Programme Area: Distributed Energy

Project: Micro DE

Title: Executive Summary - DE2003/D3.5: Modelling the Cost Effectiveness and Hence Potential Uptake of Technologies

Abstract:

Please note this report was produced in 2010/2011 and its contents may be out of date. The objective of the Distributed Energy (DE) Programme is to increase the up-take of DE through the development of integrated systems in order to reduce through-life costs, improve ease of installation and increase efficiency in the combined generation of heat and electricity. Energy consumption within buildings represents the largest single category of final energy use in the UK, with UK residential buildings accounting for ~27% of the UK energy production, ~26% of CO_2 emissions and 23% of GHG emissions. 82% of the energy consumed within UK domestic buildings is for space heating and hot water production. The “Micro DE” FRP (a scoping and feasibility study) was commissioned to understand the range of opportunities to positively impact on energy consumption / CO_2 reduction through technology development and demonstration of building control systems in combination with micro-generation/storage technologies. The project is a feasibility study, with a core element to help shape the benefits case for a much larger project / field trial.

Context:

The project was a scoping and feasibility study to identify opportunities for micro-generation storage and control technology development at an individual dwelling level in the UK. The study investigated the potential for reducing energy consumption and CO_2 emissions through Distributed Energy (DE) technologies. This was achieved through the development of a segmented model of the UK housing stock supplemented with detailed, real-time supply and demand energy-usage gathered from field trials of micro distributed generation and storage technology in conjunction with building control systems. The outputs of this project now feed into the Smart Systems and Heat programme.

ETI Executive Summary

Programme: Distributed Energy

Project Name: Micro DE

Deliverable: DE2003 / D3.5 : Modelling the Cost Effectiveness and Hence Potential Uptake of Technologies

Introduction

The objective of the Distributed Energy (DE) Programme is to increase the up-take of DE through the development of integrated systems in order to reduce through-life costs, improve ease of installation and increase efficiency in the combined generation of heat and electricity.

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The "Micro DE" FRP (a scoping and feasibility study) was commissioned to understand the range of opportunities to positively impact on energy consumption / CO_2 reduction through technology development and demonstration of building control systems in combination with micro-generation/storage technologies. The project is a feasibility study, with a core element to help shape the benefits case for a much larger project / field trial.

The project is split into 4 work packages, represented schematically below:

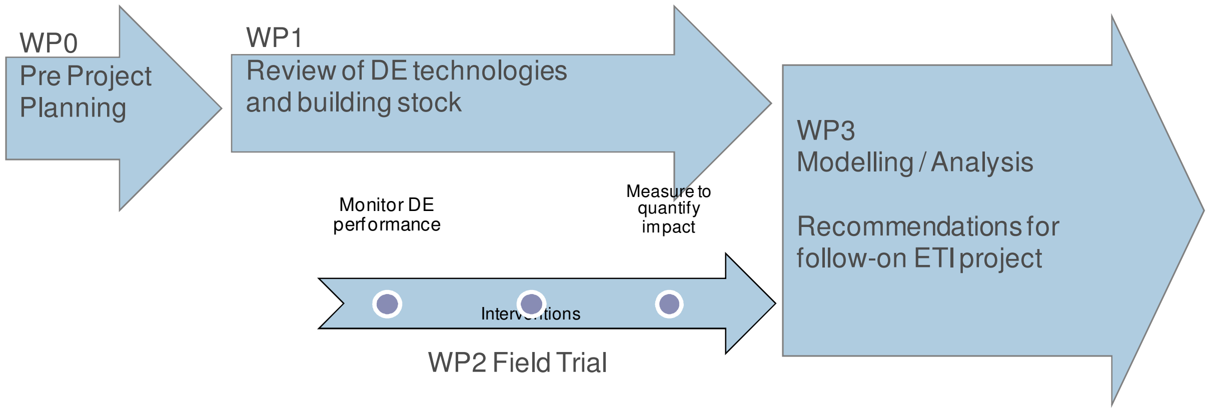

Figure 1: Micro DE Project Structure

The agreed objectives of the project were to deliver the following outputs:

- Evaluation of the potential benefits of current and emerging DE technologies in existing domestic buildings
- Categorisation of
  - The stock of existing domestic UK buildings
  - Building occupants into groups of similar energy use behaviours
  - The main appliance types (energy use patterns, control strategies, etc)
- Evaluation of the platform technologies and standards likely to be used in developing building control systems
- Analysis of the potential benefits of building energy service controls
- Provisional model of existing UK domestic housing stock as the basis for predicting µDE impact out to 2030
- Identification of development and demonstration opportunities [including an outline of how to test these in an appropriate environment]

The objective of the D3.5.1 report is to identify the opportunities to develop µDE and control technologies and quantify the potential impact on UK domestic energy use by 2040. It also addresses the impact of human interaction in the form of 'comfort taking', ie using µDE technologies / improvements in building thermal efficiency to improve occupant comfort through higher internal temperature as opposed to reduction of energy consumption.

Basis of Designs

The output presented in the report is derived from the model developed within the project, the Alpha V6.1: Stock Model. This model is developed across both the Micro-DE project and the ETI 'Optimising Thermal Efficiency of Existing Housing' (OTEoEH) project. The model deliverable from the Micro-DE project (the 'Alpha' model) is the first phase of development, focused on the impact of µDE, the model will be developed further within the OTEoEH project to full account for the effect of building physics and occupant behaviour.

The Alpha model was developed by BRE as an extension of its core BREDAM/SAP model, stock-handling and shell functionality were added by UCL (Alpha V2: Stock). BRE delivered a third version of the model, Alpha V3 to UCL to create the Alpha V6.1: Stock model used for the analysis presented in the D3.5.1 report.

The µDE technologies modelled as part of the project are, in alphabetical order:

- Air source heat pumps
- Biomass boilers
- Ground source heat pumps
- Micro CHP
- Photovoltaics
- Solar thermal
- Wind turbines

The Alpha V6.1 model was used to model 9 scenarios, these were proposed by UCL and agreed with all project participants and the ETI, they are detailed in table 1 and figure 2 below. These scenarios cover a range of future scenarios compared to a Base Case (Now) of no µDE technologies installed in the current built stock.

Three levels of performance would therefore be assessed

- **Physical constraints:** a 100% technology take up where physically possible (e.g. sufficient physical space for ground source heat pump and biomass), no other constraints, installing one technology at a time with optimistic performance assumptions modelled as per BREDEM 2009. Results presented by stock segmentation and technology.
- **Financially and performance constrained:** assumes that µDE is only installed at those properties where an installed system would have a sufficiently short payback period.
- **No uptake:** assumes that no µDE technologies have been installed.

Three time periods were to be investigated:

- **Now:** stock size, levels of insulation, technological performance, costs and CO2 factors are as is at present.
- **Green Deal:** Efficient fabric i.e. thermal efficiency measures applied to every property in the stock; all other factors the same as Now. Measures are applied where physically possible across the stock: hot water tank insulation; loft insulation; floor insulation; new double-glazed windows. Note, no decarbonisation of the grid is assumed for this scenario.
- **2040 Scenario:** Fabric as Green Deal but technology performance improved in line with predictions for 2040. Also, electricity grid carbon intensity, fuel and µDE prices are all as per predictions for 2040.
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	Now	*Green Deal*	*2040*
Optimistic 100% uptake where physically possible	**Base case 100% uptake** 2010 scenario with µDE in properties where physical constraints allow (no financial constraints)	**Efficient stock 100% uptake** Green Deal scenario with thermal efficiency in the whole stock; and µDE in properties where physical constraints allow (no financial constraints)	**2040 100% uptake** 2040 scenario with thermal efficiency in the whole stock; and µDE in properties where physical constraints allow (no financial constraints)
Constrained financially	**Base case constrained** 2010 scenario with µDE in properties where financial and physical constraints allow	**Efficient stock constrained** Green Deal scenario with thermal efficiency in the whole stock; and µDE in properties where financial and physical constraints allow	**2040 constrained** 2040 scenario with thermal efficiency in the whole stock; and µDE in properties where financial and physical constraints allow
No uptake	**Base case** Base 2010 scenario	**Efficient stock** Green Deal scenario with thermal efficiency measures rolled out to the whole stock	**2040** Identical to TE-2010; except that prices are updated to 2040, to use as a benchmark for financial constraints in the £µDE-TE-2040 scenario

Table 1: The Nine Scenarios to be Modelled

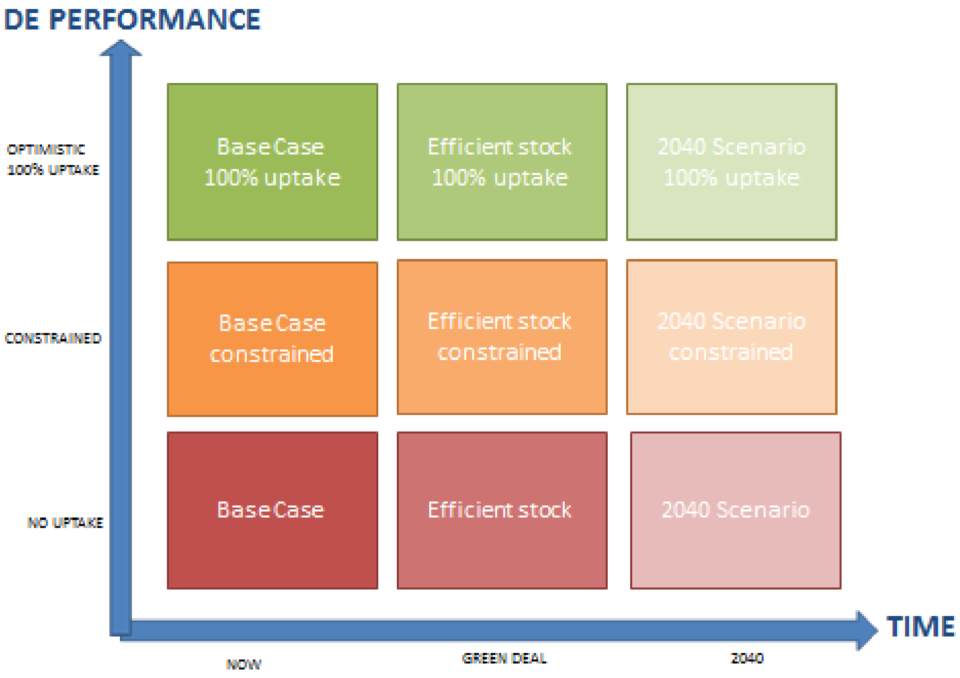

Figure 2: Scenarios Matrix

Within the six scenarios that include µDE deployment (i.e. the orange and green scenarios above), each µDE technology is modelled independently; i.e. there are no combinations of µDE technology, and no changes to occupant behaviour. Two additional runs (Base scenario and Green Deal) were made with comfort take-back temperature algorithms, to assess the effect of those algorithms on the model.

Section 2 of the report summarises the assumptions under which the model runs have been performed, these take in the following constraints

- Building stock
- Technology parameters
- Other modelling assumptions
    - 2010 constraints
        - Technical constraints
        - Financial constraints
- 2040 uptake constraints
    - Technical constraints
    - Financial constraints
    - Time varying assumptions (technological characteristics, CO_2 emissions and prices)
    - System prices
- Internal temperature correction and 'comfort taking

Internal Temperature Correction

The internal temperature correction differs from the base 9 scenarios as follows. The nine scenarios are modelled with a constant internal temperature, the internal temperature correction predicts an internal temperature based on the efficiency of the building fabric and heating system. This is used in two ways:

1) To predict the likely internal temperature experience, and hence give a more realistic estimate of internal temperature
2) Use this estimate of internal temperature to estimate the energy cost of comfort taking when improvements to the building fabric are made.

The impact of this approach is that buildings with poor fabric and inefficient hating systems are more likely to have a colder internal temperature when the external temperature is low. This is modelled using an 'E-value' (the required energy consumption by the principal heating device to maintain a 1ºC temperature difference between outside and inside temperatures during steady state conditions ignoring incidental gains and ventilation heat losses) measured in W/m^2K. Analysis of data from the 1,400 dwellings analysed as part of the Warm Front study established a relationship between dwelling heat transfer characteristics ('E-value') and internal temperatures, as such changes in temperature resulting from changes in the heat transfer characteristics of a building can thus be deduced.

Section 3 of the report presents the results from the model in terms of the 'Green Deal' scenario.

It should be noted that the full level of functionality required to produce the scenarios required additional post processing of data generated by the Alpha model, with Excel (v2007 or later) spread sheets: these spread sheets therefore form part of the model . Future versions of the model may incorporate some of this functionality as part of the core code, rather than post-processing, but the Alpha version of the µDE model was never envisaged to have this functionality.

Results and Key Findings

As indicated earlier the alpha V6.1 version of the model is a preliminary version of the model being developed across both the micro DE and OTEoEH projects, as such the absolute values presented should not be relied upon, rather the differences between base case and the various scenarios are of more value.

Outputs are presented in the following areas:

1) Impact on µDE up-take
2) Impact on grid electricity consumption
3) Impact on gas consumption
4) Impact on CO_2 emissions
5) Impact on fuel costs

Specific outputs for ground source heat pumps are also presented for the current housing stock, thermally efficient housing stock and 2040 stock

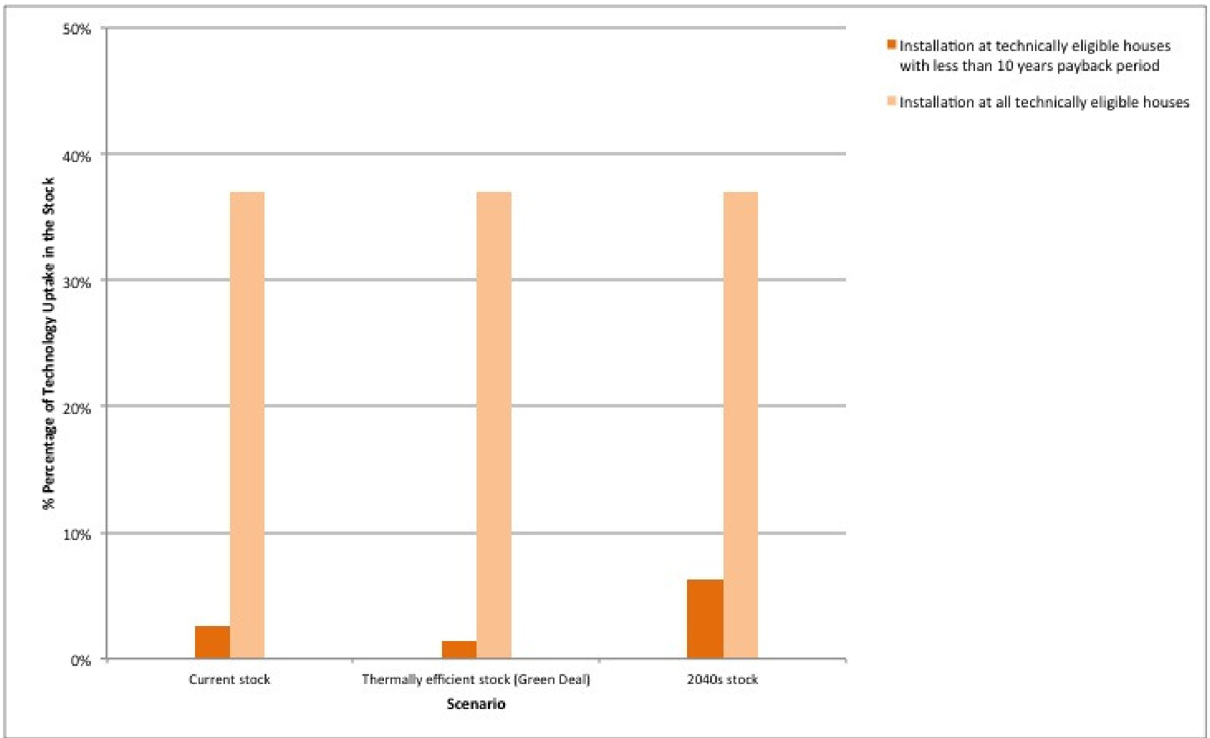

Figure 3: Uptake of ground source heat pumps

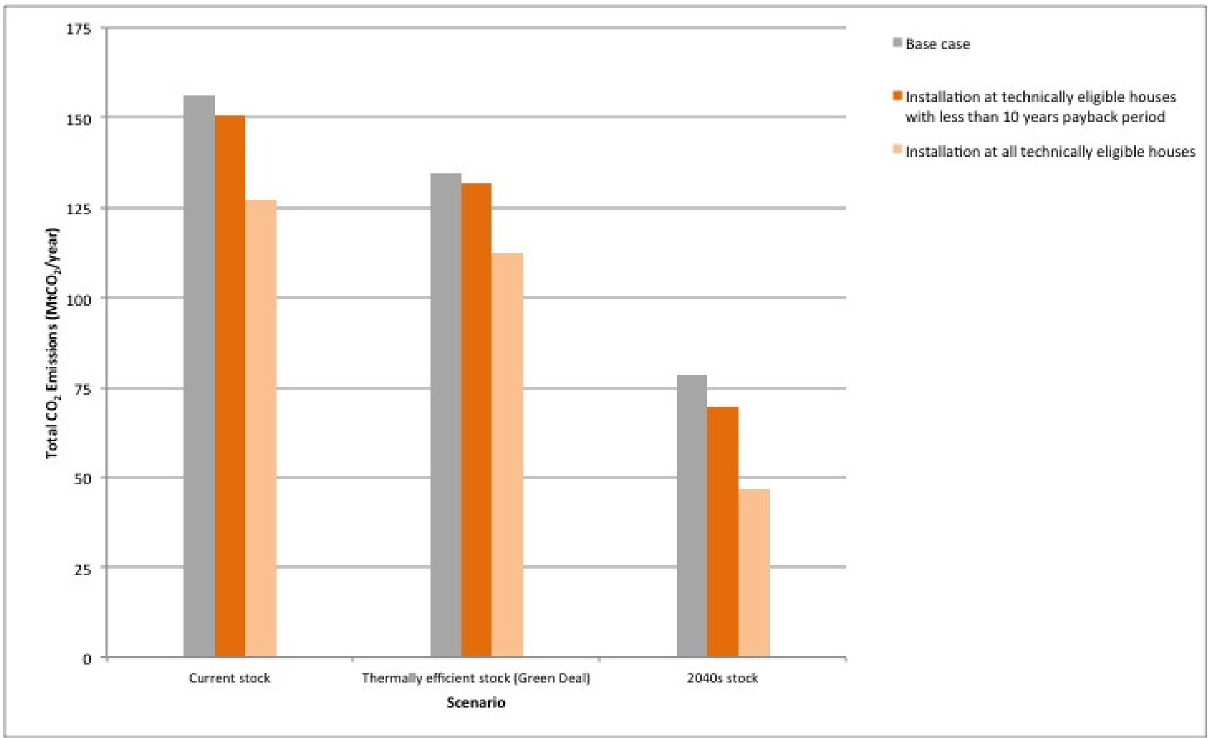

Figure 4: Impact on CO_2 emissions of ground source heat pump uptake

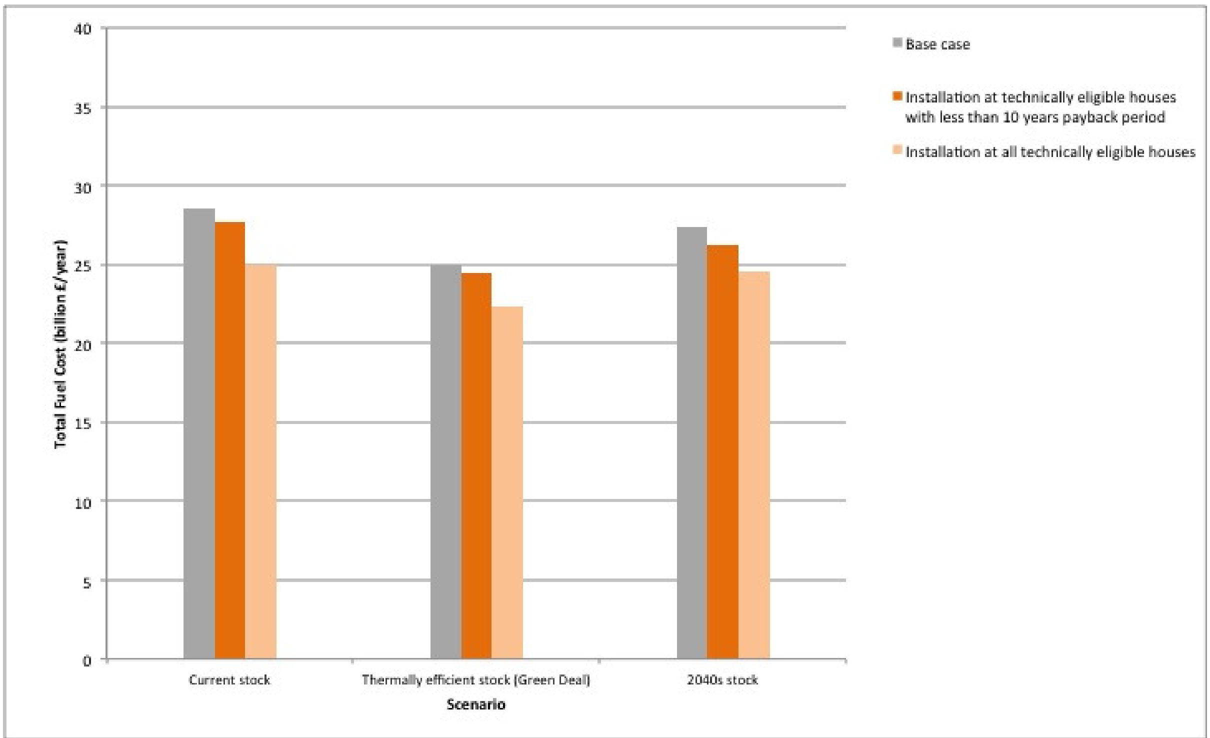

Figure 5: Total fuel cost of domestic ground source heat pumps

Section 3 also includes outputs from the temperature correction algorithm, i.e. the potential impact of comfort taking.

Energy(GW)	Base	Green Deal	Savings
Without temperature correction	67	56	16%
With temperature correction	63	51	19%

Table 2: Energy savings (GW) from the Green Deal, with and without comfort-taking

CO_2 (MT)	Base	Green Deal	Savings
Without temperature correction	147	127	14%
With temperature correction	139	117	16%

Table 3: CO2 savings (MT) from the Green Deal, with and without comfort-taking

The results of the analysis, shown above in tables 2 and 3, illustrate the effect of using this algorithm. Note that the space heating energy demand and CO_2 emissions without the temperature correction are higher than with the correction. The reason for this is due to the lower internal temperature than is typically used in BREDEM. Secondly, the results show higher savings in case of temperature correction between the Base and Green Deal, this is due to the location of the stock along the temperature curve pre and post Green Deal and the 'saturation' point after which no more temperature is taken.

All outputs will be refined further as part of the thermal efficiency project.

Further work

The Micro-DE FRP was originally planned as a pre-cursor to a larger demonstration project focused around µDE, control and storage technologies. Such a project would draw heavily on the experience gained through the execution of the FRP. During the execution of the FRP the strategy of the ETI has developed in this area, to this end it is not planned to have a stand-alone Micro-DE demonstration project, rather this work will be 'bundled' with demonstration projects from other ETI projects in the Distributed Energy, Buildings, Transport and Energy Storage and Distribution programmes. This will potentially form a city scale demonstration project encompassed by the Smart Systems project.

From a µDE perspective, the following aspects need to be considered for inclusion in the Smart Systems project. These have been reviewed and agreed with the Distributed Energy SAG.

- Pre- Installation and Design
  - Integrated assessment of legacy systems including storage, heat exchangers, and control.
  - Monitoring / Diagnostic tools for optimum design of future systems.

- Installed Systems
    - Buildings Energy Management Systems for heat [and electricity], e.g. heat management with zoning.
    - Integrated Micro Distributed Energy Technology Development [e.g. Heat pumps, solar thermal, with storage].
    - Systems optimisation and control tools.
    - Data management, monitoring, and integration with Smart Grid.
    - Condition and feedback monitoring.