Alpha Phase: Milestone 1 Report

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Glossary of Terms:

ABS:	Area-Based Scheme delivered by a Community Intermediary
ADMD:	After Diversity Maximum Demand – An index used in the design of electricity network infrastructure to meet anticipated demand on the network, where demand is aggregated over many customers and accounts for peak load a network is likely to experience over its lifetime (an overestimation of typical demand).
AO:	Anchor Organisations are large organisations that are unlikely to relocate and have a significant stake in their local area. They have sizeable assets that can be used to support their local community's health and wellbeing and tackle health inequalities, for example, through procurement, training, employment, professional development, and buildings and land use.
ASHP:	Air Source Heat Pump
Balancing Services:	Balancing Services refer to distributed demand-side responses dispatched and monetised to help balance the wider electrical grid, derived from contracted services or consumer behaviours.
Boolean:	A result that can only have one of two possible values: true or false.
CalTrack:	CalTRACK is a set of methods for estimating avoided energy use, related to the implementation of one or more energy efficiency measures, such as an energy efficiency retrofit or a consumer behavior modification. CalTRACK methods yield whole building, site-level savings outputs.
CBA:	Cost Benefit Analysis
CDM:	Construction Design and Management Regulations
CEM:	Common Evaluation Methodology Tool used for Cost Benefit Analysis by ENA. The primary purpose is to allow the user to assess the merits of deferring reinforcement by employing flexibility solutions for one or more years, but can also be used to evaluate a range of interventions.
CMZ:	Constraint Managed Zone - This is a geographic region served by an existing network where network requirements related to network security of supply are met through the use of flexible services, such as Demand Side Response, Energy Storage and stand-by generation.

Comfort Take Back:	Increased energy demand through changing occupant behaviour, namely increased use of their heating systems (or other core building systems such as lighting) following the retrofit. This increased consumption relates to restoration of a desired comfort level rather than through inefficient system operation.
DG:	Distributed Generation
DNOs:	Distribution Network Operators - licensed companies that own and operate the electricity network from the National Gid intake (132kV) to the end users. Please note that whilst DNOs traditionally operate reactive or passive grids, in this case various forms of active management are discussed, usually segregated under the role of the Distribution System Operator (DSO). For simplicity, the term "DNO" will be used throughout this report as a catch-all for both DNO and DSO functions.
ECO:	Energy Company Obligation (Grant to help householders living on low income and spend high proportion of income on heating).
EE:	Energy Efficiency - the process of reducing the amount of energy required to provide products or services.
ENA:	Energy Networks Association
ENWL:	Electricity NorthWest
EPC:	Energy Performance Certificates (in context of houses) / Energy Performance Contracts (in context of contractor)
EV:	Electric Vehicle
EWI:	External Wall Insulation
Explicit Flexibility:	Flexibility services that can be arranged and delivered in real time or on short notice, and where the volume is controllable, usually based on ongoing flexibility contracts
FCA:	Financial Conduct Authority
GDPR:	General Data Protection Regulation
Implicit Flexibility:	Flexibility services arising from customer responses to price signals
HP:	Heat Pump

KPI:	Key Performance Indicator
kWh:	Kilowatt hour (measure of energy use)
Malus:	A financial penalty incurred by a trader, investor, or banker when an investment or deal results in a loss.
MEETS:	Metered Energy Efficiency Transaction Structures (see Section 1)
MES:	Metered Energy Savings (described in Section 1)
MEV:	Mechanical Extract Ventilation
M&V:	Measurement and verification
NOx:	Nitrogen Oxides (group of gases that are formed during combustion of fossil fuels)
O&M:	Operation and Maintenance.
PAS2035:	British Standard for Retrofitting Dwellings (outlines how retrofit projects should be managed and delivered).
PPA:	Power Purchase Agreement (long-term electricity supply agreement between two parties).
Recurve:	An open-source platform in the US that helps utilities leverage their smart meter data to quickly and accurately measure energy usage and the impact of efficiency and demand flexibility on the grid.
ROI:	Return on Investment (profitability metric).
RIIO-ED2:	Ofgem's framework for setting price controls that set the outputs that the electricity Distribution Network Operators (DNOs) need to deliver for their consumers and the associated revenues they are allowed to collect. ED2 is the five-year period from 1 April 2023 to 31 March 2028
SHDF:	Social Housing Decarbonisation Fund, which will be used to deliver a Metered Social Benefits retrofit scheme.
SIF:	Strategic Innovation Fund
SROI:	Social ROI, a methodology to quantify the social (i.e. non-financial) value of a project. A model to perform the quantification is being developed for ENA by Sirio and consists of an excel based model and proxy list.

T&C: Terms and Conditions

ToU: Time of Use Tariff

WHR: Whole House Retrofit – the practice of taking a holistic retrofit approach which includes house-wide building fabric, key inefficiencies in core building services such as lighting and heating and a whole-house financing solution aligned with occupant needs.

Executive Summary

EP notes that this report is an Interim Report; Changes in partner teams have delayed input from the Anchor Organisation (Manchester City Council), which has meant there has been insufficient data at the time of writing to assess the Metered Social Benefits retrofit scenario for the Social Housing Decarbonisation Fund ("SHDF") scheme.

As a result, this interim report will focus on the generic procedure to produce value stacks, testing this approach throughout descriptions of the Area Based Scheme ("ABS") retrofit scenario. If, and when, data around the SHDF scheme becomes available, EP will issue an addendum report.

Currently, this interim report provides the following key information & analysis to the RetroMeter consortium:

1) A review of the Discovery phase value stack and the feasibility and applicability of the various component value and revenue streams moving into the Alpha phase
2) A definition of Alpha-phase retrofit scenarios with input from Energy Systems Catapult (ESC), Carbon Co-op and Electricity North West (ENWL).
3) A summary of data gaps and delivery model challenges to be further explored and addressed within the business models and scale up plan later in the RetroMeter project.
4) A mapping of risks for each actor, with discussions of how risk management approaches will be integrated into revenue stream assessments and partner responsibilities.
5) A draft feasible value stack for Metered Energy Savings (MES)-enabled retrofit schemes.

In addition, conversations are ongoing with the flexibility and forecasting teams at ENWL to improve the estimation of flexibility and improved forecasting revenues. However, EP plans to complete a further iteration when sufficient data is available, integrating these value streams alongside an assessment of the SHDF scenario. Despite hurdles in onboarding partner perspectives and gathering detailed retrofit design data, this report has achieved the following aims:

- **Aim 1:** Section 2 outlines changes to the discovery phase value streams, outlining fresh perspectives on their applicability and ability for monetisation throughout the pilot phase (Alpha and Beta) and beyond. Additional detail is presented on the various partner responsibilities required to apply and assure value streams. Appendix A maps changing value stack concepts from Discovery Phase moving into the pilot phase.
- **Aim 2:** Alpha-phase retrofit scenarios are defined in Section 1, highlighting distinguishing factors between the two schemes, along with pertinent stakeholders and success metrics
- **Aim 3:** Sections 3 and 4 summarise revenue-specific data sufficiency and gaps, whilst Section 5 discusses how partners can assist with filling these data gaps and improving ongoing value stack estimates.
- **Aim 4:** The risks and challenges within the delivery model are assessed within Section 5's risk matrix, with further summaries to be produced, explored and addressed later in the RetroMeter project. Partner responsibilities are defined within Section 1 with related costs outlined in Section 6.

- **Aim 5:** Section 3 and 4 present categorised value stacks for both network and non-network value streams. This leads to a presentation of net present value figures within Section 7 for the ABS scenario as currently defined.

Due to onboarding delays and data insufficiencies, the following elements of the deliverable specification are missing:

1) Cost Benefit Analysis (CBA) and revenue stream assessments for the SHDF retrofit scenario (input from Manchester City Council and Carbon Co-op pending)
2) Detailed challenge assessments (to be conducted for SHDF and ABS in parallel when data is sufficient)
3) Validation of success metrics from Manchester City Council
4) Confirmation of exhaustive risk management matrix (pending SHDF risk perspective – a key element, particularly around reputational and equitability risks).
5) Data required for accurate estimations of flexibility and improved forecasting revenues (conversations pending at time of writing).

As many elements of the CBA approach will be iterative and ongoing, EP plans to complete a further iteration when sufficient data is available. The proposed timeline for gathering the missing datapoints is as follows:

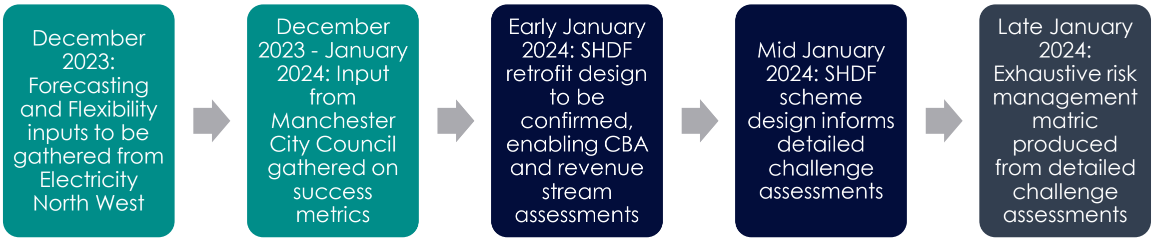


Figure 1: The proposed timeline for gathering missing data points

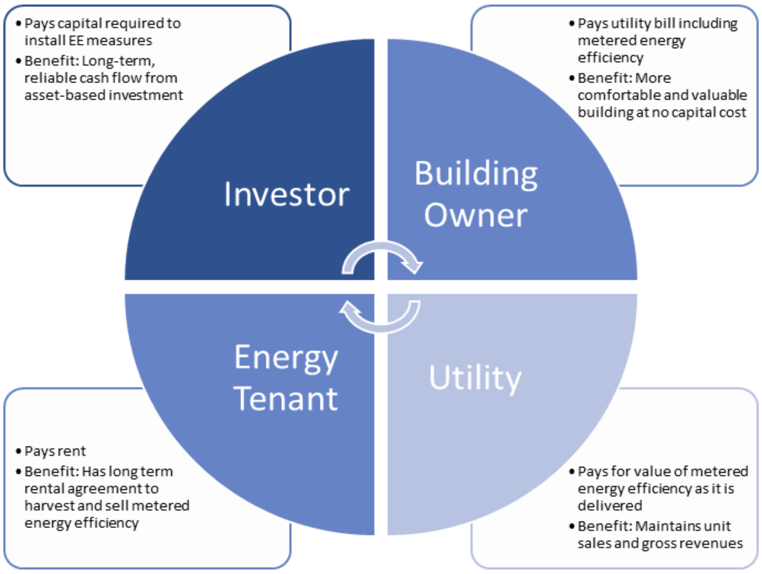
1) Introduction to RetroMeter and value stack approach

The Strategic Innovation Fund (SIF) RetroMeter project, through which this report was funded and produced, aims to advance the state-of-the-art of the UK's retrofit ecosystem by creating an open-source, replicable MES methodology, based on learnings from international experience, specifically CalTrack and Recurve in the USA. Though we aim to create a Metered Energy Efficiency transaction structure which is adaptable to any project or technology set, the methodology's applicability to real-life scenarios will be validated through the delivery of a pilot retrofit scheme in Greater Manchester, during the Alpha and Beta Phase of this project. The learnings from those schemes will then underpin the development and deployment of a transaction structure, or structures, that are based on metered efficiency and 'pay for performance'. These may be similar in structure to the Metered Energy Efficiency Transaction Structures (MEETs) developed in the USA and promoted by the MEETS Coalition.

According to the Coalition, MEETS are financing transactions in which:

1. A project developer, or energy tenant, signs a standard, long-term rental agreement with a building owner.
2. Under the agreement, the energy tenant pays for, installs and maintains energy efficiency upgrades to the building, acting as an investor. This delivers the capital financing required to make substantial efficiency upgrades to the building, based on a long-term Power Purchase Agreement (PPA) with the utility for the metered energy efficiency;
3. The utility bills the building owner, at retail rates, for the amount of energy the building would have used if it had not been upgraded, thus transferring the yield of metered energy efficiency to the utility;
4. The investor/energy tenant receives payments from the utility, under the PPA, for the value of the metered energy efficiency as it is delivered.

This process is summarised below:



- Pays capital required to install EE measures
- Benefit: Long-term, reliable cash flow from asset-based investment

- Pays utility bill including metered energy efficiency
- Benefit: More comfortable and valuable building at no capital cost

- Pays rent
- Benefit: Has long term rental agreement to harvest and sell metered energy efficiency

- Pays for value of metered energy efficiency as it is delivered
- Benefit: Maintains unit sales and gross revenues

Figure 2: The financing process for MEETS-type MES schemes

The MEETs Accelerator Coalition describes MEETs as "a fundamentally different approach to energy efficiency [that] aligns the interests of all stakeholders" and aims to tackles the issue of "energy waste in the built environment". Through MEETS, building owners, investors and utility companies can each benefit from cost-effective capital investment, aggressive maintenance of Energy Efficiency (EE) installation and maximum engagement with tenants to improve EE behaviours. These structures offer potential advantages to both private and public funders of retrofits including: paying for actual performance i.e. measured improvements in energy performance; and incorporating measures of interest to Environmental, Social and Governance (ESG) driven and impact investors.

However, in order to assess the feasibility of enabling retrofits in the UK through a MEETS type structure, the pilot retrofit scheme design will need to be fully defined. The current Alpha Phase of this project examines two different retrofit scheme designs, with differing target markets, funding solutions and value stacks. These retrofit schemes and their key distinguishing factors are outlined below in Table 1.

Table 1 RetroMeter Retrofit Scheme Designs

Retrofit Scheme: Area Based Scheme ("ABS")	Retrofit Scheme: Metered Social Benefits utilising the Social Housing Decarbonisation Fund ("SHDF")
1. Targets a local geography, particularly relevant for addressing network constrained zones. 2. May focus on specific replicable housing technologies with standardised retrofit offer. 3. Utilises community based social marketing to recruit new applicants, no central landlord.	1. Targets Social housing managed by Manchester City Council Housing Services – the programme will cover 6 projects distributed across Manchester's geography. 2. Overall programme size is much larger – up to ~1,600 homes. 3. Works will be tailored from project-to-project, as each project is sufficient scale. Works could include External Wall Insulation,

4. Funding approach will vary home to home, based on owner-occupant preferences. 5. Fabric-first approach with no heat pumps installed during Alpha phase	Air-source Heat Pumps and heating controls, ventilation and LEDs. 4. Works must satisfy SHDF criteria such as attainment of EPC C and achieving space heating demand of 90 kWh/m^2/year. 5. Higher level of involvement from Manchester City Council and Greater Manchester Combined Authority.

Further definition of these two retrofit scenarios can be found in Appendix B. We should note at this stage that there is only sufficient data to assess parts of the ABS approach, with assessment of the SHDF scheme and the remaining ABS elements to be provided as a supplementary deliverable.

These two retrofit scheme designs are necessarily complex and involve a large ecosystem of stakeholders. The following table serves to breaks down the roles and responsibilities of these key stakeholders. It is worth noting this list is not exhaustive, and excludes a breakdown of the supply chain actors, such as manufacturers, suppliers and engineers, as these are largely covered under the Delivery Agent (DA) and Contractor (C) roles. A more comprehensive breakdown of supply chain actors can be found in the Discovery Phase WP3 D5-D8 Report.

Table 2 Stakeholder Roles and Responsibilities

Roles	Responsibilities
Delivery Agent (DA) / Community Intermediary	• Engaging with target householders • Aggregating projects / finance • Procuring design, sub-contractors and installers • Facilitating retrofit works • Financial accounting • Project administration • Scheme Quality Assurance (e.g. quality systems and process, quality ways of engaging with people) • Coordinating Reporting • Measurement and verification of savings
Investor (Inv)	• Defining financial and project-scope requirements • Reviewing and Accepting Projects based requirements. • Making funding available
Institutional Anchor Organisation (AO)	• Providing political remit • Managing reputational risk • Disseminating Learnings
Network Partner (DNO)	• Providing price ranges and payments for network benefits • Verification of network impacts • Uptake of network forecasting outputs • Publishing Data (current and predicted constraint areas)
Household / Consumer (HH)	• Providing repayments (where required in the financing model) • Providing site access and permissions • Providing access to smart meter data, bill data • Supporting savings verification e.g. post-project satisfaction surveys, case studies, open homes events • Informing DA of significant changes to building use

	• Where applicable, upfront financial contributions to capital investment required for the retrofit
Contractor (Con)	• Quantity Surveyor • Delivery of high-quality installations to the agreed specification • O&M activities • CDM Coordinator • Technical / Construction Quality Assurance
Data Warehouse (DW)	• Aggregation and storage of smart meter and internal temperature data collected from target households • Automated categorisation of data into different householder archetypes, energy efficiency measure packages and geographies. • Licensing of categorised data (with and without interventions) for comparison-group methodology. • Standardisation (project performance summaries).
Methodology Working Group (MWG)	• Modifications to MES methodology based on real-life retrofit outputs • Creation of a Standard Setting Organisation (BSI standard or similar)

Both the ABS and SHDF schemes have a different set of key actors taking on these stakeholders' roles during the Beta Phase pilot retrofit scheme. These key actors are identified below:

Table 3 Key Stakeholders for each retrofit scheme design

Roles	ABS Stakeholders	SHDF Stakeholders
Delivery Agent (DA)	Carbon Co-op (as aggregator ESCO)	Manchester City Council (and Carbon Co-op as monitoring partner)
Investor (Inv)	MCC, householders – details to be confirmed with Carbon Co-op	DESNZ (SHDF), MCC Housing Revenue
Institutional Anchor Organisation (AO)	Local Community Association	Manchester City Council Net Zero Team
Network Partner (DNO)	ENWL	ENWL
Household / Consumer (HH)	Retrofit Beneficiaries, mix of fuel vulnerable and able-to-pay households based on tailored funding available.	Leaseholders and tenants in social housing managed by MCC, houses targeted are EPC D
Contractor (Con)	Carbon Co-op will have contracting relationship with household, and will have contracting arrangements with traders, installers and architects.	Turnkey Contractors in CLI framework – details to be confirmed with MCC
Data Warehouse (DW)	Owner Uncertain – Further discussions with ESC needed	Owner Uncertain – Further discussions with ESC needed
Methodology Working Group (MWG)	Energy Systems Catapult	Energy Systems Catapult

Retrofit delivery schemes must be evaluated against pre-defined success criteria agreed upon with the key project stakeholders and partners. The delivery team must be accountable for ensuring the solution is appropriate and acceptable to all those involved and align all stakeholders within the same financial and risk management structure. The consortium of partners have identified five key desired attributes for a successful retrofit delivery model, shown overleaf in Figure 3:

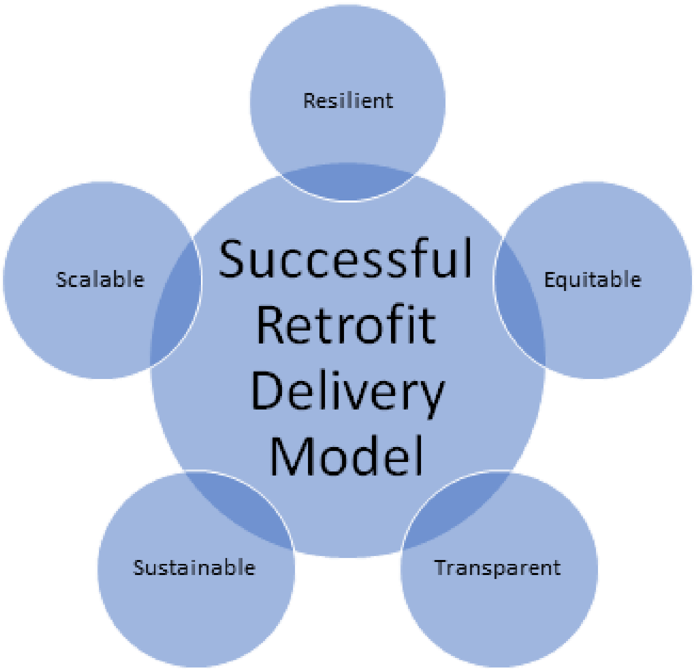


Figure 3: The attributes underpinning a "successful" retrofit delivery model.

These desired attributes are described in more detail in Table 4 and have been mapped against key performance indicators. The delivery team should be required to incorporate these objectives into their retrofit scheme design and monitor the results once the scheme has been deployed.

Table 4 Proposed success attributes for Beta Phase pilot retrofit scheme:

Desired Attribute	Description	Objectives, Aims, Key Performance Indicators (KPIs)
Sustainable	Persistence over time and financially self-sustaining Must be able to engage with a range of consumers / households.	1. Is profitability index (the present value of future cash flows divided by the initial investment) > 1? Or a safe margin of 1.2 or higher? (quantitative/ Boolean) 2. Will the model keep providing benefits for customers and delivery agent(s) at least the next ten years? (Boolean) 3. Have projected/modelled heat demand requirements been reduced by at least 30%? 4. Are energy cost savings > loan repayment interest? (Boolean). 5. Is Social Return on Investment (SROI) (developed for ENA) > 1.1? (quantitative / Boolean)

		6. Common Evaluation Methodology (CEM) Tool: Quantification of number of years that method can defer network reinforcement >= 5 years (Boolean).
Robust / Resilient	Persistence in varied and volatile market conditions, and with changing access to revenue streams **whilst providing a level of consistency to the supply chain**. Acknowledges, and can adjust to, policy and regulatory framework changes around retrofit, and the boom-bust cycle of funding sources. One such example is the DNO funding uncertainty due to 5-year price control blocks.	1. How many randomly selected revenue streams can be lost whilst the model persists? (Quantitative / Boolean [>= 1 viable redundancy within revenues]). Can the model persist when >=1 network benefits are lost? 2. Does the model function throughout a probabilistic approach to sensitivity analysis where individual key parameters (costs and revenues) can be varied by +/- 10%, to return the calculated NPV (+/-5%)? 3. Have all identified risks been mitigated to yield a total score < 7 against the risk matrix (see Appendix E)? 4. Are predicted energy savings accurate based on methodology? (Metered post-retrofit monthly energy savings have Coefficient of Variation of the Root Mean Square Error (CVRMSE)< 15% and Normalised Mean Biased Error < 6% compared to RetroMeter methodology predicted monthly energy savings for > 50 homes).
Equitable	The ability of the method to recognise that each person has different circumstances and allocate the resources and opportunities needed to ensure an equal outcome. The ability of the method to be flexible and adaptable to different customer segments and requirements, in order to avoid energy injustice.	1. Percentage of retrofit clients living in fuel poverty, areas of deprivation or within other key socioeconomic classifications requiring equitable action (proposed threshold of 30%) 3. Presence of comfort and underheating improvements for retrofit clients living under fuel poverty (>30% of those surveyed: qualitative) 4. Creation of evidence base supporting DNO license conditions around fairness and equitability (Boolean)
Transparent & Holistic	The ability of the method to be reviewed & challenged, thereby reducing information asymmetry. The ability of the method to assess its own success or propose and generate improvements within the method and across the UK policy landscape.	1. Presence of measured and verified project impacts (Boolean or proportion of retrofit portfolio). 2. Surveys of retrofit clients and delivery agent(s) to highlight any persistent uncertainty or information asymmetry. (qualitative) 3. Proportion of project outcomes published on ENA or made available for review. Does the communication highlight pilot scheme's achievements and downfalls? (Qualitative). 4. Creation of platform to respond to client issues, information asymmetry and uncertainty.
Scalable / Replicable	The ability of the method to be replicable and scalable to different geographies, residential archetypes and stakeholder arrangements in a timely and low-transaction cost way. The ability of the method to be standardisable, enabling open-source solutions to unlock new	1. Alpha phase should aim to arrive at a minimum or, where relevant, maximum scale figure for each retrofit delivery scenario that will be deployed in the Beta Phase (Boolean). 2. Evaluate value that comes from short term vs long term (uncertainty informed view) 3. Publication of user-friendly code and detailed documentation of the core methodology (Qualitative).

	routes for commercial deployment.	

In order to ensure the retrofit delivery model achieves these desired attributes, the costs and revenue streams associated with the retrofit delivery must be defined, mapped, and evaluated in order to create a feasible value stack, and thus, a business model for a MEETS type solution in the UK. The scope of this report, therefore, focuses on defining the value streams, and evaluating their feasibility as robust revenues. We should note that many elements of the value stack will provide societal value, but will not be directly monetiseable within the proposed retrofit scheme designs. These will be referred to as value streams, whilst revenues or revenue streams refer to the monetiseable component of this value stream. There may be both value and revenue stream components to a single service depending on where value is captured and where monetary externalities persist.

As part of this analysis, Sections 3 and 4 of the report focus on adding precision and accuracy to both network and non-network value estimates, and Section 5 details stakeholder-specific mitigation actions to address data gaps and delivery risk. Section 6 maps out the costs for delivering retrofits and managing risks, which feeds into the Cost-Benefit Analysis approach in Section 7.

2) Definition of feasibility / priority of value stack revenue streams produced in the discovery phase

This section aims to provide an overview of value streams discussed in the Discovery phase, updating the consortium's view on their feasibility and importance moving into the Alpha phase. Based on the information provided to date, feasibility analysis of the value streams discussed during the Discovery phase (shown in Appendix C) was conducted, highlighting the feasibility of deploying the value streams as revenues during the Pilot (Alpha/Beta) phase or within post-Beta retrofit concepts, as shown below in Table 5, with the methodology defined overleaf:

Table 5 Value Stream Feasibility; On the left, green/ yellow boxes represent a higher ability to monetise value stream and orange/red boxes represent a lower ability. On the right, the lighter green boxes represent 'yes' responses, yellow boxes represent 'maybe' responses and red boxes represent 'no' responses.

Value Stream Description	**Ability to Monetise Value Stream (0 = never monetisable, 1 = very difficult to monetise, 5 = directly monetisable)**	**Included for Pilot (Alpha/Beta) Phase?**	**Included for post-Beta concepts?**
Load Reduction (Energy cost savings)	5	Yes	Yes
Identification of Non-Routine Consumption (underheating)	1	No	Maybe
Increase in real estate / rental value	3	No	Yes
EPC Uplift	2	No	Yes
Health Improvements (improved indoor environment for given heat demand)	3	Maybe	Yes
Comfort-takeback	2	Evaluated during Pilot	Maybe
Emissions Reductions (including Air Quality) at the point of fossil fuel consumption	2	No	Maybe

Deferred Network Reinforcement (Load Reductions)	4	Yes	Yes
Peak Capacity Uplift / Load Shaping (deferred network reinforcement)	3	Maybe	Yes
Provision of Implicit Flexibility (relating to heat demand)	2	Maybe – household / building owner decision	Maybe – household / building owner decision
Provision of Explicit Flexibility	4	Maybe	Yes
Air Quality Improvements (near power stations providing containment / capacity reserve) - due to reduction in demand	0 (This revenue stream will be combined with the emissions reduction value above moving forward)	No	Maybe
Reduced Public Infrastructure Costs due to improved forecasting	1	Maybe	Maybe
Avoided demand / connection charges	2	No	Maybe
Reduced private infrastructure costs (EVs / REG)	2 (This revenue stream will be combined with the avoided connection charges value above moving forward)	No	Maybe

N.B. not all value streams are monetiseable as revenue flows, and their proposed inclusion may vary as the SHDF scheme is assessed. Some value streams may be mutually exclusive or inclusive, for example health improvements and comfort takeback value will be mutually exclusive based on the householder ability-to-pay, and rental uplifts are mutually inclusive of load reduction savings, as the latter must be sufficient to subsidise or negate the former.

The table above shows the variation in the feasibility and ability to monetise each revenue stream, drawing out an important point: the costs and benefits of each retrofit scheme will need to be assessed in terms of both the net benefit for participating actors, and for society as a whole (as described further in Section 7). Taking this approach will enable the evaluation of both monetiseable revenue flows and positive externalities (where benefits are realised, but not captured by the boundary of the retrofit scheme). This approach also enables competing value streams to be compared and evaluated. For example, current Demand Flexibility Service (DFS) and implicit flexibility services compare historic consumption models to real time consumption during peak periods. Therefore, in the long-term, reducing historic and ongoing consumption through whole house retrofit will reduce the counterfactual against which householders are paid for their demand "turn-down" The competition between these value streams will be evaluated further throughout Milestone 2.

This approach also aligns with HM Treasury's Five Case model (2018), where the value of an intervention is assessed in terms of its strategic fit; its economic case and impact on social value; the commercial case for supply-side viability; the financial sustainability of the solution; and the ability for delivery partners to successfully manage and deliver the intervention. As retrofit schemes are often large-scale and integrate public funds, alignment with the Five Case model will support the upscaling of the RetroMeter solution moving forwards.

The method for arriving at the feasibility of the value stack is as follows:

1. Do the measures installed enable or affect the quantum of the revenue stream? I.e. without flexible assets such as smart-controlled heat pumps with adequate insulation for thermal inertia to be maintained, flexibility revenues are not possible. Equally, further investigation into the impact of flexible operation on heat pump coefficient of performance may be required to determine if there are any interactive effects.
2. Will the pre- and post-installation data be sufficient to measure and verify the monetiseable impact? I.e. if there is not a sub-hourly meter available to verify a flexible demand side response, then flexibility revenues will not be viable.
3. Is there an actor or contracting route present to value/monetise the revenue stream? I.e. if an NHS trust is not involved in a pilot, or has no interest in running a warm homes prescription programme, there is no route to monetise beneficial health outcomes.
4. Does the actor have sufficient ability or willingness to pay? I.e. a homeowner living in fuel poverty may not have sufficient financial resources to sign up to a "comfort-as-a-service" style contract, however much they desire the higher level of comfort. Equally, a homeowner may determine they are willing to accept finance, but the lender may decide their credit-worthiness, or ability-to-pay, is insufficient to offer a loan.

Where one or more of the questions outlined above has lowered the feasibility of a value stack in the alpha / beta phase or for future concepts, this will be drawn out as a feasibility challenge. These feasibility challenges will then be assessed by EP and the RetroMeter consortium to identify potential strategies to address these challenges, and thresholds which could enable the revenue stream to be realised and captured. These elements are shown below in Figure 4 and may be updated during the course of the project:

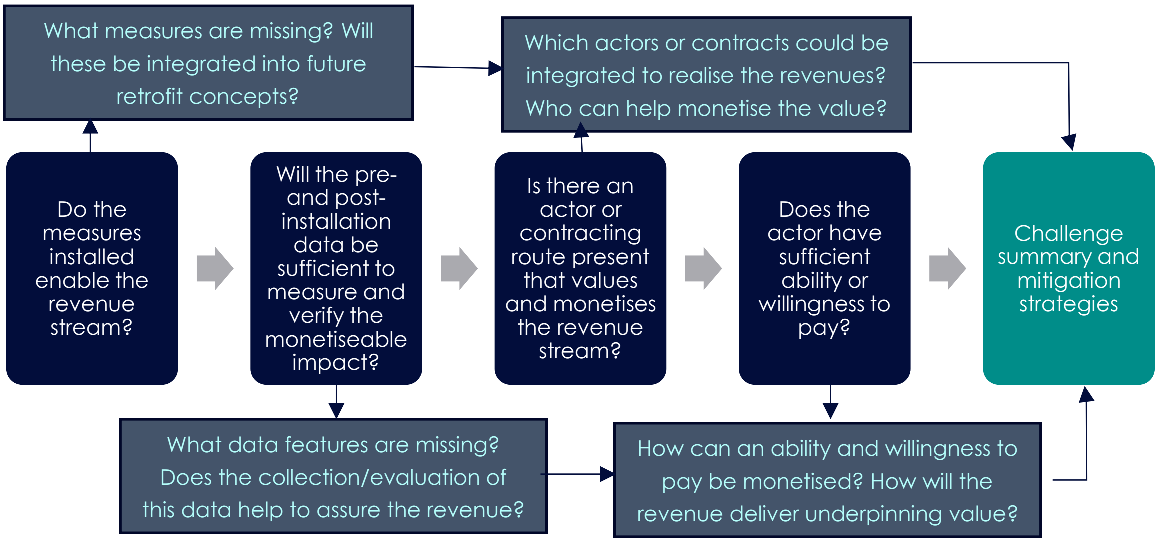


Figure 4: A chart showing how feasibility challenges will be drawn out, summarised and mitigated.

In order to understand the distribution of feasibility risks and their mitigation strategies, we will use the categorisation approach outlined by the Stakeholder Roles in Table 6. On top of the stakeholder categories, we can overlay a range of responsibilities, namely who is responsible for: balancing; measuring and verifying; accounting; paying benefits and receiving benefits for the relevant revenue stream. This will show the various sub-services required to deliver a value / revenue stream, which will connect each value stream to concrete costs, enabling calculation of a net benefit figure from the perspective of the RetroMeter consortium and each delivery actor individually.

Table 6 Partner-Specific Responsibilities

	Sub-services required to deliver a value stream: Relevant partners responsible for:				
Revenue Stream	1. Balancing energy flows	2. Measuring and verifying impacts	3. Accounting for services	4. Paying monetary benefits	5. Receiving monetary benefits
Load reduction (energy cost savings)	No balancing services required for this revenue stream	Delivery Agent	Delivery Agent	Household	Household and Contractor (performance bonus or malus)
Identification of Non-Routine Consumption (underheating)	No balancing services required for this revenue stream	Network Operator / Data Warehouse	Delivery Agent	Network Operator	Delivery Agent
Increase in real estate / rental value	No balancing services required for this revenue stream	Delivery Agent	Delivery Agent and Anchor Organisation	Anchor Organisation, potentially building owner / household	Contractor and Delivery Agent
Energy Performance Certificate (EPC) Uplift	No balancing services required for this revenue stream	Delivery Agent	Delivery Agent and Anchor Organisation	Anchor Organisation	Contractor and Delivery Agent
Health Improvements	No balancing services required for this revenue stream	Delivery Agent & Healthcare Institution	Healthcare Institution	Healthcare Institution	Delivery Agent
Comfort-takeback	No balancing services required for this revenue stream	Delivery Agent and Household	Delivery Agent	Household	Delivery Agent and Contractor
Emissions Reductions (including Air Quality) at point of fossil fuel consumption	No balancing services required for this revenue stream	Delivery Agent & Healthcare Institution / Government	Delivery Agent & Healthcare Institution / Government	Healthcare Institution / Government	Delivery Agent
Deferred Network Reinforcement (Load Reductions)	No balancing services required for this revenue stream	Network Operator / Data Warehouse	Network Operator	Network Operator	Delivery Agent

Peak Capacity Uplift / Load Shaping (deferred network reinforcement)	Consumer / Household Response	Network Operator / Data Warehouse	Network Operator	Network Operator	Delivery Agent
Provision of Implicit Flexibility (relating to heat demand)	Consumer / Household Response	Energy Supplier (via smart / time of use meter)	Energy Supplier (via smart / time of use meter)	Energy Supplier (via smart / time of use meter)	Household
Provision of Explicit Flexibility	Network Operator (pre-contracted flexibility)	Network Operator	Network Operator	Network Operator	Household / Anchor Organisation (depending on who controls assets and who Network Operator holds contract with)
Reduced Public Infrastructure Costs due to improved forecasting	No balancing services required for this revenue stream	Network Operator / Data Warehouse	Network Operator	Network Operator	Delivery Agent
Avoided connection charges and private infrastructure costs	No balancing services required for this revenue stream Balancing for private infrastructure via the Anchor Organisation - Social housing provider or community land trust (increasing consumption for storage & thermal inertia when costs are low)	Delivery Agent / Anchor Institution	Delivery Agent	Anchor Institution	Delivery Agent

The categorisation in Table 6 above considers both network and non-network value streams and costs. Although this SIF project focuses on innovative network solutions, both types of revenue will be important for satisfying the goal of launching a transparent, open-source MEETs-type solution. This is because a flexible set of revenue streams will need to be available or integrated to enable the RetroMeter solution to be adopted by both public-interest and commercial delivery agents across the UK.

Despite their shared importance, these value streams will be treated differently in the upcoming sections to add precision to value estimates, and highlight the conditions and thresholds that need to be satisfied for a value stream to be converted into viable, monetiseable revenues. Table 7, overleaf, outlines how precision and accuracy will be improved for each category of value stream, with methods ranked based on their specificity:

Table 7 Methodology for improving value estimates

Network Revenue Streams	Non-network revenue streams
Methods to improve accuracy & precision: 1. Use of Common Evaluation Methodology to find geography-specific ceiling prices 2. Validation with real historic flexibility contracts 3. Discussions with forecasting team to determine the valuation of improved information and data access 4. Literature Review for equivalent flexibility values paid in other projects or regions	Methods to improve accuracy & precision: 1. Discussions with stakeholders in the Alpha and Beta phase 2. Literature Review for equivalent services or value streams paid in other projects or regions 3. Population-scale modelling where value streams persist as externalities 4. Proportional estimations and assumptions

This section has now outlined how we expect value streams to be monetised and tested in real world retrofit pilots, as well as who will be responsible for various aspects of this monetisation and piloting. Methods have been defined to arrive at accurate monetiseable values for the revenue streams in question, which will be applied in Sections 3 and 4 below. Following on from this, Section 5 will outline how the stakeholder responsibilities outlined in Table 2 will be implemented, and uncertainty and risk managed. Finally, Section 7 will discuss the thresholds and trigger points at which value and revenue streams not included in the pilot phase should be integrated within the cost benefit analysis, outlining how we will determine the key conditions and decision points enabling this integration.

3) Adding precision and accuracy to network value estimates: methodologies and data sufficiency

Improving the accuracy of network value estimates will be a key component of this SIF project, enabling stakeholders to understand the contribution that network-based revenues can make to the financing and upscaling of regional retrofit schemes. As conversations with the current Delivery Agent (Carbon Co-op) are ongoing, some revenue streams currently have insufficient data to improve valuation accuracy at the time of writing. Table 8 summarises the methodologies and data sufficiency for each network value estimate:

Table 8 Value Stream Modelling Approach and Data Sufficiency

Value Stream	Estimation Methodology	Data Sources	Data Sufficiency
Identification of Non-Routine Consumption (underheating)	Method 3 - Discussions with ENWL forecasting team to determine the valuation of improved information and data access	Discussions with ENWL forecasting team	Insufficient data at time of writing – further conversations scheduled
Provision of Implicit Flexibility (relating to heat demand)	Method 4- Literature Review for equivalent flexibility values paid in other projects or regions	Publicly available Time of Use tariffs Octopus Saver Sessions	Sufficient Data
Peak Capacity Uplift / Load Shaping (deferred network reinforcement)	Method 1 - Use of Common Evaluation Methodology to find geography-specific ceiling prices (modification of the hours of availability required or baseline peak capacity)	Common Evaluation Methodology fixed assumptions Modelled reduction and sensitivity in heat pump size from retrofit specifications. * Percentage deviation from peak capacity from large-scale academic modelling (Love et al., 2017)	Sufficient Data
Deferred Network Reinforcement (Load Reductions)	Method 1 - Use of Common Evaluation Methodology to find geography-specific ceiling prices. Method 2 - Validation with real historic flexibility contracts	Common Evaluation Methodology fixed assumptions Modelled reduction and sensitivity in heat pump size from retrofit specifications *	Sufficient Data
Provision of Explicit Flexibility	Method 1 - Use of Common Evaluation Methodology to find geography-specific ceiling prices Method 2 - Validation with real historic flexibility contracts	Common Evaluation Methodology fixed assumptions Modelled reduction and sensitivity in heat pump size from retrofit specifications * Maps of Constrained Network Zones	Insufficient data at time of writing – awaiting input from ENWL flexibility team.
Reduced Public Infrastructure Costs due to improved forecasting	Method 3 - Discussions with ENWL forecasting team to determine the valuation of improved information and data access Method 4- Literature Review for equivalent flexibility values paid in other projects or regions	Discussions with ENWL Capacity Strategy Engineers	Insufficient data at time of writing – further conversations scheduled

**N.B. the ADMD assumptions are key to these value streams, as discussed in Appendix F.*

Updated Value Estimate - Provision of Implicit Flexibility (relating to heat demand):

Two updated estimates are provided for implicit flexibility, which although not valorised through the Network Operator, provides network benefits. The first approach utilises the "Saving Sessions" run by energy suppliers such as Octopus, where the householder is given notification of an opportunity to "turn-down" electricity demand in return for reward points, which can then be spent to displace energy costs. The value of the reward for avoided consumption varies across suppliers and various iterations within Octopus' Saving Sessions– references from the 2022 heating period state an abatement price of £2.25 / kWh (Chatfield, 2023 and Energy Review, 2023), whilst more recent sources claim an abatement price as high as £3.37 / kWh. These rates are funded through National Grid's Demand Flexibility Service (www.nationalgrideso.com, n.d), which pays suppliers a rate between £3 and £6 for each kWh they motivate their customers to save (Energy saving scheme, 2023).

The second approach uses a heat pump-specific tariff, also from Octopus, which offers cheap electricity prior to morning and evening peaks, enabling the occupant to set their heat pump to "charge" the home with heat during these hours, displacing more expensive heating consumption during peak rate hours, as shown in Figure 5 below:

Cosy Octopus

Electricity

Day rate:	27.21 p/kWh
Peak rate (16:00 - 19:00):	43.54 p/kWh
Cosy rate (04:00 - 07:00 & 13:00 - 16:00):	16.33 p/kWh
Standing charge:	49.77 p/day

Description

Cosy Octopus is a heat pump tariff with six hours of super cheap electricity every day to warm your home.

Figure 5: The breakdown of the time of use charges within the Cosy Octopus flexible tariff.

Both approaches are enabled by whole-house-retrofit, as without sufficient insulation, the home cannot store sufficient thermal energy to meet occupants' desired comfort levels during the "turn-down" period. The derivative revenues from this value stream will not be measured directly by the RetroMeter modelling approach, but instead may be captured during the modelling of the impact on future heat demand as the works specifications are codified. Therefore, this value stream is unlocked by the retrofit, but must be monetised by the householder, which in turn provides financial returns for any loans that the retrofit must service. We should note Estimate 1 applies only for pre-retrofit electrical heat demand.

Table 9: Updated value estimates for Implicit Flexibility (relating to heat demand)

Updated Value Estimate 1	Estimate 1 method	Updated Value Estimate 2	Estimate 2 method
£115.7 / year	1-2 hour sessions (avg 1.5 hours) * post ADMD post WHR HP demand * price per unit (taken to be £2.25 / kWh) (Chatfield, 2023 and Energy Review, 2023) * 12 sessions / year	£233.2 / year	3 hours of displaced peak rate (cosy rate - 13:00 - 16:00) + 3 hours of displaced day rate for cosy rate (04:00 - 07:00)

Updated Value Estimate – Load Shaping / Peak Capacity Uplift:

The value of load shaping and peak capacity uplift has been estimated through a single valuation method, described below:

*Duration of flattened peak (3 hours 16-19:00 both winter days and weekend) * Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit (1.4285) * number of days Nov – Feb (120) * flexibility ceiling price (£1.5 / kW / h)*

= ~ £771.43 of network value per Whole House Retrofit (WHR) per year.

This method draws on the assumption that the curve of the heat pump's evening demand peak can be flattened, or with the correct programming and building fabric, avoided during the 16:00 – 19:00 winter peak. Figures 6 and 7 below help to validate this assumption, showing lower kurtosis during this evening peak period:

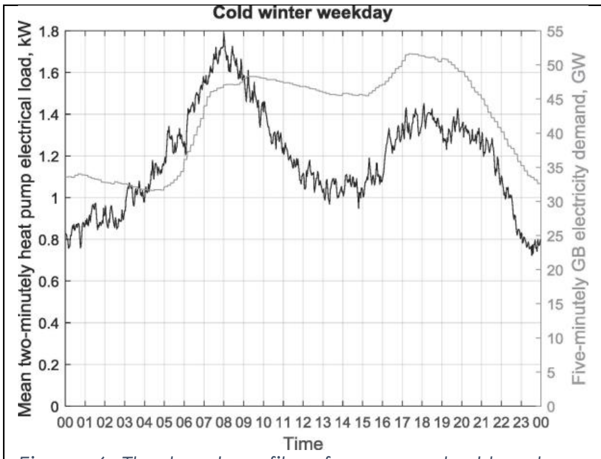


Figure 6: The load profile of aggregated heat pumps (black) during a cold winter weekday, against the general UK electricity load profile (lighter grey), showing the flattening of the evening peak. (Love et al., 2017)

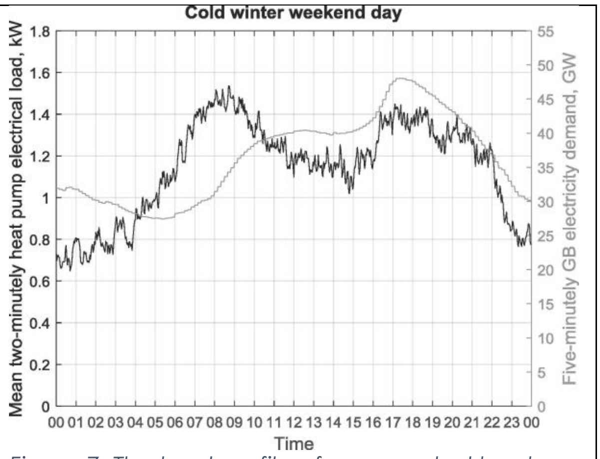


Figure 7: The load profile of aggregated heat pumps (black)during a cold winter weekend day, against the general UK electricity load profile (lighter grey), showing the flattening of the evening peak. (Love et al., 2017)

Whilst there is sufficient data to make an initial estimation of this value stream, we should note that improved modelling using the ENA's Common Evaluation Methodology may be required to update the valuation of this revenue stream. In addition, we should note that this value stream may be mutually exclusive with the deferred network reinforcement value stream below, as both fund the reduction in peak demand and therefore the need for reinforcement. However, reduction of peak demand also provides values derived from the avoided use of fossil-fuel generators which may be "switched on" to meet peak demand. An implicit assumption here is that the national peak remains at 16-19:00, however increased heat pump and EV penetration is likely to change that. Reports from ESC's Living Lab suggest we're already seeing signs of a new peak in the early morning as a result of EV charging. This point will be investigated further throughout our work in Milestone 2 to determine the risks and sensitivities underpinning these peak-ADMD-based value streams.

Updated Value Estimate – Deferred Network Reinforcement:

The value of deferred network reinforcement has been estimated through a single valuation method, described below:

*Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit (1.4285) * lowest value per kW ADMD (£36.46) * 5 years contract duration (assumed – varies with ED period)*

= £260.42 of monetiseable network revenues per Whole House Retrofit (lifetime)

This method assumes that a 6.6/11kV Transformer (Ground Mounted) providing <500 kVA of power supply at a cost of £18,193 can be deferred for 5 years based on the reduction in required heat pump size provided by whole house retrofit (WHR). Table 10 shows the input cost assumptions underpinning this revenue, provided by ENWL:

Table 10: Input cost assumptions underpinning the value calculation of deferred network reinforcement

Asset Type	**Measure**	**Cost**	**Minimum Cost per kW / kVA**	**Cost per Home (assumed 200 homes per substation)**	**Notes**
LV Main overhead line	per metre	£17.72	-	-	
LV Main underground	per metre	£138.80	-	-	
LV Service	each	~£1,904	-	-	
6.6/11kV Transformer (Pole Mounted)	each	~£4,468	£59.57	£22.34	Assumed 75 (50-100) kVA rating from this source
.6/11kV Transformer (Ground Mounted) < 500kVA	each	~£18,193	£36.46	£90.97	225 homes assumed (~2.2 kW ADMD per home)
6.6/11kV Transformer (Ground Mounted) >= 500 & < 750kVA	each	~£22,905	£36.65	£114.53	
6.6/11kV Transformer (Ground Mounted) >= 750kVA	each	~£30,281	£40.32	£151.41	

Ongoing Validation

This section has provided initial estimations and updates to network value streams wherever possible. However, we know that the underlying assumptions to these estimations may change or be challenged throughout the Alpha phase and beyond. As such, Section 5 discusses how each partner can contribute to the ongoing measurement and verification (M&V) of value streams, and assist with the improvement of accuracy and quantification throughout the value stack.

The M&V process will utilise the initial value estimations above as benchmarks and key performance indicators to ascertain the accuracy and viability of these revenue streams in real-world conditions. These will form the baselines against which data collection procedures, reflexive assessment and post-project reporting can be framed and standardised.

Whilst this section has focused on the total absolute value of these revenue streams, we must continue to note that not all of this value will be monetiseable, with some value falling as externalities. The understanding of what differences persist between the monetised and non-monetised (I.e. focused on social value) cost benefit analysis will be further developed in Section 7.

Integration of GB-focused Energy Efficiency Research

There are two key sets of tools and outputs from GB-focused energy efficiency research which could support the modelling of network value estimations arising from whole house retrofit. The first of these is the project titled "Demand Forecasting Encapsulating Domestic Efficiency Retrofits", or "DEFENDER" toolkit. The second of these is the "Proportional Investment of Networks in Energy Efficiency Retrofit" or "PIONEER" project.

The first of these two approaches, defined by DEFENDER, uses a range of project-level data (Smart Meter readings, EPC descriptions, nearest weather station data) to generate heat demand profiles for use in network planning and at the household level. These profiles are designed to enable the integration of pre- and post-retrofit heat demand modelling into existing forecasting processes and identifying where and how a DNO such as ENWL could invest in energy efficiency. The solution, namely the Glow Simulator tool, cannot be applied at this stage due to the limited data availability, particularly for the SHDF scheme. It is envisaged that this tool could provide inputs to both schemes in tandem, once they are sufficiently defined. However, due to data sharing limitations, it is likely that Carbon Coop may need to operate the tool internally and provide resultant outputs to EP to inform our ongoing work.

The second of these two approaches, PIONEER, was focused on network cost savings from avoided network reinforcement and reduced flexibility procurement and direct cost savings on customer bills and carbon savings from avoided energy consumption. This project output a longlisting criteria and a list of locations that could be utilized for a future trial in delivering, quantifying and verifying network benefits. These longlisting criteria included the following attributes for a pilot region.

The ideal pilot region should be / have:

1. Representative of the types of property that a BAU scheme would target
2. Sufficiently wide variety of household types to address uncertainties
3. Not unique
4. Feasible to trial

In addition, DNO benefits were calculated, in the form of a ceiling price – which is the maximum amount a DNO could contribute to an energy efficiency measure in order for the benefits to be realised. The figures discussed by PIONEER align with our calculated figure (~£52/property/year contracted from unit costs alone, or ~£58/property/year contracted), providing a range to target from £44/property/year contracted (lower outlier) to the target threshold of £82/property/year contracted. We should also note that this range had a longer upper tail, with a maximum of £258/property/year contracted, demonstrating the variability in the geography of flexibility valuation and local constraints.

Alongside the validation of our calculated figure, PIONEER presented a range of factors that will affect the ceiling price, as described below:
Higher local network reinforcement costs.

Regional Factors:

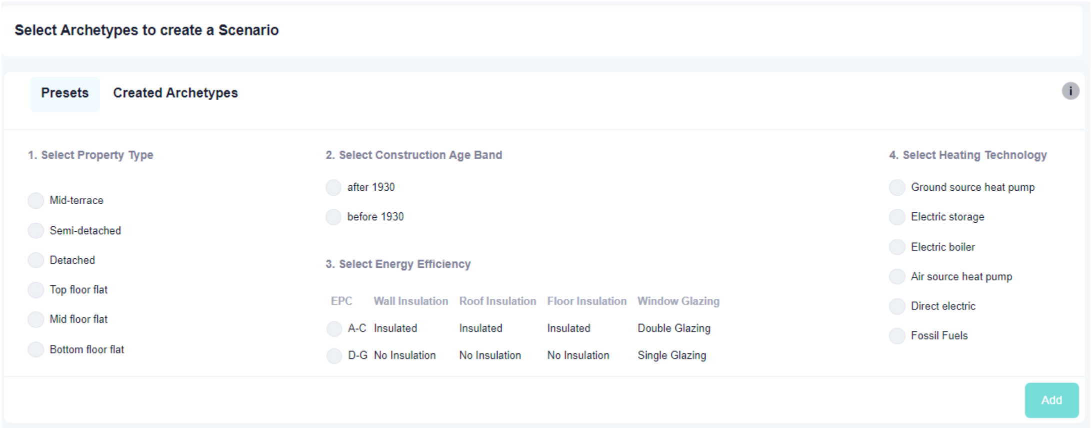
1. Availability of flexibility.
2. Rate of demand growth.
3. Shape of demand on the network.

Property-by-property Factors:

4. Existing heating technologies.
5. Property occupancy.
6. Property and Retrofit type.

Potential actions resulting from the integration of GB-focused energy efficiency research may include:

1) Utilise the DEFENDER Analysis and Insights Report (Frontier Economics, 2023) to verify the network value estimates produced throughout this section, aligning future CBA and discounting approaches defined by DEFENDER as relevant and useful for CBA approaches in the Beta phase and beyond.
2) Integrate DEFENDER's cost-benefit analysis (Carbon Trust, 2023a) of common archetypes, thermal efficiency measures and peak load reductions, noting the difference in methodologies such as use of ADMD figures.
3) Discuss the testing of the DEFENDER toolkit utilising archetypal definition of the ABS and SHDF schemes as they are confirmed. EP is still determining whether it will be feasible to collect and store the necessary project-level data, or whether Carbon Coop is able to complete modelling internally to avoid the sharing of disaggregated or sensitive project-level data, as shown in the figure below:



Select Archetypes to create a Scenario

Presets **Created Archetypes**

1. Select Property Type
○ Mid-terrace
○ Semi-detached
○ Detached
○ Top floor flat
○ Mid floor flat
○ Bottom floor flat

2. Select Construction Age Band
○ after 1930
○ before 1930

3. Select Energy Efficiency

EPC	Wall Insulation	Roof Insulation	Floor Insulation	Window Glazing
○ A-C	Insulated	Insulated	Insulated	Double Glazing
○ D-G	No Insulation	No Insulation	No Insulation	Single Glazing

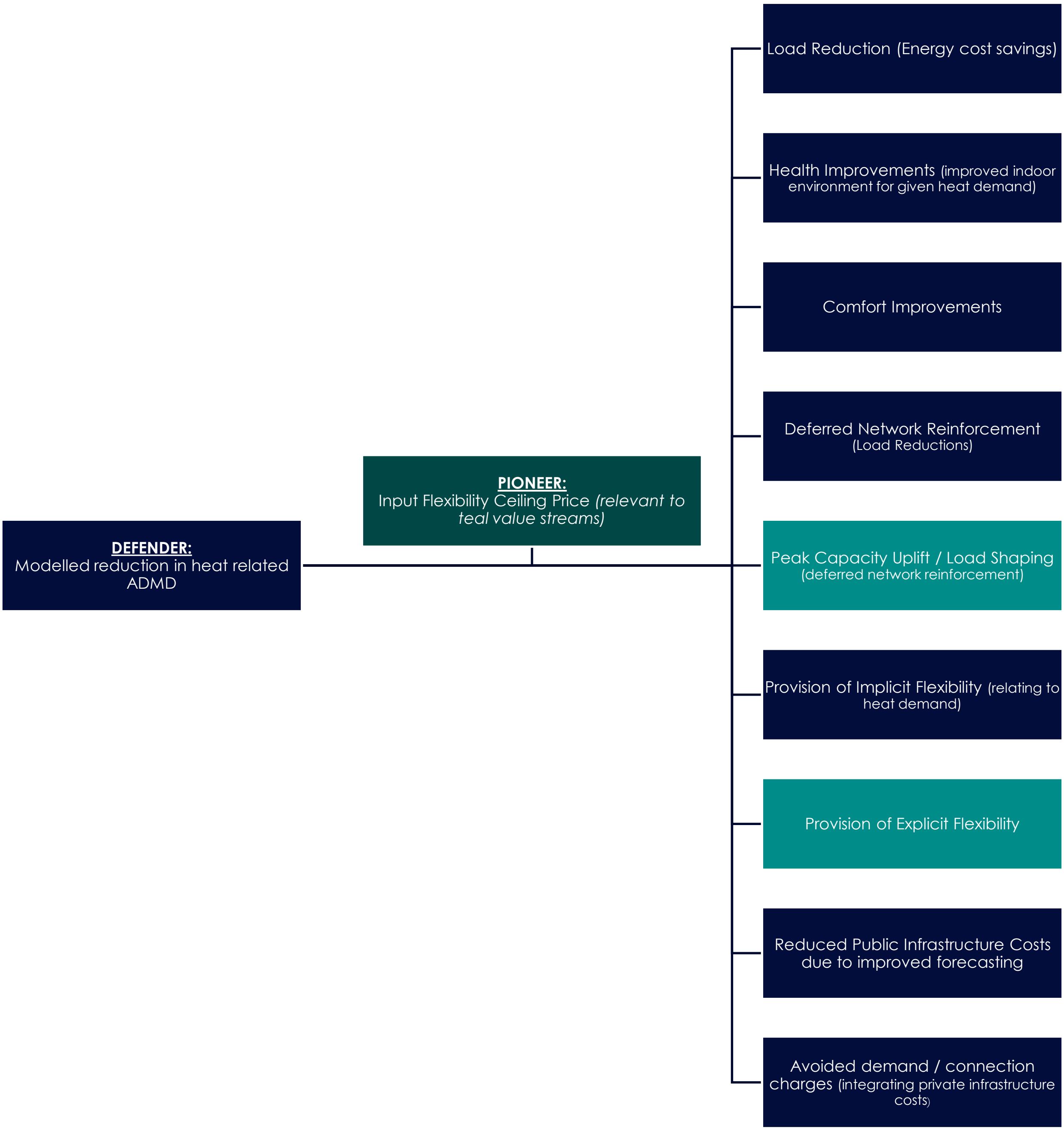
4. Select Heating Technology
○ Ground source heat pump
○ Electric storage
○ Electric boiler
○ Air source heat pump
○ Direct electric
○ Fossil Fuels

4) Utilisation of the housing archetype methodology (Carbon Trust, 2023b) and DFES integration of energy efficiency transitions into future business model approaches,

defining the start point and scale-up plan for retrofit scenarios and metered energy saving transactions.

5) Integrate PIONEER outputs, for use in validating and modelling ceiling prices; and through longlisting criteria for future pilots and the proposed business models for RetroMeter.

The figure below shows how improved modelling of the reduction in heat related ADMD (from DEFENDER), and improved modelling of flexibility ceiling prices (from PIONEER) could be integrated in future iterations of value stack estimations:



4) Adding precision and accuracy to non-network value estimates: methodologies & data sufficiency

Although not the focus of the SIF, improving the accuracy of non-network value estimates will be a key component of this project. This is because these non-network value streams can enable and motivate diverse stakeholders to adapt and take-up the RetroMeter solutions, upscaling deep retrofit activities through both public and private sector delivery partners.

As conversations with the current Delivery Agent (Carbon Co-op) are ongoing, and revenue streams are innovative with new evidence pending, some estimations may be improved based on further data made available across the consortium. Table 11 below outlines the current modelling approaches and data sources utilised for estimating varies non-network revenue streams.

Table 11 Value Stream Modelling Approach and Data Sufficiency

Value Stream	Estimation Methodology	Data Sources	Data Sufficiency
Load Reduction (Energy cost savings)	Primary calculations of heat demand pre and post-whole house retrofit Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions (Network loss reductions are integrated using Method 1 - Use of Common Evaluation Methodology to find geography-specific ceiling prices)	Modelled reduced heat demand / heat pump sizing due to WHR. Publicly available electricity tariff data. Assumptions regarding heat pump duty cycle.	Sufficient Data.
Increase in real estate / rental value	Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions	US EPA - Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments (2023)	Sufficient Data.
EPC Uplift	Method 1 - Discussions with stakeholders in the Alpha and Beta phase Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions	Knight Frank Article about how improving EPC rating increases home value (Frank, O., 2022)	Sufficient Data.
Comfort takeback	Method 1 - Discussions with stakeholders in the Alpha and Beta phase Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions Method 3- Population-scale modelling where value streams persist as externalities	Data will be sourced through Carbon Coop, using qualitative surveys of the household and their willingness to pay for comfort-takeback.	Insufficient Data – qualitative data from Alpha phase evaluation required
Health Improvements	Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions Method 3- Population-scale modelling where value streams persist as externalities	Energy Systems Catapult Warm Home Prescription (ESC, n.d.)	Sufficient Data.

Emissions Reductions (including Air Quality) at point of fossil fuel consumption	Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions Method 3 - Population-scale modelling where value streams persist as externalities	NOx value = ENA Social Value Framework - Proxy List - 22.09.2023 CO2 value = Alpha Phase - Project Management Book Template - CBA [CBA Fixed Data Cell F26]	Sufficient Data.
Avoided connection charges and private infrastructure costs	Method 1 - Discussions with stakeholders in the Alpha and Beta phase Method 2 - Literature Review for equivalent services or value streams paid in other projects or regions Private Infrastructure costs will utilise Method 4 - Proportional estimations and assumptions	GTC UK Article on user payments for electricity distribution network connections (GTC-UK, n.d.) Checkatrade electricity supply connection costs (Checkatrade, 2022)	Sufficient Data.

Updated Value Estimate – Load Reduction (Energy cost savings):

The value of load reduction value streams has been estimated through two valuation methods, described below:

The first method only considers the savings that a whole house retrofit (WHR) approach provides, comparing against a baseline where a heat pump is installed without any additional building fabric improvements. This approach uses the average modelled change heat demand across 7 homes, an exemplar building size (of 72m^2), a heat pump Coefficient of Performance of 2.8 and the assumed energy price, capped at 27.5 p/kWh, over a 25 year project lifespan. The coefficient of performance is realistic given updated research from the UK's Energy Systems Catapult's article on heat pumps (n.d.) found a coefficient of performance ranging from 2.44 (cold days of the year) to the average figure of 2.80.

The second method integrates the cost of baseline gas consumption, estimating fuel costs using modelled data. One should note the importance of the depth of a whole house retrofit and its impact on this modelled heat demand reduction, which will vary as retrofit specifications are confirmed, particularly for the proposed SHDF scheme. The approach to convert this into a lifetime value per household uses the average change in annual bill costs based on modelled data, multiplied by a 25 year project lifespan.

Table 12: Updated value estimates for load reductions (energy cost savings)

Updated Value Estimate 1	Estimate 1 method	Updated Value Estimate 2	Estimate 2 method
£11,970 (approx.)	change per m^2 in heat demand due to WHR (67.7 kWh/m^2/year)/ Coefficient of Performance (2.8) * m^2 * 25 year lifetime *electricity price cap (27.5p)	£13,889.46	Average modelled bill savings taken from CC ABS costs and savings spreadsheet * 25 year lifespan

Updated Value Estimate – Increase in real estate / rental value:

Without specific data on tenancy type or home values, it has not been possible to modify the estimation method for increased real estate values or ongoing rental rates. Therefore, the calculation method is the same, but utilising the most up-to-date figures provided by Bleyl et al. (2018) (see Figure 8 below). Although findings from recent years are more scarce, a meta-analysis by the UK's Royal Institution of Chartered Surveyors (Sayce, S., 2022) found rental premiums varied from 1.5% (Finnish example - adjusted for neighbourhood characteristics) to 12.87% (Welsh example, notable for significant regional and tenure variation). These figures equate to a whole lifetime value of £1,200 - £10,240, showing the conservative nature of the estimate provided below.

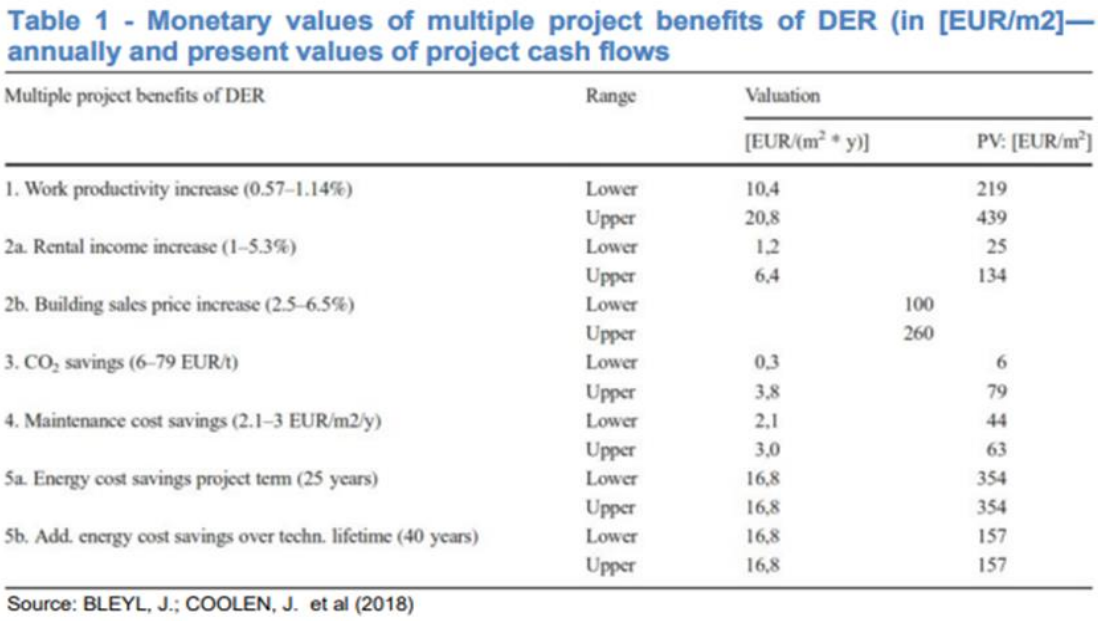


Table 1 - Monetary values of multiple project benefits of DER (in [EUR/m2]— annually and present values of project cash flows

Multiple project benefits of DER	Range	Valuation	
		[EUR/(m² * y)]	PV: [EUR/m²]
1. Work productivity increase (0.57–1.14%)	Lower	10,4	219
	Upper	20,8	439
2a. Rental income increase (1–5.3%)	Lower	1,2	25
	Upper	6,4	134
2b. Building sales price increase (2.5–6.5%)	Lower		100
	Upper		260
3. CO₂ savings (6–79 EUR/t)	Lower	0,3	6
	Upper	3,8	79
4. Maintenance cost savings (2.1–3 EUR/m2/y)	Lower	2,1	44
	Upper	3,0	63
5a. Energy cost savings project term (25 years)	Lower	16,8	354
	Upper	16,8	354
5b. Add. energy cost savings over techn. lifetime (40 years)	Lower	16,8	157
	Upper	16,8	157

Source: BLEYL, J.; COOLEN, J. et al (2018)

Figure 8: Excerpt from an analysis of deep energy retrofits using cashflow assessments and project-level multiple benefits.

The calculation method is as follows:

*Nominal increase in rental income (converted to GBP /m2/yr) * Area of Exemplar Home (m²) * 25 year lifespan*

= £1,927 of additional value per Whole House Retrofit (lifetime)

Updated Value Estimate – EPC Uplift:

The value of EPC uplift has been estimated using up-to-date information (Frank, O., 2022) from the housing sector connecting "green" premiums with EPC Uplift. This estimation methodology assumes 50% of target homes receive an uplift from EPC Rating D to EPC Rating C, and that the other 50% will receive an uplift from EPC Rating E to EPC Rating C, averaging the uplift between these two figures. Looking at a range of sources, uplift figures vary significantly from 3% (Bhimji, S., 2023) to 7% (Rightmove, 2023) when moving from EPC E to EPC C. This wide range is also found in research into value uplifts from retrofit across the European continent (RICS, 2019). However, as we have assumed all homes start at an EPC rating of E at the lowest, our estimate is conservative.

As the green premium is proportional to a home's starting value, data and assumptions from an imagined exemplary case were reutilised from the Discovery Phase, assuming an initial unit valuation of £80,000. We should note that the value of EPC Uplift will vary home-to-home depending on the baseline EPC rating, with homes rating B or above receiving lower values from EPC uplifts, whilst homes rated F or below will increase the value of the EPC uplift further, above the quantified estimation below. Taking these assumptions, the calculation method for EPC uplift is as follows:

*Proportional increase in house value due to Average EPC Uplift (assuming 50:50 split of D > C and E > C) * assumed value of exemplary home in Oldham (£)*

= £4,720 of additional value per Whole House Retrofit (lifetime)

Health Improvements (improved indoor environment for given heat demand):

Many households who receive energy improvement measures are found to have increased their energy demand through increased use of their heating systems (or other core building systems such as lighting) following the retrofit. This is often described under the term "comfort take-back". Although "comfort take-back" may lower overall greenhouse gas, energy and cost savings, one must take care not to take a normative approach (I.e. deciding to what degree "comfort-taking" should occur). This is because some "comfort take-back" is part of the rebound effect (the reduction of efficiency gains due to lower price signals), but in many cases "comfort-taking" relates to the restoration of equitable energy consumption. One must recognise that some "comfort take-back" does always not raise the energy consumption of a household above their peers, but can restore healthy indoor environments and levels of comfort to households living in fuel poverty. Under-heated homes can affect the heart, lungs and brain, increasing the risk of viral infections and a range of cardiovascular disease (BBC News, 2022).

As such, although comfort takebacks can lower the monetisable returns and unit economics of a retrofit scheme, where households are lifted out of fuel poverty the reduction in occupant healthcare costs along with increases in productivity and wellbeing often deliver net positive social value to the UK economy as a whole. Work from Sheffield Hallam University assessing the Energy System Catapult's Warm Home Prescription programme, one of the largest in the UK (with 823 patients receiving a warm home prescription), helped to quantify this social benefit. Their work found that every £1 of expenditure on warm home prescriptions delivered £5.1 of wellbeing social value (Smith, R., 2023).

Given the average estimated cost per patient household was £1,000, this equates to **a social value improvement of £5,100 / year for every recipient of a retrofit who matches the demographies and housing conditions considered by this report**. Although not every home supported by the RetroMeter solution will match these conditions, and the £5,100 of value is not fully monetisable, this figure is taken as the contribution of health improvements where relevant within the RetroMeter value stack. Although further estimation is possible, as 13.4% (Department for Energy Security and Net Zero, 2023) - 34% (Ogwuru, C. *et al.*, 2022) of English households meet the government's definition of being fuel-poor, any improvement in accuracy would require data on the socioeconomic status of the RetroMeter retrofit recipients, as well as a host of assumptions regarding well-being and healthcare outcomes. Accessing this data is out of scope for this project and collection of it would require overcoming ethical and data privacy considerations, and there are further questions of ethics when assessing personal health outcomes and societal wellbeing. As such, we will use the £5,100 figure described above when modelling the net social benefit of the RetroMeter solution, which when applied proportionally to each home based on the 13.4 – 34% of UK homes experiencing fuel poverty equates to a value of ~£685 - £1735 per home.

Emissions Reductions (including Air Quality) at point of fossil fuel consumption:

The value of emissions reduction has two components – air quality improvements and greenhouse gas emission abatements. Both of these components are considered within the estimation of this value stream, but one should note that there may be different approaches to monetisation depending on where the responsibility for displaced/abated emissions lies, and who bears the costs of air-quality-related illness. Whilst a disaggregated approach is possible, the calculation method for the value of combined emissions abatements and air quality improvements is as follows:

*= [(NOx emitted by pre-WHR gas consumption - NOx emitted by post-WHR electricity consumption) * Value of 1kg of NOx abated (SROI source)] + [(CO2 emitted by pre-WHR gas consumption - CO2 emitted by post-WHR electricity consumption) * Value of 1kg of CO2 abated (2021 ETS source)]*

= £887 of additional value per Whole House Retrofit (lifetime)

We should note the use of 2021 ETS figures aligns with Electricity North West's carbon valuation approach, but conversations are ongoing regarding updating fixed references for the Alpha phase of this project.

Avoided connection charges and private infrastructure costs:

The value of avoided connection charges (through reduced electrical demand due to WHR) is totally dependent on the local geography and grid capacity at the home in question. The latest industry figures put the price of an electricity connection at £1,720 / kVA capacity increase (Checkatrade, 2022). However, we can assume that each low voltage feeder supplies 100 homes (Leeds City Council, 2023), and that this feeder will require a connection capacity uplift within the project's 25 year lifespan. We can also assume that the size of this uplift would be reduced due to the application of WHR approaches and reduced heat pump demand. This assumption will become more accurate or conservative as heat pumps and electric vehicles reach higher levels of market penetration.

Taking this assumption, the calculation method for the value of avoided connection charges is as follows:

*= (1/100 homes served by demand connection increases (Leeds City Council, 2023)) * Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit * value per kVA demand increase*

= £ 24.57 of additional value per Whole House Retrofit (lifetime)

The avoidance of private infrastructure costs also relates to the final revenue stream displayed in Table 5 "Reducing Private Infrastructure costs – Electric Vehicles and Renewable Generation". This value stream has 3 distinct components:

1) the reduction in local grid constraints unlock opportunities for installing distributed generation (DG) or electric vehicle (EV) infrastructure without inducing additional private power capacity costs;

2) the presence of contracting relationships with flexibility aggregators and demand-responsive energy tariffs improves the financials of the DG and EV technologies; and

3) local storage associated with these technologies could be used to optimise heat pump power draw from the grid.

This secondary revenue stream has not been evaluated separately as the primary value driver (reduction of local grid constraints) is implicit within the avoided connection charges revenue stream, and would lead to double-counting. In addition, none of the retrofit concepts focus on DG or EV technologies. However, this value stack can be used qualitatively in ABS approaches to help motivate households to conduct a WHR where these technologies are already present.

Ongoing Validation

This section has provided initial estimations and updates to non-network value streams wherever possible. As with our assessment of network revenues, we know that the underlying assumptions to these estimations may change or be challenged throughout the Alpha phase and beyond. As such, Section 5 discusses how each partner can contribute to the ongoing M&V of value streams, and assist with the improvement of accuracy and quantification throughout the value stack.

This will follow the same process as described in Section 3: the M&V process will utilise the initial value estimations above as benchmarks and key performance indicators to ascertain the accuracy and viability of these revenue streams in real-world conditions. These will form the baselines against which data collection procedures, reflexive assessment and post-project reporting can be framed and standardised.

Whilst this section has focused on assigning values to these revenue streams, we must continue to note that not all of this value will be monetiseable, with some value falling as externalities. The understanding of what differences persist between the monetised and non-monetised (I.e. focused on social value) cost benefit analysis will be further developed in Section 7.

5) Stakeholder roles in improving estimates and mitigating risks

Currently, the Beta Phase pilot is being developed from learnings from the ongoing, area-based scheme being delivered by Carbon Co-op in Levenshulme, South Manchester. It should be noted that the retrofit plans, identified for householders involved in this scheme, have not yet been delivered. In addition to this, minimal engagement with Manchester City Council has been undertaken to determine the scope for using the SHDF to deliver retrofits for RetroMeter's Beta Phase. As such, various aspects of both retrofit delivery models are pending verification. A detailed breakdown of the current data gaps that need to be addressed, is presented in Table 22 in Appendix B.

The data gaps highlight the current lack of granularity in the Beta Phase Pilot Retrofit Scheme Design, which impact the accuracy and precision of the value stack revenue streams and costs associated with deploying the schemes. As more data is made available on the current pilot scheme, the consortium of partners will continue take an iterative approach to updating delivery risks, costs and revenue streams to improve current estimates. Table 13 summarises this approach.

Given the broad scope of domestic retrofit, the variety of tenures and archetypes, the variety of financing and delivery models available, this section is broad in scope. Likewise, many of the stakeholders operate not just at a local authority level, but also on a regional or national scale.

Table 13 Partner Specific Actions to address Data Gaps

Value Stream Affected	Carbon Co-op	Energy Systems Catapult	Manchester City Council
Load Reduction, Increase in rental value, Comfort Improvements, Deferred Network Reinforcement.	Define the target market of buildings that undergo retrofit in Beta ABS. Suggest properties in CMZ and served by overhead infrastructure.	N/A	Define the first tranche of homes targeted under the SHDF.
All	Clarify whether Beta ABS will have a similar scope of conservation measures. Defining and segmenting fabric-first approach and interventions, along with expected impact. Clarify	Detail the modelling outputs and confidence, especially around comfort take-back. Provide Peer reviewed estimates around comfort take back included	Clarify the final list of measures that will be implemented based on the British Standard: PAS2035.

	whether heat pumps will be included.	in ECO and WHD impact assessments	
Energy cost savings, Load Shaping, Provision of Implicit and Explicit Flexibility.	Explore and secure the funding approach for Beta ABS (grant, loan, householder contributions, flexibility payments, other).	Describe the key roles and commercial proposition / ownership associated with the data warehouse.	Define how much SHDF can cover for the retrofits of target properties in Beta scheme. Explore funding approaches, if needed.
Deferred Network Reinforcement, Load Shaping, Air Quality Improvements, Reduce Public Infrastructure costs.	Finalise the run rate for Beta ABS (total homes targeted).	Clarify whether minimum / maximum number of properties per year should be targeted.	Determine and finalise the scale for Beta scheme.
Load Reduction, Identification of Non-Routine Consumption, Comfort Improvements, Deferred Network Reinforcement, Load Shaping, Provision of Implicit and Explicit Flexibility.	Define monitoring kit to be deployed in homes, modelling tools to be used and specific targets to be achieved.	Confirm the metering technologies required for the methodology.	Define baseline data, explore occupancy information available, confirm monitoring according to PAS2035.
All	Confirm cost to deploy energy efficient measures per property.	Define the costs associated with data procurement, cleaning and analysis per property.	Confirm the costs defined to retrofit properties. Ensure data is granular and accurate per property.

In addition to improving the accuracy and precision of estimations, each stakeholder will also be required to manage various delivery risks during the pilot Beta Phase retrofit scheme through specific mitigation actions. These risks, and the mitigation actions associated with each one, are highlighted in the table below.

Table 14 Risk Register and Mitigation Actions for Retrofit Delivery. Details of the risk scoring method can be found in Appendix E. Scores have been given to risks based on conversations with relevant project partners, and the accuracy of these scores will be improved as the current ABS is delivered.

Type	Risk	Consequence	P	C	TS	Value Streams Affected:	Stakeholder Specific Mitigation Actions:
Data	GDPR non-compliance in procuring, analysing and storing personal data from households	Liable to lawsuits and decreases public trust and willingness to engage.	1	3	3	Deferred Network Reinforcement, Air Quality improvements, Reduced public infrastructure costs, Avoided	DA : Inform participants about data collection, storage and processing at point of data collection. DW : Restrict personal data usage and encrypt where

						demand / connection charges	possible. Store data on GDPR compliant software.
Modelling	Insufficient or poor-quality smart meter data from consumers (post retrofit)	Reduces accuracy of methodology used to calculate energy savings, resulting in performance gap and limiting value of retrofit.	4	4	16	Load Reduction (energy cost savings), Identification of Non-Routine Consumption, Deferred Network Reinforcement, Load Shaping, Reduced Public Infrastructure Costs	Con: Target Households with accredited smart meters installed / install accredited smart meters in target households. HH: Report any issues with smart meters. MWG: Ensure methodology aggregates data such that non-routine events do not alter accuracy of predictions.
Financial	Consumers takeback 'comfort' such that energy savings from retrofit are not realised	Limits the financial incentives / value streams to DNOs from overall reduction in energy use	3	4	12	Load Reduction (energy cost savings), Deferred Network Reinforcement, Air Quality Improvements, Reduce public infrastructure costs	DA / AO: Target a diverse range of householder archetypes (fuel poor, able to pay etc) to aggregate energy usage, and therefore, minimise the effects of comfort takeback.
Technical	Compatibility issues and retrofit design complexities related to integration of new EE technologies with existing infrastructure.	Unsuccessful / poor implementation of retrofit generating lower energy savings	2	3	6	Load Reduction (energy cost savings), Identification of Non-Routine Consumption, Increase in real estate value, EPC uplift, Health Improvements, Comfort-takeback	DA: Procure specialised expertise / sub-contractors for newer technologies. Conduct quality surveys of targeted households. Ensure robust contract administration (to approve cost overruns and parties liable). Con: Ensure contractor qualifications are sufficient.
Financial	Cost overruns: complex assessments, unforeseen structural issues, changes in scope and supply chain disruption lead to unexpected expenses.	Lack of householder trust / low engagement in scheme, not enough scale to see benefits	3	3	9	Deferred Network Reinforcement, Load Shaping, Air Quality improvements, Reduced public infrastructure costs, Avoided demand / connection charges	DA: Ensure thorough feasibility studies are conducted on target properties prior to installation. Obtain price from contractor for works according to exact design and material specifications. Ask households to sign a simple contract that commits them to design and specifications. Con: Closely monitor project's progress against initial scope to ensure agility to course correct to avoid overspend.
Financial	Performance Gap: Retrofits fail to meet guaranteed performance levels (expected energy savings achieved) due to poor retrofit design, occupant behaviour, inadequate maintenance or	Lower energy savings, lower householder satisfaction following retrofit, lower trust. Financial disputes between stakeholders.	3	5	15	Load Reduction, Identification of Non-routine Consumption, Health Improvements, Comfort-takeback, Emissions Reductions, Deferred Network Reinforcement, Load Shaping, Provision of	DA / AO: Incorporate sufficient stakeholder engagement. Incorporate conflict management / grievance resolution clauses. Discuss what is achievable in practice with contractor at design stage. Ensure robust Design Specification. Inv: Ensure involvement of a legal expert. Ensure financing is compliant under FCA. Ensure installers are accredited and

	inaccuracy in methodology					Flexibility (implicit and explicit), Air Quality improvements, Reduced public infrastructure costs, avoided demand / connection charges, Reduced private infrastructure costs	expected work quality / O&M codified within works contracts. Con: Establish / implement underperformance mechanisms. Ensure smart meter data has high confidence to verify initial assumptions. Conduct Quality Assurance of works. HH: Report significant changes to building or energy use. MWG: Ensure methodology quantifies comfort takeback, thus quantifying occupant behaviour changes. DW: Capture and store data to inform future retrofit schemes. Ensure regular monitoring of changes to domestic EE standards.
Financial	Various types of market risk: interest rate, energy prices/ asset commodities prices, limited or boom-bust funding mechanisms (SHDF / ED periods), marginal network payments.	Limited capital available for retrofit delivery -> retrofits cannot be delivered at scale.	4	5	20	Deferred Network Reinforcement, Load Shaping, Air Quality improvements, Reduced public infrastructure costs, Avoided demand / connection charges	DA: Be responsive and flexible to changing costs. Develop appropriate contingencies. Regularly review market and macro-economic forecasts and integrate into value stack as needed. Inv / AO: Ensure retrofits target various energy asset commodities, households and draw on various financing options, incorporating de-risking playbooks. HH: Engage in credit-worthiness assessments. Con: Ensure contracts and payment schedule are fixed for an appropriate time period, spreading price risk. DNO : Assist in forecasting of price ranges and quantum within network payment, even where marginal.
Regulatory	Policy framework changes related to energy efficiency (withdrawal of existing incentives / uncertainty around future policies) can impact the financial viability of retrofit schemes.	Limited financial incentives for retrofit capital stack prevents delivery of retrofits.	4	5	20	Deferred Network Reinforcement, Load Shaping, Air Quality improvements, Reduced public infrastructure costs, Avoided demand / connection charges	DA /: Monitor and analyse changes in policy and regulation, assessing their potential impact on retrofit delivery. DA / Inv / Con: Ensure retrofit are delivered in timely manner, ensuring benefits of 5 year efficiency payment and current grants (SHDF / boiler upgrade scheme / ECO Flex) are taken advantage of. AO / : Draw upon cross-sector expertise in Advisory Board during Alpha and Beta phases. Conduct complexity analysis on market conditions.
Strategic / Business	Breakdown of trade relationships underpinning key technologies	Difficulty in delivering retrofits, reduction in public trust and	3	4	12	Deferred Network Reinforcement, Load Shaping, Air Quality improvements,	DA / Con: Develop relationships with diverse suppliers, both UK and Overseas (if applicable). Ensure installation

		scale of programme				Reduced public infrastructure costs, Avoided demand / connection charges	specifications/quotes are only binding for a limited time & encourage procurement/contracting within this window where possible. AO: Engage with authorities to advocate for policies that support stable trade relationships.
Reputational / Governance	Risks of exclusion across diverse households	Impacts trust in delivery agent & replicability of outputs	2	2	4	Load Reduction, Identification of Non-Routine Consumption, EPC uplift, Health Improvements, Comfort-takeback, Load Shaping, Provision of Flexibility, Reduced private infrastructure costs	DA /AO: Integrate EDI policies around fairness and equitability of target households. Distribute qualitative surveys to householders verifying presence of comfort improvements. DNO : Utilise Social ROI calculations at KPI. Set thresholds for targeting mixed demographics. Evaluate target areas on evidence of fuel poverty.
Reputational	Retrofit Associated Carbon Emissions (embodied carbon of technologies installed, transport linked emissions, construction operations).	Negative impacts on climate & lack of confidence from householders.	4	3	12	Health Improvements, Emission Reductions, Air Quality Improvements	DA / Con: Adhere to national and regional sustainability policies. Where possible, use low-emission vehicles and construction equipment. AO: Ensure Whole Life Assessments are undertaken to highlight areas with highest emissions. DW : Capture and store data to inform future retrofit schemes.
Social	Construction noise, pollution, disruption, Health & Safety concerns of nearby residents	Neighbours refusing to cooperate, DA possibly liable to legal implications	5	2	10	Health Improvements	DA / Con /AO: Ensure contractors comply with Considerate Constructors Scheme. Develop comprehensive H&S policies. If necessary, relocate occupants until works are complete. Draw up schedule of impact prior with aim of securing consent without need for party wall agreements.
Social	Air Quality Reduction due to poor retrofits leading to inadequate ventilation	Leaves delivery actors liable to health and safety lawsuits	2	5	10	Health Improvements	DA / Con: Ensure comprehensive and accurate site surveys. Conduct regular, on-site quality checks of the works. Ensure retrofits incorporate adequate ventilation measures.
Economic	Displacement of 'fossil fuelled' jobs (such as at fossil fuel powered sub-stations)	Negative impacts on fossil-fuel industry job stability and economy	4	1	4	Emissions Reductions, Air Quality Improvements, Reduced Public Infrastructure Costs	DA /AO: Incorporate sufficient public consultation and generate and map the impact of new 'green' jobs.

Each delivery risk, defined in the table above, will have a cost associated with the mitigation action. Whilst the values of these costs are currently unknown, the costs have been mapped and explored for each stakeholder in Section 6. As more data on the current pilot retrofit scheme becomes available, these costs can be quantified, leading to a re-assessment of the risks for each stakeholder. This iterative approach to reviewing risks is to ensure the revenue streams incorporated in the CBA are still feasible and accurate at the time of delivery, and to ensure the desired attributes summarised in table 4 are achieved.

6) Costs, cost dependencies and methods to co-produce precise and accurate costings using real-world pilot design

This section breaks down the set-up, ongoing and reactive costs associated with the project's Beta Phase for each stakeholder. Table 15 below highlights the costs associated with the delivery of the Beta Phase pilot retrofit delivery scheme, as well as the cost provider, whether the cost is quantifiable and whether it is included in the following 4 scenarios:

1. Area-Based Scheme (ABS) that excludes Flexibility revenues.
2. Area-Based Scheme (ABS) that integrates Flexibility revenues.
3. Metered Social Benefits (SHDF) that excludes Flexibility revenues.
4. Metered Social Benefits (SHDF) that integrates Flexibility revenues.

Table 15 Retrofit Delivery Cost Register

Cost Description	Set up / Ongoing / Reactive	Cost Provider	Able to quantify ?	Included in Scenario 1 (ABS w/o flex)	Included in Scenario 2 (ABS w/ flex)	Included in Scenario 3 (SHDF w/o flex)	Included in Scenario 4 (SHDF w/ flex)
Surveys (electrical, cavity wall)	Set-up	Delivery Agent / Investor / HH	Yes	Yes - known	Yes - uncertain	No – currently unknown	No – currently unknown
Design Fees	Set-up	Delivery Agent / Investor / HH	Yes	Yes - known	Yes - uncertain	No – currently unknown	No – currently unknown
Building Planning and Regs	Set-up	Delivery Agent / Investor / HH	Yes	Yes - known	Yes - uncertain	No – currently unknown	No – currently unknown
Installer Procurement	Set-up	Delivery Agent / Investor	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Contractor Framework Set up	Set-up	Delivery Agent / Investor / HH	Yes	Yes - known	Yes - known	No – currently unknown	No – currently unknown
Public Consultations (between Carbon Co-op and MCC on T&C of loan)	Set-up	Carbon Co-op and MCC	Yes	Yes- known	Yes- known	No – currently unknown	No – currently unknown
Training Costs (for tenants operating heating controls)	Set-up	Delivery Agent / Investor	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown

Construction Lawyer	Set-up	Delivery Agent / Anchor Organisation	Yes	Yes- known	Yes- known	No – currently unknown	No – currently unknown
Construction Costs	Ongoing	Delivery Agent / Investor / HH	Yes	Yes - uncertain	Yes - uncertain	No – currently unknown	No – currently unknown
Administrative Costs	Ongoing	Delivery Agent / Investor	Yes	Yes- known	Yes- known	No – currently unknown	No – currently unknown
Quality Assurance	Ongoing	Delivery Agent	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Measurement and Verification of Savings	Ongoing	Delivery Agent / Anchor Organisation / Data Warehouse	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Equipment Maintenance	Ongoing	Delivery Agent / Contractor	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Data Access and Licensing	Ongoing	Delivery Agent / Anchor Organisation / Data Warehouse	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Embodied Carbon Construction Costs / LCA	Reactive	Delivery Agent	Yes but complex	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Health and Safety policy Development	Reactive	Delivery Agent / Contractor	Yes but complex	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Market / Regulatory Framework Forecasting	Reactive	Delivery Agent / Anchor Organisation / Network Operator	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Contractor Services Validation (as per Energy Performance Contract)	Reactive	Delivery Agent / Investor	Yes but complex	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown

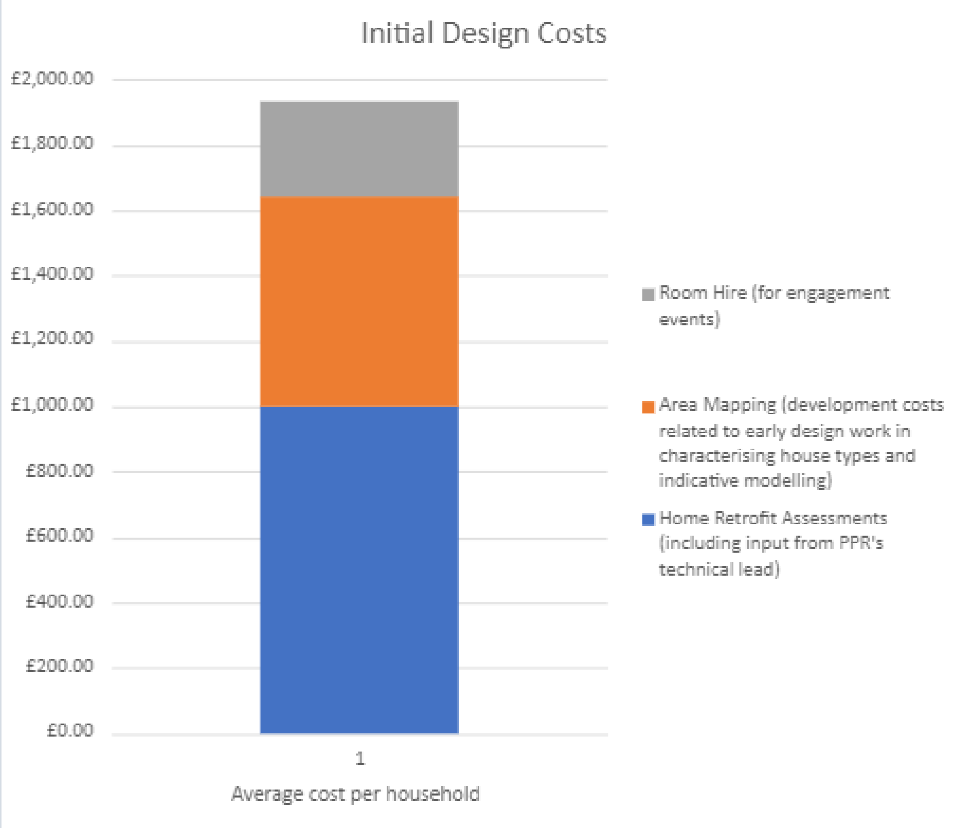
Underperformance Mechanisms	Reactive	Delivery Agent / Contractor / Investor	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
Credit-Worthiness Assessments	Ongoing	Delivery Agent / Householder	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown
EDI policy integration	Ongoing	Delivery Agent / Anchor Organisation / Network Operator	Yes	No – currently unknown	No – currently unknown	No – currently unknown	No – currently unknown

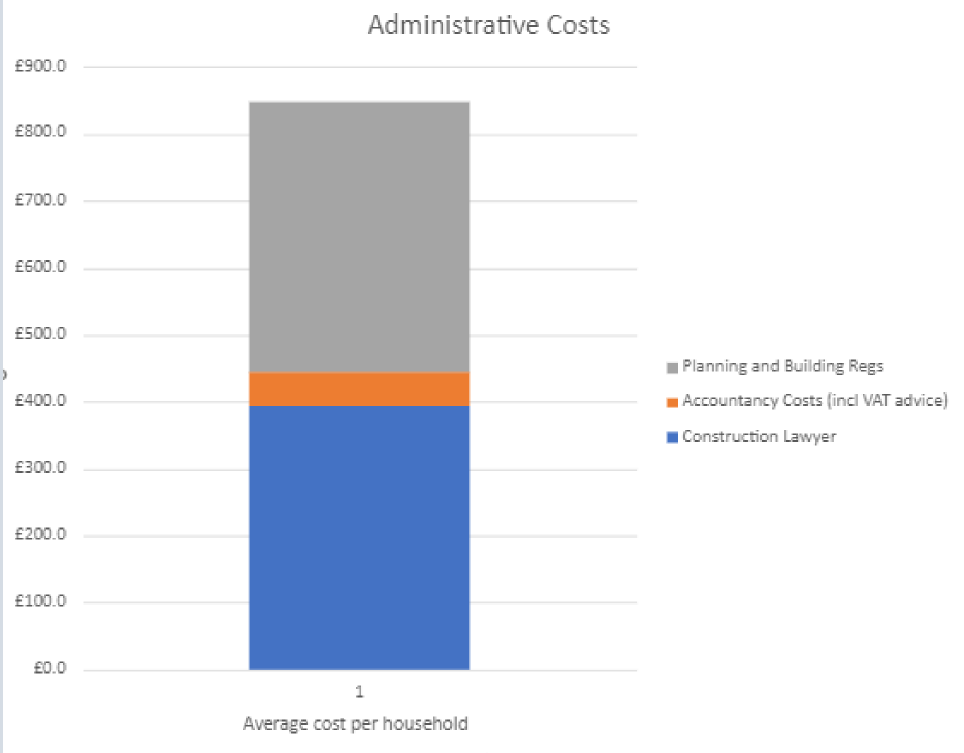
Where available, the quantitative costs associated with the retrofit delivery have been mapped and presented for the current ABS, however, various data gaps are still present and we expect the design and development costs to decrease in the subsequent phase due to the delivery of a larger scale scheme. Further engagement with project partners is needed in order to estimate the unknown costs and to improve current estimations and data insufficiencies.

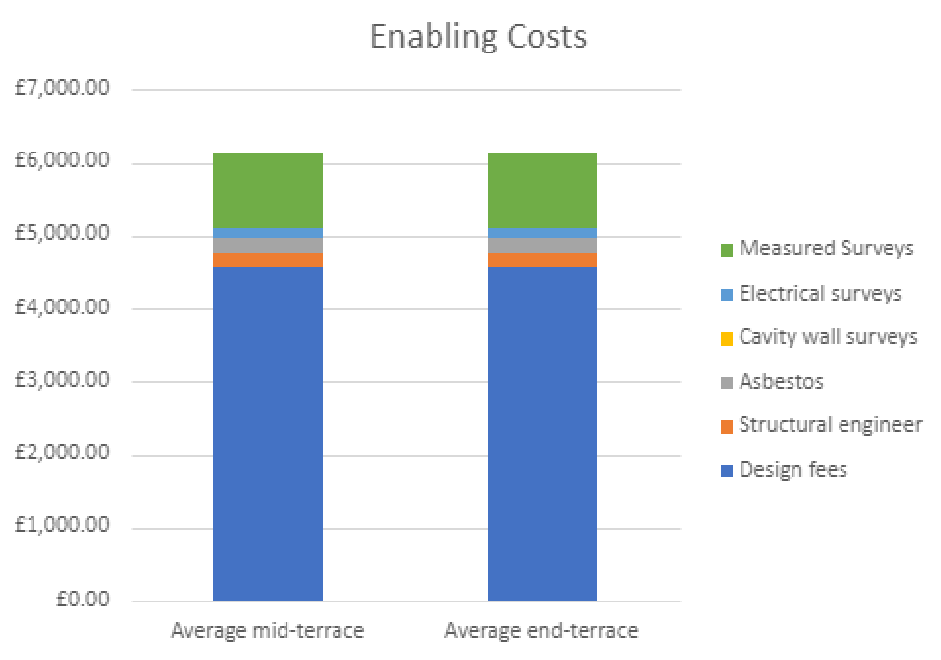
Table 16 Cost Breakdown per property for ABS

Area-Based Scheme (w/o flexibility)
Set-up Costs

Known

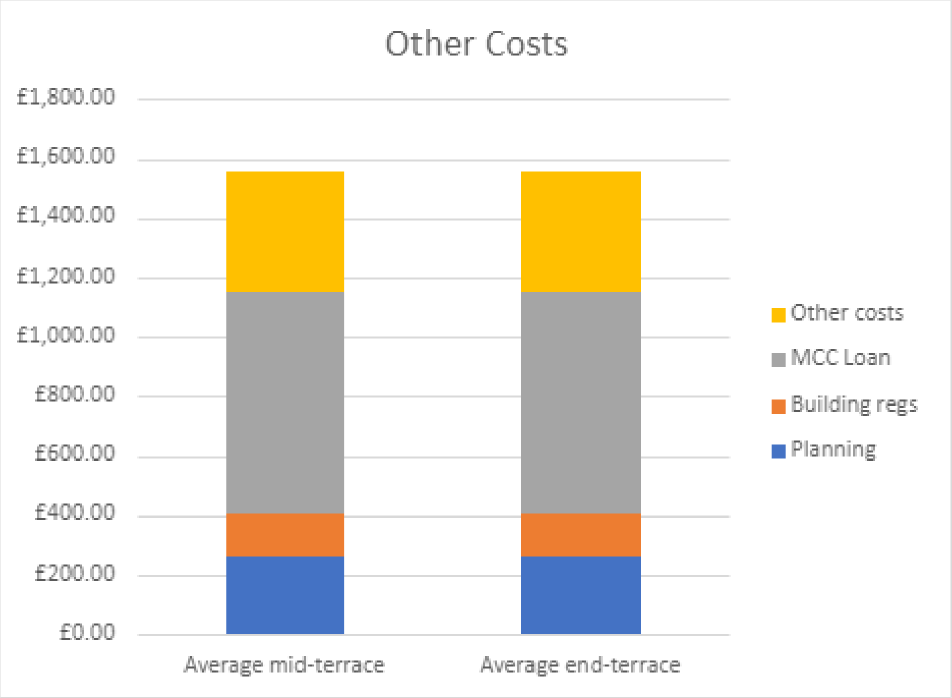

Initial Design Costs
£2,000.00
£1,800.00
£1,600.00
£1,400.00
£1,200.00
£1,000.00
£800.00
£600.00
£400.00
£200.00
£0.00
1
Average cost per household
■ Room Hire (for engagement events)
■ Area Mapping (development costs related to early design work in characterising house types and indicative modelling)
■ Home Retrofit Assessments (including input from PPR's technical lead)


Administrative Costs
£900.0
£800.0
£700.0
£600.0
£500.0
£400.0
£300.0
£200.0
£100.0
£0.0
1
Average cost per household
■ Planning and Building Regs
■ Accountancy Costs (incl VAT advice)
■ Construction Lawyer



The design fees are the most substantial fees within the enabling costs, as they include fees for a detailed retrofit design for each home, alongside fees for the contract admin and site supervision.

Uncertain

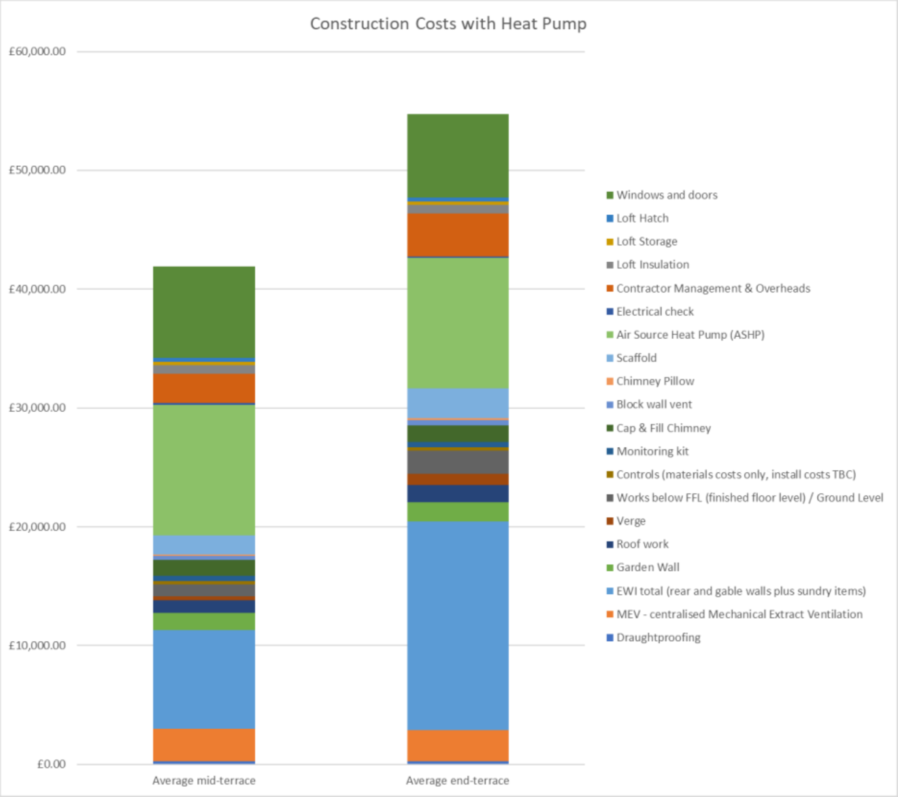


Uncertainties around:

- What ‘other’ costs include for the next phase of work;
- Whether loans for the Beta Phase will require a large loan administration cost, like the MCC loan costs stated above.

Ongoing Costs

Uncertain



Uncertainties around:

- Whether Heat Pumps will be installed in Beta Phase
- Heat Pump cost (based on bulk purchasing, supplier relationship, labour costs at the time of installation etc.):
    - The heat pump costs stated above are taken from online sources and include the cost of supplying and installing a 5-kW air-to-water ASHP system.
    - 5kW was taken from the peak heat demand post retrofit, modelled by Carbon Co-op, therefore HP costs assume fabric measures have been installed. Costs for HP will be higher if fabric measures have not been complete, as a larger HP system will be required.
    - Boiler Upgrade Scheme grants have not been taken into consideration because not all households will be eligible for this grant. Therefore, heat pump cost

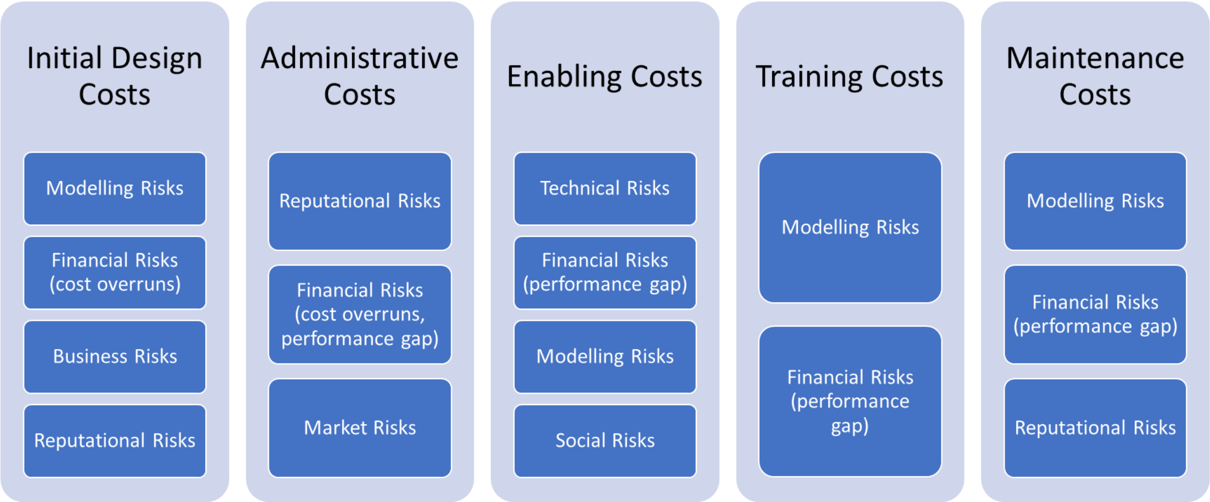
Reactive Costs

Unknown

Many of the reactive costs identified mirror the risks associated with retrofit delivery in Section 5. These risks have been represented as costs, that will need to be estimated / defined:

- Training Costs;
- Equipment Maintenance Costs;
- Further Administrative Costs (including updating data sharing agreements, repairs to equipment, financial dispute resolution etc)

These project costs above are used to mitigate many of the risks described in Section 5. The connection between these costs and the risks they aim to mitigate are shown below:



The construction costs have not been included in the diagram above because they do not directly contribute to managing the project risks.

Moreover, there is a duality in the total project costs, one which consists of the costs associated with the actual delivery of the pilot retrofit delivery scheme, but also includes costs associated with the maintenance of a data warehouse, which will collect, store and categorise the energy savings data from the retrofits. Due to lack of information currently available on the data warehouse business model, unknown costs have simply been identified in Table 17. Further discussions with ESC will ensure these data gaps are filled.

Table 17 Cost Breakdown for Data Warehouse Creation

ESC Data Warehouse costs	
Set-up Costs	
Unknown	• GDPR Compliance Checking (consultation with legal advisors) • Data Capture Systems and Connections between houses and Data Warehouse (requires consultation with Manchester City Council's data team); • Securing data acquisation;
Ongoing Costs	
Unknown	• Data Procurement / Collection (from target retrofit households); • Data External Access and Licensing (with and without interventions); • Data Transformation (Anonymisation, Aggregation and Standardisation into project performance summaries) / Data Categorisation (into different householder archetypes, energy efficiency measure packages and geographies);

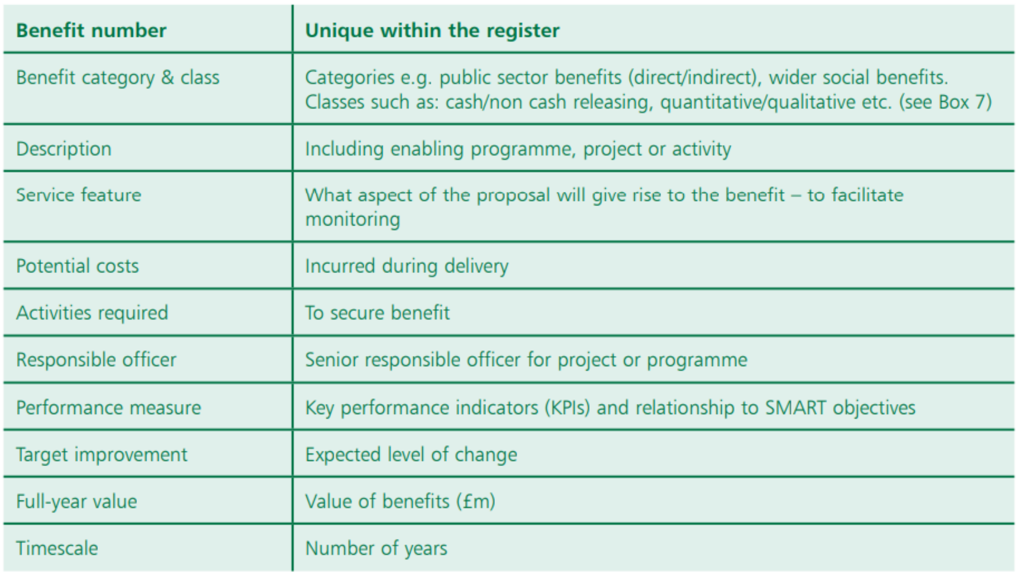
	• (Automated) Data Analysis (internal or external) for improvements to open-sourced methodology / M & V / Network Forecasting;
Reactive Costs	
Unknown	• New GDPR Regulations • New Ofgem Price Control Framework data requirements: o Changes to modelling outputs; o Changes in methodology port connection;

The CBA approach in Section 7 incorporates known, quantified costs above against the revenue streams identified, to determine the overall, estimated net benefit to project stakeholders. Further engagement and data will be required to quantify the costs of training and maintaining equipment to mitigate risks, and therefore, develop a comprehensive model incorporating all possible costs associated with retrofit delivery, which will include the costs associated with storing and accessing data in a Data Warehouse.

7) Summary of CBA approach

The CBA of RetroMeter is a fundamental aspect that will determine its uptake. The approach must be adaptable and accepted by diverse industry actors. Therefore, we will use a standard environmental CBA framework (SIF Project Management Book Template.xlsx - CBA worksheets) to analyse the net present value of the pilot retrofit scheme compared to a plausible business as usual counterfactual.

In addition, the categorisation of expected benefits within the CBA will be aligned with the benefits register approach defined by the UK Green Book:



Benefit number	Unique within the register
Benefit category & class	Categories e.g. public sector benefits (direct/indirect), wider social benefits. Classes such as: cash/non cash releasing, quantitative/qualitative etc. (see Box 7)
Description	Including enabling programme, project or activity
Service feature	What aspect of the proposal will give rise to the benefit – to facilitate monitoring
Potential costs	Incurred during delivery
Activities required	To secure benefit
Responsible officer	Senior responsible officer for project or programme
Performance measure	Key performance indicators (KPIs) and relationship to SMART objectives
Target improvement	Expected level of change
Full-year value	Value of benefits (£m)
Timescale	Number of years

Figure 9: The categorisation of expected benefits to be aligned in further CBA iterations.

Further components of the benefit register described above will be completed as part of business modelling activities within Work package 3 Milestones 2 and 3, wherever relevant. This activity will also capture benefit-related costs, enabling value streams, their costs and benefits to be evaluated individually as part of the large-scale CBA approach to enable the RetroMeter solution's value to be validated in a range of UK contexts (see sub-section titled "Description of the large-scale CBA approach").

Description of the Generic Cost-Benefit Assessment Approach

The first step in conducting a cost-benefit assessment (CBA) for the RetroMeter solution is to define the baseline counterfactual scenario – a scenario describing what interventions or changes would have occurred without the application of the RetroMeter solution.

In the baseline scenario defined by ENWL, network reinforcement would occur in 2025, requiring two substations to be reinforced per annum for three years (2025-2027 inclusive). The cost of reinforcing each substation is taken as the installation cost of an additional 1,000 kVA transformer, at current unit rates of £30,281 per installation. Otherwise, it is assumed no further interventions would occur at the properties or their connections to the substation in question, and so all RetroMeter interventions are assumed to be additional. This assumption will be reviewed at the conclusion of this section.

Now that the baseline counterfactual has been described, we can move onto outlining RetroMeter's post-intervention CBA scenarios. There are two implementations of both retrofit scenario (ABS and SHDF) that will be considered, one that integrates flexibility, and one that excludes flexibility revenues. This approach has been used as the provision of explicit flexibility is only possible in grid constrained zones where appropriate technologies have been deployed (I.e. smart heating controls), and implicit flexibility is dependent on appropriate metering infrastructure, energy tariffs and flexibility market offers from energy suppliers. As such, these flexibility revenues will not be made universally available, and so this approach will enable the RetroMeter consortium to assure service viability in a range of UK geographies and sociotechnical contexts.

As these post-intervention scenarios have significantly different implementations, the value and revenue streams proposed in earlier sections of this report will have varied levels of applicability depending on the final scenario implementation. We should note at this time that there is insufficient data at the time of writing to conduct this categorisation for the SHDF scheme, and so Table 18 below focuses on categorising the accessibility and ability to monetise revenue streams for the ABS scheme:

Table 18 Benefit Register

Benefit Description	Direct/ Indirect / Wider	Benefit Recipient	Cash releasing?	Quantifiable ?	Included in Scenario 1 (ABS w/o flex)	Included in Scenario 2 (ABS w/ flex)
Load Reduction (Energy cost savings)	Direct	Private (homeowner & DNO via reduced transmission losses)	Yes	Yes	Yes	Yes
Identification of Non-Routine Consumption (underheating)	Direct, Indirect	Private (DNO and consumers)	No	No	No (insufficient data at time of writing)	No (insufficient data at time of writing)
Increase in real estate / rental value	Indirect	Private (building owner)	Yes, at point of sale / rental	Yes	Yes	Yes
EPC Uplift	Indirect	Private (building owner)	Yes, at point of sale / rental	Yes (proportion of real estate value)	No (insufficient EPC data to model accurately, some uplift included in "Increase in Real Estate / RentalValue")	No (insufficient EPC data to model accurately, some uplift included in "Increase in Real Estate / RentalValue")
Health Improvements (improved indoor environment for given heat demand)	Indirect / Wider	Social (personal wellbeing) and Public Sector (avoided healthcare costs)	No for warm house prescriptions), Yes for comfort contributions	Maybe	No (insufficient data on fuel poverty rates)	No (insufficient data on fuel poverty rates)

Comfort Improvements	Direct	Private (Household)	Yes, where provided as a service	Yes, with sufficient data input	No (insufficient data in pilot phase)	No (insufficient data in pilot phase)
Emissions Reductions (at the point of gas consumption)	Direct, Indirect, Wider	Private (where traded on emissions trading schemes) and Social	No (except where emission abatements are certified and traded)	Yes (except for indoor air quality improvements)	Yes (non-monetiseable social value only)	Yes (non-monetiseable social value only)
Deferred Network Reinforcement (Load Reductions)	Direct, Indirect	Private (DNO and consumers)	No	Yes	Yes	Yes
Peak Capacity Uplift / Load Shaping (deferred network reinforcement)	Direct, Indirect	Private (DNO and consumers)	No	Yes	No	Yes
Provision of Implicit Flexibility (relating to heat demand)	Wider	Private (household / occupant)	Yes	Yes (at level of individual property)	No	Yes
Provision of Explicit Flexibility	Direct, Indirect	Private (DNO and consumers)	No	Yes (at level of individual property)	No	Yes
Air Quality Improvements (near power stations providing capacity reserve) due to reduction in demand	Wider	Public (avoided healthcore costs, individuals)	No	No (quantification possible but complex	No	No
Reduced Public Infrastructure Costs due to improved forecasting	Direct, Indirect	Private (DNO and consumers)	No	No	Yes	Yes
Avoided demand / connection charges (integrating private infrastructure costs)	Indirect	Private (building owner)	Yes	Yes (at level of individual property)	No	No

In order to enable their proper utilisation within the CBA framework established, revenue streams will need to be discounted to account to the value of time. To enable this, a list of relevant assumptions is summarised in Table 19, overleaf:

Table 19 Revenue Stream Assumptions

Revenue Stream	Assumptions for discounting treatment
Load Reduction (Energy cost savings)	Annualised – no additional treatment. A 25-year project lifetime has been assumed to allow annualised revenues to be compared. This is a conservative assumption compared to the asset lifespan of the fabric measures (30-40 years).
Identification of Non-Routine Consumption (underheating)	Additional value created at the point of reinforcement (2030 – 2032 inclusive)
Increase in real estate / rental value	Additional value created at the point of sale or rental (assumed to be at end of 25-year project lifespan)
EPC Uplift	Additional value created at the point of sale or rental (assumed to be at end of 25-year project lifespan)
Health Improvements (improved indoor environment for given heat demand)	Annualised – no additional treatment. Assumed rate of fuel poverty will vary from geography to geography, but likely sits between 13.4 and 34%.
Emissions Reductions (including Air Quality) at point of fossil fuel consumption	Annualised – no additional treatment
Deferred Network Reinforcement (Load Reductions)	Benefit occurs in years where reinforcement did not occur due to deferral, with costs deferred until 2030 from a 2025 baseline.
Peak Capacity Uplift / Load Shaping (deferred network reinforcement)	Additional value created for 5-year contracting period up until the point of reinforcement (deferral period assumed to be 2025-2030)
Provision of Implicit Flexibility (relating to heat demand)	Annualised – no additional treatment
Provision of Explicit Flexibility*	Additional value created for 5-year contracting period up until the point of reinforcement (deferral period assumed to be 2025-2030) **Explicit (contracted) flexibility services are assumed for only the remainder of the ED contracting period (i.e. up to 5 years). Beyond that all flexibility revenues are implicit and benefit the whole network through DSF programmes.* *Where a pilot occurs outside of a constraint management zone, there will either be no explicit flexibility revenues, or deferred revenues based on the costs of future theoretical reinforcement.*
Reduced Public Infrastructure Costs due to improved forecasting	Additional value created at the point of reinforcement (2030 – 2032 inclusive)
Avoided connection charges and private infrastructure costs	Additional value created at the point of private connection reinforcement (assumed to be at end of 25-year project lifespan)

The table above shows the temporal aspects for the revenue streams considered by this report. It should be noted that some of these assumptions may differ from real conditions, but wherever possible a conservative estimation has been applied by accounting for the revenue stream at the latest plausible opportunity (often the end of the 25-year project lifespan). This may reduce the accuracy of some revenue stream estimations, but aligns with a conservative approach.

This approach also allows segregation of near-term revenues with higher confidence from long-term future revenues (such as those derived from real estate sales), as presented by the varied NPV terms (10, 20, 30 and 45 years) in Tables 20 and 21 below, with terms beyond 20 years including real estate sales and other revenues assumed to occur at the end of the 25-year project lifespan (see Table 19 above). With these revenue streams and the costs defined by the Delivery Agent, the NPV for different scenarios was calculated for a 1500 home retrofit:

Table 20 Scenario 1 (ABS without flexibility revenues)

Term (years from first year of RIIO-ED2)	NPV (£m)	Integrated Social Value NPV (£) per home (1,500 home programme)	Monetised NPV (£) per home (1,500 home programme)
10	**£2.40**	£1,599.35	£826.12
20	**£107.07**	£71,382.41	£70,609.18
30	**£182.36**	£121,573.95	£120,800.72
45	**£182.36**	£121,573.95	£120,800.72
Whole Life NPV	**£182.36**	£121,573.95	£120,800.72

Table 21 Scenario 2 (ABS with flexibility revenues)

Term (years from first year of RIIO-ED2)	NPV (£m)	Integrated Social Value NPV (£) per home (1500 home programme)	Monetised NPV (£) per home (1500 home programme)
10	**£9.57**	£6,380.05	£5,606.82
20	**£122.90**	£81,935.01	£81,161.78
30	**£204.33**	£136,218.36	£135,445.13
45	**£204.33**	£136,218.36	£135,445.13
Whole Life NPV	**£204.33**	£136,218.36	£135,445.13

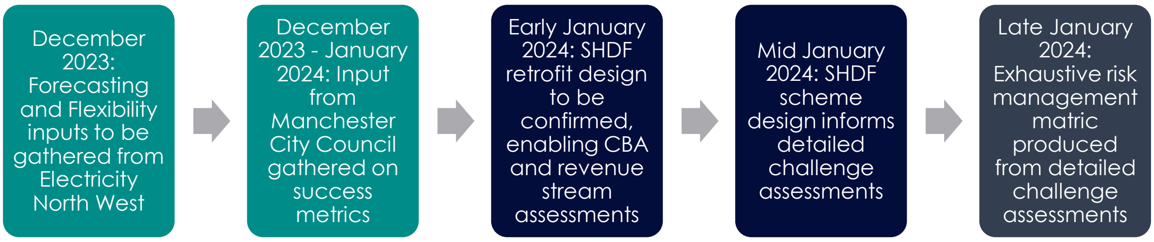
Along with the scenario-specific CBA presented above in Tables 20 and 21, there is a need to define a large-scale CBA approach capturing social values and externalities which cannot be directly monetised or accounted for at a local government or regional level, such as improvements to network forecasting methodologies, the reduction of emissions and pollutants at capacity-reserve power stations and the improvement of project potentials for related low-carbon technologies such as solar PV and electric vehicle infrastructure. This large-scale CBA can then be filtered to provide region-specific CBA outputs for future retrofit scenarios based on the high-level overview.

This approach will be iterative, aligning with any significant changes to legislation, data availability or related-stakeholder business models (e.g. around implicit flexibility). The approach will be as follows:

1) *Fill all feasible data gaps for the current overview of the RetroMeter value stack. (see figure 1)*
2) *Identify remaining data gaps along with potential changes to business models and national legislation. For each remaining data gap, or where there is an ongoing challenge in measuring, verifying or monetising a revenue stream, the following approach will be used:*
    a. *Identify if and when will key data points be available*
    b. *Identify if and when the retrofit scheme changes significantly*
    c. *Identify which value stack implementations are feasible as various challenges are addressed (such as access to new ED-period flexibility contracts)*
3) *Improve cost data by integrating costs of risk management*
4) *Produce social and monetised ROI indicators, with automated calculations wherever possible.*
5) *Map the applicability of the CBA, determine the need and action plan for further iterations*
6) *Disseminate & gather feedback as needed, using to inform the next iteration of this process.*

Whilst the CBA approach has so far been described in the context of specific retrofit schemes for the Alpha and Beta Phases of this project, to unlock a universally-applicable, and open-source, MEETS-type solution for various retrofit models in the UK, the CBA model will need to be flexible in its ability to incorporate different household typologies and retrofit schemes, and need to be adaptable to both community-interest and commercial use cases. This will allow the solution to be evaluated, improved and deployed by both the private and public sectors.

The commercial and community perspectives of the varied component actors of a RetroMeter solution will be the focus of further iterations of the CBA (output within Milestone 2 deliverables), enabling value cases and business models to be assessed in turn, motivating further uptake. These elements will be aligned with the actor-specific and revenue-specific risk management approaches introduced in Sections 5 and 6 to produce net costs and benefits per partner and revenue. By deploying intelligent automation, this will support the rapid iteration of cost benefit assessments, sensitivity analysis and adaptation for new contexts. Figure 1 below shows the timeline for gathering and integrating further data and feedback from project partners:



To conclude, this report has identified detailed costs, revenue streams and social value contributions from a range of RetroMeter-enabled services. Programme-wide and per-home net present value indicators have been calculated for the ABS, yielding a 45-year value ranging from £135,833 – £150,243 per WHR, depending on the exclusion or inclusion of flexibility services respectively. An adaptable CBA approach has been established and described, providing a clear path forward for future iterations of this work.

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9) Appendices

Appendix A: Changing names for Discovery Phase value streams

Appendix B: Data Gaps for Beta Phase Pilot Scheme

Table 22 Data Obtained for Alpha and Current Insufficiencies

Data Category	Area-Based Scheme		Metered Social Benefits	
	Alpha	**Beta**	**Alpha**	**Beta**
Target Markets	Current pilot focuses on groups of properties in Levenshulme. Properties are mid-terrace and end-terrace.	Uncertain whether Beta Phase will build on this geographical cluster. Uncertain what mix of tenures will be targetted.	Current programme includes c. 1000 terraced and semi-detached homes in M9 and M40 postcodes: - Anita and George Leigh Street - Newton Heath - Monsall high rise - Riverdale maisonettes	Uncertain which tranche of homes will be targetted first and how much the scope will change by the start of Beta Phase.
Conservation Measures	Current measures: - Top up loft insulation - Loft storage - Insulated Loft Hatch - Part-Glazed External Door - Double-Glazed window - 175 mm insulation to pitched roof - Draught-proofing - Decentralised Mechanical Extract Ventilation - EWI to wall - Insulation to solid floor external - Cap and Fill Chimney - Block uncontrolled wall vent - Chimney Balloon	Uncertain whether Beta Phase will have following: - Similar scope fabric + ventilation works - More advanced works (including windows, IWI on front, doors) - As above plus electrification of heat (via ASHP) Uncertain whether all measures are applied in all houses, or selectivly applied.	Measures under SHDF are guided by requirement to follow PAS2035 (fabric-first strategy). SHDF only funds measures that take households up to EPC band C. Measures could include: - EWI - ASHP - Heating controls - Ventilation - Low energy lighting	Final determination on measures come from retrofit assessments. These measures could change drastically for Beta Phase. No information provided on this yet.

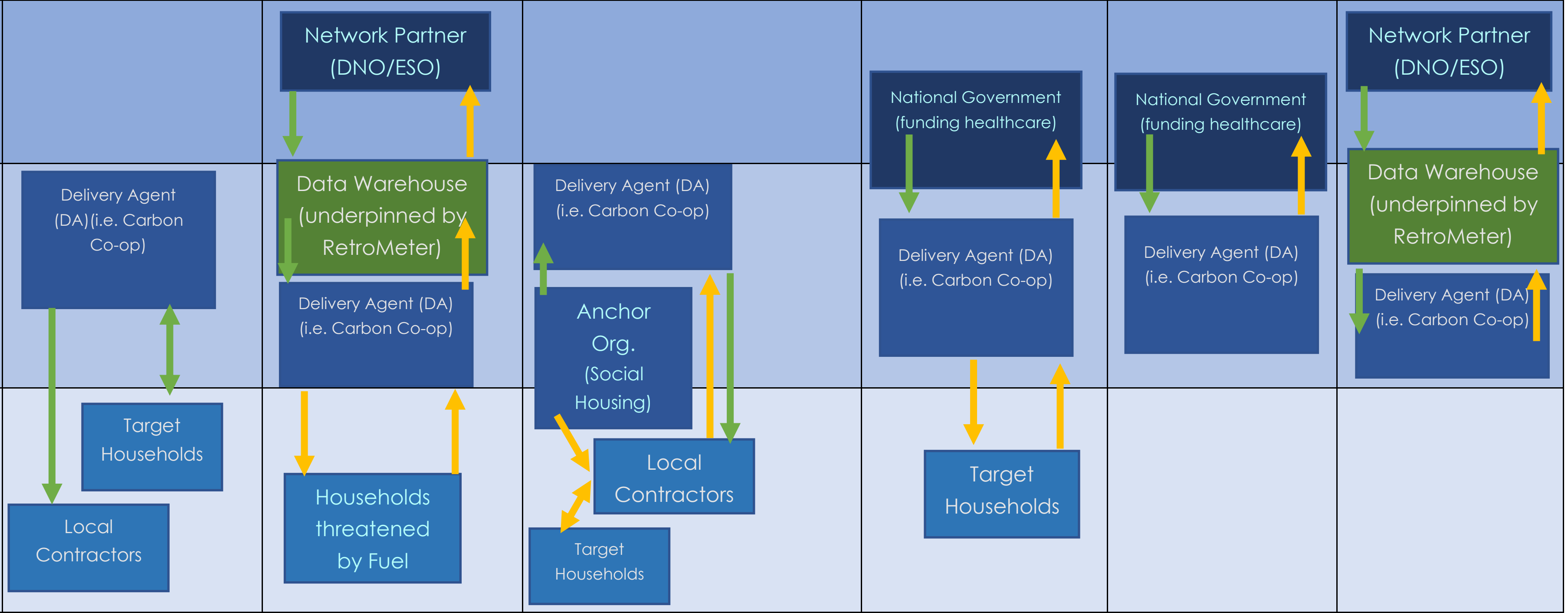
Funding Approach	Current phase utilises: - Carbon Co-op grant funding - Loan funding via Care and Repair / MCC - Householder contributions The grant funding and loan funding are one-off funds, that are legacies from previous CC programme.	Uncertain whether Beta Phase will: - Need to secure another grant funding element (MCC Housing Revenue Account, ECO) - Require other loan funding - Require higher / lower Householder contributions - Require flexibility services via ENWL - Need to secure other forms of finance (credit union, private sector green financing loans) The eligibility will vary from home to home, with different grant funding options over different geographies and demographics.	SHDF will only fund 50%, with remainder funded by housing provider (MCC). Total estimated cost: £49.71m of which: - SHDF grant is £11.65m - £41.15m relate to grant eligibility works - £29.5m contribution from MCC.	Uncertain how much Beta pilot could cover from this programme. Data is not granular enough (funding for each ECM, boiler replacement strand).
Run rate	Current Phase includes 7 homes	Uncertain how many homes will be targetted in Beta.	MCC SHDF programme covers 1,603 properties. Most relevant strand (boiler replacement group) is around 1,000 homes.	Scale with beta needs determing. Final numbers will depend on programme decision from MCC. Uncertain how many homes will need testing to sign up for smart metering service.

Modelling Outputs	Current Phase does not specify particular energy targets. Assessment approach provides baseline data for: • Heating preferences • Space heating demand • Peak Heat Load • Fuel use • Energy use • KgCO2e • Fuel costs Monitoring kit being installed will provide data on: • Air quality sensor • Particulate matter (dusts and air pollution) • Volatile Organic Compounds (VOCs), chemicals and gases • Carbon dioxide, to evaluate airflow • Temperature & humidity sensors • Smart heating controls • A small HEMS (Home Energy Management System) to link everything together Qualitative data collection via surveys, HRP and post works. Surveys will need to include home owner declaration of any changes not linked to heating: replacement of old electrical equipment, EV, behavioural changes (working from home, having a child) etc.	Uncertain whether Beta Phase will: • Use PPR's HRP modelling tool and associated metrics • Similar monitoring kit (or reduced as dictated by grant/loan requiremetns and ESC data requirements) • Use a similar framework for qualitative data collection It is also uncertain how much this will affect programme delivery costs. ESC will require, at the minimum: • Pre-retrofit Smart meter data • Post-retrofti Smart meter data • Post-retrofit sub-metering of Heat Pumps • Post-retrofit internal temp. • Pre and post retrofit weather data • Pre retrofit solar irradiance.	SHDF funding criteria requires an increase to EPC band C. Space heating demand of 90 kWh/m2/year should be achieved. Acceptable evidence for this is outputs from modelling (e.g. using SAP or PHPP). PAS2035 assessment requirements must be followed, data should be obtained around: • A whole dwelling assessment • Occupancy Information • Annual Fuel use • Fuel costs • CO2e	Uncertain what baseline data is and what degree of occupancy information is available. Monitoring will need to follow requirements of PAS2035 – will remain similar/same for Beta Phase pilot. ESC will require, at the minimum: • Pre-retrofit Smart meter data • Post-retrofti Smart meter data • Post-retrofit sub-metering of Heat Pumps • Post-retrofit internal temp. • Pre and post retrofit weather data • Pre retrofit solar irradiance.

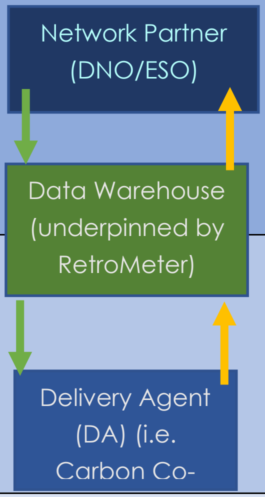
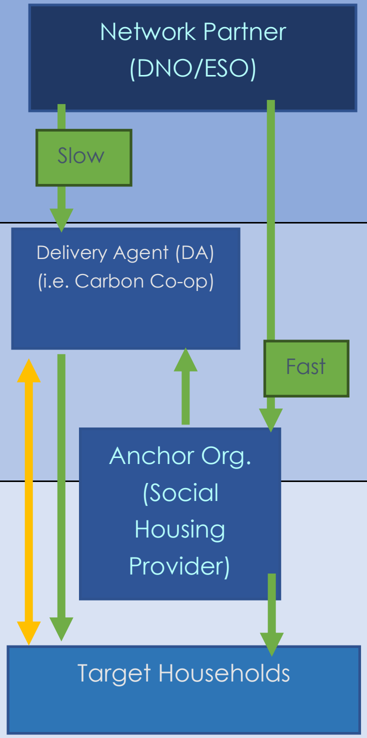
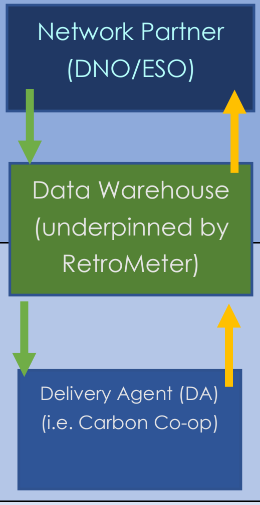
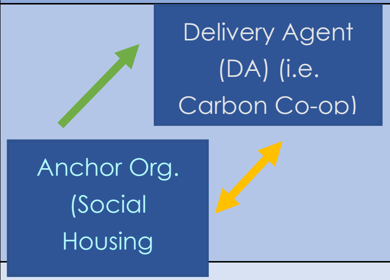
This document is marked as confidential

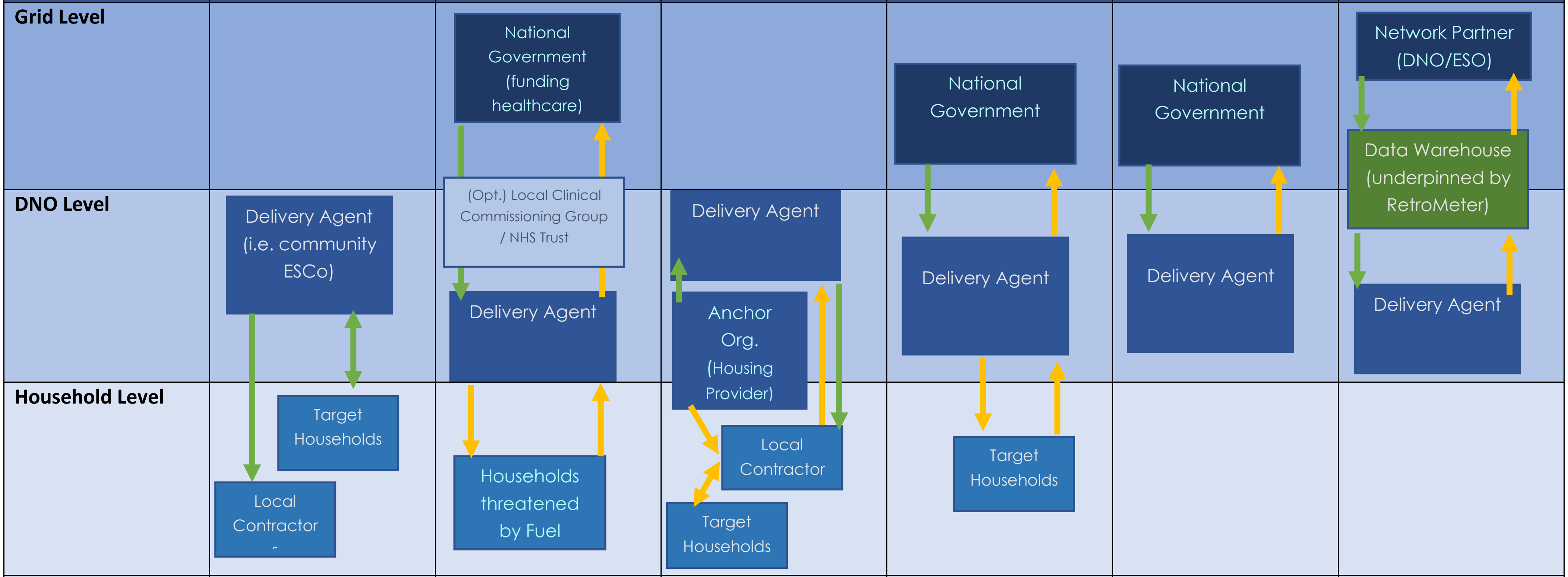
Rough cost per property	Total average for current phase: • Mid-terrace: £39,100 • End-terrace: £53,000	Uncertain how scale, varying conservation measures and modelling equipment in Beta Phase will impact costs.	MCC estimated costs of retrofit at an additional £16.5k per property. This is on top of the works already planned (e.g. Decent Homes, Safety, planned repair/renewal programmes). Boiler strand of the programme estimates measures of EWI/ventilation/ lighting/controls/ ASHP at around £19,700 per home.	Uncertain how accurate and granular these costs are. Uncertain whether costs will vary from household to household.

Appendix C: Definitions of Discovery Phase Revenue Streams:

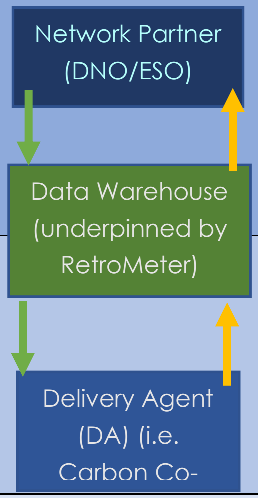
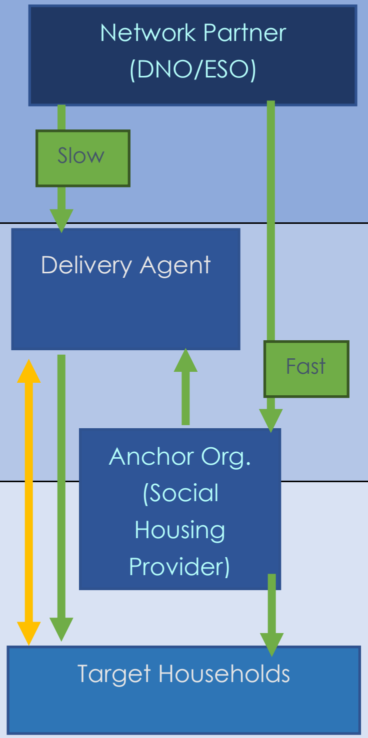
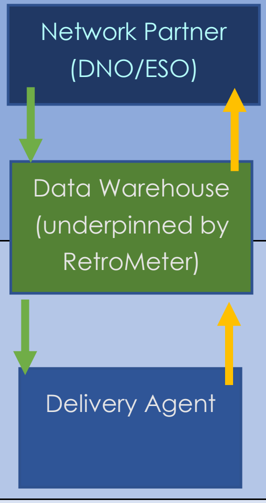
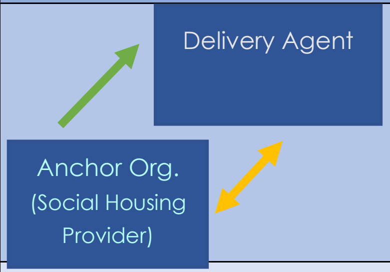


Revenue Stream for “Metered Social Benefits underpinned by SHDF” model	Load Reduction (Energy cost savings) [A]	Identification of Non-Routine Consumption (underheating) [B]	EPC Uplift (housing provider or community land trust only) [D]	Comfort Improvements [D2]	Emissions Reductions / Improved Environment (i.e. Air Quality) [E]	Deferred Network Reinforcement (Load Reductions) [F]
Regional / National Grid Level (i.e. Scale of Local and National Government)		Network Partner (DNO/ESO)		National Government (funding healthcare)	National Government (funding healthcare)	Network Partner (DNO/ESO)
DNO Level (i.e. Scale of Local Authority or Regional Institution such as Housing Provider)	Delivery Agent (DA)(i.e. Carbon Co-op)	Data Warehouse (underpinned by RetroMeter) Delivery Agent (DA) (i.e. Carbon Co-op)	Delivery Agent (DA) (i.e. Carbon Co-op) Anchor Org. (Social Housing)	Delivery Agent (DA) (i.e. Carbon Co-op)	Delivery Agent (DA) (i.e. Carbon Co-op)	Data Warehouse (underpinned by RetroMeter) Delivery Agent (DA) (i.e. Carbon Co-op)
Household Level (i.e. Scale of an individual occupant or owner-occupant)	Target Households Local Contractors	Households threatened by Fuel	Local Contractors Target Households	Target Households		
Narrative	Intervention returns are shared between target households and the DA. The DA reviews savings against contractor estimations and provides a bonus or malus depending on project performance.	Household smart meter data, analysed by the DA, identifies likely underheating alongside the outcomes of retrofit. This insight into underheating and comfort takeback is shared with grid operators via a data warehouse in return for funding.	City councils invest in local contractors’ delivery of retrofits. The DA supervises the verification of Energy Performance Certificate uplift and passes on a performance payment to motivate quality delivery & verification. This will help with MEES compliance where relevant, but one should note there are major issues with EPC methodologies, particularly around electrification.	DA delivers high quality projects that unlock and “measure” comfort takebacks, improving indoor environment and local health outcomes. Local or national government (or adjacent bodies) fund in return for verified data on project outcomes.	DA delivers emissions reductions via retrofit, improving air quality and health outcomes (the scale of which will need investigation). Funding derived from emissions accounting (i.e. sale of credits or support for LA Net Zero transition.)	The impact of retrofit is quantified, particularly for KPIs such as peak capacity. Data is stored in a “warehouse” to be monetised by grid operators. This helps fund both retrofits & the data warehouse.

Revenue Stream: “Metered Social Benefits underpinned by SHDF” model	Peak Capacity Uplift / Load Shaping (deferred network reinforcement) [G]	Provision of Fast/ Slow Flexibility (technology dependent – not priority) [H]	Reduced Public Infrastructure Costs [J]	Avoided demand / connection charges [K]
Grid Level (i.e. Scale of Local and National Government)				
DNO Level (i.e. Scale of Local Authority or Regional Institution such as Housing Provider)				
Household Level (i.e. Scale of an individual occupant or owner-occupant)				
Narrative	The impact of retrofit is quantified by the DA, particularly for KPIs such as changes to load profile and “peak smoothing”. Data is stored in a “warehouse” to be monetised by grid operators. This helps fund both retrofits & the data warehouse.	The DA may develop retrofit offers which include assets providing fast or slow flexibility services to the grid, with RetroMeter verifying impact. Fast frequency services would be operated by the housing provider (i.e. city council for social housing), with revenues shared with the DA/target household. Slow flexibility services flow through DA to households.	The impact of retrofit is quantified by the DA, particularly for modelling changes to occupant behaviour, rebound effects and load profiles. Data is stored in a “warehouse”, which helps grid operators to deploy assets where needed most and with a view to future scenarios. This avoid costs which can be used to fund both retrofits & the data warehouse.	The DA exchanges information with the city council or housing provider to identify where capacity / connection charges are highest and how retrofit will help alleviate these. The DA then delivers and verifies abatements through specifications for local contractors, and shares the avoided costs from the city council to fund measurement and verification.



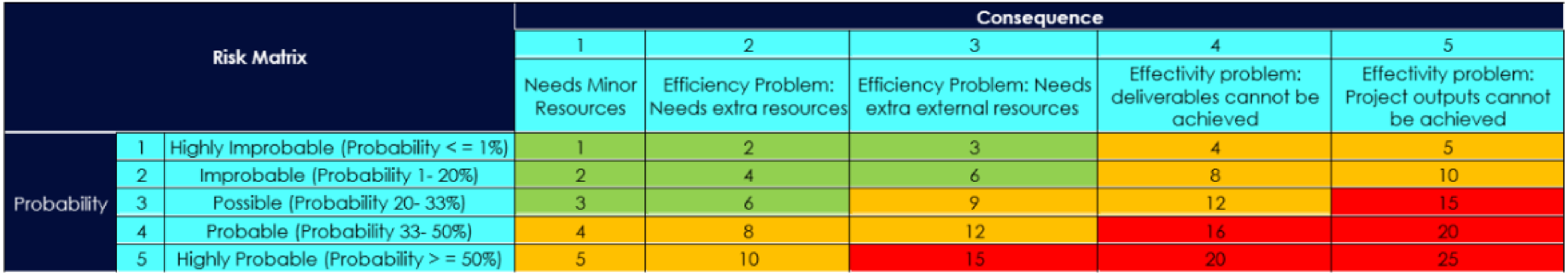
Revenue Stream for Delivery Agent Model (Area based scheme)	**Load Reduction** *(energy cost savings)*	**Identification of Underheated Homes** *(energy demand modelling)*	**EPC Uplift**	**Comfort Takeback** *(avoided healthcare)*	**Reduced Emissions & Air Pollution**	**Deferred Network Reinforcement** *(load reductions)*
Grid Level		National Government (funding healthcare)		National Government	National Government	Network Partner (DNO/ESO) Data Warehouse (underpinned by RetroMeter)
DNO Level	Delivery Agent (i.e. community ESCo)	(Opt.) Local Clinical Commissioning Group / NHS Trust Delivery Agent	Delivery Agent Anchor Org. (Housing Provider)	Delivery Agent	Delivery Agent	Delivery Agent
Household Level	Target Households Local Contractor	Households threatened by Fuel	Local Contractor Target Households	Target Households		
Narrative	Intervention returns are shared between target households and the DA. The DA reviews savings against contractor estimations and provides a bonus or malus depending on project performance.	Household smart meter data, analysed by the DA, identifies likely underheating alongside the indoor environment outcomes of retrofit. The avoided costs of health/social care fund this work via local NHS.	City councils invest in local contractors' delivery of retrofits. The DA supervises the verification of EPC uplift and passes on a performance payment to motivate quality delivery & verification.	DA delivers high quality projects that unlock and "measure" comfort takebacks, improving indoor environment and local health outcomes. Government funds in return for verified data on project outcomes.	DA delivers emissions reductions via retrofit, improving air quality and health outcomes. Funding derived from emissions accounting (i.e. sale of credits or support for LA Net Zero transition.)	The impact of retrofit is quantified, particularly for KPIs such as peak capacity. Data is stored in a "warehouse" to be monetised by grid operators. This helps fund both retrofits & the data warehouse.

Revenue Stream for Delivery Agent Model (Area based scheme)	**Peak Capacity Uplift / Load Shaping** *(deferred network reinforcement)*	**Provision of Fast / Slow Flexibility** *(technology dependent)*	**Reduced Public Infrastructure Costs**	**Avoided demand / connection charges**
Grid Level	 Network Partner (DNO/ESO) Data Warehouse (underpinned by RetroMeter)	 Network Partner (DNO/ESO) Slow	 Network Partner (DNO/ESO) Data Warehouse (underpinned by RetroMeter)	
DNO Level	Delivery Agent (DA) (i.e. Carbon Co-	Delivery Agent Fast Anchor Org. (Social Housing Provider)	Delivery Agent	 Delivery Agent Anchor Org. (Social Housing Provider)
Household Level		Target Households		
Narrative	The impact of retrofit is quantified by the DA, particularly for KPIs such as changes to load profile and "peak smoothing". Data is stored in a "warehouse" to be monetised by grid operators. This helps fund both retrofits & the data warehouse.	The DA may develop retrofit offers which include assets providing fast or slow flexibility services to the grid, with RetroMeter verifying impact. Fast frequency services would be operated by the housing provider (i.e. city council for social housing), with revenues shared with the DA/target household. Slow flexibility services flow through DA to households.	The impact of retrofit is quantified by the DA, particularly for modelling changes to occupant behaviour, rebound effects and load profiles. Data is stored in a "warehouse", which helps grid operators to deploy assets where needed most and with a view to future scenarios. This avoid costs which can be used to fund both retrofits & the data warehouse.	The DA exchanges information with the city council or housing provider to identify where capacity / connection charges are highest and how retrofit will help alleviate these. The DA then delivers and verifies abatements through specifications for local contractors, and shares the avoided costs from the city council to fund measurement and verification.

Appendix D: Format for gathering Ongoing Data Assumptions & Partner Comments

Assumption	Validation and Partner Comments

Appendix E: Risk Matrix



Risk Matrix			Consequence				
			1	2	3	4	5
			Needs Minor Resources	Efficiency Problem: Needs extra resources	Efficiency Problem: Needs extra external resources	Effectivity problem: deliverables cannot be achieved	Effectivity problem: Project outputs cannot be achieved
Probability	1	Highly Improbable (Probability < = 1%)	1	2	3	4	5
	2	Improbable (Probability 1- 20%)	2	4	6	8	10
	3	Possible (Probability 20- 33%)	3	6	9	12	15
	4	Probable (Probability 33- 50%)	4	8	12	16	20
	5	Highly Probable (Probability > = 50%)	5	10	15	20	25

Risks are named, mapped, clustered, and evaluated using the Risk Matrix above. This provides each risk entered into the Risk Matrix with a score. The risk is then categorised into one of three categories LOW, MEDIUM and HIGH (colour-coded before mitigation in column titled "TS") which detail the urgency that mitigation measures must be undertaken. All those in RED are high-priority risks that require urgent escalation/action to mitigate the risk.

The scoring system is designed to ensure the delivery agent(s) can actively manage, and mitigate, the risks that are associated with the delivery the retrofits, The definition of risk consequence is as follows: 1 – "Need Minor Resources"; 2 – "Efficiency Problem: Needs Extra Resources"; 3 – "Efficiency Problem: Needs extra external resources"; 4 – "Effectivity problem: deliverables cannot be achieved"; 5 – "Effectivity problem: Project Outputs cannot be achieved". Any consequence or probability ranking of >=4, or a total score >=9 yields a "medium" risk, with any total score of >=15 yielding a "high risk" categorisation

Appendix F: Value stream sensitivities for use in ongoing business modelling

Revenue Stream	Key Sensitivities and Input Assumptions
Load Reduction (Energy cost savings)	• **Modelled change in heat demand –** this will require careful modelling and consideration of the "depth" of the retrofit specification, which may fall below the definition of a "whole house" retrofit approach, particularly for the proposed SHDF scheme. Current figures are derived from CC's heat modelling scenarios. • **Heat pump Coefficient of Performance (CoP) –** A CoP of 2.8 is assumed based on the latest data from ESC. However, this figure should be monitored over time, varied geographies and weather conditions. Additionally, the interactive impact of flexible operation on the CoP may require further investigation. • **Energy Prices / Price Cap –** it is unclear how long current energy prices, which have peaked in the last few years, will persist. This uncertainty is exacerbated by the current energy price cap of 27.5p/kWh, the longevity of which is still to be determined. • **Estimated Project Lifespan –** a 25-year project lifespan has been assumed, as this is a conservative estimate based on the 30-40 year lifespan of fabric measures. This assumption enables annualised values to be compared, but may undergo further sensitivity analysis.
Increase in real estate / rental value	• **Increase in Rental Value (GBP/m2/year) –** This figure is derived from EU research, but is verified and compared with data from UK RICS reporting. This figure, and its conversion into GBP are key assumptions that may undergo further sensitivity analysis • **Floor Area –** The value presented is normalised by floor area and so will vary from home to home based on size. • **Estimated Project Lifespan –** As above.
EPC Uplift	• **Assumed proportion of homes under EPC C –** For the exemplar case we have assumed all homes receive an uplift from below EPC C, however this will need to be modelled on an individual home basis. • **Assumed EPC baseline to be elevated to EPC C –** It is assumed that 50% of homes receiving EPC uplift will move from EPC D to EPC C, and that the remaining 50% will move from EPC E to EPC C. However, this is a key assumption for this value stream, and should be modelled with the specific homes targeted with retrofit in the pilot phases and beyond.
Health Improvements (improved indoor environment for given heat demand)	• **Ratio of social value to investment in warm home prescriptions, quantum of investment for a single warm home prescription –** Research shows that the average cost of a warm home prescription is £1000 per patient household, delivering £5.1 of social value per pound invested. Both the ratio and overall quantum of this investment are key assumptions, and so future evaluations of warm home prescriptions should be monitored to validate these figures • **Proportion of homes experiencing fuel poverty –** Research shows that the proportion of homes experiencing fuel poverty ranges from 13.4 – 34%, however this should be determined with the specific householders targeted with retrofit in the pilot phases and beyond, using data and engagement derived from Carbon Coops delivery approach.
Emissions Reductions (including Air Quality) at point of fossil fuel consumption	• **Modelled change in heat demand –** this will require careful modelling and consideration of the "depth" of the retrofit specification, which may fall below the definition of a "whole house" retrofit approach, particularly for the proposed SHDF scheme. Current figures are derived from CC's heat modelling scenarios. • **Natural Gas and Grid Emissions Factors –** The abatement of air pollution is derived from both an efficiency gain and fuel switch – from the combustion of gas to the use of electricity. As the electrical power may also be derived from fossil-fuelled generators, the specific and time-dependent emissions factors should be monitored to validate this figure. • **Value of NOx and CO2 abatements –** SROI and ETS sources should be used to validate these valuation figures on a regular basis.

<table>
<tr>
<td>Deferred Network Reinforcement (Load Reductions)</td>
<td>
• **Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit –** This factor will be key not only to this value stream, but a whole host of values derived from network benefits. This input is also derived from a further range of input assumptions and estimates, as shown in the table below:
<table>
<tr><td>Heat Demand from HP prior to Whole House Retrofit (WHR)</td><td>9</td><td>kW</td></tr>
<tr><td>Reduction in Heat Demand from WHR</td><td>0.65</td><td>kW</td></tr>
<tr><td>Heat Demand from HP following Whole House Retrofit (WHR)</td><td>6</td><td>kW</td></tr>
<tr><td>ADMD Impact as proportion of total heat demand</td><td>2.1</td><td>proportion</td></tr>
<tr><td>ADMD Impact before WHR</td><td>4.285714286</td><td>kW</td></tr>
<tr><td>ADMD Impact after WHR</td><td>2.857142857</td><td>kW</td></tr>
<tr><td>Difference in ADMD due to WHR</td><td>1.428571429</td><td>kW</td></tr>
</table>
This table shows the use of standardised heat pump sizes (9 and 6 kW), but also demonstrates the use of a key figure – the “ADMD Impact as proportion of total heat demand”, estimated as a proportion of 2.1. This estimate was determined within the RetroMeter consortium during the Discovery Phase, but is validated by the work of Love *et al.* (2017). This research, namely the data presented in Figure 8 shows ADMD drop off with increased diversity, from an initial figure of 4.0 with no diversity (a single heat pump), dropping off to 2.0 within a portfolio of 40 homes (yielding an ADMD proportion of 2.00). This figure drops off further when the portfolio is expanded to 100/275 homes, falling to 1.8 kW (yielding an ADMD proportion of ~2.22) and 1.7 kw (yielding an ADMD proportion of ~2.35). A conservative estimate within this range (2.1), has been applied in our calculations.
• **Value per kW ADMD abated –** The value input here, ~£36 / kW ADMD abated, was derived from 202-2021 reinforcement unit costs. This figure will need further investigation, particularly around in integration of inflation, ancillary hardware, labour and project management costs, the impact of the latter 3 of which is uncertain.
• **Duration of flexibility contract -** A 5-year flexibility contract is assumed, but this will vary based on when retrofits are delivered within the DNO ED period. Additional modelling will be needed to determine this for specific pilots and schemes, but additional consideration of when “delivery” and contracting occurs is needed, particularly where the delivery timeframe is more than 6-12 months, as this will determine the remainder of the ED period for which contracting is feasible.
</td>
</tr>
<tr>
<td>Peak Capacity Uplift / Load Shaping (deferred network reinforcement)</td>
<td>
• **Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit –** As above.
• **Duration of the flattened load peak** – It has been assumed that the current peak in grid electrical demand (4pm-7pm) persists for the whole of the project lifespan. However increased heat pump and EV penetration is likely to change that. Reports from ESC’s Living Lab suggest we're already seeing signs of a new peak in the early morning as a result of EV charging. This point will be investigated further throughout our work in Milestone 2 to determine the risks and sensitivities underpinning these peak-ADMD-based value streams. Additionally, comparison of the peaks produced by the work of Love et al. (2017) with the grid load profile may require further monitoring and investigation, as the portfolio of 703 homes integrated additional variations, including the type of heat pump (air or ground source), whether the heat pump provided domestic hot water (DHW) or just space heating, and whether it incorporated one or more of a number of types of supplementary electric resistance heating. This shift
</td>
</tr>
</table>

	in electrical use and peak load may also feed into iterative review of the impact of diversity on ADMD figures. • **Flexibility ceiling price –** The flexibility ceiling price is defined by the value of flexibility and the avoidance of network reinforcement and other flexible services which would require additional flexibility to be contracted.
Provision of Implicit Flexibility (relating to heat demand)	• **Persistence of the Demand Flexibility Service scheme –** it is assumed that this scheme will persist throughout the lifespan of the project, but industry consultations and guidance should be monitored to test the sensitivity and challenge this assumption. • **Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit –** As above. • **Number of Sessions and Price per kWh of demand response** – These figures vary from energy supplier to energy supplier based on their implementation of the Demand Flexibility Service. Modelling based on individual homes and tariffs will be required to test the sensitivity of this value stream under estimation method 1. • **Duration of the flattened load peak** – As above. Estimation method 2 assumes the peak is occurring 4pm – 7pm.
Provision of Explicit Flexibility*	• **Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit –** As above. • **Value per kW ADMD abated –** As above. • **Duration of flexibility contract –** As above.
Avoided connection charges and private infrastructure costs	• **Difference in After Diversity Maximum Demand (ADMD) due to Whole House Retrofit –** As above. • **Number of homes served by demand connection increases –** research from Leeds City Council (2023) indicates that each demand connection serves ~100 homes. However, this will likely vary with geography and local infrastructure requirements/energy intensity and should undergo further sensitivity analysis. • **Value per kVA demand increase –** Figures from the UK building supply forum "Checkatrade" indicate the cost of an increased demand connection to be £1,720 / kVA capacity increase. However, these figures are from 2022 and have not undergone any inflationary uplift and should therefore undergo further sensitivity analysis. A useful question to ask would be "what is the expected change in maximum demand of a property with and without the efficiency measures?"; and "how suitable is the actual supply per property?". This would reveal the advantage of doing a cluster-based retrofit versus a scattered effect program: o With a cluster there are greater pressures on the DNO network in a localised area so we may need to reinforce, but there could be economies of scale of if we needed to do a clustered network upgrade e.g. if we had to replace every services cable and cut-out on a street, compared to piecemeal upgrades. o On a scattered approach there is less likelihood of a need for significant network reinforcement due to the increased load of HPs and equally any savings would be insignificant in the grand scheme of things. o On both approaches, if the service cable or cut-out need replacing then these costs are individual to a property, but there could be some economies of scale. o Another consideration is if any of these properties would need any capacity upgrades for anything else anyway e.g. EV charging. As items such as cut-out changes are universal to both programs the cost of reinforcement might still exist even if not to accommodate a HP.

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