvey/

- **Scenario 2**: A version of the proposed approach with the sample doubled to 20,000

Scenario 1: 10,000 sample, proposed approach
This involves a target 10,000 sample after wave 1, with an achieved sample of 8,000 level 2 data collection by wave 4, and an annual sample of 100 homes at level 3 from wave 2 onwards.

Total 5 year estimated cost (£M): **30.3**

Table 7 shows how this breaks down for each contributor. The main cost are felt in waves 2-4 as the level 2 data is collected at scale, then reduces to what is likely to be the standard level at wave 5 until a full refresh is commissioned or the survey is closed down.

Contributor	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
RCUK (60%)	1.1	4.4	4.5	4.6	3.7
DECC (25%)	0.5	1.8	1.9	1.9	1.5
OGB (15%)	0.3	1.1	1.1	1.2	0.9
Total	**1.8**	**7.3**	**7.5**	**7.7**	**6.1**

Table 7: Showing the costs (£M) per contributor for each of the five waves for the proposed design with a 10,000 sample.

Scenario 2: 20,000 sample, with proposed approach
This involves a target 20,000 sample after wave 1, with an achieved sample of 16,000 level 2 data collection by wave 4. Annual sample of 100 homes at level 3 from wave 2 onwards.

Total 5 year estimated cost (£M): **47.1**

Table 8 shows how the costs vary for different contributors as the sample size doubles. Importantly this is of greater benefit to the minority partners whose contribution may only increase by £200-500K but get access to much more precise data and/or better sub-sample analysis.

Contributor	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
RCUK (60%)	2.0	6.8	7.0	7.3	5.2
DECC (25%)	0.8	2.9	2.9	3.0	2.2
OGB (15%)	0.5	1.7	1.8	1.8	1.3
Total	**3.3**	**11.4**	**11.7**	**12.1**	**8.7**

Table 8: Showing the costs (£M) per contributor for each of the five waves for the proposed approach with a 10,000 sample.

Conclusions

Even with multiple partners the costs to individual organisations here may make a 20,000 sample unachievable, especially when put in context next to the current internal budgets for supporting this kind of work. It is likely that a sample of this size could only be supported if the move to utilising the survey as a source of innovation development and testing is followed. This runs the risk of the sample validity being affected and is not without other challenges such as the means of managing the innovation panel members' risks of equipment failure and so on.

The main alternative if a larger sample size is preferred is to increase the level of research council investment and/or to follow the example of the English Longitudinal Study of Aging[22] and work with international partners to develop internationally linked data. This would have the effect of increasing the research council stake, and reducing the government funding. This would take it more into line with many of the UK panel and cohort studies where funding splits are closer to 80% RCUK funding and 20% government funding. While the split could be done, it does raise risks of the study losing links with policy audiences, though this risk could be managed by a commitment to host or employ a UKEL-specific researcher to sit within each government organisation.

b. Proposed governance structure

Annex E reviews a range of other longitudinal and mixed design surveys to understand what forms of governance are related to longer-term success and resilience. The governance structure is going to need to balance the need for strong scientific leadership to ensure the quality of the data, with effective stakeholder engagement to ensure the outputs remain relevant and influential.

The scale of the study in terms of different constituencies that it serves and the complexity of the data make it similar to Understanding Society. We anticipate that a governance structure that takes the best of that approach while being cognisant of the need to keep the number of partners to a manageable level and ensure streamlined processes.

The proposed governance structure takes its cues from Understanding Society, but presents a less complex structure that reflects the needs of a UK Energy Lab. The overall suggested structure is set out at Figure 3. The two key components are:

- **The Funders' Board**. This is the place where the different funding organisations meet to agree budgets and define their aims and priorities for the survey. Initially this is the commissioning agent.
- **The Survey Leadership Team**. This comprises principle investigator, the survey director from the field force organization, the surveyor manager

[22] See: http://www.elsa-project.ac.uk

from the surveyors' side and the lead technologist responsible for the monitoring. This is the commissioned agent.

These two structures meet at the Management Board where the funders' aims and priorities are discussed with Survey Leadership team to determine how and whether they can be delivered.

Two other structures provide accountability and engagement with the wider community:

- The **Steering board** is the place where a range of stakeholder voices from industry, innovation research and development, civil society, wider policy can communicate their ideas, concerns and other input. This ensures the survey remains relevant to as wide a constituency as possible. The steering board helps to keep an eye on the longer term and ensure the survey can navigate different funding contexts successfully.
- The **science and technology advisory group** ensures the survey continues to develop methods of fieldwork and analysis, continues to act ethically (especially given likely advancements in 'quantified self' and the context of the 'internet of things') and safely. A specific technologies sub-group here is likely to prove useful in keeping abreast of both what monitoring technologies are available and the rise of energy technologies that might have an impact on the survey data.

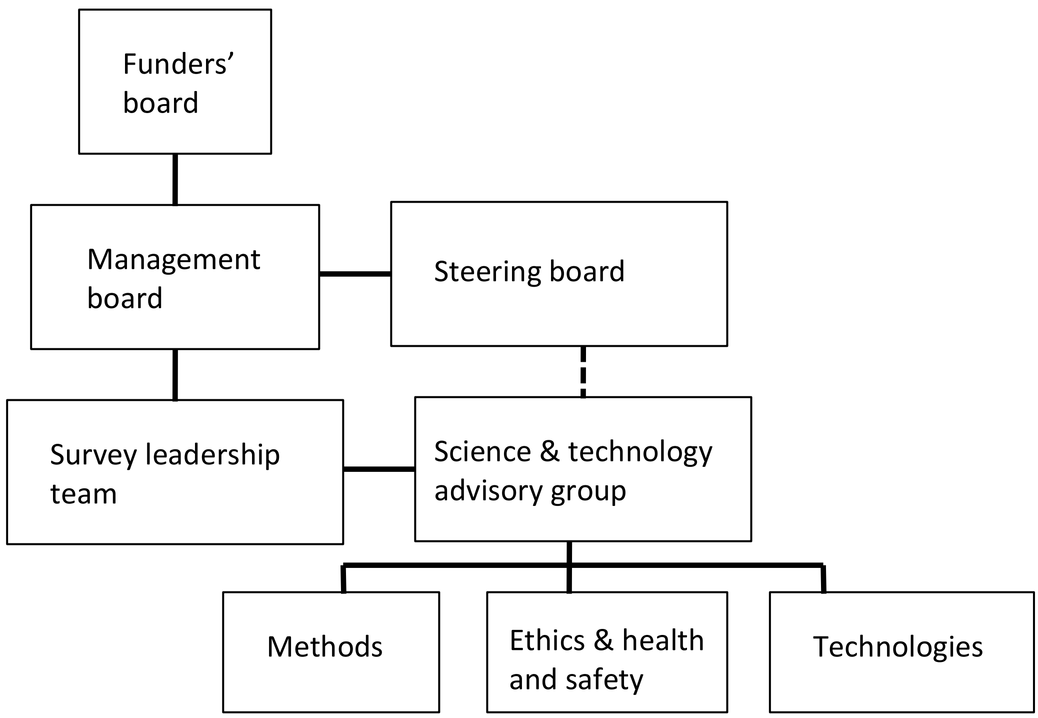


Figure 3: A diagrammatic representation of the proposed governance structure for the UK Energy Lab.

The approach above provides a short-term management architecture circulating anti-clockwise around the four central structures (feeding down from the funders' board) and longer-term strategic planning and 'landscape responsiveness' that could circulate up from input via the advisory sub-groups and via the steering board.

Steering vs. management vs. advisory boards

In many of the structures we reviewed for this report the management board here (given how it is constituted) would normally be the governing board. While such an approach would no doubt work and no directly affect the survey functioning, it does raise questions about the ability of the survey to retain adaptability over the long-term. Providing a space where external, interested parties can not only voice an opinion but also, in some substantial way, *influence* the general direction of the study provides an opportunity for the UKEL to remain relevant and even become agenda-setting. Without such a space, there would be a need to conduct more frequent consultation exercises. While such exercises are invaluable, they do not enable a sense of ownership of the study by the wider community. Generating a sense of ownership will be critical in ensuring it becomes seen as an essential part of the research landscape and returns maximum value. This is the role and function identified for the steering board. This board plays a similar role to the 'governing board' identified in the Understanding Society governance structure.

c. Management structure & costs section

A proposed management structure is set out in **Annex G**. This recommends an approach similar to that used in both Understanding Society and by the Centre for Longitudinal Studies[23]. We estimate that the overall team would need to be about 10-13 strong comprising a principle investigator, survey management team comprising senior researcher and specialists across social, buildings, energy and environment. There will need to be technical specialists to manage the equipment and systems as well as support staff on communications and panel management in general. The overall costs for the management of the panel and being able to output useable data is in the region of about £2.0M to £2.5M per year depending on the location of the team and amount of budget set aside of testing and development of equipment and field-testing. For the purposes of modelling the costs above we have assumed roughly £2.0M in management and analysis costs, but would recommend (as this is the minimum to gather the data and process it effectively) a higher amount to manage risks around impact and stakeholder engagement.

[23] See: http://www.cls.ioe.ac.uk

7. What next?

a. Next steps for this project

This report is intended to inform funding decision-making regarding whether to move ahead with development of a UK-wide longitudinal energy demand panel. The work on this feasibility project has now completed, though key elements of the work here are potentially being picked up by the RCUK Centre for Energy Epidemiology as part of their wider programme.

Below we set out possible future phases of a UK EL to inform decision-making regarding investment in further development, and identify when a possible launch would be possible.

b. Potential future phases

Annex F sets out in detail what the potential next phases are, and the lead-time for commissioning the first waves of a UKEL. This has also been operationalized into a planning calculator provided alongside **Annex F**, to assist in future planning.

The timetable for delivery of the UK Energy Lab (set out at Table 9) could operate on a two-track basis. The first track is the development of the content of the first stage and set up of the survey delivery organization or consortium. In parallel development of the measurement methods and protocols for the first wave of level 2 and level 3 data collection is advised. The costs for these development phases have not been explored here, but seen as a series of individual projects, none are likely to cost more than around £200-500K each, with one of them (concentric rings design and testing) already being funded via the RCUK End-Use Energy Demand Centres' Working with Centres call as a joint venture between Edinburgh and the UCL CEE.

Financial Year (illustrative)	Track 1: developing wave 1/level 1 data	Track 2: developing level 2 and 3 data
2014-2015	Commissioning survey team Wave 1 content development and consultation; pilot 1 starts.	Project commissioned to Identify key measures and instruments; conduct initial tests Project to test concentric rings design; begin in situ testing
2015-2016	Survey team appointed,	Project to test remote data collection;
2016-2017	Pilot 1 ends; Pilot 2 is completed. Wave 1 launch	Complete in situ testing; compete concentric rings design; Field trial 1, level 2; Field

		trial 1, level 3 begins
2018-2019	Wave 1 completes Wave 2 launches	Field trial 1, level 3 ends; field trial 2 and live pilot for level 2 data; field trial 2 and pilot for level 3; Wave 2 launches with level 2 and 3 elements

Table 9: A proposed timetable for launching a UK Energy Lab, and developing methods and tools for the more complex level 2 and 3 data collection.

The timetable shows that it is possible to get wave 1 underway by 2017, with major piloting in 2016. However, the collection of complex level 3 data is operating under a tight timetable, and so as suggested above it may be better to wait a further year before this is rolled out to enable fuller testing. That said, with the announcement of the funding of the Edinburgh-CEE EUED Working with Centres call level 2 and level 3 will benefit from co-testing (as in the concentric rings design and testing project) thus allowing their development in parallel. This project will start reporting important findings for the UKEL in the next 18-20 months.

ANNEXES
These are provided in separate documents.

ANNEX A: Case for a UK Energy Lab
ANNEX B: Available Data
ANNEX C: Design and Methods
ANNEX D: Ethical considerations
ANNEX E: Governance
ANNEX F: Piloting and pragmatics
ANNEX G: Non-domestic settings