Smart Meter Data and Public Interest Issues – The National Perspective

Discussion Paper 1

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Foreword

Much discussion about smart energy data is understandably focused on its likely use in consumer feedback, in enabling the future smart grid, and in the potential for commercial applications, but it could have wider uses. In summer 2015, TEDDINET*, the Centre for Sustainable Energy and Sustainability First launched a joint 'research challenge' to understand how future household smart-meter energy data might be deployed to serve the public interest. We jointly commissioned two university researchers to consider these questions and for each to write a short discussion paper, one on the national perspective and the other on sub-national issues, for publication and debate.

The sponsors have provided assistance and guidance, and financial support. But the papers and the views expressed in them are those of the researchers concerned.

Following an invited workshop with interested parties, the papers will be published on the TEDDINET, CSE and Sustainability First websites:

https://teddinet.org/
https://www.cse.org.uk/
http://www.sustainabilityfirst.org.uk/

* TEDDINET – Transforming Energy Demand through Digital Innovation NETwork.

TEDDINET is an academic research network addressing the challenges of transforming energy demand in our buildings, as a key component of the transition to an affordable, low carbon energy system. Funded by the UK EPSRC (Engineering and Physical Sciences Research Council), TEDDINET's primary purpose is to share knowledge and enhance the impact of existing research.

Contents

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1. Executive Summary

It is expected that smart meters will be installed in approximately 27 million domestic properties and 2 million small business premises by the end of 2020. The data from these smart electricity and gas meters can help modernise the energy industry, facilitate the evolution of a smart grid in the UK and aid the development of new and innovative energy services for commercial organizations. However there are also public interest uses of smart meter data that could bring significant benefit to many stakeholder groups across the UK.

This paper – one of two companion papers looking at these issues – will examine some of the strengths and key limitations of existing energy datasets and highlight the benefits derived from smart meter data. Public interest uses of smart meter data in areas such as policy, academic research, the energy industry and benefits direct to the consumer will be discussed. The other paper in this series looks at these issues from a sub-national perspective (1).

The arrangements for accessing smart meter data are documented and potential barriers deriving from these arrangements are discussed. Finally recommendations that seek to address these barriers in areas such as policy and governance, data privacy and informed consent and data resources are provided. The need for a strong, co-ordinated voice for public interest perspectives amongst existing industry actors is highlighted.

It is hoped that this (and the companion) discussion paper will prompt debate and encourage action to ensure that vital public interest uses of smart meter data do not get marginalized as the smart meter system continues to evolve.

2. Introduction

This paper focuses on the national perspective and is one of two papers commissioned by the Centre for Sustainable Energy [1]and Sustainability First[2], and funded by TEDDINET[3]. The second companion paper focuses on sub-national and local perspectives (1). Both documents focus on domestic electricity and gas smart meter data and aim to act as discussion documents and to provide practical recommendations for a range of organisations with an interest in the potential public interest benefits of smart meter data. There is also a technical annex which, along with Section 3 below, provides more detail on existing energy datasets.

The Smart Metering Implementation Programme (SMIP) aims to install smart electric and gas meters in all (relevant) domestic properties in GB with an expectation that around 53 million smart meters will be installed by end 2020. Smart meters can provide high resolution (e.g. half-hourly) electricity and gas consumption data which has never previously existed on a national scale.

These streams of high resolution energy data will offer new avenues for organizations to develop innovative commercial services provided to either energy consumers or other organizations in the energy sector (particularly as the smart grid develops). However, as the energy consumer is intrinsically involved in the £10+ billion investment in the Smart Metering Implementation Programme (as industry costs will, to some extent, be passed on to consumer energy bills), it is important that public interest uses of smart meter data are not marginalized by an understandable focus on energy industry issues. The Department of Energy and Climate Change (DECC) estimates a net gain of over £6 billion (NPV to 2030) from the Smart Meter Implementation Programme resulting from reduced energy consumption (e.g. via behaviour change prompted by feedback via In-Home Displays provided with smart meters) and reduced costs savings in several areas e.g. reduced expenditure on energy infrastructure and operational efficiencies such as reduced site visits for meter reads (2).

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[1] CSE - https://www.cse.org.uk/

[2] http://www.sustainabilityfirst.org.uk/

[3] http://teddinet.org/

This paper deliberately does not seek to tightly define *public interest* but rather takes a broad view that it involves the combined long-term interests of consumers, citizens, investors and the environment (3). Although this paper will, at times, somewhat artificially categorize public interest uses of smart meter data with a focus on one particular stakeholder group, the reality is that in many cases the delivery of public benefit will cut across several groups. For example, academic research will often feed into the development of government policy while commercial organizations and commercial services can deliver both profit and significant public benefit.

Public interest uses of smart meter data include the potential to dramatically improve the evidence base underpinning academic research and government policy at central, regional and local levels. Equally there is likely to be considerable public benefit deriving from an improved evidence base to better inform organizations delivering services to, for example, tackle fuel poverty or increase energy efficiency in the UK housing stock.

This paper will investigate public interest use of smart meter data, barriers to the realization of public benefit from the smart meter implementation programme, and discuss possible solutions to reduce barriers and improve the potential for public benefit from the Smart Meter Implementation Program (SMIP).

3. What's new about Smart Meter data compared to what already exists?

Existing domestic energy data

Several researchers working in the domestic energy sector have commented on the historical shortage of good quality energy data that contributes to a reliable evidence base for research, policy evaluation and other public interest uses, while acknowledging the potential for new data sources such as smart meter data to improve the existing situation. (4–6).

Historically the evidence base in the domestic energy sector has been reliant on national statistics, large nationally representative surveys or data collected during small research projects or field trials focused on a specific subject. National statistics such as the Digest of UK Energy Statistics (DUKES) [4] and Energy Consumption in the UK (ECUK) [4] are aggregated to such large geographic areas that they have limited value to many research, policy or public interest uses, where more granular data is often required. The Department of Energy and Climate Change's (DECC) sub-national statistics[4] offer higher resolution data with energy consumption aggregated to Middle Level Super Output Area (MSOA), Lower Level Super Output Area (LSOA) and, for the latest dataset available (2013), postcode. Aggregation to relatively small areas such as postcode enhances the utility of this dataset with a further advantage being near universal coverage with the statistics based on over 27 million electric and 23 million gas meters across England, Scotland and Wales.

However datasets where the primary unit of analysis is the home/household are considered to have higher utility in many scenarios. Large nationally representative surveys such as the English Housing Survey (EHS), the Scottish Household Survey and the National Survey for Wales[4] have been a historic source of energy related data in the UK domestic sector. While these surveys contain variables relevant to energy consumption in domestic houses such as household demographics and building characteristics, the actual energy consumption data is limited.

[4] See Technical Annex for more information regarding these datasets.

The 2011 Energy Follow Up Survey (EFUS)[4] provides a much richer source of energy data with a subsample of 2,616 EHS respondents receiving 4 levels of further monitoring:

- Interview Survey (2,616 homes) - Questions on usage, patterns and behaviours for a wide variety of appliances and lighting as well as heating patterns and thermal comfort.
- Temperature monitoring (a sub-sample of 823 homes) – Internal and external temperature data.
- Electricity and gas consumption (a sub-sample of 1,345 homes) – from meter reads
- Sub-meter electrical monitoring (a sub-sample of 79 homes): electricity monitors installed to examine patterns of lighting, appliance and electrical cooking use.

With the matched data from participants' EHS records, EFUS 2011 is a rare nationally representative dataset that combines data across the socio-technical spectrum with demographics, building characteristics, energy consumption and variables providing information on energy consuming practices and behaviours at the household level. Additionally sub-household monitoring provides high resolution data for the construction of electricity and temperature profiles.

The Household Electricity Use Study (HEUS)[5] is similar to EFUS in that it constitutes a nationally representative sample of English households (owner occupiers only) with very detailed monitoring of electricity at the sub-meter/appliance level. Participants were also surveyed about environmental attitudes, energy behaviours and use of appliances etc.

As well as nationally representative samples such as HEUS and EFUS, there are several datasets generated from smart meter research projects including Low Carbon London, the Energy Demand Research Project (EDRP) and the Customer Led Network Revolution[5]. These datasets offer high resolution energy consumption data (e.g. half-hourly) but the publically accessible datasets are anonymized and have many of the accompanying variables of interest (e.g. socio-demographics, building characteristics) removed.

Finally, there are datasets derived from administrative or quasi-administrative data. The Energy Performance Certificate (EPC)[5] Register stores data generated by EPC surveys which include detailed

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[5] See Technical Annex for more information regarding these datasets.

building and energy efficiency characteristics (size, building type, insulation) and modelled energy consumption and energy efficiency ratings using the Reduced Standard Assessment Protocol (RdSAP).

DECC's National Energy Efficiency Data-framework (NEED)[2] highlights the enhanced value that is often generated when datasets are linked. Here DECC have used Ordnance Survey's AddressBase as a central spine and linked energy consumption data, EPC data, energy efficiency data from HEED, VOA data and modelled socio-demographic data from Experian at the home/address level to create a powerful dataset that has demonstrable utility for policy development and evaluation (7).

Although there is a publically available NEED dataset (50,000 records) and an end-user-licence version (4 million records) available via the UK Data Service, both datasets are anonymized and contain a reduced set of variables while access to the full domestic dataset (27 million records) is usually restricted to DECC (and occasionally other government departments).

However there are several issues that limit the utility of these existing datasets for certain applications:

- Spatial aggregation / unit of observation
- Temporal resolution
- Temporal correlation
- Anonymization / de-identification
- Data linking – Reduced ability to link datasets
- Accuracy/quality of energy data
- Accessibility of data – restrictions on access or use
- Representativeness

While some public interest uses of energy data can happily work with aggregated data, many forms of research or other public interest uses require data where the primary unit of observation is the house, household or home (house + household). Aggregated data, even to relatively small geographic areas, such as sub-national statistics entails the use of averages which disguises the diversity of energy consumption profiles and reduces the ability to link data at a granular level for analysis of energy consumption alongside relevant contextual variables.

The quality and temporal resolution of energy data in many existing datasets is also a concern. In many cases, energy consumption data is an annualised figure which is seasonally adjusted or weather corrected and may be based on estimated readings and subject to considerable processing by data providers (e.g. annualised energy data provided to NEED) or self-reported from billing information with potential "human error" (e.g. EHS) (8).

In addition to temporal resolution, there is also the issue of temporal correlation. Each element of data relating to a unit of analysis (e.g. a home) in a data framework such as NEED is collected at different times. This makes interpreting the data challenging as it is difficult to assess whether observed relationships between variables relate to the same entity.

It is important to note that the extent to which these limitations in data-frameworks such as NEED matter, depends on the public interest question that is trying to be answered. Broadly speaking, the more finely balanced the decision, the more these types of limitations are likely to limit the utility of the data. Where broad-brush understandings, or clear benefits, are apparent then such data is likely to be very useful and fit for purpose.

Anonymization or de-identification of domestic energy data is generally required in order to comply with research ethics, commercial practices or relevant legislation (e.g. the Data Protection Act). The issue for anyone wishing to use de-identified data is that the processes to anonymize the data (e.g. statistical disclosure control) often remove or aggregate variables of interest while inherently removing the ability to link to other datasets. The inability to link any of the existing datasets covered by this report to other data of interest is a significant factor in an assessment of their (reduced) utility for public interest uses.

Finally representativeness is an issue for several datasets that otherwise contain high-resolution energy data (e.g. datasets from HEUS, Low Carbon London, the Energy Demand Research Project, and the Customer Led Network Revolution).

A summary of existing datasets is provided below. This is not intended to be an exhaustive list of available datasets but rather is intended to be indicative of existing data available for public interest uses in the domestic energy sector.

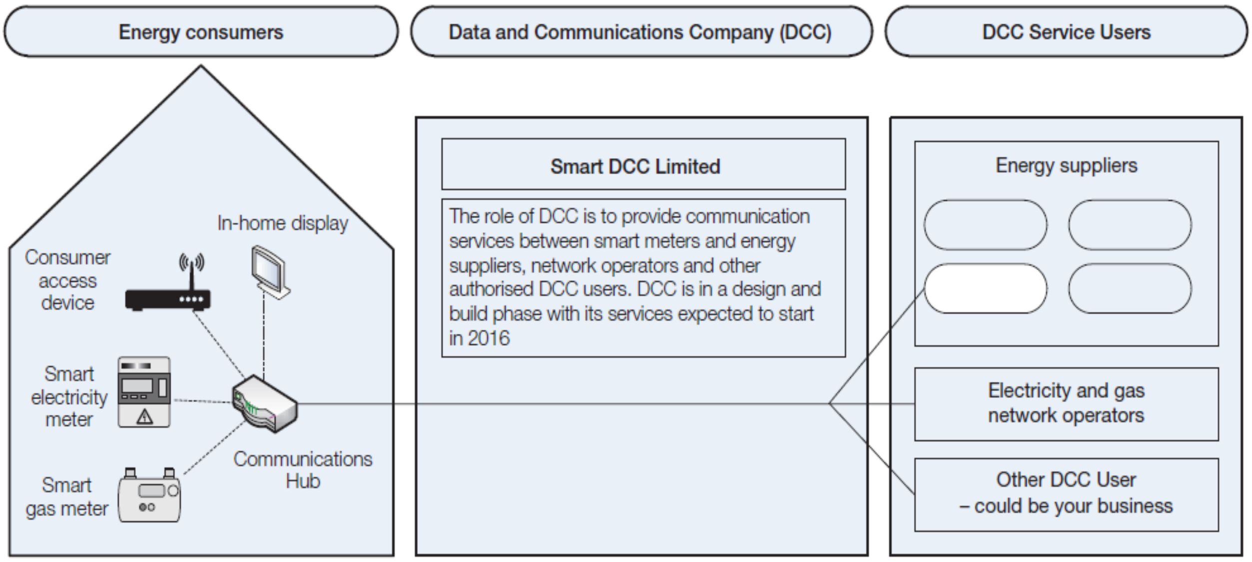
Dataset	Key Positives	Key Negatives
Sub-national energy statistics	• Near complete coverage of electricity and gas meters in GB	• Aggregated statistics • Very limited set of contextual variables • Annual energy data only
NEED	• Near complete coverage of electricity and gas meters in GB • Dwelling-level data • A reasonable set of contextual variables (e.g. building characteristics, socio-demographics).	• Annual energy data only • Access to the full dataset is highly restricted beyond DECC. • Accessible data is de-identified thus further data linking is not possible • Uncertainties limit its utility for making finely balanced decisions.
Low Carbon London	• Dwelling-level data • High temporal resolution energy data (e.g. half-hourly)	• Very limited set of contextual variables • Limited sample (5,567 households) • Accessible data is de-identified thus further data linking is not possible • One-time dataset
Energy Demand Research Project	• Dwelling-level data • High temporal resolution energy data (e.g. half-hourly)	• Very limited set of project-specific contextual variables • Limited sample (~11,000 domestic participants) • Accessible data is de-identified thus further data linking is not possible • One-time dataset
Customer Led Network Revolution	• Dwelling-level data • High temporal resolution energy data (e.g. half-hourly)	• Limited set of contextual variables • Limited sample (~14,621 households) • Accessible data is de-identified thus further data linking is not possible • One-time dataset

Energy Performance Certificate (EPC) data	• Dwelling-level data • Standard methodology for collecting data (RdSAP) • Large set of contextual variables (building characteristics) • Large dataset (> 9m buildings)	• Energy consumption is modelled and annual. • Some concerns with quality of EPC data (9) • Access to bulk data is restricted to “approved recipients” and the financial cost of purchasing data can be prohibitive.
Energy Follow Up Survey	• Dwelling-level data • Sub-dwelling energy consumption for some participants • High temporal resolution energy data (e.g. half-hourly) for some participants. • Large set of contextual variables across the socio-technical spectrum	• Small (but representative) sample (2,616 homes) • Accessible data is de-identified thus further data linking is not possible • Repeat but cross-sectional dataset
Home Electricity Use Study	• Dwelling-level data • Sub-dwelling energy consumption for some participants • High temporal resolution energy data (e.g. half-hourly). • Moderate set of contextual variables across the socio-technical spectrum	• Small sample (251 homes) • Accessible data is de-identified thus further data linking is not possible • One-time dataset • Limited to owner-occupiers
English Housing Survey (EHS) / Scottish Household Survey (SHS) / National Survey for Wales (NSW)	• Dwelling-level data • Nationally representative samples • Large set of contextual variables across the socio-technical spectrum	• Limited energy consumption data – annual (from bills) where available. • Accessible data is de-identified thus further data linking is not possible • Repeat but cross-sectional dataset

Smart meter data

The Smart Meter Implementation Programme aims to install smart electricity and gas meters in over 27 million dwellings in the UK by the end of 2020 (10).

Figure 1 - Smart Metering System (11)



Smart meter data provides several significant improvements over most existing sources of domestic energy data.

Firstly, smart meter data is collected and, in most cases will be provided, at the meter level. This is important because it enables analysis of energy consumption at the household/dwelling level which is critical to many public interest uses.

Furthermore smart meters can provide data at a higher temporal resolution than most previous sources of energy consumption data where energy consumption is often an annual figure. Smart meters will record electricity and gas consumption data at 4 levels of granularity:

1. Monthly
2. Daily
3. Half-hourly

   - For electricity, 3 months of half-hourly export and 3 months of reactive half-hourly (import & export) data will also be available.
4. 10 second – electricity data via Consumer Access Devices (CADs) [6]and the Home Area Network (HAN) only.

This higher resolution data has many advantages over annual energy consumption which was historically the most granular data available in many cases. For example, for both electricity and gas:

1. Monthly data – will enable more detailed analysis of seasonal variation in energy consumption and the impact of weather. It will also facilitate improved analysis of the impact of energy efficiency and other interventions on energy consumption as pre/post intervention consumption can be identified with far greater accuracy than is the case with annual consumption (12).
2. Daily data – will facilitate research and related public interest uses into intra-week profiles of energy consumption such as analysis of the variance in energy consumption between weekends and weekdays.
3. Half-hourly data – will enable analysis of intra-day patterns of energy use. This will allow us to gain a better understanding of the diversity of daily consumption profiles and the potential for shifting energy from peak to off-peak times.
4. 10 second data (electricity only) – has the potential to enable Non-Intrusive Load Monitoring (NILM) analysis through the disaggregation of meter data to identify energy consumption for individual appliances or energy consuming devices.

Another advantage of smart meter data is that it is ongoing or longitudinal. Most existing sources of energy data are one-time or repeat cross-sectional i.e. they come from individual field trials or from ongoing national surveys that do not revisit previous participants. Smart meter data is inherently longitudinal as data is collected at the meter point *ad infinitum* (theoretically). The advantage of this is that it allows us to study the persistence of interventions and changes in patterns of energy consumption over long periods of time.

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[6] Consumer Access Devices connect to smart meters and provide a range of additional functionality. See page 18 for more details.

It should be noted, however, that smart meter data on its own will have limited value for many public interest uses, even given the advantages outlined above. For many applications related to smart meters, additional data will be required to maximise the value and utility of the smart meter data. For example, knowledge of the energy consumption of a dwelling, even at higher levels of granularity, is unlikely to lead to greater insight in the energy sector unless we also know something about the physical properties of the building and/or information about the energy-consuming behaviours and practices of the inhabitants. There are two primary routes for the provision of additional data alongside smart meter data.

Firstly, electricity and gas data can be collected and distributed by Consumer Access Devices (CADs) which connect to the smart meter or communicate with it via the Home Area Network (see figure 1 above). Alongside the smart meter data, CADs could also collect a vast array of additional (non-meter) data which will be, in many instances, limited only by cost and the willingness of householders to collect and share the data. For example, CADs could monitor indoor temperatures, relative humidity and lighting levels via additional sensors or monitors placed in the home. Furthermore CADs could interact with Home Energy Management Systems (HEMS) to collect information such as thermostat settings and even data relating to occupancy via geo-tethering and/or motion sensors that are available with some HEMS. Equally they could interact with smart appliances as well as smart boilers, for example, to collect detailed information relating to the operation of the heating system.

Secondly, smart meter data can be linked to other datasets using existing data-linking methodologies. Where the consent of the energy consumer is obtained, smart meter data could usefully be linked to existing survey data (e.g. EHS, EFUS), new (proposed) surveys such as the Longitudinal UK Energy Survey (13), administrative data such as EPCs and a range of new data streams that are likely to become available when the Internet of Things (IoT) becomes established.

By combining linked data sources and smart meter data alongside paired data sources (i.e. CADs), it should become possible to build a detailed, holistic picture of energy consumption and the drivers of energy consumption in domestic buildings in the UK that will inform research, policy and a raft of other public interest uses for decades to come.

A further benefit of smart meter data is that it is “raw” or unprocessed. The key energy datasets with national coverage (e.g. NEED, DECC’s sub-national statistics) use annualised energy consumption for gas and electricity that is derived from relatively complex energy industry processes. For electricity, Estimated Annual Consumption is part of the settlement process and uses an algorithm containing weather and other variables to estimate annual consumption where meter readings do not cover the exact 12 month period in question (14). For gas, the Annualised Quantity algorithm is used to establish each supplier's portion of gas distribution (network) costs for the next 12 month period. The Annualised Quantity algorithm works in a similar fashion to EAC but additionally gas consumption is often weather-corrected (8). Weather correction highlights the reality that gas is predominantly used for heating and so gas consumption is more sensitive to impact of colder or warmer weather. The AQ algorithm entails adjusting gas consumption to a long-term average weather year so that gas consumption is adjusted down during colder years (particularly in winter) and upwards in warmer years. Thus the weather-corrected gas consumption attempts to remove the impact of colder or warmer weather and should therefore better reflect the impact of other drivers (e.g. uptake of insulation or other energy efficiency interventions) on annual gas consumption.

The methodology and algorithms used in the AQ and EAC processes is well documented but the data inputs to the various variables are not available beyond the organizations that create the annualised electricity and gas consumption data. While the use of pre-processed annualised energy consumption can be highly beneficial in many scenarios (as, for example, it makes it easier to compare energy consumption across years where we want to remove the impact of weather), it is suboptimal in scenarios where we might want to study the impact of weather as variable of interest. A more common issue is where we want to compare energy consumption that has been through an annualisation process with energy consumption that hasn't. This makes it difficult to compare, for example, energy consumption from specific research projects or surveys such as EDRP or EFUS with data from NEED or DECC's sub-national statistics. In other words, it is quite easy for users of these datasets to, unknowingly, be comparing apples with pears when attempting to compare energy consumption from different data sources.

As smart meter data can be collected and delivered in a consistent and unprocessed form, it could be said to provide a more accurate and reliable source of energy consumption data than most (or any) existing energy dataset.

To summarise, the key benefits of smart meter data are:

1. Unit of observation – meter point data means that energy consumption can easily be prescribed to individual dwellings (in most cases).

2. Temporal resolution – Data at monthly, daily or half-hourly granularity is a significant improvement on existing annualised data.
3. Raw / unprocessed data – data has not been through any additional processing
4. Longitudinal – data is collected on an ongoing basis.
5. Consistent framework for data access.
6. Linkability data – the utility of smart meter data will be greatly increased when linked to other data

4. What could the smart meter data be used for in the public interest?

Smart meter data could be incorporated into a wide range of uses that could lead to public benefit. These public interest uses will range from cases where there is clear and direct public benefit such as improved government policy for tackling fuel poverty to cases where the public interest is less obvious (although still served) such as where public benefit is accrued from actions taken by industry (e.g. avoiding cost and improving resilience in the UK's energy generation and distribution infrastructure). Key areas of public interest include:

- Direct to the energy consumer / household
- Government policy
- Academic research
- Energy Industry
- Other

It should be noted that that many public interest uses of smart meter data (including examples provided below) will involve actors from multiple sectors and will cross the somewhat artificial boundaries of the "key areas" listed above.

Public benefit direct to the energy consumer

The most obvious public benefit from using smart meter data relates to uses that directly inform or benefit the energy consumer. The benefit or public interest is served on two levels in this scenario. Firstly, benefit is accrued as individual members of a collective (e.g. reduced bills) and secondly, given the right incentives and actions, there could be a collective benefit from aggregated individual benefits in the form of contribution to dealing with the UK's energy trilemma of energy security, cost, and climate change mitigation.

An obvious benefit of smart meter data relates to billing with approximately 80% of those households already with smart meters believing that their bills are more accurate. However, there are many additional direct benefits. Primarily due the enhanced ability to monitor energy consumption provided by the In-Home Display (IHD), around 70% of smart meter customers are more conscious of their energy consumption while 79% state that they have taken practical steps to save energy such as turning their heating system down, moderating appliance use and turning off lights (15).

While some research suggests that energy saving resulting from consumers using IHDs for identification of energy consuming devices and monitoring of their energy consumption has a relatively short-term effect, DECC research expects persistent average savings of approximately 3% (16).

The direct benefit to the public in relation to energy saving and energy efficiency could be further enhanced by the development of energy advice services using consumers' smart meter data to tailor advice based on their specific energy consumption and circumstances. These advice services could be delivered by energy suppliers or other commercial entities; or by government agencies, charities, not-for-profit organizations or social enterprises.

One example of such a service has been developed by the Energy Saving Trust. Their Smart Meter Advice Portal (SMAP) has been developed to provide detailed energy consumption data to householders via a private web portal alongside tailored energy saving advice relating to, for example, energy behaviours or the installation of energy efficiency measures in the home (17). The project has trialled the service on 30 homes in Scotland but this type of service could be scaled up substantially providing financial and data privacy barriers can be overcome.

Another initiative developed by EON should benefit vulnerable consumers or those in fuel poverty. Vulnerable or fuel poor are more likely to be on pre-payment tariffs and currently pre-payment tariffs usually have higher rates than credit tariffs (such as monthly direct debit). EON's Smart Pay As You Go pilot project aims to eradicate the existing difference between these tariffs / payment methods and make the same rates available to smart pre-payment customers. An additional advantage to smart meter pre-payment customers will be that they will have additional payment channels (e.g. smart phone apps) allowing them to top up anytime and anywhere (15).

Government Policy

Smart meter data can enhance evaluation of current or previous policies while facilitating the development of future evidence-based policy in a number of areas. An example of existing policy evaluation is where DECC investigated the actual energy savings experienced after a range of energy efficiency interventions in the domestic housing stock prompted by the government's Carbon Emissions Reduction Target (CERT) and Energy Efficiency Commitment (EEC) policies (12). This type of policy evaluation would be significantly enhanced by higher resolution smart meter data providing more confidence in results with reduced uncertainties.

Evidence-based policy development (at central and local levels) will be enhanced in areas such as energy efficiency and fuel poverty. For example the current official Low Income High Cost definition of fuel poverty used in the UK (18) requires data on household income and energy costs. In the absence of actual data in the areas (which is often unavailable or inaccessible) modelled data is often used. Smart meter data can provide accurate, high resolution data on energy costs that can either be used directly or as inputs to the development of more accurate models. This can be used to formulate better policy to tackle fuel poverty at national levels as well as improved tools and methodologies for the identification, targeting and delivery of fuel poverty schemes at local levels (*see paper 2* (1) *for more detail on the sub-national perspective in this area*).

Government policy clearly cuts across public interest uses of smart meter data in other sectors and stakeholder groups. Thus the use of smart meter data to, for example, enhance academic research or inform development of the smart grid can equally be used to inform policy in these areas.

So, research investigating the impact of switching tariffs or the uptake of new Time of Use tariffs across different consumer segments can inform government policy and market regulation with the aim of reducing potential inequities that disadvantage specific customer groups. If smart appliances or Home Energy Management Systems connected to smart meters are found to be particularly beneficial in terms of reducing energy consumption or energy bills then government policy can reflect this by promoting their uptake through tax incentives, rebates or other non-financial mechanisms. Changes to smart pre-payment meters might prompt government policy to ensure that pre-payment customers do not face higher tariffs than credit customers.

Smart meter data can inform the development of a smart grid in the UK by, for example, highlighting areas of the country where DSR would have the most impact or energy storage might be most effective. This can inform government policy to reduce barriers and incentivise the energy industry to implement innovative approaches that develop a smart and flexible network in an effective and beneficial manner (19).

Finally, smart meter data could be used to enhance the evidence base for government policy by replacing annualised energy consumption data in existing datasets such as DECC's sub-national statistics and NEED with higher resolution smart meter data. Additionally greater sharing of this data between government departments would aid government policy in other sectors.

Academic Research

As well as enhancing the evidence-base for policy development, smart meter data could be greatly improve the availability of energy data available for academic research. There are many examples of academic research projects with clear public interest outcomes including the TEDDINET IDEAL project which utilises data from smart meters and other sensors to provide personalised feedback to householders (20), the Low Carbon London project which used smart meter data to investigate the impact of time of use tariffs (21), and the VCEE project which aims to investigate energy saving relating to smart meters, and energy shifting relating to time of use tariffs, amongst fuel poor consumers (22).

Equally smart meter data will enhance many forms of research that are not directly related to smart meters themselves. These include, for example, more accurate and granular analysis of energy profile diversity, evaluation of new tariff structures to determine which consumer groups benefit versus those that don't, and analysis of the impact that switching supplier or tariff has on consumers' energy consumption and energy bills.

Additionally new forms of research such as Non-Intrusive Load Monitoring may be possible using smart meter data (although existing NILM techniques often require data at greater temporal resolution than smart meters currently provide) to disaggregate energy consumption from individual meters down to individual appliances. This will provide further insight to energy behaviours and energy consuming practices within the home e.g. which appliances and devices are used and when as drivers of electricity consumption while gas data can provide insight into heating patterns and cooking practices.

Energy Industry

A number of public interest uses of smart meter and smart grid data will be primarily driven by the energy industry (including energy suppliers, network operators, the national grid, and other associated organizations including new organizations that are likely to evolve offering new energy services enabled by smart meter data).

Smart meters will remove the requirement for annual home visits by meter readers, will help network operators detect and resolve outages more quickly, and improve fraud detection; all of which should help keep bills down or improve service.

Smart meters will enable Demand Side Response/Management (DSR/DSM), with examples such as Time of Use tariffs having been trialled by several organizations across the UK. As smart meters can provide energy consumption at 30 minute intervals, it will enable 30 minute settlement and Time of Use tariffs that aim to shift energy consumption from peak to off-peak times. While this will not save energy *per se,* it could allow consumers to save money when they shift consumption to cheaper off-peak hours. There may also be significant indirect savings and public benefit through the avoidance of significant investment in peak generation plant and additional investment in network resilience if peak load is reduced.

Combined with other forms of smart appliance data, smart meter data can provide direct benefit to the public via a range of new products and services. For example, existing thermostats and timers/programmers often result in homes being heated when no-one is home and/or being heated to higher or lower temperatures than is desired (23). Smart heating controls combined with smart meter data can save energy by heating a home only when needed and to the desired temperature while potentially shifting some energy consumption to off-peak times through automated DSR.

While a full discussion of all public interest uses of linked smart grid technologies and data is beyond the scope of this paper it is worth noting than there are many public benefits that will be largely hidden from public view. For example, an ability to draw upon actual data for modelling and assessing a combination of Demand Side Response, energy storage and other technologies that add flexibility to the UK's energy system. This in turn should allow us to avoid or reduce additional and unnecessary investment in energy infrastructure, better balance the supply and demand of electricity and ensure the utilisation of low carbon energy sources is maximised (19).

Other areas where smart meter data could be used in the public interest

There is vast potential for smart meter data to be used in the public interest in addition to the areas mentioned above. Firstly, it can be linked to data from other areas/sectors with Health being an obvious example.

The potential for energy data to produce public benefit from academic research when linked to health data has be shown with several epidemiological studies linking energy data with relevant health data to investigate the positive and negative health impacts of energy efficiency interventions on factors such as cold-based winter mortality (e.g. Excess Winter Deaths) and morbidity, and indoor air quality (with potentially higher levels of indoor air pollutants such as tobacco smoke, $PM_{2.5}$ and radon gas) (24,25).

Smart meter data can be combined with other smart home technologies and data from health sensors and monitors to provide assisted living systems to, for example, the elderly or others with significant health or medical conditions.

Price comparison sites and energy switching campaigns (e.g. Big Energy Saving Week 2015: Switch (26) supported by the Energy Saving Trust, Citizens Advice, and DECC) would benefit from the use of consumers actual energy data as current advice about best tariffs currently relies on estimated savings based on average consumption (which will be inaccurate for many households) or manually entered bills (which are prone to user error). Smart meter data would allow for more accurate consumption data to be used as an input to calculations and thus more accurate estimates of savings for different tariffs to be provided.

5. What are the currently anticipated arrangements on public interest uses of smart meter data?

The smart meter Data Access and Privacy Framework aims to put control firmly in the hands of the energy consumer regarding the use of their smart meter data. There are several categories of users who will be able to access smart meter data with differing conditions regarding their access and use of the data:

a) Energy consumers or households
b) Energy suppliers
c) Network operators
d) Third parties or Other Users

Energy Consumers

Energy consumers will have direct access to their own smart meter data via the In-Home Display (IHD) or other Consumer Access Devices (CADs). Currently an In-Home Display providing near real-time energy consumption data as well as other data (e.g. tariff etc) must be provided with every smart meter, although alternative IHDs such as smart phone apps may be trialled in the future.

It is currently anticipated that IHDs will be the primary engagement channel for consumers regarding their energy consumption and the increased ability to identify and monitor energy-consuming devices and behaviours is estimated to result in energy reduction of approximately three percent on average (16).

Additionally householders may be able to access their smart meter and a wide range of other data collected (or collated) by CADs or access data provided to them by third parties where they have given consent for third parties to access their data via the DCC Gateway.

Energy Suppliers

Monthly data is accessible to energy suppliers without consent but it can only be used for billing purposes or to fulfil statutory requirements. The use of data for marketing purposes is only allowed with explicit, opt-in consent while half-hourly data (which is considered to be the most intrusive) can also only be accessed with explicit, opt-in consent.

The framework for energy supplier access to data stipulates (27):

1. Allow suppliers to access monthly (or less granular) energy consumption data, without customer consent, for billing and for the purposes of fulfilling any statutory requirement or licence obligation;
2. Allow suppliers to access daily (or less granular) energy consumption data for any purpose except marketing, with clear opportunity for the customer to opt out; and
3. Require that suppliers must receive explicit (opt-in) consent from the customer in order to access half-hourly energy consumption data, or to use energy consumption data for marketing purposes.
4. Allow suppliers to access half-hourly energy consumption data for use in approved trials, with clear opportunity for the consumer to opt out.

Network operators

Network operators should be able to access half-hourly energy consumption data from all domestic customers without consent, provided that (11):

- The data was only used for regulated purposes (e.g. developing and maintaining an efficient, co-ordinated and economical network etc.);
- Network operators submitted plans detailing which data they would access, for which purposes, and how the data would be treated such that it can no longer be associated with a single domestic consumer (for example, through aggregation);
- That these plans were approved by Ofgem, before data was accessed.

The current arrangements stipulate that plans for aggregation by network operators would need to meet the following criteria:

a) Explain clearly what energy consumption data will be accessed, in what format, over what period of time, from which consumers, and for which specific purposes. Those purposes must be relevant to the regulatory requirement to develop and maintain efficient, co-ordinated and economical systems for the distribution of electricity and gas;

b) Identify and quantify the benefits that could be delivered for different groups through access to this data (e.g. network benefits, consumer benefits, future development of smart grids etc.);

c) Demonstrate that practices, procedures and systems can be implemented to aggregate or otherwise treat the data to ensure as far as is reasonably practicable that it can no longer be associated with an individual premises.

d) Explain clearly how, where, when and by whom collation, maintenance, usage and deletion of the data would take place securely and cost-effectively;

e) Show that consideration has been given to best available techniques for minimisation, aggregation, anonymisation and/or other treatment of data;

f) Be accompanied by a Privacy Impact Assessment, as recommended by the Information Commissioner's Office.

Third Parties / Other Users

Third parties who want to access smart meter data directly will be required to accede to the Smart Energy Code and become a DCC Gateway user in the category of "Other". The following conditions apply (28) whether the data is being accessed directly via the DCC Gateway or indirectly (via an existing DCC User).

1. the User has the Appropriate Permission in respect of that Smart Metering System; and
2. (where that User is not the Import Supplier, Export Supplier, Gas Supplier, Electricity Distributor or Gas Transporter for that Smart Metering System) the User has, at the point of obtaining Appropriate Permission and at such intervals as are reasonably determined appropriate by the User for the purposes of ensuring that the Energy Consumer is regularly updated of such matters, notified the Energy Consumer in writing of:

   2.1. the time periods (by reference to length) in respect of which the User obtains or may obtain Consumption Data;

   2.2. the purposes for which that Consumption Data is, or may be, used by the User; and

2.3. the Energy Consumer’s right to object or withdraw consent (as the case may be) to the User obtaining or using that Consumption Data, and the process by which the Energy Consumer may object or withdraw consent

6. What are the implications of these anticipated arrangements?

The obligations placed on third parties or Other Users by the Smart Energy Code provides reasonable protection in relation to data privacy for energy consumers but may have a negative impact on public interest uses of smart meter data. This is due to the potentially high costs involved with obtaining and administering both data and consent from energy consumers for all uses beyond billing and other regulatory purposes.

As third parties are unlikely have existing systems in place to manage ongoing interactions with the energy consumer in a similar manner to those established in the billing and account management systems of large energy suppliers, organizations operating in the public interest may be disadvantaged by the smart meter data access framework in some cases.

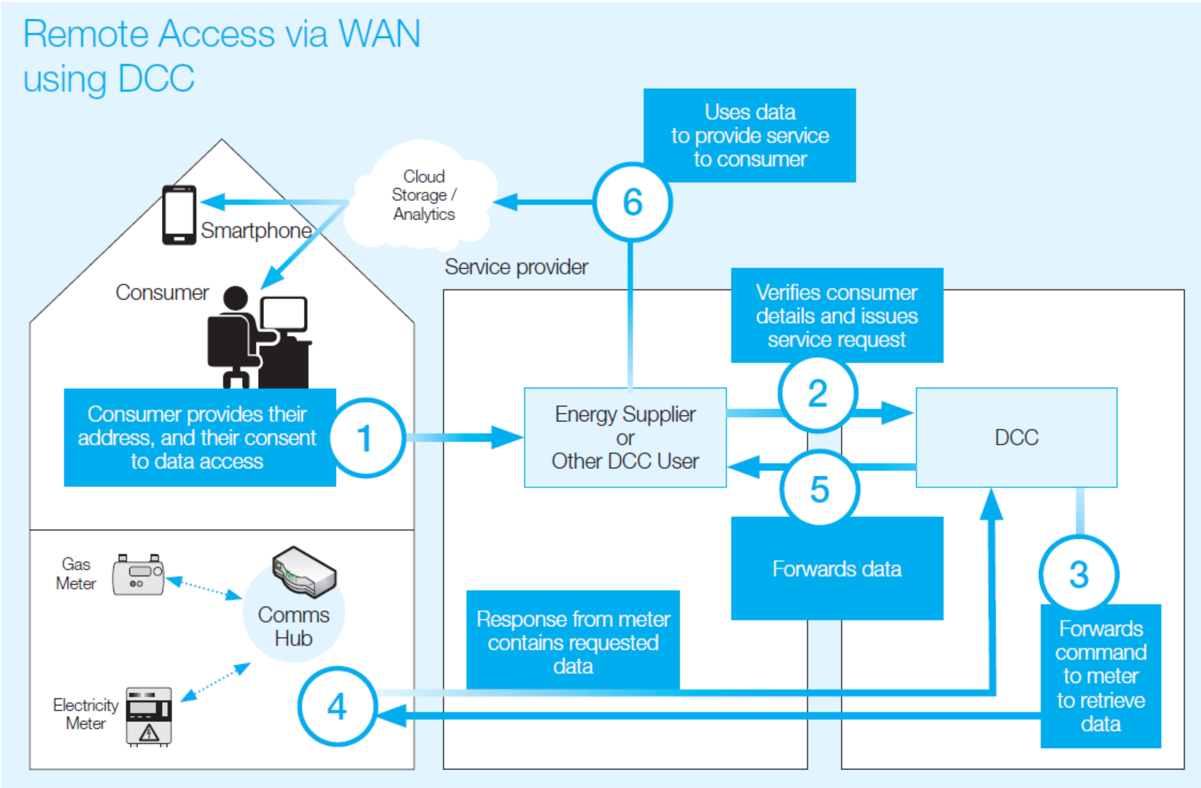
There are two primary routes to access smart meter data and one indirect route:

1. Accessing data via the DCC Gateway and Wide Area Network (WAN)
2. Accessing data via Consumer Access Devices (CADs) and Home Area Network (HAN)
3. Accessing data indirectly e.g. via an existing DCC user who will act as a conduit, passing data from the DCC Gateway to the ultimate end-user.

Accessing data via the DCC Gateway and Wide Area Network (WAN)

As the marginal cost of providing and installing large numbers of Consumer Access Devices (CAD) will be relatively high, it seems likely that most organizations who wish to access a large volume of smart meter data will do so via the DCC Gateway (directly or via a third party).

Figure 2 – System diagram of data access via DCC Gateway (10)



A summary of the process to access data via the DCC Gateway is shown in Figure 3 below.

Figure 3 - Process for becoming a DCC user (SECAS 2015).

This process is intentionally rigorous in order to ensure that the overall security of the total smart meter system is maintained. To complete the process to become a DCC user an organization must be able to demonstrate that it complies with many financial, technical and organizational standards, including (28):

- Several ISO standards e.g. ISO 27001 (relating to Information Security)
- Smart meter data privacy standards – monitored by privacy audits

- Credit cover – to cover expected "explicit charges". This primarily applies to energy suppliers.

It should be noted that ISO 27001 certification alone will often take an organization over 12 months to complete.

Therefore, although there is no unit/message (per record) charge for accessing data via the DCC Gateway, it is expected that the costs involved with developing and maintaining a system to interact with the DCC Gateway will be substantial. These costs include:

- Development and maintenance of an IT system to access smart meter data via the DCC Gateway (that complies with all relevant standards).
- Completion of the DCC user entry process.
- Development and maintenance of an IT system to obtain and maintain consent from the energy consumer (that meets the data privacy obligations as specified by the SEC).
- Ongoing communication with the energy consumer / data subject regarding consent to use smart meter data.

Accessing data via Consumer Access Devices (CADs) and Home Area Network (HAN)

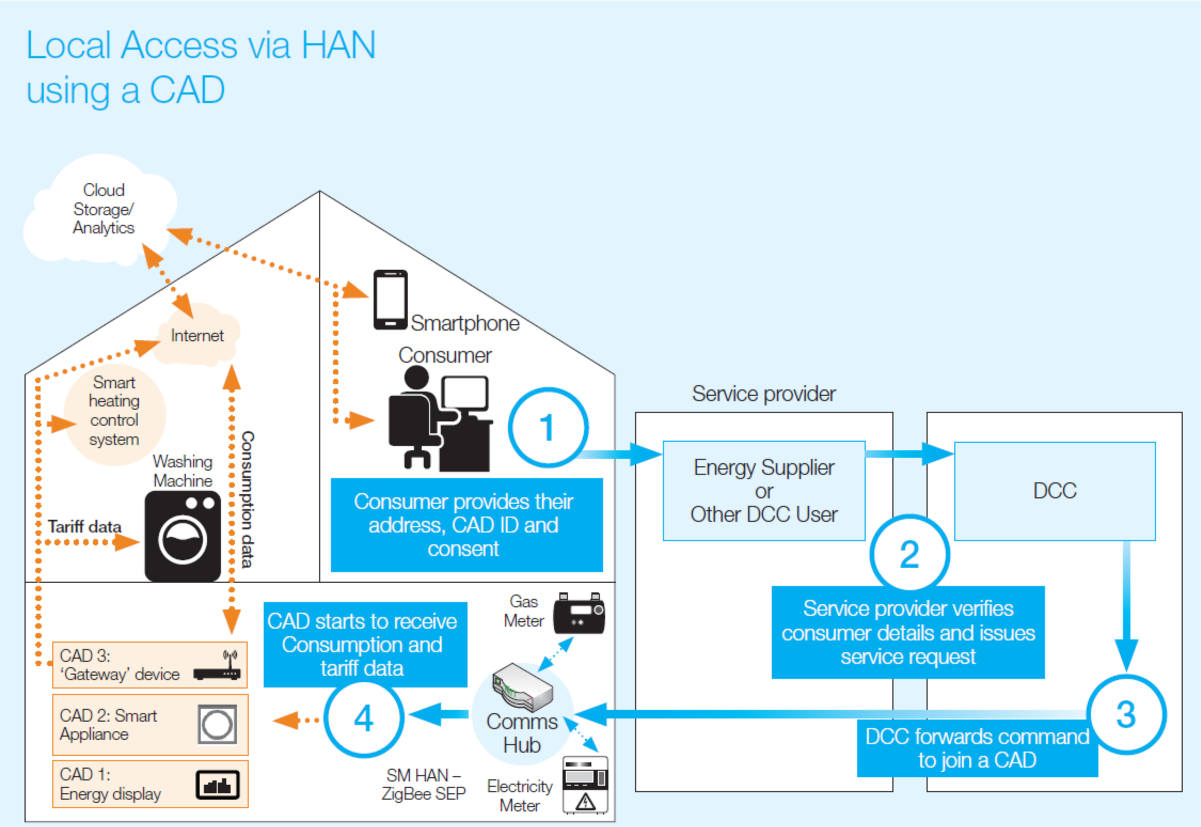
The alternative route to accessing smart meter data is via Consumer Access Devices (CADs).

A CAD can communicate with smart meters via the Comms Hub and Home Area Network (HAN). A CAD can obtain data from smart meters and potentially transfer data to third parties via broadband or 3G/4G mobile networks. Although CADs can obtain data via the HAN they cannot transmit data via the DCC Wide Area Network (WAN) and Gateway. Therefore accessing data via CADs may avoid some costs associated with accessing data via the DCC Gateway but has a number of different issues, including:

- Pairing – initially all pairing (of a CAD to a smart meter) must be completed via a command/message sent via the DCC Gateway. Therefore most of the effort and costs of obtaining data via the DCC Gateway will also apply to users wishing to pair CADs and obtain smart meter data via CADs.
    - Local pairing – the government is committed to providing a method for energy consumers to pair CADs with their smart meter directly (i.e. without going through

the DCC Gateway). However the technical details and timescale for this solution are not yet available.

Figure 4 – System diagram of data access via CADs (10)



- Provision of CADs – Although it is hoped that innovative (and cheaper) forms of CADs will become available (e.g. via smartphone apps), currently CADs could cost from tens to hundreds of pounds depending on the range of functionality provided. CADs will also be required to adhere to various technical standards (e.g. Zigbee) to ensure security is maintained in the Home Area Network (HAN).
- Data Privacy – Explicit consent will be required when pairing a CAD to a smart meter and any subsequent exchange of data is determined by the contractual relationship between consumer and the organisation operating the CAD.

Accessing data indirectly via an existing DCC User

The current arrangements for accessing smart meter data do not preclude an organization obtaining data *indirectly* from the smart meter system. The most likely scenario of obtaining smart meter data indirectly is where an existing DCC user acts as a conduit by passing data from the DCC Gateway to a third party organization. Existing DCC users might be mandatory DCC users such as energy suppliers or Other Users who have become DCC users specifically to distribute smart meter data as a (commercial) service. Equally it may be possible to access data from Consumer Access Devices indirectly.

The benefit to organizations to access data indirectly is that they will avoid many of the costs of developing and maintaining a system to directly interface with the smart meter system, which could be prohibitive to many (particularly smaller) organizations acting in the public interest. However it is currently unclear whether any organizations will be willing to offer a data distribution service and what the cost of such a service might be. Organizations providing a service on a commercial basis may charge a substantial fee to reflect the high costs incurred with setting up such a service.

It should also be noted that the cost and effort relating to informed consent from the energy consumer regarding all uses of their data will still apply to organizations accessing data indirectly i.e. An organization will need to obtain individual customer consent in exactly the same manner when accessing data indirectly as directly.

Informed consent

Although the Government addresses privacy concerns by putting consumer choice at the heart of the Data Access and Privacy Framework, this could have a detrimental impact on public interest uses of smart meter data. Few would argue with the Government objective of maximising the control a consumer has over the use of their own smart meter data. Energy consumers have control over the granularity of data that can be accessed by energy suppliers (including opt-in for all marketing uses) while all other users and uses of data require explicit opt-in consent. On the surface, this seems to be a fair and equitable solution that protects the rights of the public. Despite media scare stories, DECC research has indicated that burglary and other crime that could be theoretically be facilitated by high resolution smart meter data (e.g. half-hourly data revealing occupancy patterns) are not a major concern for the UK public. However they are concerned about an increase in direct marketing by energy suppliers through the use of their smart meter data and questioned what legitimate reasons exist for using smart meter data beyond monthly data for billing purposes (29).

One potential issue is that while energy suppliers have an initial and then ongoing direct channel of communication with householders (via smart meter installation and then through billing), other organizations seeking to obtain consent for public interest uses of smart meter data will incur significant transaction costs. Not only will they incur costs in communicating with the energy consumer to obtain initial consent but they will then have to manage consent and provide feedback on the uses of data on a regular (perhaps annual) basis to the consumer, including providing the opportunity and means to withdraw consent at any time. This is likely to be place a significant administrative and financial burden on most public interest organizations that do not have existing relationships with energy consumers and appropriate customer management systems.

A further issue is that every organization will require a specific consent to use a consumer's smart meter data (whether accessing the data directly or indirectly). Not only is that an additional burden for every organization but it also is likely to lead to a scenario after smart meter roll-out that consumers will quickly lose track of which organizations they have provided consent to, and for what purposes. This will be similar to current scenarios in other sectors where a substantial proportion of the public have little or no understanding of the consent they have provided to search engines, smart phone apps or web sites regarding the use of their data. While the public seem to be relatively relaxed about the trade-off between a loss of data privacy in many areas of life if they receive a tangible benefit in return (e.g. useful products and services), there is survey evidence to suggest that many people are more concerned if there is an intrusion on privacy within the home (31), particularly when the temporal resolution increases.

Other Implications and barriers

There are a number of other barriers organizations may face when making public interest uses of smart meter data. For example, the regulatory framework relating to smart meters (and many other areas of the energy industry) was developed with the operations of existing large energy suppliers, network operators and other bodies as a primary focus. For example the Smart Energy Code (28) is a document of over 800 pages that provides a legal framework for the smart meter system in the UK and there are more than a dozen documents of similar length that provide detailed specifications of the many legal, technical, financial and operational standards for organizations engaging with the Smart Meter Implementation Programme (SMIP). Smaller organizations who wish to deliver public interest uses of smart meter data will, in many cases, lack the skills and capacity to engage with the highly detailed legal, governance and technical frameworks and thus they will become significant barriers to entry to the smart meter system. These issues are discussed further in paper 2 (1).

7. Arrangements and recommendations to remove barriers and facilitate public interest uses of smart meter data

Some of the barriers to public interest uses of smart meter data identified above will be difficult to remove or reduce. However there are some issues that could be addressed.

Policy, Regulatory and Governance barriers

The regulatory framework and other policy mechanisms can help stimulate innovative public interest uses of smart meter data or potentially stifle such uses through unintended consequences of policy creating barriers to stakeholders acting in the public interest.

The Smart Energy Code and other areas of SMIP governance currently focus on the operations of energy suppliers, network operators and other established energy industry organizations. It is likely that many organizations using smart meter data in the public interest will lack the legal, technical and organizational resources to comply or even engage with a small percentage of the mandatory standards required to access or use smart meter data. This will be a significant barrier to entry for those many organizations who may wish to make use of the data for broad public interest purposes and applications.

Furthermore the use of smart meter data by the energy industry to, for example, enable demand side response applications may be jeopardised by widespread mistrust of energy suppliers in the UK (32). It seems likely that other trusted bodies (e.g. NGOs, charities) would be in a better position to engage with the public to promote public interest uses and beneficial applications using smart meter data (although the recent media coverage of E.On and Age UK may not have helped in this regard).

Recommendations:

Government and relevant industry bodies (e.g. SECAS[7]) should address issues in this area by consulting with organizations who are not mandatory SEC parties to understand how access to smart meter data can be facilitated for third parties and Other Users of the smart meter system.

Consideration should be given to modification of the SEC and other relevant documentation to facilitate access to smart meter data to non-mandatory SEC parties. There is an existing mechanism to enact changes to the Smart Energy Code (the Modifications Process – Section D of the SEC) but there is currently a low rate of participation of public interest groups on relevant SEC panels or sub-committees. The Government should consider actions to encourage further participation of public interest bodies on SEC panels, committees and working groups

Training and guidance material should be developed and provided to non-mandatory SEC parties and knowledge should be disseminated through appropriate events and channels etc.

The Government should consider where organizations, other than large energy suppliers, acting in the public interest can better engage with the UK public regarding beneficial uses of smart meter data. Policy could be developed to assist such organizations to offer energy services (e.g. DSR) to the UK public using smart meter data.

See paper 2 (1) *for a sub-national perspective on these issues*

Data Privacy and Informed Consent

Energy suppliers may end up with a near monopoly on the use of smart meter data in a similar manner to their current control of energy data simply because they have existing and ongoing channels of communication with energy consumers (e.g. via bills) that will be difficult and expensive for other organizations to replicate. The SMIP data privacy framework states that reasonable steps must be taken to verify that consent has been obtained from the energy consumer and that

[7] Smart Energy Code Administrator and Secretariat

feedback is provided back to the energy consumer on a regular basis. Thus the cost of obtaining and maintaining consent to use smart meter data could be significantly higher for organizations wishing to use smart meter data in the public interest than, for example, energy suppliers.

Recommendations:

Government and other bodies responsible for the development of the Smart Energy Code and other SMIP regulatory and governance frameworks should consider (and promote) alternative approaches to obtaining and maintaining consent that are relevant to non-suppliers and will facilitate public interest uses of smart meter data. Funding research or a working group with a specific remit to provide input on public interest perspectives to the Data Access and Privacy Framework review in 2018 should be considered.

Technical Resources

Overall security of the smart meter system is rightly a priority but the cost of developing systems that meet the mandatory technical standards in order to connect to the DCC Gateway to access smart meter data could be prohibitive to many organizations beyond the large energy suppliers.

Recommendations:

Due to the high establishment costs of gaining access to data through the smart meter system, Government should consider whether a “central” resource or service could be developed for non-commercial or public interest uses of smart meter data. Such a smart meter data hub might be comprised of a combination of one or more of the following elements:

1. An interface with the DCC Gateway – that acts as a simple channel to obtain data from the DCC Gateway and pass it on to users of the data.
2. A more comprehensive data platform providing additional management, processing and preparation of data in order to provide it to public interest users in useful formats.
3. A data consent/privacy repository which tracks and manages energy consumer permissions regarding the use of their smart meter data. This could act as a central “system of record” for both consumers and data users to manage data consent and remove potential ambiguity and misunderstanding inherent when consent is provided to multiple individual organizations.

Public Interest Advisory Group

The development of the Smart Meter System in the UK has, perhaps understandably, thus far been dominated by government and "big players" in the energy sector. While the Government's stated ambition is to encourage innovation through the use of smart meter data by a broad range of stakeholders, there must be a significant concern that this ambition will not be realised unless action is taken to reduce existing barriers. While there are opportunities and mechanisms for organizations acting in the public interest to be heard, there is little evidence of this eventuating in any meaningful manner.

Recommendations:

The Government should consider relevant actions to facilitate the creation of a public interest advisory group to advise on appropriate actions to facilitate public interest uses of smart meter data. However for such a group to be effective, it will require leadership and impetus and significant commitment from a range of public interest stakeholders. This group could take a holistic view and advise on issues across all areas relating to the public interest use of smart meter data. Such a group might, for example, provide additional representatives to relevant SEC bodies currently dominated by existing energy industry organizations. This group should also act as an aggregator and amplifier for the views of smaller public interest stakeholders who are currently under-represented in relation to the Smart Meter Implementation Programme. Finally this group can help identify areas where further research is required to investigate the extent of any potential barriers, as well as solutions that may remove or reduce these barriers.

8. Conclusion

This paper has described the key limitations of existing household energy datasets (e.g. the quality, accessibility, temporal and geographical granularity of data) and the advantages of smart meters which include access to high resolution, unprocessed data of consistent quality with a clear data access and privacy framework.

Public interest uses of smart meter data in relation to government policy, academic research, energy industry innovation and direct consumer benefit have been discussed. For example smart meter data could be used to generate tailored energy advice to householders, to inform government policy to target and mitigate fuel poverty, to develop Demand Side Response mechanisms such as Time of Use tariffs, and as an improved evidence base for academic research across the socio-technical spectrum.

The arrangements for accessing data from the smart meter system were discussed and potential barriers highlighted e.g. the effort and high cost involved with developing an interface to the DCC Gateway and issues with obtaining informed consent from energy consumers to use their smart meter data.

Finally some recommendations have been made that could help address these barriers. Government could review some areas of the regulatory and governance framework for smart meters to facilitate public interest uses of the data. Data privacy and obtaining informed consent from energy consumers could be a particular issue for organizations acting in the public interest and consideration should be given to highlighting public interest perspectives ahead of the Data Access and Privacy review scheduled for 2018. Consideration could also be given to the development of technical resources that facilitate access to smart meter for public interest users, while research investigating the extent and impact of potential barriers would provide a more robust evidence base to inform any action or response by relevant stakeholders.

Perhaps the most beneficial action could be to set up a body to co-ordinate the perspectives of public interest actors and take a holistic view of benefits and barriers and thus provide a strong presence promoting public interest uses of smart meter data in a landscape which is currently dominated by (large) commercial energy industry actors.

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