Electricity Distribution

# Demand Forecasting Encapsulating Domestic Efficiency Retrofits (DEFENDER)

## Dissemination Webinar

8th June 2023

nationalgrid

# What is the impact and value of energy efficiency to electricity networks?

| Presenter(s) | Organisation |
|---|---|
| Nick Devine | National Grid |
| Laura Glover<br>Ben Robertson | Carbon Trust |
| Joshua Cooper | Hildebrand |
| David Thorn | GHD |
| Alex Whittaker | Frontier Economics |

# Agenda

| | | |
|---|---|---|
| **01** | Introduction | 10:00-10:05 |
| **02** | Modelling energy efficiency’s impact on heating demand | 10:05-10:40 |
| **03** | Current and future impact of energy efficiency on electricity networks | 10:40-11:25 |

# 01

## Introduction

# Context

**A transition to electrified low carbon heating will greatly increase network demand**

**>600,000 heat pumps are expected on NGED's network by 2030**

**Energy efficiency retrofit will play significant role in net zero transition**

# Context

DNOs' RIIO-ED2 license conditions allow them to procure EE services where they are cost-effective

*"..promoting the uptake of measures to improve Energy Efficiency, where such services* **cost-effectively** *alleviate the need to upgrade or replace electricity capacity and support the efficient and secure operation of the Distribution System.*

*This may include procuring Energy Efficiency Services,* **where it is economic and efficient** *to do so."* – SLC 31E

# Context

**Existing domestic customer profiles do not include building factors**

**Top down models of domestic demand growth**

**Limited (albeit growing) sample of heat pump users**

**Existing learning on EE value highly locational and specific**

# Aim

Develop models of **how the energy efficiency (EE) of building fabric will affect** electrical heat demand on a per-household and network level.

Use these models to discern the **value of EE** to electricity networks and our customers.

# Objectives

**Generate a set of house archetypes and develop demand models (electricity and heat) using smart meter data**

**Model EE impact on demand profiles**

**Develop bottom up approach to integrate these models into forecasts**

**Assess the impact on network**

**Perform an economic assessment of the potential benefits**

# Scope

## Workstream 1

Build and trial a tool capable of generating load profiles for different combinations of electric heating and EE measures for a series of house archetypes

## Workstream 2

Build on existing NGED processes to assess the long-run cost-effectiveness of EE integrated with traditional reinforcement and flexibility services

# Outputs

Working with: Carbon Trust

EPC derived building archetype set

Profiling tool, Glow Simulator

Working with: Carbon Trust, hildebrand

Working with: Carbon Trust, GHD

DFES compatible EE scenarios

Tools to assess the value of EE to DNOs

frontier economics

# 02

# Modelling energy efficiency's impact on heating demand

# Modelling energy efficiency’s impact on heating demand

| | | |
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| **01** | Overview of house archetypes and EE scenario creation | Ben Robertson, Carbon Trust |
| **02** | Overview of calculation of heat demand from smart meter data | Josh Cooper, Hildebrand |
| **03** | Demonstration of the Glow Simulator | Josh Cooper, Hildebrand |
| **04** | Q&A | Nick Devine, National Grid |

# Modelling energy efficiency's impact on heating demand

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# Building archetypes

**Archetypes are used to differentiate individual properties based on thermal performance.**

**They allow us to link datasets to:**

a) **Use smart meter data to generate a heat demand profile**

b) **Estimate heat demand decreases based on the type of energy efficiency upgrade**

# Building archetypes

## Archetype
(property type)

**Built form**
- Mid-terrace
- Semi-detached
- Detached
- Bottom floor flat
- Mid floor flat
- Top floor flat

**Construction age**
- Before 1930
- After 1930

**Floor type**
- Solid floor
- Suspended floor

**Roof type**
- Pitched roof
- Flat roof

**Wall type**
- Cavity wall
- Solid wall

## Sub-archetype
(level of insulation)

**Window glazing**
- Single glazing
- Double glazing
- Triple glazing

**Floor insulation**
- No insulation
- Partial insulation
- Insulated

**Roof insulation**
- No insulation
- Partial insulation
- Insulated

**Wall insulation**
- No insulation
- Insulated

= 2,904 possible combinations
*(many do not exist in reality)*

# Archetype database

## Extract of archetype database with SAP-modelled Heat Transfer Coefficients (HTC)

| Arche-type | Built form | Age | Wall type | Floor type | Roof type | Floor insulation | Roof insulation | Wall insulation | Window glazing | % of NGED's network | HTC (W/K) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-1 | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | None | None | None | Single | 0.07% | 918.7 |
| 1-2 | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | None | Partial | None | Single | 0.05% | 890.3 |
| 1-3 | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | Partial | None | None | Single | 0.00% | 880.2 |
| 1-4 | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | Full | None | None | Single | 0.00% | 874.0 |
| 1-5 | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | None | Full | None | Single | 0.08% | 853.3 |
| 1-6 | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | Partial | Partial | None | Single | 0.00% | 851.9 |

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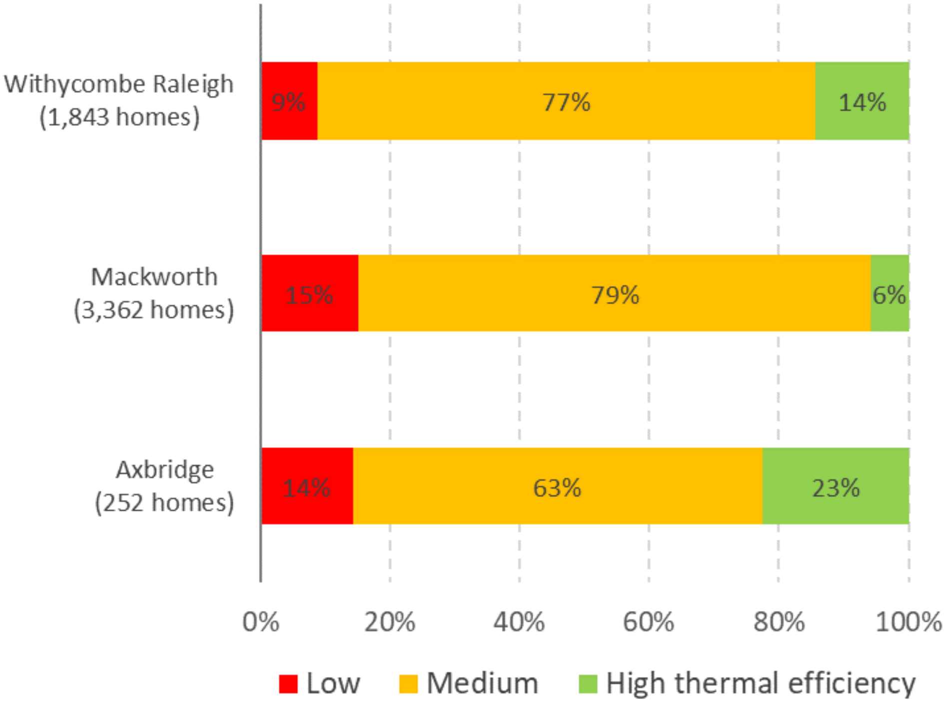
| **1-6** | Semi-detached | Before 1930 | Solid wall | Suspended | Pitched | Partial | Partial | None | Single | 0.00% | 851.9 |

Heat demand decreases by 7.1%

# Energy efficiency scenarios

- Buildings were classified into low, medium and high thermal efficiency based on their level of insulation.
- Cost optimisation model determines the optimal fabric measures to upgrade a home to medium or high thermal efficiency.
- Rate of installations linked to DFES rate of heat pump uptake under the Consumer Transformation scenario.

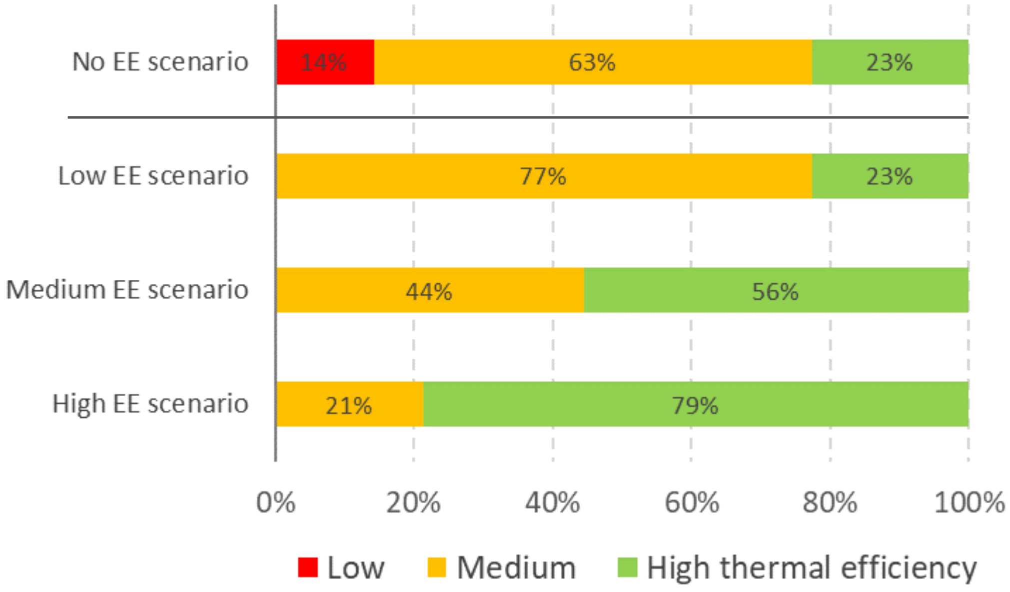
**Case study areas:
baseline building stock summaries**



# Energy efficiency scenarios

- **No EE scenario**
  Counterfactual scenario with no EE measures
- **Low EE scenario**
  EE measures installed to upgrade inefficient homes to being heat pump ready
- **Medium EE scenario**
  EE measures match the number of measures installed in the CCC’s Balanced Pathway from the 6th Carbon Budget
- **High EE scenario**
  High levels of EE measures installed in homes with ‘low’ or ‘medium’ thermal efficiency

**Axbridge: 2050 Energy Efficiency Scenarios (Consumer Transformation)**



# Modelling energy efficiency’s impact on heating demand

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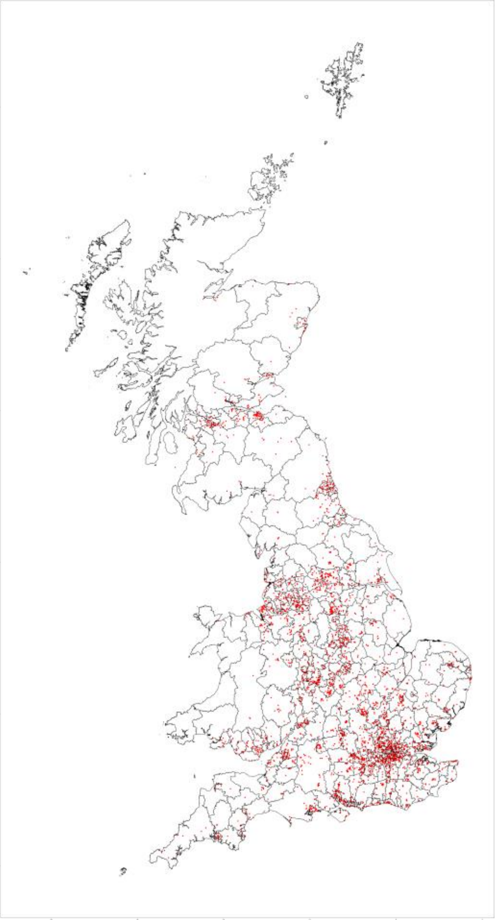
# Smart meter data shows today's reality

Domestic smart meters contain 13 months of half hourly data for electric and gas consumption.

Gas data is key to showing heat demand and characterise building fabric

Models were created from homes represented across the UK



# Building fabric is expressed as heat loss co-efficient expressing the kWh per change in temperature

$Q_{day}$ is the energy required for the day

$T_s$ is the internal "set point" of heating

$T_{ext}$ is the outside temperature

$$hlc = \frac{Q_{day}}{\max(T_s - T_{ext}, 0)}$$

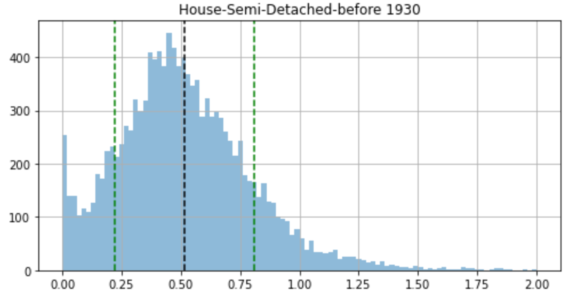
**HLC is size and time invariant**

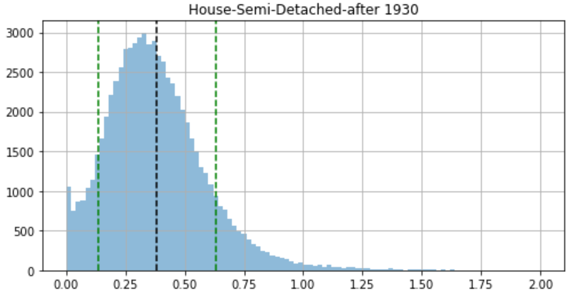
**Energy (Q) can be calculated from the changes in external temperature ($T_{ext}$) if the set point is assumed**

# HLC is treated as a random variable for each property type

Bayesian training is used to fit the real, observed data Energy and External Temperature to a statistical distribution

$$\begin{bmatrix} hlc_{semidetached\_house} \\ hlc_{detached\_house} \\ \vdots \\ \vdots \\ hlc_{flat\_bottom} \end{bmatrix}$$



# Bayesian models can “generate” data

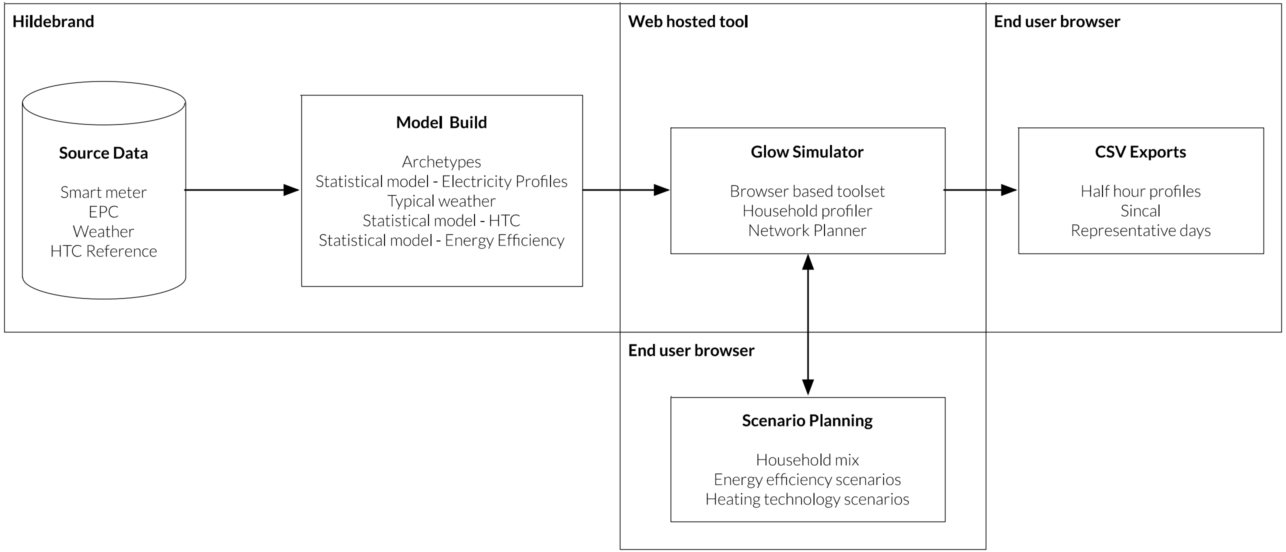
Based on a chosen house type and temperature input, a sample is drawn, this drawing puts diversity into the model

**[ 20, 19, 17, 16, 15 … time series of  temperature**

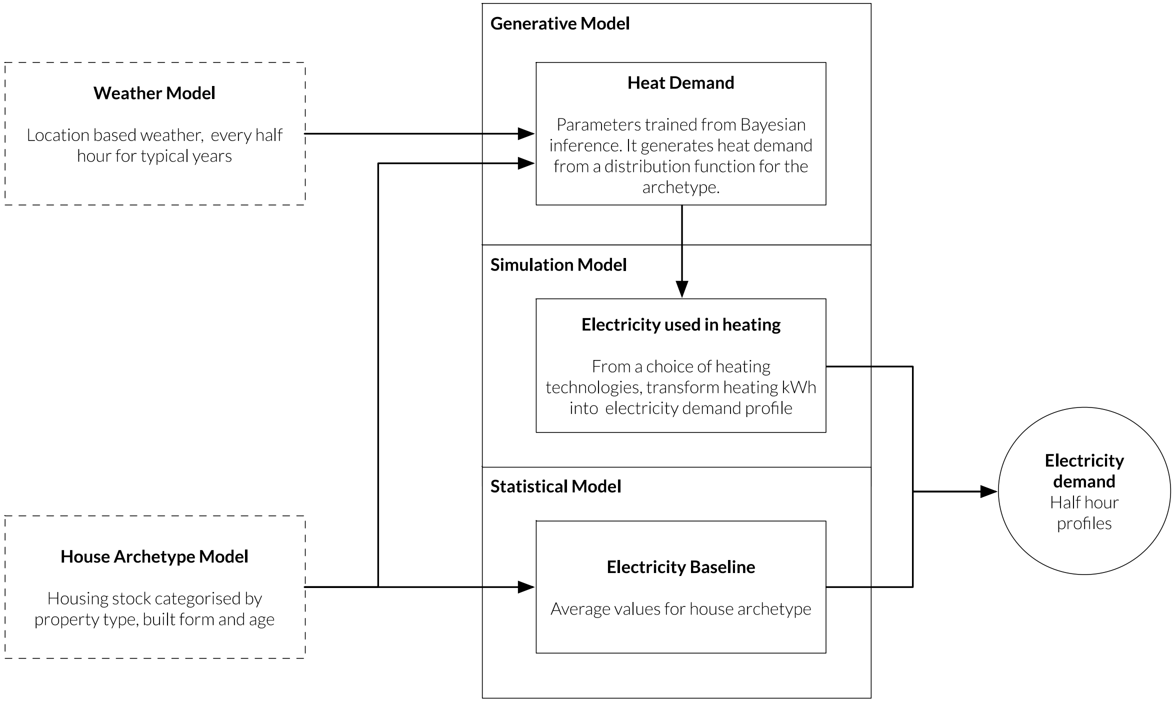
$$hlc * \max(\mathbf{19} - T_{ext}, 0) = Q_{day}$$

**[ 0, 0, 3, 4, 5 … time series of  heat energy**

# Glow simulator is a system that trains models, plans and simulates scenarios



# Glow simulator uses household models and ”sums” them at a network level



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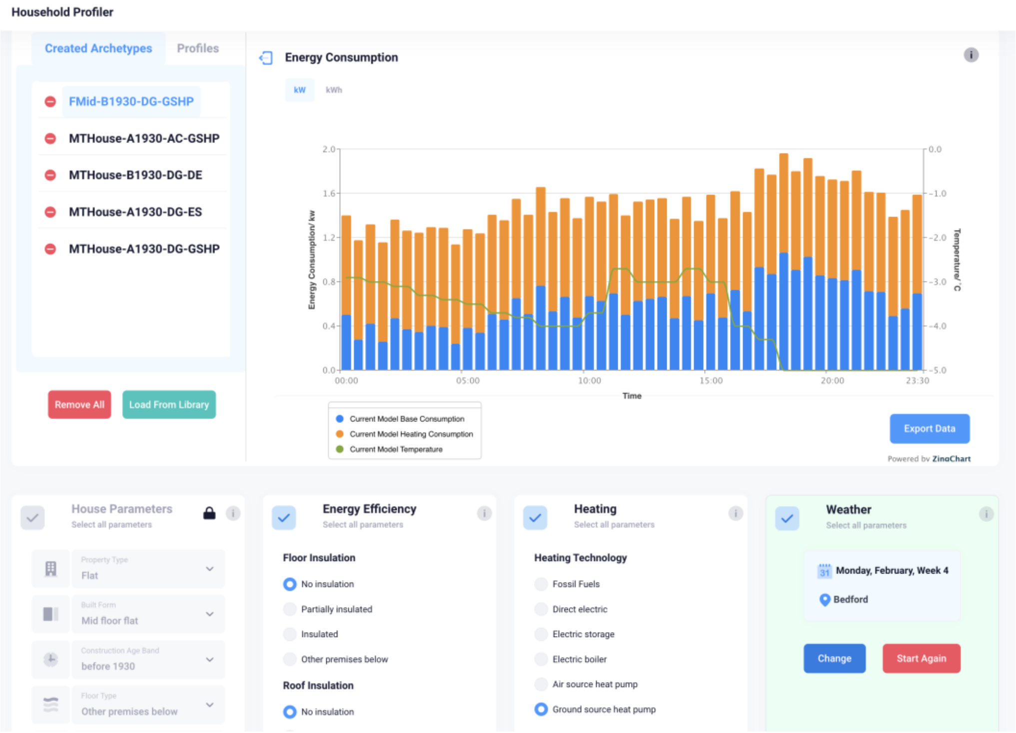
# Demonstration



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# Q&A

## Ask questions using the Q&A option at the bottom of the Zoom webinar window

# 03

# Current and future impact of energy efficiency on electricity networks

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| 03 | SIF follow on project, PIONEER | Alex Whittaker, Frontier Economics<br>Laura Glover, Carbon Trust |
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# Current and future impact of energy efficiency on electricity networks

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# Overview of case study network investigation

Working with:

Derived half-hourly demand profiles for each distribution substation

## GHD scope:

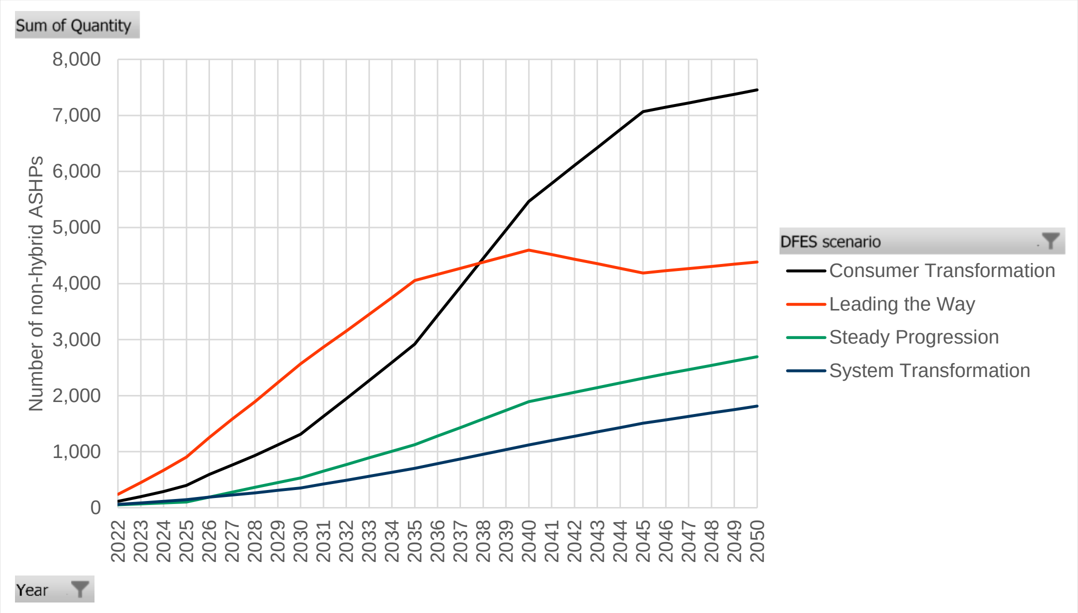
- Literature review
  *…of existing and prospective approaches to modelling impact of energy efficiency measures as part of DNO demand forecasting processes (DFES)*
- Network model validation
  *…preparation and validation of 11kV network models for trial areas*
- Case study investigation
  *…results of network modelling using derived half-hourly demand profiles*

# Overview of case study network investigation

## Modelling assumptions

- DFES Consumer Transformation scenario for HP uptake
  - Carbon Trust assumptions about level of retrofit EE measures applied to housing

- Representative days
  - Intermediate (average autumn/ spring conditions)
  - Winter (average winter conditions)
  - Extreme (1-in-20 winter conditions).



# Overview of case study network investigation

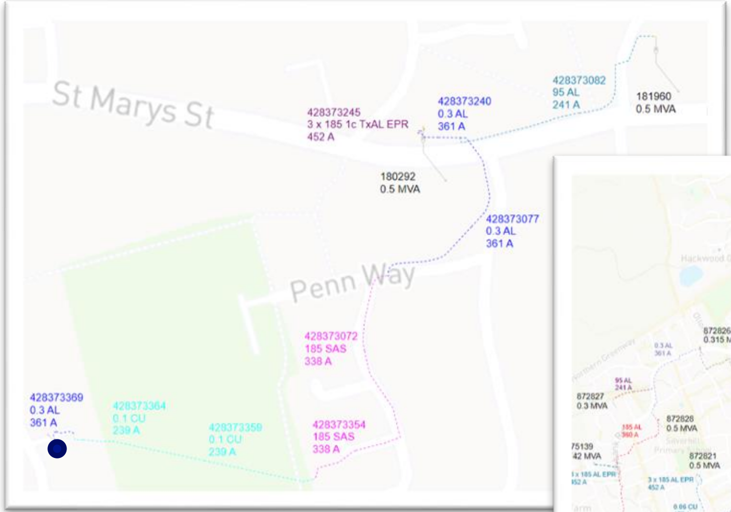
## Case study areas

Three areas:

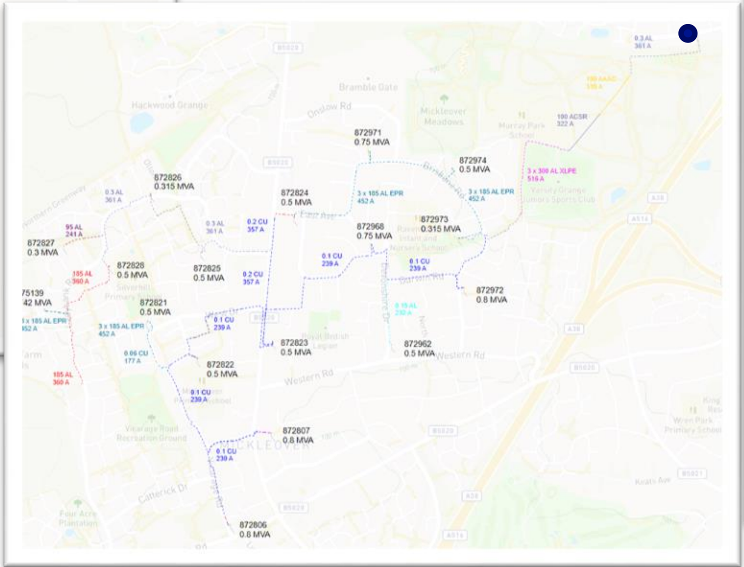
- Axbridge feeder 1 (2 HV/LV substations)
- Mackworth feeder 10 (17 HV/LV substations)
- Withycombe Raleigh feeder 24 (13 HV/LV substations)

# Overview of case study network investigation

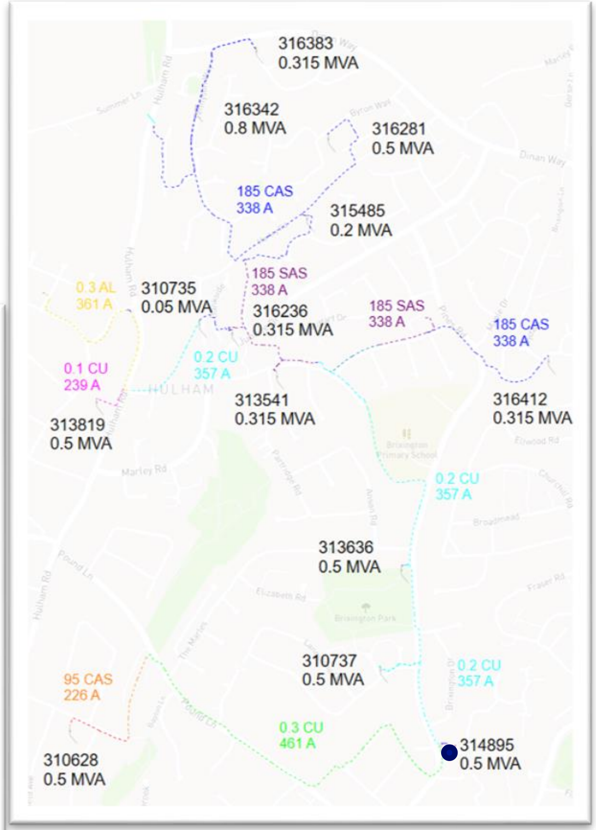
## PSS SINCAL models




Axbridge




Mackworth



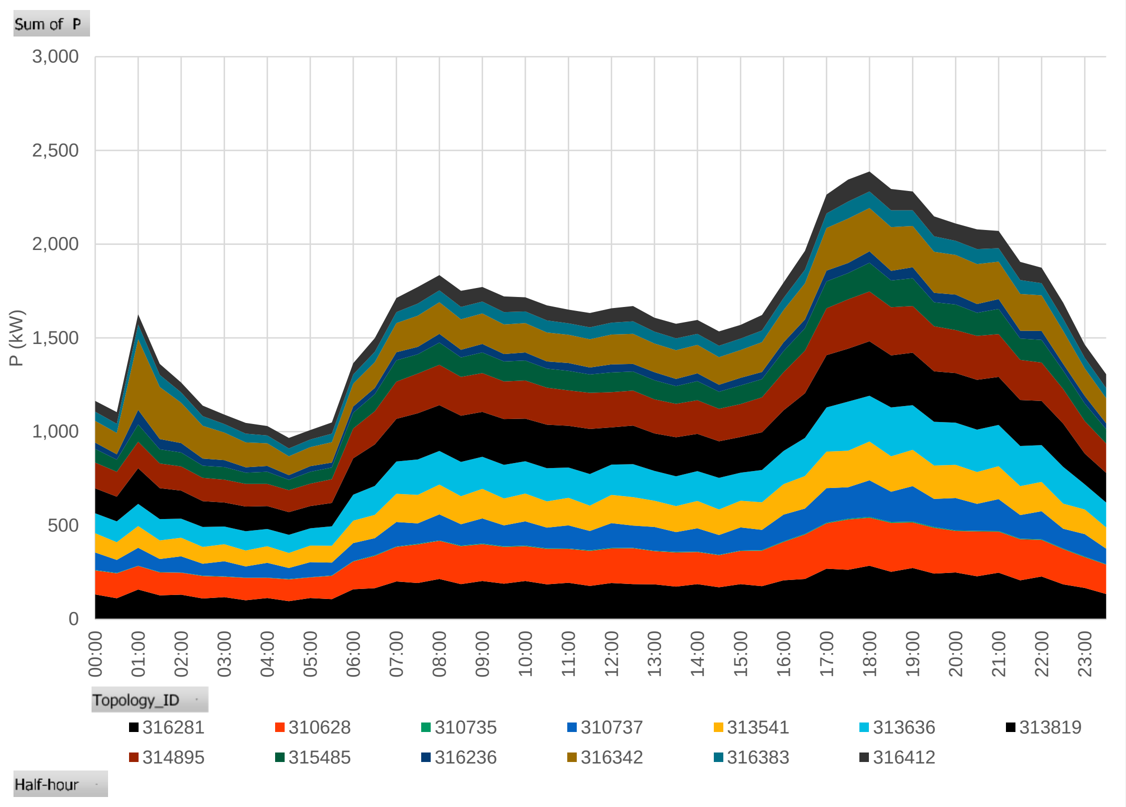

Withycombe Raleigh

# Overview of case study network investigation

## Application of profiles

- Half-hourly profiles applied in a timeseries database file
- Stacked for illustration

| Average per distribution substation | 2022 | 2050 |
|---|---|---|
| Peak demand (kW) | 207.3 | 333.3 |
| Load factor (%) | 60.9% | 76.7% |

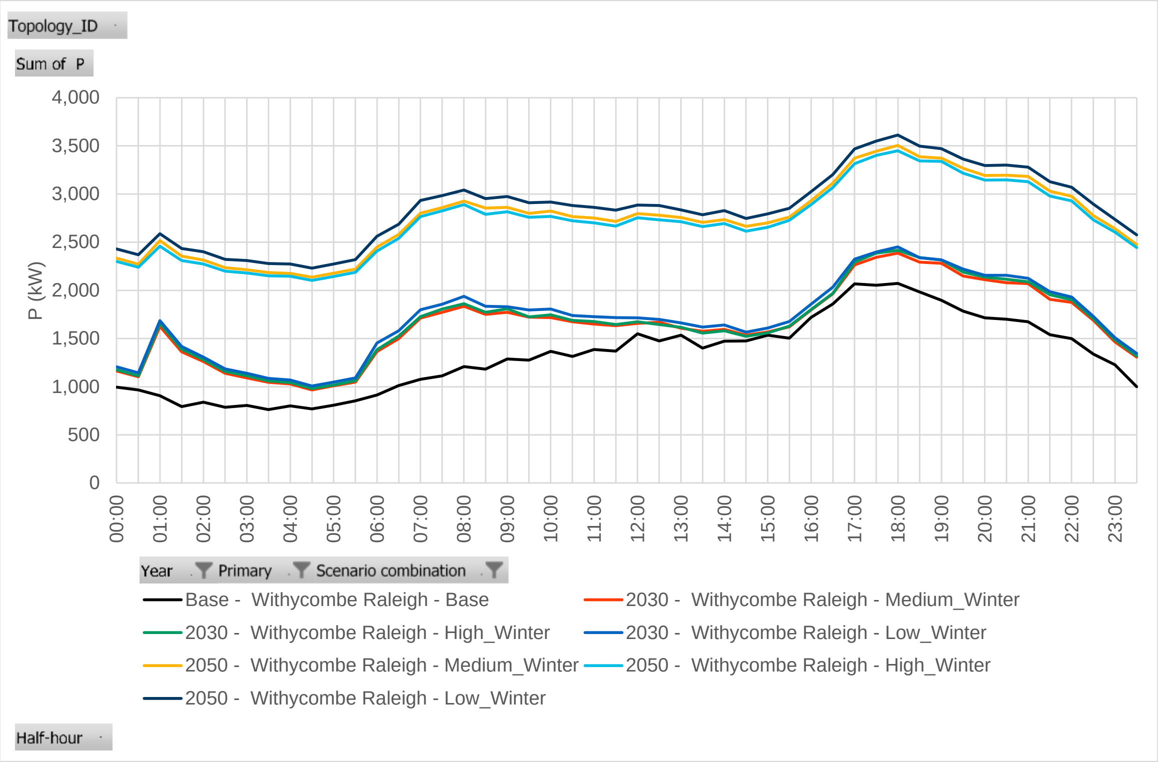



Withycombe Raleigh example (2030, winter, medium EE)

# Overview of case study network investigation

## EE retrofit measures

- Half-hourly profiles (2030, 2050)
  - Include DFES Consumer Transformation HP uptake
  - Differences correspond to low/medium/high scenarios for EE retrofit measures (combined with HP uptake)

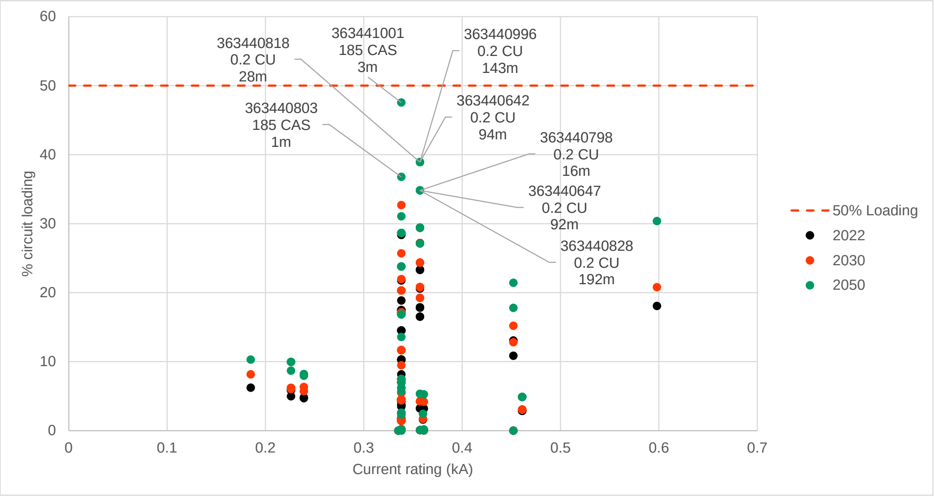



Withycombe Raleigh example (winter day)

# Overview of case study network investigation

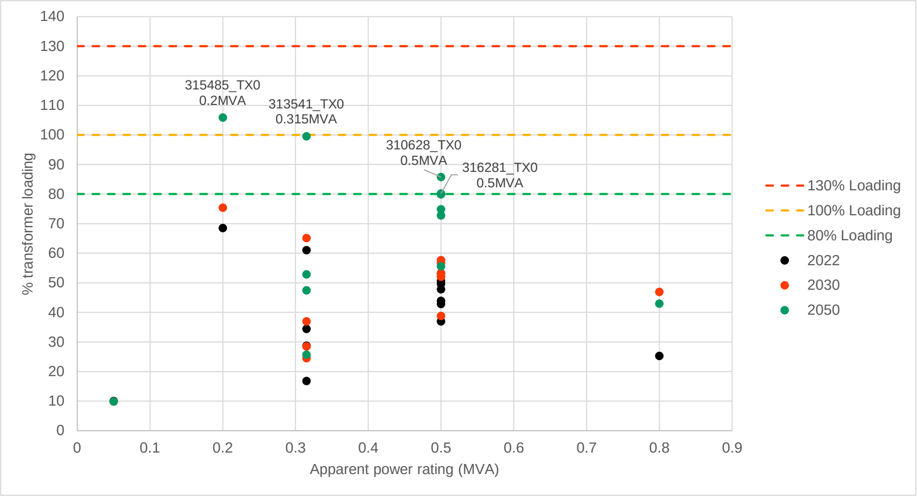
## Circuit loading

50% loading - N-1 threshold (allowing for backfeed of an adjacent HV feeder)




## Transformer loading

- 80% loading – Pro-active replacement threshold
- 100% loading – Nameplate rating threshold
- 130% loading – Cyclic rating threshold




Withycombe Raleigh examples

# Overview of case study network investigation

## Findings

- Limited circuit upgrades required
  - Up to 23 circuits in Mackworth feeder area (out of 123) exceed 50% threshold up to 2050 (based on medium EE, winter day profile)
  - None in Axbridge and Withycombe Raleigh feeder areas
- Limited transformer upgrades required
  - Up to 7 transformers in Mackworth feeder area (out of 16) exceed 80% threshold in 2050 (based on the medium EE, winter day profile)
  - Up to 4 in Withycombe Raleigh feeder area (out of 13)

## Conclusions

- 2030 and 2050 demand profiles illustrate HP uptake and (small) differences between scenarios for EE measures
- Range of planning criteria assessed for illustration, but other factors may apply
- Comparable with alternative approaches, but consider scope
- PSS SINCAL being implemented as 11kV planning tool, with potential to expand into other areas

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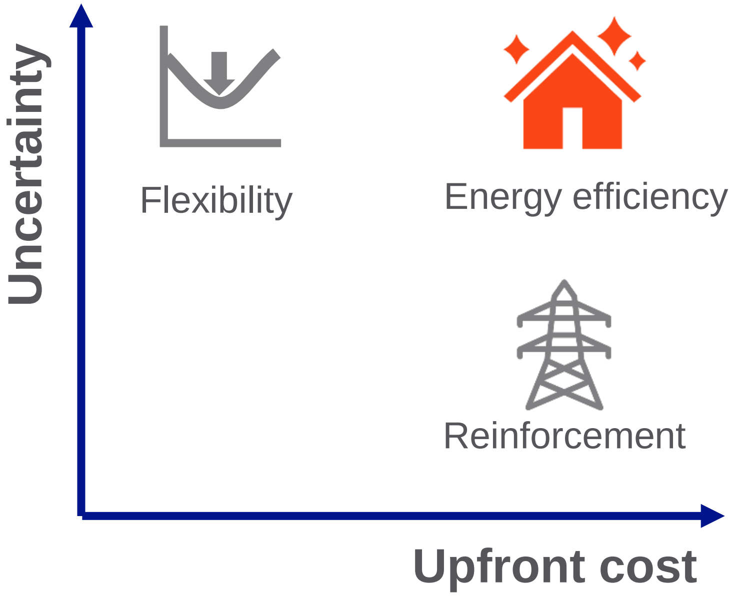
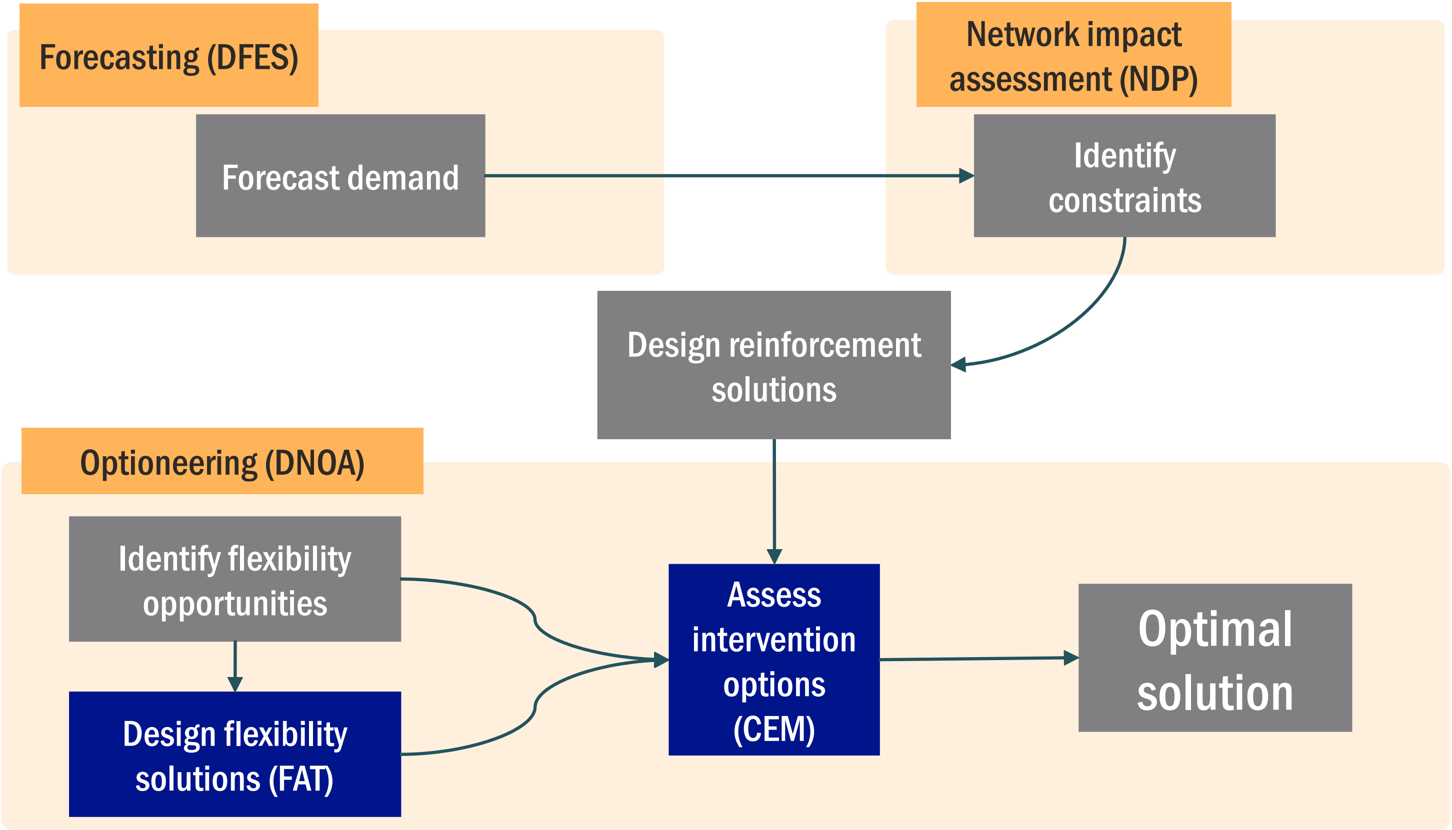
# This work package assessed the business case for such interventions

- Can the procurement of EE services be integrated into the existing processes used by DNOs?
  - Focussed on the 33kV and higher levels of the network, as this is where the majority of strategic planning is currently undertaken.
- Under what conditions, and over what proportion of the network might EE services be cost-effective?
- What types of scheme might be most likely to bring forward any value?

# EE may substitute / complement flexibility and conventional reinforcement



# EE interventions need to be integrated into this process



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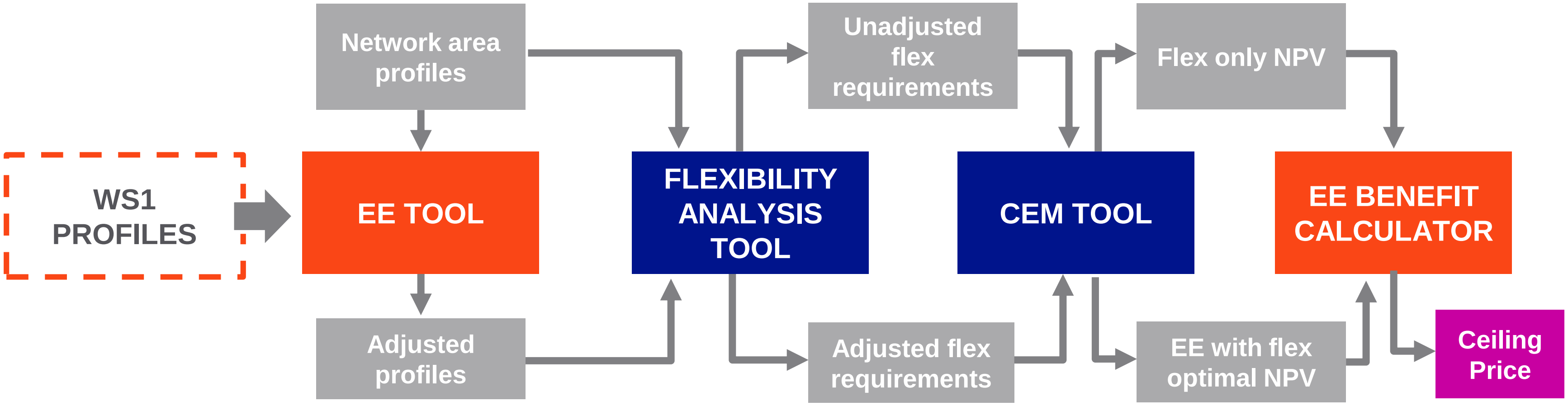
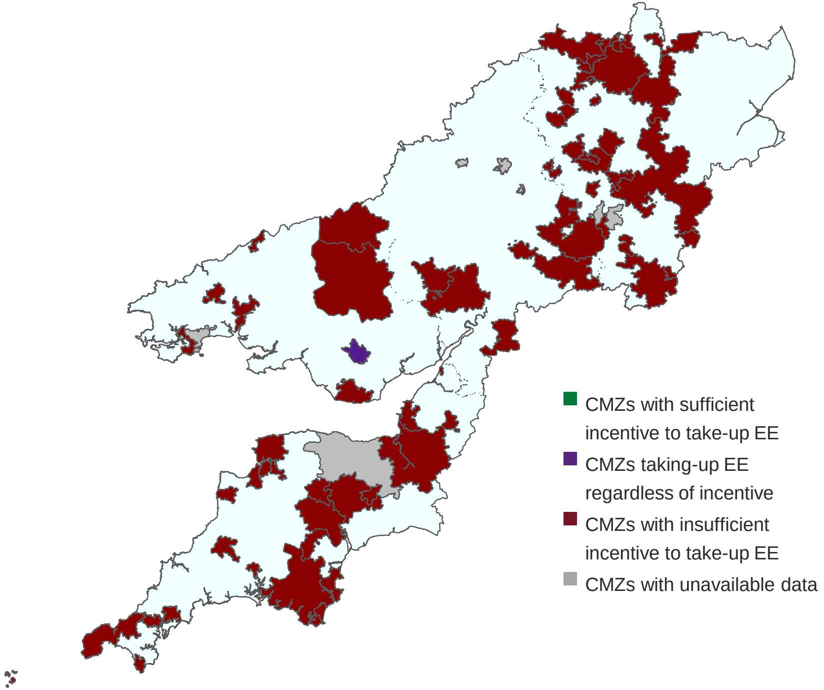


# Ceiling price is mostly driven by reinforcement cost per dwelling – and therefore rurality

| | |
|---|---|
| **Reinforcement cost** | Reinforcement cost per dwelling **typically higher in rural areas** due to long cable distances, single transformer feeders. |
| **Scheme scale** | If reinforcement is due soon, a larger scheme can have a higher ceiling price. |
| **Type of property** | Retrofits like suspended floor insulation can have higher value-for-money. |
| **Rate of demand growth** | Providing demand exceeds network constraints, slower growth extends duration of benefits from EE. |
| **Availability of flexibility** | EE benefits greatest if flexibility available but somewhat limited – but exact effect varies by CMZ. |

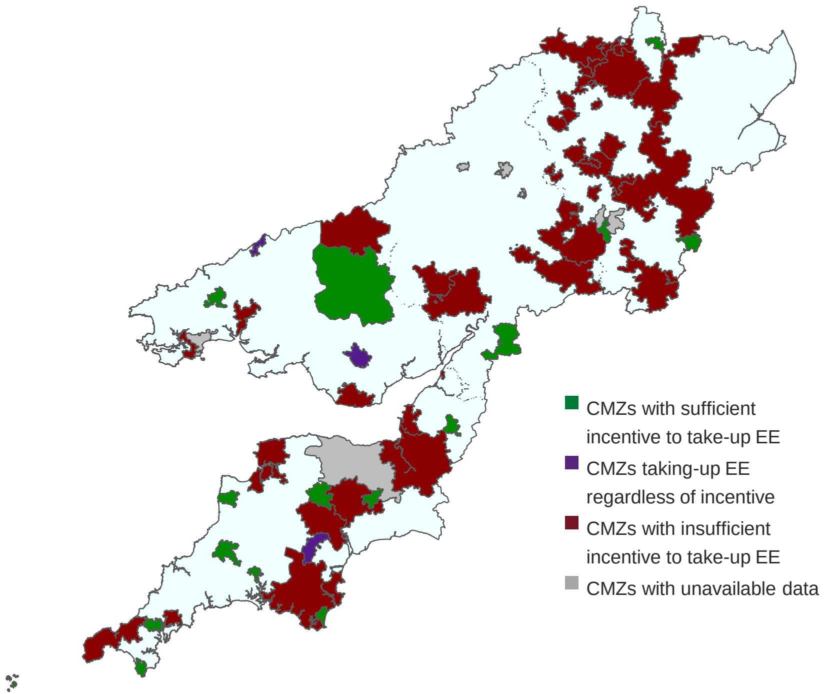
# The ceiling price is low relative to the cost of interventions

- The net cost to the consumer of EE (i.e. costs of retrofit less bill savings) are typically around £2,000.
- The DNO's ceiling price is never more than a few hundred pounds (and often much less than this) as EE does not typically 'buy' many years of reinforcement deferral.
- This shows that it will generally not be cost effective for DNOs to provide large grants for EE.



# In some areas these sums might be sufficient to bring *forward* EE

- If EE measures are installed shortly after ‘fit and forget’ reinforcement, they have no benefit to DNOs.
- So if a DNO can pay to bring forward retrofits that would otherwise have occurred a few years in the future, it may obtain the full benefits at a fraction of the cost.
- We estimated such an intervention *might* provide value in c25% of CMZs – although note there may still be non-monetary barriers that prevent retrofits.



# DNOs may have some scope to stack / reveal additional value

| | |
|---|---|
| **Displaced generation (inc carbon)** | Much greater than value to the DNO. Already reflected in bills to an extent (more with MHHS) – but perhaps not fully valued by consumers? |
| **Capacity adequacy** | |
| **Balancing** | No direct impact of EE on balancing costs. Better insulated homes may enable HP DSR? |
| **Transmission network** | EE measures in import-constrained zones could mitigate costs of constraints – but difficult to see how this could be compensated for. |

# Scheme design could help make the most of the DNO's value

## Bring forward measures that would have occurred later

- Loans rather than grants
- Time-limited offers
- Co-ordinating local partners

## Target non-monetary barriers to take-up

- Spread awareness of benefits & funding
- Partnerships around non-monetary benefits (health / noise…)

## Target electrically heated properties

- Direct electric resistive
- Trigger on HP installation (but need to avoid incentivising HPs in 'wrong' place)

## Target high-value areas and properties

- Value concentrated in small % of areas
- Need to set funding in line with individual performance of properties

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# SIF* PIONEER – Discovery Phase

## DEFENDER

- Demonstrated that EE interventions could be integrated into a DNO's toolkit, but for modest benefit.
- Showed where these benefits are likely to be greatest.
- Identified broad ways in which DNO intervention might help bring forward EE measures.

## PIONEER

- What commercial models could deliver these benefits?
- Trials and monitoring to assess their effectiveness.
- Initial Discovery phase to lay the groundwork and assess feasibility.

** This project is funded by energy network users and consumers through the Strategic Innovation Fund, a programme from the UK's independent energy regulator Ofgem managed in partnership with Innovate UK.*

# SIF PIONEER – Discovery Phase

## Identify trial areas

**WP1**

**Further NGED tool development**

↓

**WP2**

**Demonstrator location long listing**

## Design the scheme to be trialled

**WP3**

**Identify existing and potential funding strategies for fabric retrofit**

**WP4**

**Initial identification of routes for DNOs to impact domestic fabric retrofit**

↓

**WP5**

**Development of the Alpha phase plan**

# SIF PIONEER – Discovery Phase

| | | |
|---|---|---|
| 1 | **Further NGED tool development** | 1. Review of learnings from DEFENDER<br>2. Tool development required for Discovery phase – e.g. ability to summarise and sort CMZs on the basis of factors such as ceiling price and expected HP uptake<br>3. Scoping of potential future tool developments for Alpha / Beta |
| 2 | **Demonstrator location long listing** | 1. Defining the criteria for demonstrator locations (needs to be broadly favourable for EE interventions, but still representative)<br>2. Translating these criteria into quantitative metrics to produce a longlist<br>3. Engaging with local authorities to develop a short list accounting for local funding environment, supply chain etc |

# SIF PIONEER – Discovery Phase

| | | |
|---|---|---|
| 3 | **Identify existing and potential funding strategies for fabric retrofit** | 1. Understand the current investment case for energy efficiency measures<br>2. Understand the current funding landscape that DNOs must be additional to<br>3. Understand the gaps in the current funding landscape, which DNO funding could be targeted towards |
| 4 | **Initial identification of routes for DNOs to impact domestic fabric retrofit** | 1. Identify the key decision makers and decision points in the implementation of domestic energy efficiency retrofit<br>2. Identify novel business models in the UK and internationally which have led to successful implementation of domestic energy efficiency measures<br>3. Complete an initial assessment of the decision points where DNO funding could have maximum impact, which will be taken forward to Alpha |
| 5 | **Development of the Alpha phase plan** | 1. Consolidate findings from WP1-WP4 into a work plan for the Alpha phase, shortlisting demonstrator locations and funding routes to be considered |

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| **03** | SIF follow on project, PIONEER | Alex Whittaker, Frontier Economics<br>Laura Glover, Carbon Trust |
| **04** | Q&A | Nick Devine, National Grid |

# Q&A

## Ask questions using the Q&A option at the bottom of the Zoom webinar window

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