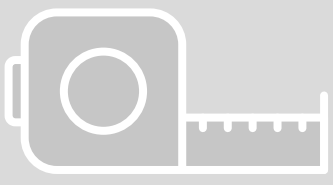
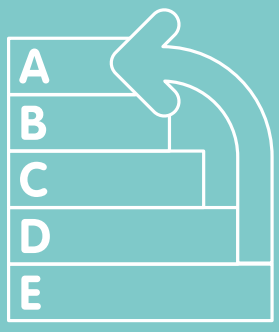
METERED ENERGY SAVINGS NEXT STEPS

Unlocking home retrofit financing by reliably measuring energy savings

July 2022





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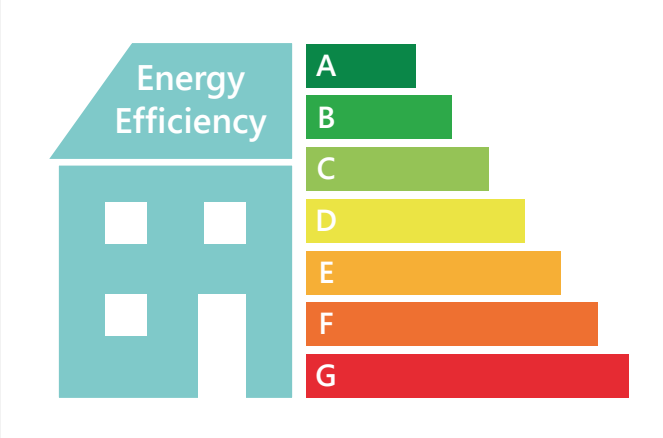
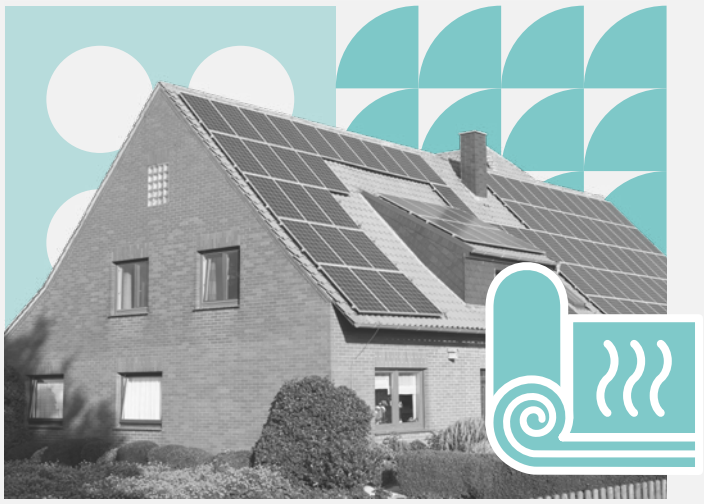
EXECUTIVE SUMMARY

Achieving net zero carbon emissions in the UK by 2050 requires decarbonising around 27m homes through a combination of energy efficiency measures and low carbon heating. To attract the necessary £250bn to decarbonise homes, **the financial community for home retrofit need to develop affordable, appealing financial products.** Designing and promoting suitable financial products requires robustly quantified evidence to underpin promised benefits.

Householders (and other stakeholders) must have confidence that refurbishments and low carbon technologies in their home will deliver the promised level of performance - in terms of the cost/energy saving and improved comfort and wellbeing. Ongoing research by Energy Systems Catapult into consumer attitudes towards decarbonisation of homes has identified that **low confidence regarding energy savings is a key barrier** that prevents many from taking steps to decarbonise their home or take on finance to do this.



In practice, energy savings are difficult to measure as they represent the absence of energy use. Currently, the savings expected from energy upgrades are typically estimated using models (e.g. SAP) that assume fabric performance based on visual inspection and standard usage patterns.

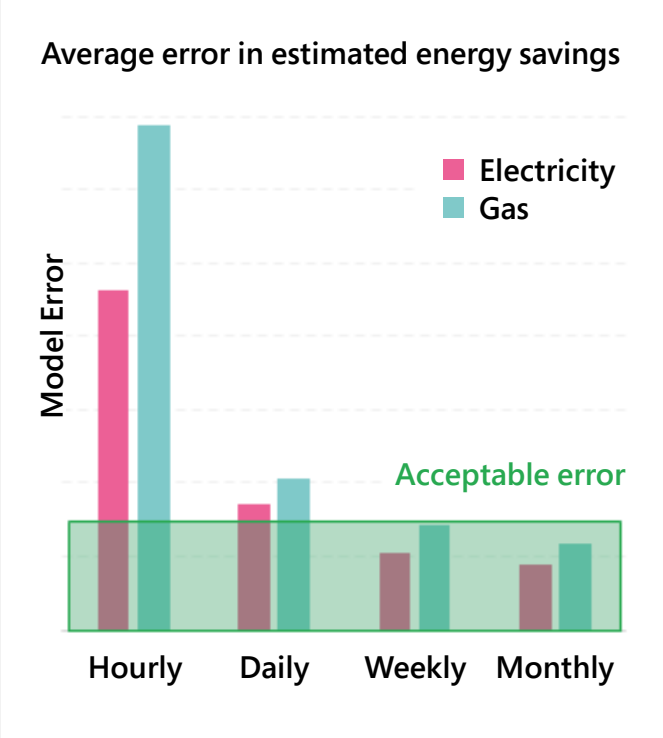


Existing methodologies are unreliable because they don't account for the wide variation in usage patterns and quality of the energy efficiency works. This undermines the incentives on suppliers to deliver well designed and executed improvements and increases the risk to consumers that the expected benefits of the work are not realised. The introduction of MCS and PAS 2035 standards are a breakthrough, but a gap persists around measurement of actual energy (and cost) savings.

Existing methodologies are also unable to reliably estimate sub-daily (e.g. half-hourly) savings, which are important in quantifying carbon savings. This is because many low carbon technologies aim to shift energy usage to less carbon intensive times of the day.

A standard method for accurately measuring energy savings using metered energy data would provide confidence and unlock financial product and business model innovation. It would support greater customer confidence in low carbon technologies and encourage new business models such as comfort-as-a-service or performance guarantee-based offers. This would help grow the market and the commensurate finance products which will be required to decarbonise the UK housing stock.

This project took several steps towards defining that standard methodology. It evaluated existing **open-source methodologies** originally designed for commercial properties on UK homes, as these methodologies require only smart meter data and external temperature. **The project demonstrated that existing approaches appear suitable for estimating monthly, weekly, and potentially daily savings on UK homes.**



Existing approaches were also found to be suitable for estimating sub-daily (e.g. half-hourly) savings on portfolios of properties. However, the project found that **existing approaches are inadequate for estimating sub-daily savings on individual homes.**

Additional work is required on three fronts, and this would move the industry forward in achieving a reliable and practical methodology to measure and report energy savings:

1. Additional work is required to improve the accessibility of the monthly/weekly/daily approaches to enable widespread use, through the creation of user interfaces and guides suitable for a broader range of users.

2. The conclusions of this report ideally require validation on a larger, fully representative sample of UK homes – particularly regarding the accuracy of the daily savings estimates - as this project relied on a small sample of only 42 homes.

3. Further research is required to develop and test a methodology that would estimate half-hourly savings on individual homes to sufficient accuracy. This is likely to require both additional data collection from homes (i.e. not just smart meter data) and advances in the algorithms used. Since collecting additional data has significant practical and financial implications, the industry would likely benefit from a systematic, data-driven analysis of the extent to which different additional data sources tend to increase the accuracy of savings estimation.

OVERVIEW OF WORK

The project was partly funded through the Welsh Government's Optimised Retrofit Programme (ORP) that is treating thousands of social housing properties across Wales with energy efficiency retrofit measures, and partly funded through a grant from the Microgeneration Certification Scheme (MCS) Charitable Foundation. Data from 42 homes was collated for the analysis.

The project team has made substantial progress, including:

- Capturing user profiles, use cases and needs, building on the work of the Green Finance Institute's (GFI) working group on metered savings during 2020-21.
- Evaluating existing practice and new developments in US and European initiatives, including signing a collaboration MOU with the Horizon-2020 project SENSEI.
- Aligning any proposed metered savings protocol with the new British Standard on Building Performance Evaluation (BS 40101), which defines a methodology for a comprehensive evaluation of retrofit outcomes. In particular, the BPE standard comprehensively addresses the non-energy benefits of a retrofit project, while specifying the need for energy savings to be evaluated against a comparator (baseline) - the metered savings protocol will provide a convenient, compliant tool for retrofit evaluators to generate this comparator and 'measure' savings.

- Analysing the capabilities and limitations of two key current methodologies, CalTRACK and SENSEI, in terms of their ability to create counterfactual comparators for individual dwellings and portfolios, and their ability to evaluate savings at a greater-than-daily resolution.
- Developing an understanding of the specific applications and use cases for metered savings in a UK context.
- Creating new visualisations of residential energy use and savings that will aid analysis of energy consumption patterns and comprehension of the output of a savings meter.
- Reviewing the outputs of the BEIS 'SMETER' programme and incorporating its findings into the research.
- Developing minimum data requirements for the use of metered savings techniques, including a method for evaluating the 'spikiness' of residential consumption data.
- Identifying where further development is needed to close the gap between available methods and the envisaged applications, and the direction this research should take.

The project has been based around three primary applications, which were characterised in detail through a process of industry consultation facilitated by GFI and user interviews:

1. **Retrofit Performance** Evaluation of Individual Dwellings (For use within PAS 2035/BSI Standard): Here a ***Retrofit Evaluator*** is interested in the energy savings (with financial and emissions impacts) of an individual dwelling retrofit.

2. **Retrofit Portfolio Evaluation** for assessing and verifying Network Services (Flexibility): Here a ***Network Analyst*** is interested in assessing and verifying the Network Services provided by a portfolio of interventions, including deferral of network reinforcement or demand-side flexibility services.

3. **Retrofit Portfolio Evaluation** for assessing risks and return on investment (informing targeting and pricing of intervention investments): Here a ***Financial Analyst*** is interested in the energy savings (with financial and emissions impacts) of a portfolio of dwelling retrofits.

The project evaluated the performance of two existing methods for calculating 'counterfactual' baseline energy consumption for metering energy savings on an hourly basis:

- CalTRACK, selected on the basis that it is already widely used for commercial properties, is simple and easy to interpret, and has an existing open-source implementation.

- SENSEI, on the basis that it offers a state-based approach that might better handle occupancy than CalTRACK, and is still relatively easy to interpret and has an existing open-source implementation.

CONCLUSIONS

The analysis has demonstrated that existing methods including CalTRACK and SENSEI **offer a useable solution for daily, monthly, or further aggregated time periods, but are unable to provide reliable measurement and verification of savings on a sub-daily basis for single dwellings.** Table 1 summarises how current methods can address the key applications.

Application	Method	Outputs	Description	Status
1a. Single dwelling retrofit energy savings evaluation	1. Single dwelling daily	Daily counterfactual model (electricity [and gas]) Daily avoided energy use	CalTRACK hourly (with results aggregated up to daily) or CalTRACK daily if hourly data is not available	Existing methodologies are reasonably effective in some cases and could be further refined.
1b. Single dwelling resource curve evaluation	1b. Single dwelling half-hourly (electricity [and gas])	Half-hourly counterfactual model (electricity [and gas]) Half-hourly avoided energy use	Further research required	Methodologies are inadequate for time-of-use applications for single dwellings. Available methods are hourly and would require adaptation for half-hourly applications.
2. Portfolio resource curve evaluation	2. Portfolio half-hourly	Half-hourly counterfactual model (electricity [and gas]) Half-hourly avoided energy use	Sum energy usage across portfolio for each (half) hour and then apply CalTRACK hourly (OpenEEmeter, 2019)	A CalTRACK-like approach for portfolios of dwellings appears effective given portfolios of >10-20 properties. Available methods are hourly and would require adaptation for half-hourly applications.
3. Portfolio retrofit energy savings evaluation	3. Portfolio daily	Daily counterfactual model (electricity [and gas]) Daily avoided energy use	Sum energy usage across portfolio and then apply CalTRACK hourly (OpenEEmeter, 2019) (with results aggregated up to daily) or CalTRACK daily (OpenEEmeter, 2019) if hourly data is not available	Existing methodologies are reasonably effective and could be further refined.

Table 1: Suitability of the tested methods for various end-uses and applications

Further work is needed to develop a method that can fulfil the requirements of protocol 1b in Table 1, and indeed to establish whether such a method can be developed.

The project has made progress towards a metered energy savings solution for the UK and has highlighted the need for such a protocol, building on the work carried out under the GFI's CEEB initiative during 2020-21. A series of user interviews and further research with stakeholders convened by GFI concluded:

1. The relevance and methodology of this work has been validated through conversations with all the stakeholders, with all parties supporting further refinement investigations.

2. Changes are likely to be required across the UK's energy data infrastructure to support metered energy savings and performance business models. For example, determining the specification of network dispatch proving tests will assist in supporting network-based use cases by providing clear thresholds of accuracy and confidence to work towards and test against.

3. The importance of resident comfort, fuel and carbon savings should all be considered and integrated as these methodologies develop and evolve over time. The variability between domestic and non-domestic sectors, in terms of available inputs and desired outputs, should not be underestimated. As such final solutions should be adaptable and flexible wherever possible in order to maintain an open field of potential applications and value streams.

4. Data and data collection methodologies remain one of the key barriers to producing, evaluating, and improving metered savings methodologies. The collection and sharing of high-quality data (data from smart meters) should be given high importance by industry actors and policy makers alike, and access to existing data should be improved wherever possible.

5. In home devices and real-time monitoring may be able to provide a cost-effective solution to some, but not all, of these issues, and so a holistic approach is needed as the UK moves forward with decarbonisation.

IMPACT & NEXT STEPS

The business case and engineering need for metered savings will only grow as electrification of heat and transport demand continues across the UK, particularly in grid-constrained areas, and this urgency is likely to be heightened by the current gas price crisis if it accelerates electrification.

In particular, intra-day (hourly/half-hourly) methods will be required for:

Accurate energy cost or peak avoidance savings calculations where time-of-use tariffs are in use;

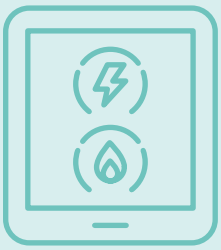
Accurate evaluations of avoided carbon emissions that consider temporal and locational variation in the carbon intensity of electricity.

Extensive research and analysis work has been carried out using calculation methods developed around the world to identify a promising starting point for a UK methodology.
This research concludes:

1. The limited quantity of data available rendered it impractical to develop a completely new model that could be confidently recommended as suitable for widespread use.
2. Models using hourly consumption and external temperature (e.g. CalTRACK and SENSEI) that perform adequately on commercial properties perform poorly on individual domestic properties at sub-daily (hourly or half-hourly) granularity. This is because:
   - Domestic energy usage includes many spikes resulting from behaviours that are not fundamentally driven by time or temperature.
   - Even usage that has a relatively strong time-dependent component tends to move between adjacent hours and therefore is hard to accurately model.
3. Existing hourly models are therefore not suitable for use cases that require assessment of peak usage for single dwellings.
4. Spikiness of the data seems to be a good predictor of how accurate a model will be. When considering data with a half-hourly or higher granularity, smoothing methods may improve accuracy but will also hamper the assessment of shifts in demand peaks.
5. Aggregating outputs from an hourly model up to daily may enable sufficiently accurate counterfactuals for a single dwelling to be produced using CalTRACK.
6. Aggregating readings from 10-20 dwellings may enable sufficiently accurate hourly counterfactuals to be produced using CalTRACK.
7. Existing models largely operate on hourly not half hourly resolution, so work to extend these models and open-source packages to half hourly would be beneficial for usage in the UK.

While further work is needed to prepare them for general use by retrofit and finance professionals, methods for calculating daily counterfactuals for portfolios of homes are found to be largely fit for purpose. In some cases, these methods can be used for individual dwellings, and in this role, they will provide a useful tool for conducting a building performance evaluation under the new BS 40101 standard. Reciprocally, projects conducted that conform to the Standard BPE level under BS 40101 will capture data of sufficient quality, granularity, and over sufficient time to be compatible with methods and models explored by this project. However, challenges with obtaining access to the required volume of energy data has meant that less progress has been made on half-hourly ('time of use') methods. While the project does conclude that currently available methods can be used to provide time-of-use evaluations across portfolios of homes, significant further research is needed before this approach offers a viable solution for individual dwellings. The intra-day 'spikiness' of energy use in homes is simply too great for current approaches to work reliably, and alternative approaches developed in non-residential contexts do not appear to offer a solution.

A future half-hourly method for metering savings will need to incorporate either probabilistic methods to better handle consumption spikes, or additional explanatory data on household energy use, which could be sourced from in-home sensors or behavioural insights from large-scale studies of energy use.



Fortunately, the analysis conducted during this project and findings from the 'SMETER' projects commissioned by BEIS, showed that additional metering products do not need to impact occupant comfort or convenience. Some of the data collected by SMETER projects – including smart meter data, heating controls data and room sensor data – may also be directly useful in a future phase of development of metered savings.

There are several specific follow-on projects that would support the goal of ensuring there is an accessible protocol for metered energy savings across most use cases:

1. Focus on opening up access to smart meter (especially gas) data for research and development purposes. This could include a small funding allowance that can be used to reimburse third party providers of data for the cost of administrative effort in providing their data sets. A central register of data sets with descriptions including the type of data contained and any access requirements should be set up and maintained by a public purpose organisation (e.g. Energy Systems Catapult or Building Performance Network).
2. Refine and productise the daily calculation methods described in this report for single-dwelling and portfolio retrofit evaluations, including the creation of user interfaces, Application Programming Interfaces etc that enable widespread use. This will also necessitate validating the conclusions of this report using a larger, more representative sample of homes.
3. Extension of existing models to work with half hourly data may be desirable for use cases in the UK where tariffs and CO2 emissions are (or will be) available at half hourly granularity.
4. Research and development on half-hourly methods that will allow time-of-savings and load shaping applications to be realised, including:
   - probabilistic methods to better handle unpredictable peaks in household energy consumption.
   - the effects of additional explanatory data including:
     - disaggregation of usage using submetering and/or non-intrusive load monitoring.
     - data and modelling of energy-user behaviour.
5. Research exploring the critical points/step changes in the trade-offs between modelling accuracy and intrusiveness/cost when considering the collection of additional data.

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