# The EDEM methodology for housing upgrade analysis, carbon and energy labelling and national policy development

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## ABSTRACT

The ESRU Domestic Energy Model (EDEM) has been developed in response to demand from policy makers for a tool to assist in analysis of options for improving carbon and energy performance of housing across a range of possible future technologies, behaviours and environmental factors.

A major challenge is to comprehend the large variation in fabric, systems (heating, hot water, lighting and appliances) and behaviours across the housing stock as well as uncertainty over future trends. Existing static models have limited ability to represent dynamic behaviour while use of detailed simulation has been based on modelling only a small number of representative designs.

To address these challenges, EDEM has been developed as an easy to use, Web based tool, built on detailed simulation models aligned with national house survey data. From pragmatic inputs, EDEM can determine energy use and carbon emissions at any scale, from individual dwelling to national housing stock.

EDEM was used at the behest of the Scottish Building Standards Agency and South Ayrshire Council to quantify the impact of upgrades including new and renewable energy systems. EDEM was also used to rate energy/carbon performance of dwellings as required by the EU Directive (EU, 2002).

This paper describes the evolving EDEM methodology, its structure and operation then presents findings from applications.

While initial EDEM projects have been for the Scottish housing stock the methodology is structured to facilitate project development and application to other countries.

## 1. INTRODUCTION

The UK building stock is responsible for over 40% of the country's $CO_2$ emissions. To achieve the Government's target of 60% reduction by 2050 requires implementation of radical upgrades. Domestic energy and carbon calculation methods in current use, such as the Standard Assessment Procedure (SAP; BRE, 2005), are based on simple energy balance methods that do not fully account for the dynamic characteristics of buildings and climates. Neither do they dynamically represent the many different upgrade options that may be applied. As buildings have extended lifetimes, it is important to assess performance under likely future contexts, such as climate change and the introduction of new technologies.

EDEM has evolved from work previously carried out on the assessment of housing upgrades (Clarke *et al*, 2004). Underlying EDEM is the output from simulations of models representing existing dwellings and all possible combinatorial upgrades. Dynamic modelling gives advantages over static calculations, particularly in the areas of ventilation, comfort, controls and renewable energy integration (Tuohy *et al*, 2006a).

EDEM has been designed for use by: policy makers engaged in the development of building regulations in response to national policy drivers; building stock owners/managers to appraise the impact of improvement measures; local authorities in a performance rating context or individual home owners looking to assess potential upgrades.

While the projects reported on in this paper are set in the Scottish built environment, the EDEM methodology is more generally applicable and projects are under development for applications in other countries with significantly different building stock and climate.

EDEM is dependent on background survey data allowing a decomposition of the housing stock into characteristic parameters which can be used to determine energy and carbon performance, in this case the background data describes the Scottish stock.

## 2. SCOTTISH HOUSING

There are around 2,278,000 dwellings in Scotland of which 4% are vacant and 2.5% are due for demolition. The majority of dwellings are either houses (62%) or flats (38%). Over 40% of all dwellings were built within the last 37 years, with 24% constructed between 1945 and 1965.

The 2002 Scottish House Condition Survey (Scottish Homes, 2003) identified 7 predominant house types: Detached, Semi-detached, Terraced, Tenement Flat, Four-in-a-Block, Conversion and Tower/Slab Block.

The 2002 House Condition Survey established a mean NHER rating of 4.5 (on a scale of 0/poor to 10/good) for the Scottish housing stock, with an associated mean SAP rating of 46.5. $CO_2$ emissions were around 16.2 million tonnes per year. By comparison, the 1996 House Condition Survey established a mean NHER rating of 4.1 and a mean SAP rating of 43, indicating a 10% improvement since 1996, with 12% of all dwellings achieving an NHER rating of 7-9 and no dwellings attaining a rating of 10.

From the 2002 survey, around 86% of dwellings have whole house central heating, with a further 8% having partial central heating. This represents a 6% improvement since 1996, with the number of dwellings with no central heating down from 13% to 5.5%. This small but significant figure gives rise to concerns about fuel poverty and the health-related problems associated with hypothermia, condensation and mould growth.

Although around 90% of houses have loft insulation, in only 27% of cases does this meet the 1991 Building Standards (or better).

## 3. STOCK MODELLING

While it is a straightforward task to identify house types from an architecture and construction (AC) viewpoint, the task becomes intractable when viewed thermodynamically. Two separate houses, each belonging to the same AC group, may have substantially different energy consumption patterns as a result of dissimilar energy efficiency measures having been previously applied. (The effects of occupant behaviour are not considered at this point.) Likewise, two houses corresponding to different AC groups may have the same energy consumption (after normalisation relative to floor area) because the governing thermodynamic-related design parameters are the same.

The approach adopted was to operate only in terms of thermodynamic classes (TC) so that different AC types may belong to the same TC. A representative model was then formed for each TC and its energy performance determined by simulation using real, representative weather data. Any actual house may then be related to a TC via the present level of its governing design parameters. Should any of these parameters be changed as part of an upgrade then that house would be deemed to have moved to another TC.

The simulation results for the set of representative models, scaled by the appropriate factors representing their proportion of the overall population, then define the possible performance of the entire housing stock, present and future, for the climate, exposure, occupancy and system control assumptions made within the simulations. By varying these assumptions and re-simulating, scenarios such as future climate change and improved living standard may be readily incorporated.

Performance predictions, in the form of regression equations defining energy use as a function of prevailing weather parameters, are encapsulated within EDEM. The impact of technologies that may be considered independent of house type, such as local or community CHP and the like, were separately modelled within EDEM.

The evaluation of any given upgrading scenario is a three stage process. First, the context for the analysis is set (climate etc). Second, the performance of the existing dwelling (or dwellings) is quantified by assigning the dwelling(s) in question to appropriate TC(s) based on governing parameters, this level of performance is set as the ‘base’ for comparison. Third, the proposed changes in fabric or systems are applied (which brings about its relocation to different TC(s)), the energy and carbon savings through the application of these upgrades is then simply 'read off' (see section 4.4 and figure 1). Because each TC corresponds to a different combination of the governing design parameters, the required upgrade is immediately apparent from the TC relocation.

Within the Scottish housing stock projects, it was ensured that simulations encapsulated the assumptions underpinning the UK's SAP procedure so that EDEM would give equivalent results when in SAP emulation mode (SAP emulation mode is set by selecting appropriate context parameters i.e. climate, grid intensity etc.)

## 4. EDEM FORMULATION

Model formulation can be partitioned into three parts covering context, fabric and systems parameters. Together these allow a user to establish the magnitudes of energy, $CO_2$ and cost savings likely to be achieved via different combinations of the fabric and system upgrades or allow the effects of changes in climate or behaviours to be quantified. The context, fabric and system parameters are described in this section and operation of the tool is illustrated.

The model formulation described here is for the Scottish housing stock projects in EDEM. When EDEM methodology is applied to another country the underlying parameters, simulation models and contexts may be different. The starting point for developing a project is a sound knowledge of the stock to be analysed.

### *4.1 Stage 1: Context Setting*

The context for the calculations captures the occupant behavioural factors and other external environmental factors which form the background to the performance calculations. The principal parameters of which various levels can be selected are: climate, heating demand profile, hot water demand, appliance energy use, grid carbon intensity, fuel costs and capital costs for upgrades. The default setting of the context parameters for the Scottish projects aligns with the assumptions underlying the UK SAP calculations. Contexts can be selected to represent possible future scenarios such as alternate climate or increased internal temperature set-points, increased hot water demand, increased fuel tariffs, reduced grid carbon intensity etc.

The mapping of energy use to CO2 emissions is based by default on current UK normalised figures as published by the Carbon Trust, i.e. 0.42 kg/kWh for electricity and 0.19kg/kWh for gas. The alternative to the default, selectable through the 'grid intensity' context parameter, is a lower carbon grid (0.32 kg/kWh for electricity) consistent with the Governments renewable energy targets. Such parameters may be redefined where EDEM is being applied in a non-UK or other future context.

Default unit costs and standing charges are embedded in the tool based on the standards set for SAP. An option also is a scenario where costs are 2x current levels. Capital upgrade costs are based on current industry costs. Future versions may incorporate financial metrics such as payback and net present value etc.

The calculation of the domestic energy rating band and the associated environmental index, as defined within SAP, is output for both the 'base' and the upgraded case.

### *4.2 Stage 2: Fabric Appraisal*

The ESP-r system (URL1, 2007) was used to determine the fabric-related energy behaviour of standard house designs, corresponding to the different TCs, when each were subjected to long term weather conditions that typify the range of possibilities for Scotland.

The range of designs to be processed were established as unique combinations of principal parameters that were considered to be the main determinants of energy demand and that may be adjusted as part of any upgrade: insulation level (6), capacity level (2), capacity position (3), air permeability (3) and window size (3) when considering large housing stocks; plus exposure (5) and wall-to-floor ratio (2) when addressing individual dwellings. If each of these parameters can exist at the level indicated in parentheses above then there will be 3,240 (6 x 2 x 3 x 3 x 3 x 5 x 2) potential TCs that represent the universe of possibilities. That is, any possible house design, existing or planned, will correspond to a unique combination of these parameters and therefore belong to one, and only one, TC.

It is important to note that most of the TCs do not yet exist because, in general, the Scottish housing stock may be regarded as poor in terms of energy use and carbon footprint. Instead, the majority represent future possibilities that will result from the application of fabric upgrades to the existing stock.

Long term simulations were carried out and the predicted energy demands normalised by floor area to facilitate intercomparison. The TCs were then re-simulated for each of the relevant context combinations

To enable the simulations, a standard house model was constructed comprising living, eating and sleeping areas with appropriate parametric modifications applied to realise the individual TCs. The assumptions underlying this model correspond to an average house as determined from appropriate publications (Bartholomew and Robinson, 1998; BRE, 2005; CIBSE, 1999; Scottish Homes, 2003; Shorrock and Utley, 2003).

### *4.3 Stage 3: Systems Appraisal*

Dwelling energy demands are extracted from the TC simulations as above. Next, heating/cooling, ventilation, hot water, and lighting systems are applied. System type, fuel type and controls are used to set a space heating efficiency value in line with CIBSE and SAP defaults (BRE, 2005; CIBSE, 1999), the BRE Domestic Energy Fact File (Shorrock and Utley, 2003) and the Carbon Trust's Building Market Transformation project database (MTP, 2006). Hot water load is determined in relation to standard domestic system capacities , water usage rates, losses and efficiencies (BRE, 2005), while lighting and appliance energy use are calculated using a standard model for the UK (CSH, 2007). A wide range of fuels and systems are selectable including renewables: mono- or poly-christalline / amorphous PV, micro wind t, solar thermal, air / ground heat pumps, wood / biomass boilers, CHP etc.

### *4.4 EDEM Tool operation and use*

The EDEM tool has been implemented in C++ and is available as a download or a web-tool. Figure 1 shows the main interface and is annotated (A, B,..U) to facilitate description of its operation.

The core of EDEM is the principle that the values of fabric (A), system (B) and context (C) parameters define the current dwelling determinant parameters (D) and performance results (E).

A set of parameters can be 'set as base' (F) and this set of input parameters (G) and results (H) used as the reference against which any changes will be compared.

When parameters are changed from base the new values are reflected in the current determinant parameters (D) and results (E), comparison with base case is shown by the delta (I) and % (J) values.

A data set (inputs, outputs and calculation variable values for the base and improved dwelling) can then be saved (K).

Project selection (L) sets up the appropriate data tables, calculations, parameters and pre-defined dwelling categories (M) for the specified project. The EDEM methodology has been implemented in a structure designed to allow development of new projects that can then be made available for selection through the standard interface (L).

As an alternative for manually setting each of the parameter values for a given property, parameter values can be selected through the pre-defined dwelling categories (M) which have been established to represent the most frequently occurring TCs within the project. Also the parameters can be modified through the fabric (N) or system (O) sliders, moving the sliders to the right incrementally improves dwelling carbon performance.

It is possible to enter more detail than through the primary parameter values (A, B) by selecting the 'detailed inputs' (P) option which opens up a more detailed input screen (Q). In this mode interpolation is used between the results for the simulated TC's to provide the increased resolution. For fabric improvements interpolation is based on calculated area or volume weighted elemental improvements rather than the bundled packages of improvements which the standard inputs allow. The detailed input also allows the user to enter directly parameters such as seasonal efficiency of the heating system, floor area, local wind speed etc. rather than use the inferred defaults. Additional systems such as secondary heating system can also be input at this stage.

It is possible to integrate analysis over a housing stock consisting of multiple dwelling categories with different occurrence using the ‘multi-dwelling’ function (R). Here the base, and improved dwelling and occurrence within the stock is input for each of the categories and then entered, the displayed results then represent the stock average and the saved file contains results by category, total and average.

The results for the base and improved cases can also be displayed real-time in an energy performance certificate format (S, T). This is calculated based on the UK standard calculation methodology in the UK Governments SAP.

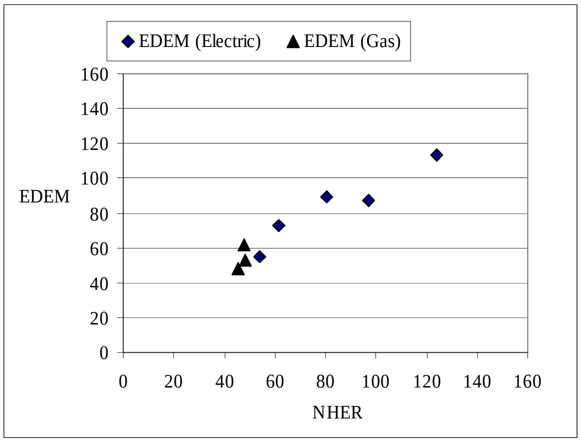
The current version of the tool also displays additional data to provide insight into calculations and parameter settings (U) this may be removed or expanded in future.

## 5. EDEM VERIFICATION

Detailed models of 5 real houses were subjected to simulation, energy efficiency improvements applied and the simulations re-run (such improvements essentially relocating the house to another TC). The houses and their variants were then assigned to a TC based on the level of their governing principal parameters. The predicted heating energy demands resulting from the detailed simulations were then compared to the value associated with the matched TC model. The results indicated discrepancies ranging from 3% to -13%, indicating that the TC approach is a reasonable proxy for the real situation.

A second study compared EDEM output with energy performance as determined using the National Homes Energy Rating (NHER) methodology, which is in common use by UK Local Authorities. A Local Authority Energy Officer carried out detailed surveys using the NHER ‘Surveyor’ tool and in parallel filled out a questionnaire which gathered EDEM inputs. The EDEM tool was used to calculate carbon and energy performance data for both electric and gas systems and the results compared to those from NHER. Acceptable agreement was found as shown in Figure 2.

*Figure 2: $CO_2$ emissions (kg /$m^2$ yr) – EDEM vs. NHER Surveyor.*



## 6. EDEM APPLICATION

EDEM (URL2, 2007) is designed to be flexible in its application. The context is defined, pragmatic input data gathered, a representative TC identified and upgrades/new technologies selected and the outputs expressed in terms of energy, carbon, cost and a ratings label

An application will typically proceed as follows. The context of the analysis is set, e.g. ‘current UK standard’ or ‘2050 climate with high indoor comfort’, and input data entered. The governing parameters are inferred from the input data and an appropriate TC automatically selected The energy demands for the given TC is then determined. This is used as input to the systems appraisal. Next any upgrades are applied and the calculations re-initiated. Finally, the outputs for the various combinations are collated and presented.

Application of EDEM should be combined with an understanding of the stock being studied and scoping of the feasible upgrades for the given situation. Such activities are compatible with the intentions of the EU Energy Performance of Buildings Directive.

### *6.1 National Stock Upgrade*

A digest of the 2002 Scottish House Condition Survey data has shown that the 2,278,000 dwellings in Scotland translate to a total annual space heating demand of 14.5TWh and $CO_2$ emission of 5.5MT. The space heating energy demand equates to 17% of total Scottish demand. The entire national stock can be classified into 3 TCs groups as listed in Table 1.

The largest housing sector is contained within Group 1, which includes TCs associated with unimproved dwellings constructed prior to 1981. This grouping accounts for 11.1TWh of annual space heating energy.

Practical considerations dictate that any upgrading strategy should focus on low cost technologies initially to maximise the return on investment, and be phased over time thereafter to accommodate technical advances. Reducing fabric and ventilation heat loss are the most effective measures to improve dwelling thermal performance and were assessed in this study.

*Table 1: Digest of Scottish dwellings.*

1: high thermal mass, poor insulation, large air change rate
Number of dwellings: 1,594,600
Heating demand (kWh/m$^2$yr): 87

2: standard insulation, large air change rate
Number of dwellings: 660,620
Heating demand (kWh/m$^2$yr): 47

3: high insulation, standard air change rate
Number of dwellings: 22,780
Heating demand (kWh/m$^2$yr): 26

An EDEM analysis indicated that the upgrade strategy should be to target Group 1 dwellings by improving their air tightness to standard (e.g. apply draught proofing to windows and doors) and applying insulation measures to improve insulation to standard (e.g. cavity, internal or external insulation plus double glazing and loft insulation). This will shift these properties to a Group 1 category with an associated saving of 40kWh/m$^2$.

Further analysis indicated that a second upgrade phase should then be carried out to move Group 2 dwellings to Group 3, again by improving insulation and infiltration (in this case improvements should achieve compliance with all elements of 2002 regulations).

The implementation of the first phase of improvement measures were seen to result in savings in the annual space heating energy demand of 4.7TWh (or 33.2% of the national space heating energy demand). This may be achieved by focusing solely on basic upgrades of dwellings in Group 1. In the second phase of the programme, the annual space heating energy savings would rise to 7.36TWh (51.6%) by targeting Group 2 dwellings. Overall, by improving Group 1 to Group 2 and the original Group 2 to Group 3, a phased programme would reduce the annual space heating energy demand of the Scottish housing stock from 14.5TWh to 7.14TWh (i.e. a 51.6% reduction of the space heating energy demand).

### *6.2 Regional Housing Upgrade*

A Local Authority housing stock comprising 7876 dwellings was evaluated using EDEM to determine the impact on the carbon footprint of a range of upgrades.

The housing stock was decomposed into TCs and feasible upgrades identified from Energy Savings Trust publications (EST, 2007) and survey. The upgrades were as follows.

0. The current stock with no upgrades.
1. Low cost fabric improvement. Where there is a pitched roof and a suspended wooden floor then loft insulation is increased to 300mm and suspended floors to 75mm. Dwellings to have basic double glazing and tight infiltration.
2. Major fabric upgrade. In addition to the low cost measures, flat roofs are upgraded to a U-value of 0.16, cavity wall properties have insulation added to give a U-value of 0.35 and solid wall properties are improved to a U-value of 0.6. Windows to a U-value of 1.5.
3. 2007 systems. Gas, electric and solid fuel heating systems are upgraded to condensing, instantaneous water heating boiler, air source heat pump with radiators and wood boilers with 2007 regulation efficiencies.
4. Upgrades 1+2+3.
5. Upgrades 1+2+3 plus solar water heating (920kWh/yr useful energy).
6. Upgrades 1+2+3 plus local generation by either PV or wind turbine (650kWh/yr).
7. Upgrades 1+2 plus CHP (Stirling engine except where >2 storeys then community CHP).
8. Upgrades 1+2 plus biomass (comprising individual or community wood boiler systems).

Figure 3 illustrates the impact of each upgrade option on the carbon footprint. The current carbon footprint per dwelling is 4.9 tonnes of CO$_2$ per year while future scenarios can have < 1 tonne. Further details of the study are reported elsewhere (Tuohy *et al*, 2006b).

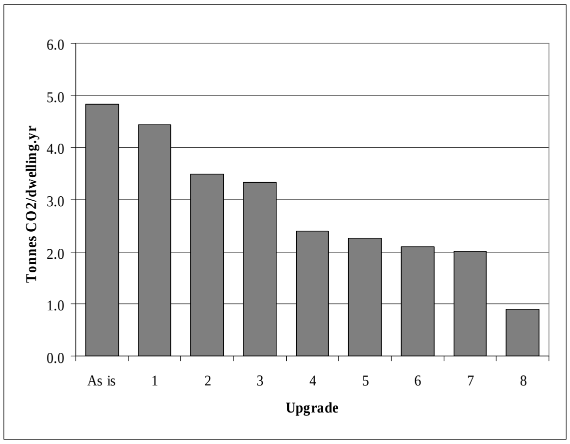


*Figure 3: Upgrade impact on carbon footprint.*

### *6.3 Dwelling Energy Labelling*

EDEM can be used to provide energy performance ratings. In this case the Environmental Index (EI) and Energy Band (EB) are calculated in accordance with a standard UK method (BRE, 2005).

Table 2 shows an example of EDEM when applied to an electrically heated 1980s top floor flat, which has previously been upgraded with cavity wall fill, double glazing and 200mm of loft insulation. The rating of the base property is ‘D’. A number of improvement scenarios were assessed aimed at bringing the fabric up to 2002 standards then applying a system upgrades: condensing boiler, ground source heat pump, community biomass heating, community CHP and a gas condensing boiler combined with solar water heating and PV panel (producing 920kWh thermal and 650kWh of electricity annually). Two options achieved an ‘A’ rating: upgraded fabric with either community biomass heating or a community CHP system.

| Upgrade | kg $CO_2$/yr | EI | EB |
|---|---|---|---|
| 0. As is | 3391 | 57 | D |
| 1. 2002 fabric | 2778 | 66 | D |
| 2. 1+ gas cond. boiler | 1679 | 81 | B |
| 3. 1+ gshp. | 1515 | 83 | B |
| 4. 1+ comm..biomass | 817 | 93 | A |
| 5. 1+ comm gas CHP | 1000 | 98 | A |
| 6. 1+ 2 + PV + solarth | 1454 | 84 | B |

*Table 2: $CO_2$ emissions ($kgCO_2$ / yr), Environmental Index and Energy Band.*

## 7. CONCLUSIONS

A methodology based on a detailed energy simulation program has been applied to a set of house designs corresponding to distinct TCs established to represent the spectrum of house types in Scotland. The outcome has been encapsulated within a Web based tool that supports policy makers concerned with the development of upgrading strategies for the national housing sector or those concerned with enacting energy rating schemes. The EDEM methodology and web tool are designed to allow further applications to be incorporated including application to the housing stock of different countries.

## ACKNOWLEDGEMENTS

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## REFERENCES

Bartholomew D and Robinson D (Eds) (1998). 'Building Energy and Environmental Modelling: Applications Manual 11', CIBSE, London, ISBN 0-900953-85-3.

BRE (2005). ‘Standard Assessment Procedure for Energy Rating of Dwellings’, Building Research Establishment Publication.

CIBSE (1999). 'Environmental Design, CIBSE Guide A, ISBN 0-900953-96-9.

Clarke J A, Johnstone C M, Kondratenko I, Lever M, McElroy L B, Prazeres L, Strachan P A, McKenzie F and Peart G (2004). 'Using simulation to formulate domestic sector upgrading strategies for Scotland', *Energy and Buildings*, 36, pp759-70.

EU (2002). 'On the Energy Performance of Buildings', Directive 2002/91/EC of the European Parliament.

EST (2007). UK Government Energy Efficiency Best Practice Program, www.est.org.uk/bestpractice.

MTP (2006). UK Market Transformation Project, www.mtprog.com.

Scottish Homes (2003). 2002 Scottish House Condition Survey, www.shcs.gov.uk/.

Shorrock L D and Utley J I (2003). Domestic Fact File, BRE Publications, ISBN 1 86081 623 1.

Tuohy P G, Johnstone C M and McElroy L B (2006a). ‘Sustainable Housing Standards: Use of Simulation in Design’ *Proc. Eurosun ’06*, Glasgow.

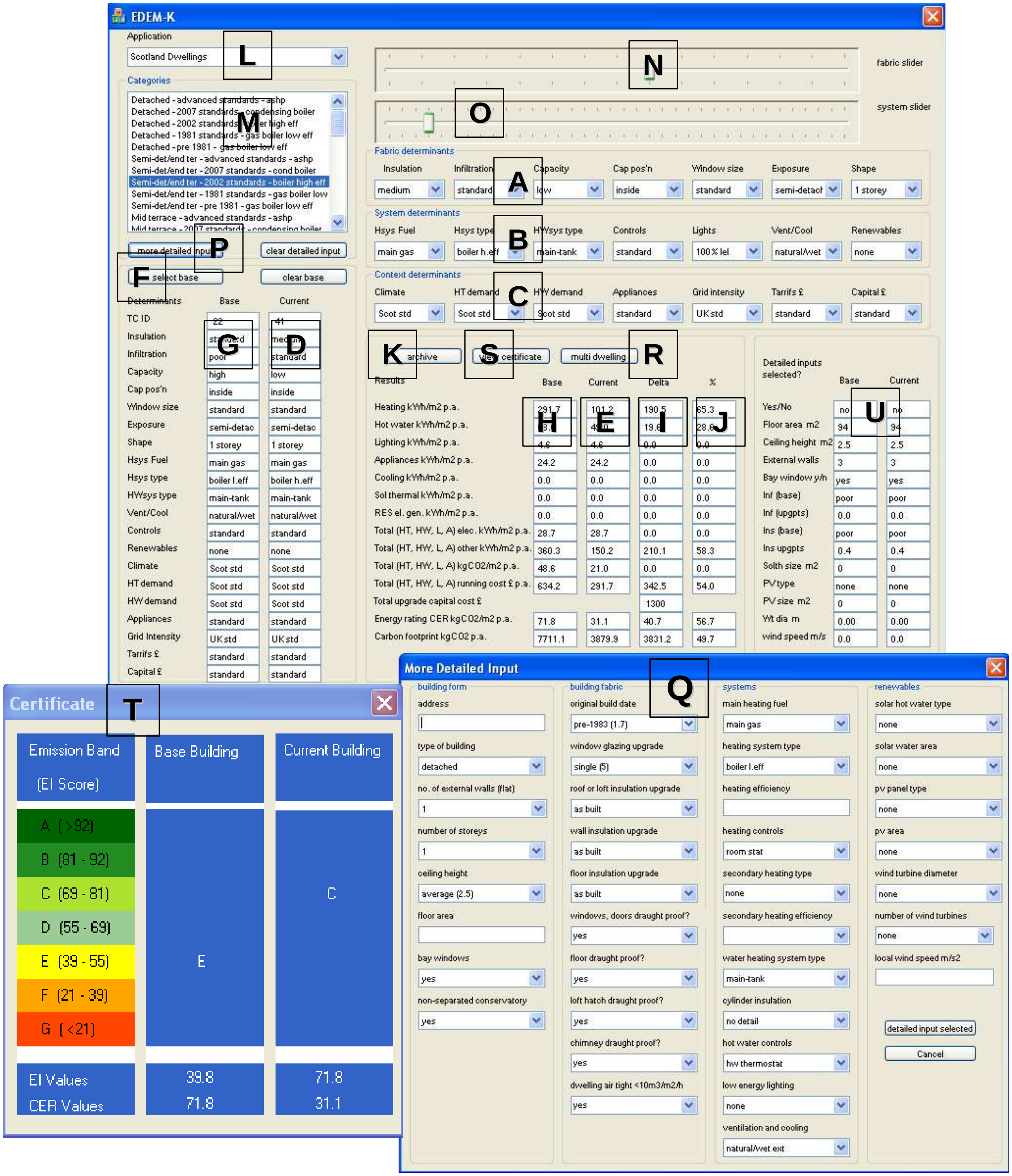
Tuohy P G, Strachan P A and Marnie A (2006b). ‘Carbon and Energy Performance of Housing: A Model and Toolset for Policy Development Applied to a Local Authority Housing Stock', *Proc. Eurosun*, Glasgow.

URL1 (2007). www.esru.strath.ac.uk/Programs/ESP-r.htm.

URL2 (2007). www.esru.strath.ac.uk/Programs/EDEM.htm.

DCLG (2006), ‘Code for sustainable homes’ www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf

*Figure 1: EDEM tool annotated (A,B,C… ,U) to illustrate operation as described in section 4.4*



EDEM-K

Application: Scotland Dwellings

Categories

- Detached - advanced standards - ashp
- Detached - 2007 standards - condensing boiler
- Detached - 2002 standards - boiler high eff
- Detached - 1981 standards - gas boiler low eff
- Detached - pre 1981 - gas boiler low eff
- Semi-det/end ter - advanced standards - ashp
- Semi-det/end ter - 2007 standards - cond boiler
- Semi-det/end ter - 2002 standards - boiler high eff
- Semi-det/end ter - 1981 standards - gas boiler low
- Semi-det/end ter - pre 1981 - gas boiler low eff
- Mid terrace - advanced standards - ashp
- Mid terrace - 2007 standards - condensing boiler

| Determinants | Base | Current |
|---|---|---|
| TC ID | 22 | 41 |
| Insulation | standard | medium |
| Infiltration | poor | standard |
| Capacity | high | low |
| Cap pos'n | inside | inside |
| Window size | standard | standard |
| Exposure | semi-detac | semi-detac |
| Shape | 1 storey | 1 storey |
| Hsys Fuel | main gas | main gas |
| Hsys type | boiler l.eff | boiler h.eff |
| HWsys type | main-tank | main-tank |
| Vent/Cool | natural/wet | natural/wet |
| Controls | standard | standard |
| Renewables | none | none |
| Climate | Scot std | Scot std |
| HT demand | Scot std | Scot std |
| HW demand | Scot std | Scot std |
| Appliances | standard | standard |
| Grid Intensity | UK std | UK std |
| Tarrifs £ | standard | standard |
| Capital £ | standard | standard |

Fabric determinants

| Insulation | Infiltration | Capacity | Cap pos'n | Window size | Exposure | Shape |
|---|---|---|---|---|---|---|
| medium | standard | low | inside | standard | semi-detach | 1 storey |

System determinants

| Hsys Fuel | Hsys type | HWsys type | Controls | Lights | Vent/Cool | Renewables |
|---|---|---|---|---|---|---|
| main gas | boiler h.eff | main-tank | standard | 100% lel | natural/wet | none |

Context determinants

| Climate | HT demand | HW demand | Appliances | Grid intensity | Tarrifs £ | Capital £ |
|---|---|---|---|---|---|---|
| Scot std | Scot std | Scot std | standard | UK std | standard | standard |

| Results | Base | Current | Delta | % |
|---|---|---|---|---|
| Heating kWh/m2 p.a. | 291.7 | 101.2 | 190.5 | 65.3 |
| Hot water kWh/m2 p.a. | [illegible] | [illegible] | 19.6 | 28.6 |
| Lighting kWh/m2 p.a. | 4.6 | 4.6 | 0.0 | 0.0 |
| Appliances kWh/m2 p.a. | 24.2 | 24.2 | 0.0 | 0.0 |
| Cooling kWh/m2 p.a. | 0.0 | 0.0 | 0.0 | 0.0 |
| Sol thermal kWh/m2 p.a. | 0.0 | 0.0 | 0.0 | 0.0 |
| RES el. gen. kWh/m2 p.a. | 0.0 | 0.0 | 0.0 | 0.0 |
| Total (HT, HW, L, A) elec. kWh/m2 p.a. | 28.7 | 28.7 | 0.0 | 0.0 |
| Total (HT, HW, L, A) other kWh/m2 p.a. | 360.3 | 150.2 | 210.1 | 58.3 |
| Total (HT, HW, L, A) kgCO2/m2 p.a. | 48.6 | 21.0 | 0.0 | 0.0 |
| Total (HT, HW, L, A) running cost £ p.a. | 634.2 | 291.7 | 342.5 | 54.0 |
| Total upgrade capital cost £ | | | 1300 | |
| Energy rating CER kgCO2/m2 p.a. | 71.8 | 31.1 | 40.7 | 56.7 |
| Carbon footprint kgCO2 p.a. | 7711.1 | 3879.9 | 3831.2 | 49.7 |

| Detailed inputs selected? | Base | Current |
|---|---|---|
| Yes/No | no | no |
| Floor area m2 | 94 | 94 |
| Ceiling height m2 | 2.5 | 2.5 |
| External walls | 3 | 3 |
| Bay window y/n | yes | yes |
| Inf (base) | poor | poor |
| Inf (upgpts) | 0.0 | 0.0 |
| Ins (base) | poor | poor |
| Ins upgpts | 0.4 | 0.4 |
| Solth size m2 | 0 | 0 |
| PV type | none | none |
| PV size m2 | 0 | 0 |
| Wt dia m | 0.00 | 0.00 |
| wind speed m/s | 0.0 | 0.0 |

More Detailed Input

building form

| | |
|---|---|
| address | |
| type of building | detached |
| no. of external walls (flat) | 1 |
| number of storeys | 1 |
| ceiling height | average (2.5) |
| floor area | |
| bay windows | yes |
| non-separated conservatory | yes |

building fabric

| | |
|---|---|
| original build date | pre-1983 (1.7) |
| window glazing upgrade | single (5) |
| roof or loft insulation upgrade | as built |
| wall insulation upgrade | as built |
| floor insulation upgrade | as built |
| windows, doors draught proof? | yes |
| floor draught proof? | yes |
| loft hatch draught proof? | yes |
| chimney draught proof? | yes |
| dwelling air tight <10m3/m2/h | yes |

systems

| | |
|---|---|
| main heating fuel | main gas |
| heating system type | boiler l.eff |
| heating efficiency | |
| heating controls | room stat |
| secondary heating type | none |
| secondary heating efficiency | |
| water heating system type | main-tank |
| cylinder insulation | no detail |
| hot water controls | hw thermostat |
| low energy lighting | none |
| ventilation and cooling | natural/wet ext |

renewables

| | |
|---|---|
| solar hot water type | none |
| solar water area | none |
| pv panel type | none |
| pv area | none |
| wind turbine diameter | none |
| number of wind turbines | none |
| local wind speed m/s2 | |

Certificate

| Emission Band (EI Score) | Base Building | Current Building |
|---|---|---|
| A (>92) | | |
| B (81 - 92) | | |
| C (69 - 81) | | C |
| D (55 - 69) | | |
| E (39 - 55) | E | |
| F (21 - 39) | | |
| G (<21) | | |
| EI Values | 39.8 | 71.8 |
| CER Values | 71.8 | 31.1 |