Metered Energy Savings:

Briefing from RetroMeter project for Electricity Network Operators

What are metered energy savings from retrofit?

Deemed energy savings (for example, a change in Energy Performance Certificate (EPC) after energy saving interventions such as retrofit) involve estimating how much energy savings are expected based on the measures installed (for example the level of insulation), and how those measures are predicted to perform based on engineering-based calculations and laboratory testing.

On the other hand, metered energy savings (MES) look at the actual metered energy use (metered gas and metered electricity) after the retrofit, and compare it to what energy would have been consumed in that home during the post-retrofit period, had there not been a retrofit, i.e. a "counterfactual" energy use.

What are the benefits of metered energy savings?

Retrofit evaluation and consumer protection: MES can contribute as part of an overall retrofit evaluation by verifying whether a retrofit has achieved what the householder and other stakeholders wanted it to achieve. MES can also facilitate and assure high-quality retrofits by holding actors in the retrofit supply chain accountable for the outcome of their work, using relatively few data points in a non-intrusive way.

Energy system planning: MES can contribute to learning and research about the real-life performance of retrofits, in terms of what types of retrofit measures work best in which situations. MES can help in the planning of our future energy system by estimating how much energy will likely be required when large numbers of households transition to more insulated homes – information which is useful both for households and the wider energy network.

Leveraging finance for retrofit: MES can help to leverage financing for retrofit, by providing more confidence in the energy savings that underpin returns for private sector investment, and additional certainty of measured outcomes for public sector funders. This enables funders to pay for the performance and measurable value they receive from a series of retrofit projects, facilitating further collaboration and allowing new “pay-for–performance" business models to emerge.

How are metered energy savings relevant for electricity network operators?

For utilities and regulators, MES offers the possibility of really understanding the effect of energy efficiency on the network.

MES can help distribution networks at times of peak demand, by reducing the need to actively curtail demand or reinforce the network. Releasing additional network capacity through MES can allow electricity network operators to provide faster connections to low carbon technologies such as heat pumps, whilst keeping overall network operating costs to a minimum. This provides a wider societal benefit to all electricity bill payers through minimised additional costs of facilitating the transition to net zero.

In the right regulatory environment, distribution companies could use MES to invest in energy efficiency projects with a better economic and social return than investing in network upgrades such as new wires and substations.

What is the RetroMeter project?

The RetroMeter project aims to design and pilot metered energy savings in the UK context. The RetroMeter project is being led by Electricity North West in collaboration with Energy Systems Catapult, EnergyPro Ltd, Carbon Co-op and Manchester City Council, with funding through the Strategic Innovation Fund of the Office of Gas and Electricity Markets (Ofgem). The alpha phase of the project ran from October 2023 to March 2024.

What types of households / retrofits could RetroMeter metered energy savings methodologies be applied to?

The work of Energy Systems Catapult under RetroMeter has primarily been focused on situations where metered gas is used pre-retrofit as the main heating source and a smart meter has been in place for at least a year before the retrofit. This gas data is being used to develop counterfactuals for how much gas the household would have consumed in the post-retrofit period, had the retrofit interventions not taken place. This counterfactual can be compared to the actual usage of gas post-retrofit.

If the household has switched to electric heating (e.g. a heat pump) as part of the retrofit, the counterfactual gas usage can be compared with the actual electric heating consumption post-retrofit, but only if sub-metered consumption data for the electric heating is available.

If we're only interested in the total energy saved due to the heat pump and fabric retrofit, the comparison can be done on a simple energy basis. The process is a little more involved if the energy savings from the fabric measures need to be disaggregated from the heat pump.

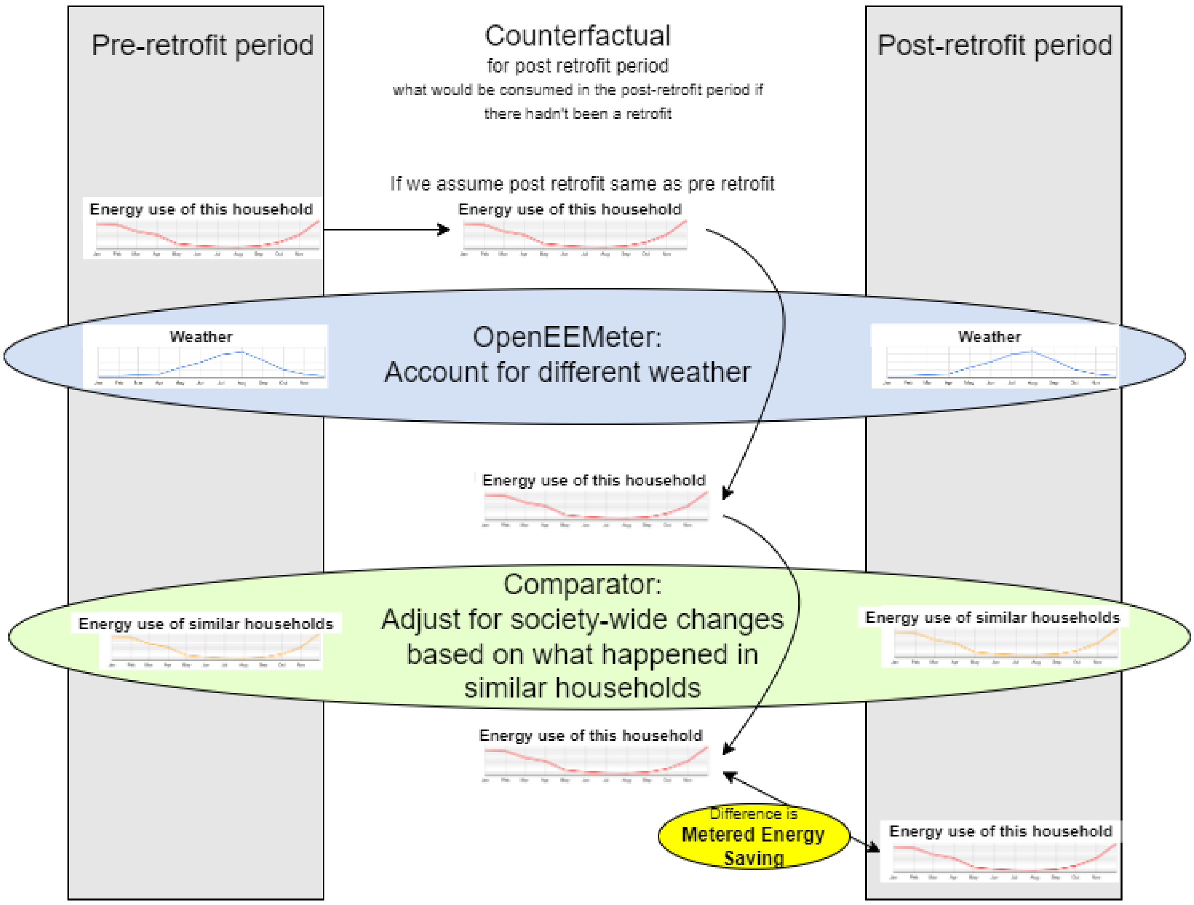
While internal temperature data is not required for implementing two of the methodologies explored in this project, if temperature sensors are installed in the home post-retrofit, this can facilitate use of the additional physics-based methodology.

What are the methodologies being tested under RetroMeter ?

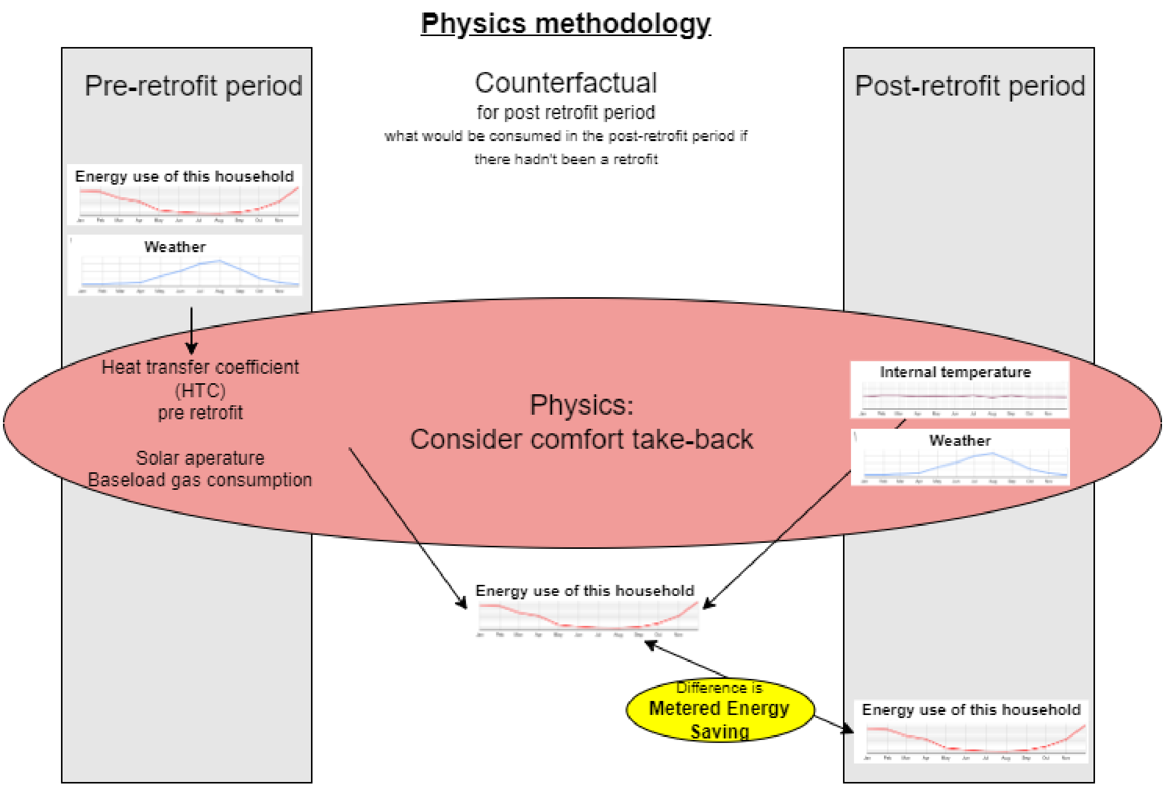
The project tested three methodologies:

1. **OpenEEmeter** (formally CalTRACK) is an MES methodology which began in California, United States and is currently maintained by the Linux Foundation. It accounts for the impact of weather on energy consumption using mean hourly external temperature and metered energy consumption in the pre-retrofit 'baseline' period, to fit regression models that also account for seasonal and other calendar effects. The most advanced version of this model does this on a daily basis, generating a counterfactual each day for what the energy use would have been given the weather conditions.
2. The **comparator methodology** builds further on OpenEEmeter by comparing the energy use in the 'candidate' household post-retrofit, to energy use in the same period for similar households which have not had a retrofit. This can help separate out the energy changes due to retrofit from the energy changes happening in society more broadly. There are different ways of finding similar 'comparator' households - matching can be done based on:
    - **Property archetypes** – candidate and comparator households having the same built form, property type, property age, Energy Performance Certificate rating, and other qualitative factors;
    - **Total energy consumption during the baseline period** – grouping households into quantiles based on their total annual energy consumption, and matching candidate households with comparators in the same category; or
    - **Energy consumption profile similarity** – comparing the gas meter time series during the baseline period of the candidate household with the profiles of the comparator households directly in the same period.

OpenEEMeter and Comparator Methodologies



3. The **physics-based methodology** developed in RetroMeter uses internal temperature data post-retrofit and accounts for "comfort take-back" (households heating their home at a higher temperature post-retrofit because of increased affordability). The physics-based methodology examines what energy households would have consumed in the post-retrofit period to achieve the internal temperatures they had in the post-retrofit period if they still had their pre-retrofit Heat Transfer Coefficient (HTC). HTC is a measure of the rate at which the heat generated in a home is typically lost out of the home through heat leakage. For modelled HTC, the pre-retrofit HTC is estimated by correlating the pre-retrofit weather with the pre-retrofit gas usage. Co-heating HTC (generated by other sources) can be used instead of modelled HTC. The model looks at both gas and electricity usage, as it assumes that a certain proportion of electricity usage generates heat in the home indirectly (electric cooking and kitchen appliances, electronics, lights). The model accounts for solar aperture estimated using weather data (external temperature, solar irradiance) and pre-retrofit gas usage. The model also accounts for baseload gas usage (i.e. gas used for other purposes than space heating and water heating and cooking – this is calculated by looking at gas usage during warm weather in the pre-retrofit period). The model also makes assumptions about boiler efficiency being an industry average.



How accurate are the methodologies?

This project made use of anonymised metered gas data from Hildebrand, a smart meter data provider. Data from 2021-22 was used to generate a counterfactual energy use for 2022-23, and assuming that no retrofit was performed in these households, if the models were perfect, the generated counterfactuals should match the actual metered data for 2022-23. The testing work examines how closely they align, providing an indicator of the accuracy of the modelling approach in real-world settings.

The results of this testing so far are evaluated in terms of:

- **Bias** – whether the reporting period predicted gas consumption is, on average, higher or lower than the metered consumption;
- **Accuracy** – how much the reporting period predicted and metered gas consumption differ, in either direction. This accuracy can be aggregated at daily, monthly or annual levels. Accuracy is measured using a statistic called the Coefficient of Variation of Root Mean Squared Error (CVRMSE), where a high CVRMSE indicates poor accuracy.

The results of the testing are summarized in the table below.

		Accuracy Median CVRMSE on annual basis for individual household *Lower number means better accuracy*	**Bias** *Close to zero means less bias*
	OpenEEmeter – accounting for changes in weather	19%	17%
	Comparator methodology – matching households on archetypes	18%	-3.9%
	Comparator methodology – matching households on average energy consumption	15%	0.01%
Best result ->	**Comparator methodology** – matching on energy consumption profile	9.4%	0.01%
	Physics methodology – accounting for comfort take back	26% (using co–heating HTC) 33% (using modelled HTC) (note: monthly not annual)	0.7%

In summary, these results show that the best approach is to use the comparator methodology, matching households on average energy consumption profiles.

How applicable are the methodologies at the individual household level vs aggregated across larger numbers of households?

While the lowest error is 9% at the individual household level, aggregating data to a 25-property portfolio successfully reduces the error to as little as 5% at the annual level, however it comes with some practical caveats that end-users must be aware of:

- The candidate properties within the portfolio must have had their interventions completed at around the same time, so that their baseline and reporting periods line up. This is necessary for ensuring that each property is fully represented at each timestep of the aggregated reporting period.
- They must also be sufficiently physically close to each other so that the same external temperature readings can be applied to each.
- MES cannot be disaggregated and attributed to individual properties with this approach.

These limitations imply that the portfolio aggregation approach is best suited to cases where a group of properties, managed by the same owner and on a single estate or terrace for example, can be retrofitted at the same time, and tied to a monitoring mechanism this is satisfied with attributing the MES to the project as a whole rather than individual properties.

How much does the accuracy of the methodologies affect the energy cost savings / financial returns?

Whilst an in-depth sensitivity analysis around the effect of the methodology on the financial returns has not been undertaken in this phase of work, it is clear that accurate metering and measurement are crucial for verifying that the predicted energy savings are actually being achieved. If the baseline is inaccurately determined, it can lead to overestimation or underestimation of energy savings. Overestimation may result in unrealistic financial projections, while underestimation may lead to dissatisfaction among stakeholders. However, one must recognise the trade-off between the additional costs that metering and measurement leverage on project financials and the additional assurances and accuracy that these services provide. There will often be a "sweet spot" between the additional transaction costs of methodology improvements and the additional verification of project performance on which impact-based revenues are derived.

The requirements for an accurate energy savings estimation will directly impact the type of financial packages that could be offered towards an MES-enabled retrofit scheme.

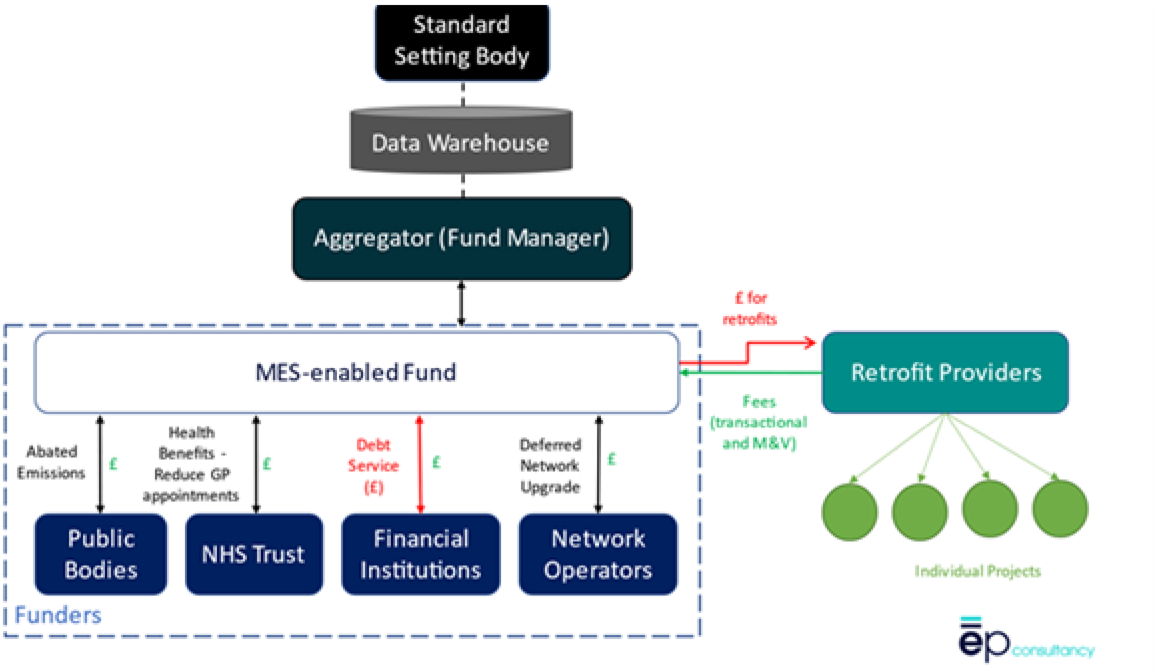
Two key factors affecting the accuracy of the MES methodology developed during this phase of work will affect the financial models:

- Number of Household Aggregations: The methodology is more accurate when aggregating 10s of houses at a portfolio level. This means financial models may need to focus on aggregated offerings.
- Time Aggregations: The methodology is more accurate at reporting monthly or annual energy savings compared to daily ones. Hourly energy savings are currently too inaccurate to introduce to the market. This means financial models will need to focus on verifying long-term benefits wherever possible.

In order to ensure the methodology does not over- or underestimate savings, financial models will need to focus on aggregated householder offerings and verifying monthly or annual energy savings. This may limit the opportunities to unlock explicit and implicit flexibility incentives from the network, quantify the emissions reductions at peak load times or identify non-routine consumption (underheating).

What sort of business models could leverage metered energy savings?

MES could help to unlock benefits for NHS Trusts, financial institutions, network operators, householders, retrofit providers / facilitators and public bodies, amongst others. In order to align the strategic goals of the different stakeholders and leverage the impact of MES for residential retrofits at scale, an aggregator business model has been identified.



Under this model, the aggregator acts as a Fund Manager for a MES Fund, developing standardised guidance, data connections and project evaluation infrastructure centrally, which can be replicated across multiple retrofit providers to apply for financing through the fund. This will reduce the transactional and capital costs associated with ad hoc retrofit schemes, and ensure schemes are de-risked and quality-assured, unlocking massive investment into UK retrofit.

What are the possible electricity-related policy enablers and blockers for metered energy savings?

Market mechanisms for electricity distribution network operators to fund retrofit

Electricity distribution network operators (DNO) may financially reward (via flexible services payments or other mechanisms) energy efficiency improvements which have been proven to reduce the demand on the electricity distribution network. However, there are challenges with leveraging MES as part of these financing mechanisms:

- Electricity DNOs primarily benefit from energy savings at peak times, rather than from total energy savings which MES methodologies are designed to capture

- In the case of "fabric first" approaches, where a gas heated home has fabric measures applied in a first stage, and a heat pump is only installed later at a second stage, it is difficult for electricity DNOs to realise and reward that value. This is because the benefit is a future benefit – in that instead of installing a larger heat pump at the second stage, a household may install a smaller one, reducing the demand on the electricity network relative to what it might have been without the fabric works. However, the electricity DNO sees no change in electricity usage at the first stage, and at the second stage the DNO still sees an increase in electricity consumption, although less than it otherwise might have been. This raises the question of how electricity network funding mechanisms for retrofit can be designed in this scenario. This links in with the recent call from the Council of European Energy Regulators (CEER), of which the UK is a member, for "anticipatory investments" to prepare the grid for the energy transition, and for work to be done around the optimal timing of investments so they are not too early or too late.

These issues would need to be addressed as part of the design of network funding mechanisms for retrofit which use MES.

Incorporating MES into ECO

The Energy Company Obligation (ECO) scheme currently focuses on quantities of different measures implemented. The government plans to introduce a pay-for-performance mechanism into ECO4, the current iteration of the ECO scheme, ahead of the 2023/24 heating season and recognises that the use of monitoring approaches could have significant benefits to the scheme, including greater efficiency in achieving the scheme's aims. There would be benefits to including an obligation to report on MES as part of the pay-for-performance approach, using a standardised methodology such as methodologies tested through RetroMeter. Benefits would include more focus and accountability on quality of measures and on actual energy savings achieved.

Way forward for metered energy savings in the UK

New collaborations and funding opportunities are currently being explored to put in place mechanisms for access to comparison group data for MES, to refine, finalise and standardise MES methodology, and to pilot MES in a variety of settings, schemes and types of households.