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The potential of ‘in-use’ performance measurement of homes: a paradigm shift for demand-side energy policy?

COLLECTION: POLICY, PROGRAMMES AND GOVERNMENT

PEER-REVIEWED PAPER

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ABSTRACT

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Home heating represents nearly a fifth of total UK carbon emissions, and reducing demand-side emissions is critical to meeting legally binding net zero targets. A fundamental strategic problem undermining effective delivery of the demand-side transition is the lack of sufficient, accurate information on individual home performance. This paper introduces in-use performance measurement – made newly viable at scale by the GB smart meter rollout – as a potential systemic response to this problem.

We review existing evidence on Smart Meter Enabled Thermal Efficiency Ratings (SMETER) as a method of measuring the Heat Transfer Coefficient (HTC) and informing the closing of the fabric thermal performance gap. We then explore the wide-ranging policy and market opportunities that a national system of in-use home performance measurement could unlock, across five key areas: policy coordination, performance management, fiscal management, market transformation, and behavioural and organisational change.

We argue that these opportunities are most fully realised through a national system, and that much of the infrastructure to support such a system is already in place. We also identify evidence and operational development work needed to make it a reality. Finally, we posit that in-use measurement extends beyond any individual policy application: by providing the informational foundations on which effective governance of demand-side energy policy depends. It creates conditions for a paradigm shift in demand-side energy policy, via the removal of information barriers that have constrained progress to date.

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INTRODUCTION

THE HOME HEATING CHALLENGE AND SOLUTIONS

Home heating represents nearly a fifth (18%) of total UK carbon emissions (NAO, 2024) and there is an urgent need to reduce this to meet legally binding UK net zero targets (UK Parliament, 2019). Demand-side heating emissions can be significantly reduced via a) energy demand reduction from improving thermal performance and behaviour change, and b) heating system upgrades, such as the move to electrification of heat (heat pumps). Improving thermal performance is also important for lowering energy costs, mitigating risks from damp and mould and reducing the risk of overheating in increasingly warm summers.

The challenge is enormous considering the heterogeneity of the stock, scale of changes required and the broad range of involved actors (policy, regulators, market actors) who variously contribute to deliver the transition (MCS Foundation, 2024). Demand-side energy performance outcomes for individual homes have traditionally been very difficult and expensive to measure (Crawley et al., 2019), making it hard to have confidence in understanding the effects of retrofit and other interventions designed to support net zero delivery. Furthermore, consumers must be protected from the, sometimes considerable, risks of poor or unintended outcomes (NAO, 2025).

We propose that a fundamental strategic problem compromising the ability to effectively deliver the transition on the demand-side is the lack of *sufficient, accurate information on individual home performance* to inform and enable good decision making and evaluate progress towards outcomes.

IN-USE HOME PERFORMANCE MEASUREMENT AND SMETER

The smart meter roll out in Great Britain (GB) has enabled the development of smart meter enabled thermal efficiency ratings (SMETER) (DESNZ, 2022b).

SMETER is a term that describes technologies that measure the thermal performance of buildings while they are occupied, or 'in-use', and at low-cost. The UK Government has been focused for the past few years on the use of SMETER technologies to measure the heat transfer coefficient (HTC). The heat transfer coefficient (HTC) in building physics measures the rate of heat loss (W/K) through the building envelope (walls, roof, floor, windows) and via air leakage, per degree of temperature difference between inside and outside. Most SMETER approaches consist of hardware (e.g. sensors), means of accessing required data and an algorithm which produces the HTC.

The essential inputs required for SMETER include energy consumption data (half-hourly data usually obtained from a smart meter) and usually publicly available external temperature and solar data. Most approaches also use internal temperature data, which can either be obtained from temperature sensors placed in different rooms in the home or from a smart thermostat, smart meter in-home display or other connected devices.[1] Some approaches also use heat meters, for example, in homes with heat pumps.

Interest in SMETER by government and the home heating and building fabric industry has increased over the past few years because it provides real-world visibility of the actual thermal performance of a building, rather than a modelled estimate based on archetypal assumptions (DESNZ, 2022b). Measuring thermal performance has a range of potential use-case applications, for example in relation to building fabric improvement interventions (e.g. energy efficiency retrofit programmes), as a tool to support heat pump sizing (City Science, 2024) and supporting future green finance and heat as a service-type applications (DESNZ, 2023). Government has focused its interest on the HTC (DESNZ, 2026c), but other useful metrics that can be measured using SMETER technologies include cooling down rates, humidity and under- or over-heating, enabling better understanding of their associated risks for occupants.

1 The most recent English Housing Condition Survey (EHCS) estimates that 14% of owner-occupiers have installed smart thermostats in the past five years. MHCLG. 2024. *English housing survey 2022 to 2023: Housing quality and condition* [Online]. Available from: https://www.gov.uk/government/statistics/english-housing-survey-2022-to-2023-housing-quality-and-condition/english-housing-survey-2022-to-2023-housing-quality-and-condition.

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The purpose of this paper is to 1) introduce in-use measurement and review existing evidence on SMETER as a method to close the fabric thermal performance gap[2] and 2) explore the wide-ranging policy and market opportunities that a national system of in-use home performance measurement could unlock, across areas including policy co-ordination, performance management, fiscal management, clean heat and grid flexibility.

CONTEXT AND EXISTING EVIDENCE

This section provides context drawn from review of existing SMETER-related literature, including housing and home energy systems, existing policies and mechanisms to deliver net zero, the underpinning role of information, the performance gap and the opportunities presented by in-use measurement.

HOME FABRIC EFFICIENCY AND HEATING SYSTEMS

Many actors are involved in home fabric efficiency and heating markets and their delivery systems. For example, fabric efficiency and retrofit actors include government setting policy and providing guidance to support and protect householders, industry providing skills, materials, and services (e.g., installers, assessors, architects) and financial institutions offering incentives (MCS Foundation, 2024). Professional advisors such as retrofit assessors, coordinators and Domestic Energy Assessors (DEAs) also play critical roles in the delivery process supporting owners and occupants to fund improvements and make decisions (DESNZ, 2023).

Home heating systems are supported by similar networks of actors and, whilst heating and building fabric delivery systems differ, there are close interrelationships between the two.

These systems and involved actors all work in concert to deliver essential home heating and comfort services, and ultimately the outcomes sought by Government of warmth, decarbonisation and lower heating costs (UK Government, 2026). They are regulated and supported by standards and policies designed to ensure householders get what they need and have sufficient protections, within the context of existing planning and legislation governing the wider built environment and energy system (e.g. planning, building regulations, energy retail market regulations).

POLICIES AND MECHANISMS TO DELIVER THE NET ZERO TRANSITION

There are many policy and market interventions in place that are expected to deliver the transition related to home heating, which are overseen by the UK Warm Homes Plan (UK Government, 2026). Much of this is led strategically by government, but many actors, such as those described above are critically involved in turning this into practice and delivery. For example, in the context of clean heat policy delivery: heat pump system actors are regulated and influenced through major Government schemes and certification bodies such as the Microgeneration Certification Scheme (MCS), which certifies installers and products to ensure quality and safety (MCS Foundation, 2024). Ongoing regulation involves maintaining product efficiency standards through eco-design legislation (DESNZ, 2024) and providing householder support through schemes like the Boiler Upgrade Scheme (BUS).

These policies and mechanisms have considerable implications for the actors, structures and processes within which they operate. All have different roles and stakes and will be influenced in different ways by interventions designed to support net zero delivery. This highlights the criticality of having an information system that incentivises desired outcomes and enables unintended ones to be mitigated.

INFORMATION AND ITS ROLE SUPPORTING POLICY AND MARKET DEVELOPMENT

Information is a crucial element of policy and market development because it underpins awareness, engagement and informed decision-making, fosters transparency and

2 Defined as the discrepancy between a building's predicted thermal performance and its actual measured performance in use.

accountability (individually and across actors), and ensures compliance with laws and regulations. Conversely, lack of information or use of inaccurate information can be expected to undermine such processes. For example, TrustMark, the Government endorsed quality scheme for work carried out in homes, does not include installation performance within its scope (Trustmark, 2022). This is a problem particularly within the context of retrofit work where performance improvement is a key desired outcome and known to be negatively impacted by split incentives[3] (Economidou and Bertoldi, 2015). The Microgeneration Certification Scheme for clean heat installations has similar problems, which are exacerbated by the increased importance of system design to achieve good operational performance[4] (Carroll et al., 2020).

As such, more consistent and accurate information, as provided by in-use performance measurement, can strengthen decision-making in relation to current Government policies, and more broadly, such as across networks of the involved actors described above. Within the context of the energy demand sector, existing reporting is currently usually by reference to EPCs (SAP and RdSAP)[5] or similar models. These systems currently rely heavily on performance estimates (as opposed to measurement) and have given rise to the energy demand performance gap (Johnston et al., 2015, CIBSE, 2013), which is described further below.

EXISTING INFORMATION SYSTEMS AND THE PERFORMANCE GAP

The energy performance of homes is evaluated using prediction models, which inform outputs such as the EPC. There is an ever-growing body of evidence showing that the energy predictions of EPCs are inaccurate when compared with measured data (Few et al., 2023, Crawley et al., 2019).

The 'energy performance gap' includes poor prediction of the thermal efficiency of the building fabric, which is used to predict the space heating energy demand on EPCs. For existing homes, the fabric performance is estimated from a short home survey. Typical U-values are assigned to different building elements, depending on type and age. Assumptions are added to include airtightness and ventilation. The resulting calculated fabric performance can be over 100% different (positively or negatively) to that measured (BTS, 2026). Evidence of the fabric performance gap has evolved slowly over time because the tests required to measure actual building thermal performance were, until recently, inconvenient and expensive (Jack et al., 2018).

The existence of the performance gap fundamentally undermines the above-described policies and market mechanisms designed to deliver net zero. For example, issues with the EPC rating system means there is likely to be significant differences between the assumed performance of flagship policy interventions (e.g. the Energy Company Obligation, BUS and MEES) and their associated emissions savings and energy bills savings for householders. As such, there is significant uncertainty in understanding whether existing interventions are the right approaches, or sufficient, leading to many questions. For example, are new homes sufficiently energy efficient? Are we targeting the right homes for retrofit? Is retrofit achieving the desired outcomes, and are consumers being protected? These leave considerable uncertainty in understanding what approaches are more or less effective in delivering net zero.

THE OPPORTUNITY PRESENTED BY IN-USE MEASUREMENT

Smart meters and connected sensors are now common and growing in numbers within homes (DESNZ, 2025b, AVIVA, 2025), and this has led to a step change in the potential for enabling accurate building performance measurement. As described below, it is now possible

3 For example, insulation installers currently have limited interest in performance-outcomes experienced by occupiers. This can be exacerbated within the rented-sector, whereby landlords are not affected by performance experienced by tenants.

4 Measured by metrics such as seasonal coefficient of performance (sCOP).

5 The Standard Assessment Procedure (SAP), is the UK-Government's national methodology for calculating the energy performance of dwellings, used for Building Regulations compliance and Energy Performance Certificates. Reduced SAP (RdSAP) is a simplified variant for existing dwellings BRE. 2025. *Sap 10* [Online]. Available: https://bregroup.com/expertise/energy/sap/sap-10 [Accessed 27/4/26].

to measure the thermal performance of the building fabric and other related metrics at a scale and cost that was previously impossible (Hollick et al., 2025).

In-use measurement has the potential to provide analysis to inform closure of the performance gap, and also enable a broader range of use-case applications that can help support net zero and wider policies, including fuel poverty and health.

Based on this potential, we consider the range of opportunities that in-use measurement presents for policy and market actors working in this space. We also consider the likely influences of measurement on policy and market development, leading to discussion and conclusions about how this could re-frame the entire approach to demand-side energy policy. However, before doing so, the next section examines the evidence base for in-use measurement and its development to date.

SMETER, THE HTC AND DEVELOPMENT OF IN-USE MEASUREMENT TO DATE

HTC MEASUREMENT STUDIES

The Government sponsored the SMETER innovation competition to drive development and testing of new methods for measuring home thermal performance (the HTC) (DESNZ, 2022b). Development of HTC measurement for existing buildings had been slow, given cost and inconvenience challenges associated with traditional measurement methods, such as co-heating tests. In response, enabled by smart meters, new methods have been developed to be used cost effectively and whilst buildings are in-use. The underlying approach utilised is similar to co-heating tests and to date, the tested uncertainty of such methods is about ±15% (10% for co-heating tests). The TEST project evaluated SMETER methods for measuring the thermal performance of homes using smart meter and other data (DESNZ, 2022b). The best of the tested SMETER methods delivered more consistent and accurate results than an expert SAP assessor (e.g. normalised mean bias error reduced by over a third).

COMPARISONS BETWEEN IN-USE HTC AND MODELLED APPROACHES

A recent measurement study of 503 dwellings showed substantial disagreement between EPC calculations (RdSAP) of fabric performance and measurements conducted with SMETERs (Whittle, 2024). The average difference between calculation and measurement was 30% and 16% of the sample had errors greater than 50%. The normalised mean bias error was 11%, showing that the EPC method tended to overestimate the heat loss from this sample of dwellings.

IN-USE MEASUREMENT MARKET AND POLICY DEVELOPMENT

Policy and commercial development of SMETER was initiated by Government innovation funding. Several commercial applications of SMETER technology are appearing in the market supported by a range of commercial SMETER providers, such as BTS, Knauf, Switchee and Purrmetrix.[6]

These commercial offerings are currently being provided mainly to those undertaking deep retrofits and Housing Associations and used for targeting retrofit, assessing performance and wider issues – underheating, risk of mould and damp (Switchee, 2025, BTS, 2025, KES, 2025). Proposals for the UK's Energy Company Obligation[7] (ECO) Pay for Performance (DESNZ, 2025a)) and Social Housing Decarbonisation Fund (Digitalisation Uplift) funding have appeared as ways to integrate measured performance into demand-side policies (DESNZ, 2022a)). However, wide-scale applications have not yet materialised. The market is therefore niche and small-scale, but there is interest in its potential from a broad range of actors.

6 https://www.buildtestsolutions.com/, https://www.knaufenergy.com/, https://switchee.com/, https://www.purrmetrix.com/.

7 The Energy Company Obligation (ECO) is a UK-Government scheme that requires larger domestic energy suppliers to fund energy-efficiency measures in homes occupied by low-income, vulnerable, or fuel-poor households.

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TECHNOLOGIES AND THEIR POSSIBLE APPLICATIONS

Different SMETER technology options have different possible applications. The main SMETER measurement techniques are described in Table 1. These vary in particular according to the approach to internal temperature measurement, with a generally increasing cost and deployment requirements associated with more measurement.[8]

Table 1 SMETER technology options.

SMETER TECHNOLOGY OPTION	DESCRIPTION
1) *'Remote' SMETER methods*	Do not require internal temperature measurements. These can be applied at scale using smart metering and weather data, as within a recent pilot (Hollick et al. 2025).
2) *Methods using a single temperature sensor located within an existing device*	Utilising for example a smart thermostat or a temperature measurement-enabled smart meter in-home display located in a central point in the home.
3) *Methods using one or more standalone temperature sensors*	Sensors typically installed in homes as part of deployment.
4) *Methods using additional measurement data*[9]	Uses, for example, data from heat metering or other types of measurement that is more complicated to install than temperature sensors. These will tend to be more costly than 1–3 due to being more complicated to deploy.

There are various possible performance assessment applications and design choices utilising the technology options described in Table 1. Key dimensions for such choices include:

Portfolio level or individual properties? Rewarding or evaluating scheme performance at a portfolio level may be sufficiently served by bulk measurements, through (no-low cost) 'remote' methods[10] (Hollick et al., 2025).

One-off measurement or to track changes over time? Choices here depend on aspects such as accuracy requirements (e.g. longer periods of monitoring are expected to reduce the variability of HTC), the technology cost (is it cost-effective to install and maintain it over a period of time?) and consumer journey and the application.

DEVELOPING IN-USE PERFORMANCE MEASUREMENT FOR HOMES AND OPPORTUNITIES

This section considers the measurement and informational possibilities offered by in-use measurement.

THE ROLE OF INFORMATION IN SUPPORT OF POLICY AND DELIVERY

As described above, information has a critical role supporting policy and market development. For example, the government role of developing policies, and delivery agents' roles in implementing them, may be enhanced by improved monitoring and evaluation of policy instruments.

In-use performance measurement can also inform key delivery functions, such as industry standards and processes (e.g. MCS and PAS2035). Market actors within industry may also be able to, through measurement, differentiate new products and services in terms of information on savings or guarantees of performance, which may aid their diffusion through networks (see below on market transformation). Householder engagement and decision making may be increased by more accurate or personalised predictions or feedback on outcomes as well as quality assurance based on performance measurement.

8 Note that in-use measurement per property costs are markedly less than co-heating test costs (and negate the hassle associated with decanting occupants for measurement purposes). The full range of SMETER costs is from £10 up to £200/300 depending on existing hardware availability and requirements in different homes.

9 Either linking up with pre-existing infrastructure in the home or newly introduced as part of deployment.

10 Bulk measurements, whilst less accurate at individual building level, have potential to provide sufficient accuracy at portfolio-level for such applications.

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The opportunities described below are most fully realised when in-use measurement is developed as a national system, rather than deployed incrementally through individual policies or schemes (as is discussed further below). As has been the case with related infrastructure such as smart meters, the most transformative benefits, including the development of a comprehensive national picture of housing stock performance and the unlocking of new market mechanisms, are likely to manifest only at scale. The infrastructure required is, to a significant degree, already in place, making the on-costs of a national system comparatively modest. However, there are also a number of novel requirements and implementation challenges, including ensuring data privacy; these are examined in the discussion.

Below we explore substantive opportunities and data system implications for the deployment of in-use performance measurement at scale across a range of opportunity areas. These opportunity areas were suggested by work undertaken for a Centre for Research into Energy Demand Solutions (CREDS) and Climate Change Committee (CCC) workshop exploring net zero Governance issues, as referenced by Torriti (2024).

Policy coordination within central Government, between the different layers of national, local and devolved government and with regulated utilities is important for the design and delivery of Net Zero heating demand approaches in multiple contexts. For example, targeted heating demand reduction through energy efficiency can offset the need for local electricity network reinforcement; and adverse health outcomes from poor internal environments could be targeted more directly.

Focusing on the first of these examples, the GB energy regulator has recognised that network operators will need to take on a bigger role in coordinating energy efficiency measures (Ofgem, 2025) whilst there is also energy industry recognition that better data on home energy use is needed to understand where interventions should be focussed and in which homes. An additional set of issues currently receiving attention is that current heat models are not able to consider flexibility from the thermal inertia of buildings (NESO, 2025), as well as the increasing need for adaptation as a result of a changing climate.

The primary limitation of existing information systems in this context is that accurate and granular stock-level thermal performance data is not available, for example to use within 'digital twins' of the energy system in order to target interventions. This limitation could be addressed by in-use performance measurement in different ways, for example (subject to controls to anonymise the use of individuals' data) it may be possible to construct a stock model based on measured thermal performance using 'remote' SMETER methods.

Information is also lacking on the conjunction of predictions of poor indoor environments and occupant health conditions. Sensors are increasingly being used to measure the indoor environmental quality of individual homes in social housing, so in principle relevant data is available in this part of the housing stock, but new and secure forms of data access would be required to practically coordinate health and energy measures.

Performance management has many roles across the home heating and energy efficiency space, both at the level of government programmes where in-use measurement has already been proposed (e.g. DESNZ 2025a) or piloted as a means of improving outcomes, and, as below, in relation to providing householders individually with assurance of work quality and operational performance.

TrustMark is the UK's Government-endorsed quality scheme for home improvements and repair work, intended to provide homeowners with assurance that registered tradespeople meet high standards in technical competence, customer service, and trading practices (Yeadon, 2023). For specific retrofit and clean heat installations adherence to standards like PAS 2035 and MCS certification is also required. The operational performance of installations is not often within scope of these standards and is a known challenge affecting take up and customer experience. In-use measurement (with appropriate validation and quality assurance) can support its inclusion within their scope. Its inclusion and implementation (via pre-and-post comparative measurement) can give customers transparency and agency over operational performance. This could also enable avenues for recourse if performance is below expectations. This is likely to be most viable and of interest via landlords (e.g. housing associations) (DESNZ, 2026c), but also potentially owner-occupiers in future. This could support the mitigation of split incentive issues, as described above (Economidou and Bertoldi, 2015).

Fiscal management relates to the provision of government support and the allocation of costs and benefits across the economy. In-use measurement could enable greater use of fiscal incentives and other policy mechanisms to transfer the costs of retrofit measures within the economy such as supplier obligations and white certificate schemes. Another opportunity is in relation to retrofit and carbon finance, where finance providers are required to report on emissions associated with their loan portfolios and are offering "green" mortgages which support retrofit activities by householders, requiring baseline and verification data. It is widely expected that the banking and finance sector will have a key role to play in funding the transition. The finance industry has called for centralised access to energy performance data such as SMETER to facilitate carbon accounting reporting (PCAF, 2021). Engagement carried out by DESNZ with finance sector stakeholders has identified interest in the use of performance information for more accurate affordability assessments, targeting poorly performing properties and verifying that retrofit work has been carried out.

Market transformation covers the totality of change necessary in the coming decades to transition the relevant markets (housing and construction, heating equipment, energy) to a more efficient and low carbon system delivering thermal comfort. A range of broader market transformative opportunities are likely to become viable as a result of the availability of in-use measurement data for individual properties and portfolios building upon performance management and other uses. For example, in-use measurement data can enable markets to develop new retrofit business models based on verified energy savings, such as Energy Performance Contracts or Energy Services Agreements. Here, the provider installs and operates energy-saving technology, transferring the performance risk to themselves. The customer pays the provider for the service (with energy bills either included depending on agreement type) and benefits from guaranteed performance and no upfront cost for the improvements. Such opportunities have been long discussed as opportunities to fundamentally change energy markets from supply to services models, but have been continually hampered by lack of sufficiently available and accurate before and after performance information, upon which agreements can rely. Commercially available examples of such models already exist at a small scale. For example, Energiesprong[11] is a whole-house retrofit approach, funded by a 30-year guarantee on performance and energy/maintenance savings, allowing the works to be paid for over time without increasing the residents' cost of living. Within the domestic sector, such models appear viable only for large housing portfolios or where long-term contracts are possible, currently limiting the market to some housing associations. Finally, more broadly such systems could better enable value creation derived via demand reductions, such as negawatt markets (Tushar et al., 2020).

Enabling behavioural and organisational change: the engagement of people, businesses and communities is critical in owning, prioritising and legitimising net-zero actions, particularly behavioural and organisational change. In-use measurement provides opportunities to better inform and influence householder and organisational behaviour. For example, improved in-use home performance information could support retrofit activities by providing greater understanding and agency for householders and communities to understand the actual performance of their homes and of retrofit, including reliable predictions of bill savings, and in doing so, helping overcome key informational barriers to action (Quadrangle, 2026).

Table 2 summarises the current information system constraints, opportunities and design requirements, and potential benefits, across each of these opportunity areas.

DISCUSSION

This section discusses the rationale for, and utility of, a national system of in-use performance measurement, drawing upon insights from the opportunity areas described above. It also considers risks and challenges associated with developing a national in-use measurement system. Finally, it describes how it could be developed considering opportunities and the current status quo, considering a) what further evidence is needed to inform evidence gaps and inform how to design such a system, and b) operationalisation needs.

11 https://www.energiesprong.org/.

OPPORTUNITY AREA	AREAS OF RELEVANCE AND KEY INFORMATION SYSTEM CONSTRAINTS	IN-USE MEASUREMENT AND KEY DATA SYSTEM IMPLICATIONS FOR HIGHLIGHTED AREAS	BENEFITS – KEY POLICY AND MARKET OUTCOMES
Policy coordination	Home energy performance interactions with housing market, health, fuel poverty and **electricity networks and flexibility**: Constraints relate to lack of granular spatial data on the performance gap and thermal inertia of the housing stock.	To include granular data on heat loss rates and thermal inertia in data systems, in order to enable coordination with public/regulated bodies such as DNOs. Supporting technology may be a mix of remote SMETER methods & internal temperature data.	• Improved monitoring, prediction and forecasting • More consistent governance across domains (e.g. DNOs, retrofit policy, health) • Reduced risks of poor decision-making • Lower system and householder costs
Performance management	Building and minimum efficiency standards, heating system governance, supplier obligations and **publicly funded retrofit programmes**: Constraints relate to performance gap-related weaknesses in predicting and reporting outcomes within model-based information systems.	To integrate the capability to measure heat loss rates into information systems, supported by validation and QA arrangements. Maximum value would accrue from the capability to measure and access HTC information for both individual and groups of homes.	• Improved evaluation and feedback on performance • Improved QA/incentives on market actors • Better targeting & prioritization of retrofit • Ability to link building performance to health effects (e.g. mould risks)
Fiscal management	'User pays' via regulation (ECO), public grants, tax incentives and **carbon pricing/financing arrangements**: Constraints relate to reliance on EPC-based information which does not accurately represent outcomes.	Case for a centralised data system to provide controlled/aggregated access to energy consumption and HTC data.	• Increased private financing for NZ • Improved economic incentives on market actors • Stronger fiscal incentives resulting in greater household engagement/activity • De-risking of carbon budget delivery
Market transformation	Property market, energy products and services and **energy efficiency retrofit and low carbon heating**. Constraints relate to reliance on modelling of thermal performance, leading to inability to accurately predict e.g. heating demand.	Need for robust QA, integration of measurement into existing standards & tools. Facilitating ease of access to measurement for innovators, supply chain actors and householders.	• Capital cost reductions and reduced spend on energy • Householder risk reduction • Innovation in performance-related products and services • Market development
Behavioural and organisational change	Engagement in owning, prioritising and legitimising net-zero actions by communities, businesses and **householders**. Constraints relate to the perceived low relevance to individuals of current information on energy performance and costs.	Need for robust QA and verification of individual performance measurements. Ability of the system to support personalised measurements (thermal performance reflecting occupant behaviour). Ease of availability of measurement tools, including to disengaged.	• Greater understanding and agency for householders and communities • Increased uptake of measures

Table 2 In-use performance measurement relevance, implications and benefits by opportunity area.

THE RATIONALE FOR, AND UTILITY OF, A NATIONAL SYSTEM OF IN-USE MEASUREMENT

One of the main reasons to develop a national system of in-use measurement is the opportunity to close the performance gap. The performance gap causes substantial and pervasive policy and market delivery problems in the context of net zero which, if not tackled, will only increase. In-use measurement also provides a vital strategic benefit of providing visibility, and therefore value, at scale to actual thermal performance, which has previously been extremely difficult.

In-use measurement that applies across the home heating and fabric systems also enables consistency in performance measurement (amongst other applications) across areas that are currently disparate and unconnected. A consistent, national system of measurement would bring individual benefits to each of the existing opportunity areas described in Table 2. However, most importantly it would also increase the ability of government to steer relevant markets and delivery systems towards more effective delivery of net zero. For example, it will become possible for government to develop overarching and measurable goals and outcome objectives (for example, to ensure positive cost and comfort outcomes for householders). These objectives could then be pursued via modified policy design and governance improvements (see below) to support, for example, consumer protection and progress tracking.

Finally, from a more pragmatic perspective, developing in-use measurement takes advantage of innovation and builds upon existing infrastructure investments. Most of the large-scale infrastructure (i.e. smart meters) and associated costs are already established, and in-use measurement will make better use of them, deriving considerable increased benefits that could not be previously imagined. Additional hardware and associated requirements can also,

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as a result of innovations in sensing products and IoT, be put in place relatively easily and at a very low cost, on a per-home basis.

WHY GO STRAIGHT TO A NATIONAL SYSTEM OF IN-USE MEASUREMENT?

Development and deployment of in-use measurement could be done in a variety of ways. For example, sensors and software algorithms could be applied incrementally over time, integrating and incentivising their deployment within existing policies. So this begs the question, why propose the development of a national system now? As has been the case with deployment of related infrastructure (e.g. smart energy and water meters), the most transformative benefits may only manifest themselves when deployed proactively and at scale. For example, in the context of heat electrification and wider ongoing electrification[12] a national system will enable in-use measurement to play a substantive informing role in identifying and mitigating network constraints and support the use of flexibility within electricity networks (Ramirez-Mendiola et al., 2023). It can also form the basis for more ambitious policy development, such as improved fiscal incentives.

In addition, a national system would enable the development of much improved national housing stock information, particularly when applied in combination with existing housing details, fabric and measure level information, such as that contained within the EPC register. Such a system would support various beneficial functions, including identification, targeting and performance management of poorly performing housing stock, as well as improved monitoring and evaluation feedback thereby improving policy effectiveness. This would also include improved policy co-ordination with other policy areas including health and fuel poverty.

RISKS AND CHALLENGES OF INTRODUCING IN-USE MEASUREMENT

There are risks and challenges present in developing an in-use measurement system which will over time highlight where there is a gap between measured performance and that predicted by EPCs. The UK Government is currently considering how best to introduce in-use measurement into its system for monitoring performance, including whether a measured in-use HTC value could be introduced into its EPC system (DESNZ, 2026a). Such work would be worthwhile as it contributes to closing the performance gap and could enable use of these measurements for policy use. Moreover, government taking a proactive approach to this should help to ensure that such issues can be managed strategically, and enable pathways to adapt policies in a controlled manner (e.g. phased transitions) from estimation to measurement.

WHAT WORK IS NEEDED TO DEVELOP A NATIONAL SYSTEM OF IN-USE MEASUREMENT?

Despite its potential, much work needs to be done to make a national system of in-use measurement a reality. Development needs include:

Ensuring effective data access and privacy

SMETER methods have been implemented thus far within the requirements of the GB smart metering Data Access and Privacy Framework (DESNZ, 2018) which controls third party access to energy consumption data within the interoperable GB system, and GDPR.[13] However, scaling up to a national system, with a range of actors, applications and consent configurations involved, is likely to need careful development to ensure both effective privacy controls and efficient data access. Many building performance metrics, including the HTC of a dwelling as measured by SMETER methods, are not personal information any more than the EPC rating of the dwelling would be (DESNZ, 2026a, DESNZ, 2018). However, energy consumption and internal temperature data, which are regarded as personal data, are required to generate the metrics. If these input data are to be collected at scale, then this will require full compliance

12 E.g. Electric vehicles, battery storage and local generation such as solar PV.

13 Data Communications Company: Operating Britain's secure smart meter network Operating Britain's secure smart meter network | Smart DCC. https://www.smartdcc.co.uk/our-smart-network/.

with the data access regulations in a manner suited to the context (for example, respecting differences between rented and owner occupied dwellings), which is also generally understood and accepted by consumers.

Further evidence development

There are initiatives including DESNZ's SMETER implementation work and a new International Energy Agency, Energy in Buildings and Community Programme Annex 94 on Validation and Verification of In-situ Building Energy Performance Measurement Techniques which are developing new evidence (IEA, 2026, DESNZ, 2022b). Recent DESNZ work has been aimed at providing evidence on causes of variation in in-use measurements of HTC and how they can be validated, how they improve prediction of policy-relevant outcomes such as heating costs and about the broader delivery systems within which measurement can be deployed (DESNZ, 2026b). Results are being fed into implementation design, however these areas are expected to continue to be the subject of further evidence work. Additionally, research needs to include social science to understand the value to householders of personalised information on the energy performance of their homes.

Operational development needs

There are some operational developments needed to support in-use measurement deployment, described below.

Quality assurance and validation: There are currently a range of commercial in-use measurement providers already on the market, but there are no quality assurance or validation standards to give confidence to customers of their quality and accuracy. The development of this is a clear role for government to lead in the short term.

Implementation and the customer journey: There are different implementation approaches available according to different use-cases for in-use measurement, with different requirements and implications for gathering necessary data, including from multiple types of pre-existing temperature sensing devices to reduce costs,[8] and for data processing. These need careful consideration to ensure that approaches involve least friction for customers and those implementing SMETER technologies. In addition, there may need to be new mechanisms for storing and re-using HTC measurements for multiple purposes.

Consideration of operational costs: In-use measurement, will need to be cost effective in order to be successfully taken up on a wide-scale. Operationally a 'minimal cost' approach needed to deliver sufficient accuracy for specific use-cases will likely be needed.

IN-USE MEASUREMENT AND THE CONDITIONS FOR BETTER GOVERNANCE OF DEMAND-SIDE ENERGY POLICY

Opportunities explored in this paper, taken together, point towards a conclusion that goes beyond individual benefits of in-use measurement in any single policy or market area. Across policy coordination, performance management, fiscal-management, market transformation and behavioural change, a consistent theme emerges: the reason existing governance of demand-side energy policy has been fragmented is not primarily a failure of institutional design, but a failure of information. Government, market actors and householders have all been operating without a shared, accurate and real-time picture of what is actually happening in homes.

Governance of the kind relevant here; encompassing government, markets and networks, operating through formal and informal processes alike (Bevir, 2012) – is by nature distributed and emergent. It does not resolve into a formal framework, and in-use measurement does not change that. What it does change is the informational basis upon which distributed governance processes depend. For the first time, it would become possible for government to set outcome-based goals and track progress against them at scale; for market actors to develop products and services grounded in verified performance rather than modelled estimates; and for householders to engage with the transition on the basis of accurate, personalised information about their own homes. These are not incremental improvements to existing arrangements, but are conditions under which effective demand-side governance becomes achievable.

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This, we argue, is the sense in which in-use performance measurement of homes represents a paradigm shift for demand-side energy policy. The disruption is not the replacement of existing institutions or frameworks, but the removal of the informational barrier that constrains them. Whether that potential is realised depends, as the preceding discussion sets out, on deliberate development choices – particularly the case for a national system, and the evidence and operational work needed to make it a reality. But the opportunity is substantial, and the infrastructure to seize it is, to a significant degree, already in place.

FINAL SUMMARY

In this paper we have identified a fundamental strategic problem compromising effective delivery of the net zero transition on the demand side: the lack of sufficient, accurate information on individual home performance. This information deficit has pervasive consequences, undermining the reliability of existing policy interventions, limiting the development of performance-based markets, and leaving government, market actors and householders without the feedback needed to understand what is working and what is not.

We introduced in-use performance measurement, made newly viable at scale by the GB smart meter rollout as a potential systemic response to this problem. Drawing on existing evidence for SMETER as a method of measuring the heat transfer coefficient, we explored the wide-ranging opportunities that a national system of in-use measurement could unlock, across policy coordination, performance management, fiscal-management, market transformation, and behavioural and organisational change.

Through the discussion, we argued that these opportunities are most fully realised through a national system rather than incremental deployment and that the infrastructure to support such a system is, to a significant degree, already in place. We also identified the evidence and operational development work needed to make it a reality.

Finally, we posited that the opportunity presented by in-use measurement extends beyond any individual policy or market application. By providing, for the first time, the informational foundations on which effective governance of demand-side energy policy depends across government, markets and networks. It creates conditions for a more coherent, outcome-focused and accountable approach to delivering the transition than has previously been achievable. That, we suggest, is the sense in which it represents a paradigm shift, by the removal of the informational barrier that has constrained progress to date.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **PowerPoint Slides.** PowerPoint Slides relating to this article. URI: https://eceeeproceedings.org/articles/63/files/6a561fed05dc4.pptx

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COMPETING INTERESTS

David Kenington and David Allinson have provided paid consultancy to DESNZ on building energy performance specialist services to the Smart Metering Implementation Programme, which relates to the subject matter of this study.

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AUTHOR CONTRIBUTIONS

David Kenington was the lead author. David Allinson provided substantial contributions in particular drawing from the SMETER evidence base and wider building physics concepts upon which the paper relies.

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