MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT THE GLASGOW SCHOOL OF ART

MEARU

ENERGY CONSUMPTION WYNDFORD ESTATE

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1. Project Brief

In 2008 The Mackintosh Environmental Architecture Research Unit (MEARU) undertook a feasibility study for CUBE Housing Association which investigated upgrade options for the housing stock on the Wyndford estate that would improve thermal efficiency and reduce energy consumption. As well as improvements in insulation levels, the recommendations also included the installation of a district heating system. In the study MEARU took 5 typical house types from the Wyndford estate and calculated theoretical energy consumption figures for the existing blocks and proposed upgrades with predicted energy loads. A key aim of the 2008 report was to propose methods to enhance thermal comfort and affordability, simultaneously improving health and well-being and minimising, if not eliminating, fuel poverty. MEARU worked with a Quantity Surveyor to evaluate the most cost effective options- at that point, external insulation was considered prohibitively expensive and therefore was not included in predicted energy calculations. CUBE HA subsequently undertook a series of upgrades to the building fabric and to the heating provision within the residential blocks across the estate.

A comprehensive programme of improvements is now nearly completed and in May 2015 CUBE HA commissioned a further study by MEARU to evaluate the impact of the retrofit upgrade and district heating system on energy use and affordability. This includes an analysis of recent fuel consumption data obtained from the Scottish and Southern Energy (SSE) who manage the district heating system on Cube HA's behalf, to assess the impact of the upgrades on the resident's fuel bills. This paper reports the initial evaluation of heat energy consumption and highlights the improved energy performance by comparing the 'before refurbishment' theoretical energy consumption value with the recorded data provided by SSE. The report also compares the cost per kWh from the 'before refurbishment' scenario with the 'after' scenario to quantify the resident's cost savings.

Later phases of the study aim to identify other possible reasons for the energy consumption by a more targeted period of monitoring of residents homes and undertaking survey work to gain qualitative data.

2. MEARU's Energy Feasibility Study 2008

MEARU's initial energy feasibility study explored practical and economic means of upgrading the residential housing stock within Wyndford estate. It provided retrofit scenarios to enhance thermal performance meeting particular minimum standards such as the Scottish Quality Housing Standard (SHQS) and the Energy Savings Trust (EST) Best Practice Refurbishment; and, where practical, moving towards German 'Passivhaus' compliance. The report identified a series of upgrades including recommendations for affordably improving the thermal envelope as well as providing new heating systems and enhanced means of ventilation.

Existing energy consumption for the existing scenario of the 5 house types was generated using BREDEM analysis to provide a breakdown of estimated space heating loads and norms for domestic hot water and electricity use (regulated and unregulated). BREDEM (BRE Domestic Energy Model) is the name given to a family of simple but reliable energy calculation procedures for dwellings. It was first developed in the early 1980s and, as a result of continuous testing and development, it has become very widely used. It can be used to estimate energy requirements in different dwelling types. See Appendix A for sample method of calculation.

In this report the existing (before refurbishment) values are compared with the measured data (annual heat energy consumption) supplied by SSE.

The 2008 report identified 5 house types across the Wyndford estate as follows:

- House type 1- 26 storey multi storey flats
- House type 2- 15 storey multi storey flats
- House type 3- 8 storey multi storey flats
- House type 4- 4 storey maisonettes
- House type 5- 9 storey multi storey flats

This characterisation of house types by block type is used in this report. However this report also identifies the variations in flat types by number of bedrooms in order to identify energy consumption differences between 1, 2 and 3 bedroom flats. In addition the analysis identifies variations in charges between rented accommodation and those which are privately owned but are connected to Cube HA's district heating system.

3. Wyndford Housing Stock Upgrades

Cube HA undertook a programme of upgrades to the building fabric over a 5 year period commencing in 2009. The high rise blocks have undergone a programme of overcladding which includes improving the thermal performance of the external envelope with 100mm of rigid insulation faced with coloured render. High performance double glazed windows (and balcony doors) with a U-value of 1.8 W/m^2K have also been installed on all high-rise blocks. These improvements will substantially reduce heat losses and reduce air permeability to which high rise blocks can be particularly susceptible.

In addition to the fabric upgrades CUBE HA installed a 1.2 MW CHP heating system. The original electric night storage heating in the multi-storey and low rise housing was very expensive and uncontrollable and during the late 2012 and early 2013, this was replaced by a district heating system which provides heating and hot water. The plant is a gas-fired Combined Heat and Power generator located on the estate, which distributes heat via hot water pipes across the scheme and heat is delivered to the dwellings via a wall mounted heat exchanger which in turn supplies modern slim line radiators with thermostatic radiator valves (TRV's) as part of a wet central heating system. These allow the resident greater control of temperatures in each room together with a central timer to allow regular heating patterns to be set to suit the occupants. Radiators have been installed in all rooms (except kitchens). Overall the new heating and hot water system allows the resident greater control over their heating and gives more instantaneous heat than the previous storage heater system. The old heating system used electric heating, based on 'on peak' and 'off peak' tariffs. Many residents were previously dissatisfied with the electric heating, which was perceived as ineffective and expensive.

All of the properties within Wyndford owned by Cube Housing Association have been connected to the district heating system and 266 privately owned houses (mainly in the maisonettes) also took up the offer of free connection to the new district heating system; assisted by grant funding secured through support from the Scottish Government and Glasgow City Council. The network is supplied by a 1.2MW gas CHP engine with three 4.5MW backup/peaking gas boilers, and a thermal store (120,000 litres). Electricity from the CHP is not supplied specifically to the estate but is exported via the public network. SSE operates and maintains the heating system, and provides metering and billing services, under a long term contract with Cube.

Some households have a credit meter and either pay by direct debit or periodic billing (such as quarterly). Others have a system similar to a prepayment meter in that they charge up their meter using a 'key' at a local shop. Like a prepayment meter, this system is designed to cease supply automatically if the balance on the meter falls into debt. In contrast with prepayment systems, however, the rate at which payments run down depends not on how much heat is used at any one time, but is set at a fixed rate designed to spread the household's annual heating bill evenly through the year. Initially this rate was based on SSE's estimate of annual consumption for different types of home, and it is revised periodically to reflect actual consumption patterns.

4. Methodology

Annual energy consumption (heating and hot water) data was provided by SSE – energy data from 1,690 properties in total. The data was provided in postcode/ house code format rather than by house address in accordance with Data Protection legislation. The data provided by SSE was from January 2014 until March 2015, while that used in this report is extracted for the 12 month period from January-December 2014. These were then cross referenced with Cube HA database of house types and averaged on a block-by-block basis.

All the blocks had completed their refurbishment works during the 12-month period from January-December 2014, and so a reasonably accurate 'before' and 'after' scenario comparison could be made.

This data has been sorted into individual blocks to allow CUBE HA to assess the different energy demands in each flat type within each block. The data has been recorded from heat meters within each individual flat - these record the energy supplied to the dwelling for the wet central heating system and the hot water, but does not differentiate between the two uses. There is no data for electrical energy use as each resident has their own supplier (and private contract with that energy supplier which is subject to data protection).

The data set was reviewed to identify any outliers - the studio flats are regularly available for let and are therefore often empty for short periods of time. Therefore any data which has 2 consecutive zero readings during the heating season (Sept to May) are excluded from this dataset to account for void or partially void flats. An average value for each house type (including variations in flat size) has been calculated and compared against the estimated annual energy consumption figure for the 'before refurbishment' scenario prepared by MEARU in 2008. A percentage improvement figure is highlighted in the table of results. NB- not all flat types were included in the 2008 study therefore where there is no 'before' figure the entry in the table is noted with an '*'.

The annual heat energy costs for each house type have been calculated using SSE tariffs and the standing charge rates applicable for both rented and owner occupied homes. An average monthly cost is indicated together with a typical winter month (January). The costs have been calculated based on SSE's current tariff unit rate of 5.22 p/kWh and fixed charges at 41.3323p/day (as of June 2015).

A tariff to reflect the previous electricity rate (for the storage heaters) has been applied to the theoretical energy consumption figures for the 'before refurbishment' scenario to calculate an indicative 'before' cost. This is then compared with the current annual energy cost and a percentage improvement figure is generated.

The report concludes with explanations of the resultant energy consumption and cost figures and makes suggestions for future in depth study to identify causes of trends.

5. Energy Analysis by House type

5.1 House type 1 - 26 Storey Blocks (4 number blocks, Total - 600 flats)

March 2008- 26 storey block prior to refurbishment May 2015- 26 storey block after refurbishment

Image 1- 26 storey block, Wyndford Road 'before' and 'after' refurbishment.

In the 26-storey block there are 6 flats on each landing; four 1-bedroom flats, and two studio flats. The studio flats are regularly available for short-term lets and therefore have a high turnover of occupants and are often empty for short periods of time. This has been accounted for in the energy calculations to ensure that the average consumptions are not lower than expected.

These blocks have undergone thermal upgrading works including improving the performance of the external envelope with 100mm of rigid insulation (Rockwool – Eco Rock) faced with coloured render. High performance double glazed windows (and balcony doors) with a U-value of 1.8 W/m^2K have also been added. The original electric storage heaters have been replaced by modern slim line radiators with thermostatic radiator valves (TRV's) and programmable domestic system controls, as part of a wet central heating system. These allow the resident greater control of temperatures in each room together with a central timer to allow regular heating patterns to be set to suit the occupants.

As evident from *Image 1* above, the aesthetic improvement to the high rise blocks is significant, the bright fresh render is a welcome change to the estate within Wyndford over and above the thermal comfort improvements which residents have experienced. The entrance lobbies of several of these 26 storey blocks have been upgraded by Collective Architects making them into attractive and more functional spaces.

Energy Consumption (for heating and hot water).

The following data has been provided by SSE and represents a typical year (12 month period from Jan-Dec 2014) for 596 dwellings. Once outliers have been removed (potentially vacant flats), the dataset for the 26 storey blocks comprises of 416 dwellings.

Table 1- 26 storey blocks, average energy consumption (heat) per block, January - December 2014 (after refurbishment).

Address	Average Annual energy (heat) consumption (kWh)	Average monthly energy (heat) consumption (kWh)
120 Wyndford Road Block	4,774 kWh	398kWh
151 Wyndford Road Block	4,492 kWh	374 kWh
171 Wyndford Road Block	5,696 kWh	475 kWh
191 Wyndford Road Block	5,210 kWh	434 kWh

Table 2- Energy consumption (heat) average per flat type (average across all 26 storey blocks).

Housetype **26 storey block**	**Before refurbishment** Theoretical annual energy (heat) consumption (kWh)[1.]	**After refurbishment** Recorded annual energy (heat) consumption (kWh)[2.]	**After refurbishment** Average monthly energy (heat) consumption	**Percentage improvement** Heat energy consumption
Studio(36m^2) *119 dwellings*	*	4,986 kWh (138kWh/m^2)	415kWh	*
1 bed flat(45.2m^2) *297 dwellings*	9,536 kWh (211kWh/m^2)	5,392 kWh (119kWh/m^2)	449 kWh	44%

1. *Theoretical figure calculated by MEARU in 2008 using BREDEM calculation.*
2. *Figures taken from data provided by SSE for Jan- Dec 2014.*

Using BREDEM methodology the 'before refurbishment' theoretical energy consumption figure was calculated on the 1 bedroom flat type. The actual heat energy consumption recorded for the 1 bedroom flat is a 44% improvement on the theoretical value calculated 'before refurbishment'. This new average annual heat energy consumption after refurbishment indicates a significant decrease.

Energy Costs

Table 3- 26 storey block, energy cost comparison, January - December 2014.

Housetype 26 storey block	Before refurbishment Theoretical annual energy (heat) cost[1]	After refurbishment Recorded annual heating cost [2]	Theoretical Annual Cost Saving	Percentage improvement in cost
1 bed flat (rented)	£654.08	£432.30	£221.78	34%
1 bed flat (privately owned)	£654.08	£521.65[3]	£132.43	20%

1. Based on the previous tariff of 6.17p/kWh and 18p standing charge per day. However this tariff would have varied depending on the energy supplier and method of payment.

2.Tariff- Unit Rate of 5.22 p/kWh for all properties plus a Fixed Charge of 41.3323 p/day .

3. Tariff for privately owned properties as above but also includes their contribution to the Capital Replacement Fund: 24.4800 p/day.

Table 4- 26 storey block, energy cost per tenure type, January – December 2014 (after refurbishment).

Housetype 26 storey block	Annual energy (heat) cost for rented property	Annual energy (heat) cost for private property	Average monthly energy cost	Energy cost for winter month (January).
Studio	£410.00 (8.223p/kWh)	£499.35 (10.015p/kWh)	£34.20 (or £41.61- private property)	£45.53
1 bed flat	£432.30 (8.020p/kWh)	£521.65 (9.670p/kWh)	£36.00 (or £43.47- private property)	£57.64

From the data provided, the annual energy cost for residents in a 1 bedroom flat in the 26 storey block is £432.30.This is an average of £36.00 a month (a typical winter month may be as high as £57.64). The tariff unit rate of 5.22 p/kWh for all properties is a relatively low rate (although it is difficult to make comparisons with other energy companies due to their complex charging structures and variations in rates). However, the fixed charge of 41.3323p/day is relatively high (this includes a 24 Hour call out service and all repair and maintenance to the Heat Interface Unit and Meter along with the metering standing charge).

Cube HA has taken cognisance of the affordability of this pricing structure as it is dependent on individual consumption. They have instituted a two tariff system, which differentiates based on usage. Now householders with low consumption pay less standing charge; although those with higher consumption pay less variable tariff charge; the net effect has resulted in a more equitable share of costs and improved affordability for householders. As individuals pay more proportionately based on their consumption habits.

5.2 Housetype 2-14 storey blocks (5 no blocks, Total - 279 flats)

March 2008- 15 storey block prior to refurbishment **May 2015- 15 storey block after refurbishment**

Image 2- 15 storey block, before and after refurbishment.

These five blocks are situated at the front of the estate, close to Maryhill Road. There are four flats on each landing, all 2 bedroom flats. Each flat is double-glazed and has its own veranda. During MEARU's 2008 study these 15 storey blocks were undergoing cavity wall insulation (70 mm Knauf Crown Supafil loose fill) which was then further enhanced by the programme of overcladding. During the overcladding the thermal performance of the external envelope was improved by the addition of 100mm of rigid insulation (Rockwool – Eco Rock) product faced with coloured render. High performance double glazed windows (and balcony doors) with a U value of 1.8 W/m^2K have also been added. The original electric storage heaters have been replaced by modern slimline radiators with thermostatic radiator valves (TRV's) as part of a wet central heating system.

Energy Consumption (for heating and hot water).

The following data has been provided by SSE and represents a typical year (12 month period from Jan-Dec 2014). Once outliers have been removed (potentially vacant flats), the dataset for the 15 storey blocks comprises of 241 dwellings.

Table 5- 15 storey block, average energy consumption (heat) per block, January - December 2014 (after refurbishment).

Address	Annual Energy consumption (kWh)[1.]	Average monthly energy consumption (kWh)[2.]
60 Glenfinnan Road	4,936kWh	411 kWh
61 Glenfinnan Road	4,654kWh	388 kWh
80 Glenfinnan Road	4,692 kWh	391 kWh
110 Glenfinnan Road	5,151kWh	429kWh
130 Glenfinnan Road	5,179kWh	432kWh

Table 6- Energy consumption (heat) per 2 bed flat, (average across all 15 storey blocks).

Housetype **15 storey block**	**Before refurbishment** Theoretical annual energy (heat) consumption (kWh)[1.]	**After Refurbishment** Recorded annual energy (heat) consumption (kWh)[2.]	**After refurbishment** Average monthly energy (heat) consumption	**Percentage improvement** Heat energy consumption
2 bed (64m^2) 241 dwellings	9,180 kwh 143kWh/m^2	4,922kWh 77kWh/m^2	410kW	46%

1. *Theoretical figure calculated by MEARU in 2008 using BREDEM calculation.*
2. *Figures taken from data provided by SSE for Jan- Dec 2014.*

The existing annual energy consumption figure (before refurbishment) is 9,180kWh and the recorded energy consumption after refurbishment is now reduced to 4,922kWh representing a 46% improvement in energy efficiency. This is a significant improvement especially since the 'before' calculations includes the cavity-insulated with 70 mm Knauf Crown Supafil.

Energy Costs

Table 7- 15 storey block, Cost of Energy Consumption (heat) per flat type, January - December 2014.

House type **15 storey block** (rented accommodation)	**Before Refurbishment** Theoretical Annual energy (heat) cost [1]	**After Refurbishment** Recorded Annual energy heating cost[2]	**Theoretical Annual Cost Saving**	**Percentage improvement in cost**
2 bed(rented)	£632.11	£407.78	£224.33	35%
2 bed (privately owned)	£632.11	£496.35[3]	£135.76	21%

1. Based on the previous tariff of 6.17p/kWh and 18p standing charge per day. However this tariff would have varied depending on the energy supplier and method of payment.

2.Tariff- Unit Rate of 5.22 p/kWh for all properties plus a Fixed Charge of 41.3323 p/day

3. Tariff for privately owned properties as above but also includes their contribution to the Capital Replacement Fund: 24.4800 p/day.

Table 8- 15 storey block, Cost of Energy Consumption (heat) per flat type, January - December 2014 (after refurbishment).

Housetype **15 storey block**	**Annual energy (heat) cost for rented property[1]**	**Annual energy (heat) cost for private property[2]**	**Average monthly energy cost**	**Energy cost for winter month (January).**
2 bed	£407.78 (8.28p/kWh)	£496.35 (10.08p/kWh)	£33.00 (or £41.36- private property)	£56.24

From the data provided the annual energy cost for residents in a 2 bedroom flat in the 15 storey block is £408 - this is an average of £34 a month, or £1.11 per day. A typical winter month may be as high as £56 however the payment schedule outlined by SSE will average this out over summer months to ensure that debts are not built up over winter. Whilst the energy consumption has improved by 46%, the cost saving to the resident in their energy bill will more likely to be 36%. This is in part due to the standing charges for the district heating system (to cover repair and maintenance). The saving might actually be greater for some residents who were on higher electricity tariffs previously and those who paid at higher rates for prepayment meters.

5.3 House type 3-8 storey blocks (7 no blocks, Total - 209 flats)

March 2008- 8 storey block prior to refurbishment May 2015- 8 storey block after refurbishment

Image 3- 8 storey block, before and after refurbishment

These blocks have been referred to as the 'Bison blocks' due to the concrete construction system from the 1960's. A particular feature of this design is that the slab concrete floor construction penetrates through the external fabric, causing a significant thermal bridge; making these properties exceptionally hard to heat. They are 8 storey high and there are four flats on each landing; two 1 bedroom flats and two 2 bedrooms flats. All flats have their own verandas. Similar to the 26 and 15 storey blocks, these have undergone a programme of overcladding which includes improving the thermal performance of the external envelope and resolving the thermal bridging issues; with 100mm of rigid insulation faced with coloured render. The verandas have been enclosed and high performance double glazed windows (and balcony doors) with a U value of 1.8 W/m^2K have also been added. The original electric storage heaters have been replaced by modern slimline radiators with thermostatic radiator valves (TRV's).

Energy Consumption (for heating and hot water).

The following data has been provided by SSE and represents a typical year (12 month period from Jan-Dec 2014). Once outliers have been removed (potentially vacant flats), the dataset for the 8 storey 'Bison' blocks comprises of 165 dwellings.

Table 9- 8 storey block, Energy Consumption (heat) per block, January - December 2014 (after refurbishment).

Address	Annual Energy consumption (kWh)	Average monthly energy consumption (kWh)
3 Carrbridge Drive	3,426 kWh	285 kWh
9 Carrbridge Drive	3,150kWh	262 kWh
15 Carrbridge Drive	3,795 kWh	316 kWh
15 Invershin Drive	4,027kWh	336 kWh
11 Kirkhill Place	4,015kWh	335 kWh
25 Wyndford Road	4,553kWh	379 kWh
76 Wyndford Road	3,427kWh	286 kWh

Table 10- 8 storey block, energy consumption (heat) per flat type, January - December 2014.

Housetype **8 storey block**	**Before refurbishment** Theoretical annual energy (heat) consumption (kWh)[1.]	**After refurbishment** Recorded annual energy (heat) consumption (kWh)[2.]	**After refurbishment** Average monthly energy (heat) consumption	**Percentage Improvement** Heat energy consumption
1 bedroom (48m^2) 84 dwellings	5,873 kWh 122kWh/m^2	3,563 kWh 74kWh/m^2	296kWh	39%
2 bedroom (66m^2) 81 dwellings	• (As above – data in asterisk field?)	4,030 kWh 61kWh/m^2	335 kWh	*

1. *Theoretical figure calculated by MEARU in 2008 using in BREDEM calculation.*
2. *Figures taken from data provided by SSE for Jan- Dec 2014.*

The 2008 report calculated the theoretical energy consumption of the 1 bedroom flat to be 5,873kWh which compared with the measured data provided by SSE which shows a 39% improvement in energy consumption.

Energy Costs

Table 11- 8 storey block, energy consumption cost per flat type, January - December 2014.

Housetype 8 storey block	Before refurbishment Annual energy (heat) cost [1]	After refurbishment Recorded Annual energy (heat) cost [2]	Theoretical Annual cost saving	Percentage Improvement in Cost
1 bed flat(rented)	£428	£336	£92	21%
1 bed flat(private)	£428	£425[3]	£3	0.7%
2 bed flat(rented)	*	£361	*	*
2 bed flat(private)	*	£450[3]	*	*

1. Based on the previous tariff of 6.17p/kWh and 18p standing charge per day. However this tariff would have varied depending on the energy supplier and method of payment.

2.Tariff- Unit Rate of 5.22 p/kWh for all properties plus a Fixed Charge of 41.3323 p/day

3. Tariff for privately owned properties as above but also includes their contribution to the Capital Replacement Fund: 24.4800 p/day

Table 12- 8 storey block, energy consumption cost per flat type, January - December 2014.

Housetype 8 storey block	Annual energy (heat) cost for rented property	Annual energy (heat) cost for private property	Average monthly energy cost	Energy cost for winter month (January).
1 bed flat	£336 (9.43p/kWh)	£425 (11.93p/kWh)	£28.00 (or £35- private property)	£36
2 bed flat	£361 (8.96p/kWh)	£450 (11.17p/kWh)	£30.00 (or £37- private property)	£42

From the data provided the annual energy cost for residents in a 1 bedroom flat in the 8 storey block is £336- this is an average of £28 a month. A typical winter month this may increase to £36. The 2 bedroom flat is not significantly greater with an annual energy cost of £361.

5.4 Housetype 4- Traditional Maisonettes and 'Walk-Up' Flats (Total Flats – 284)

March 2008- Maisonette and walk up flats prior to refurbishment

June 2015- Maisonette and walk up flats after refurbishment

Image 4- Traditional Maisonettes and 'Walk-Up' Flats, before and after refurbishment

The maisonettes are situated throughout the Wyndford Estate. The upper and lower maisonettes are a mix of 2 bedroom and 3 bedroom flats, with the upper maisonettes accessible by a common close that contains seven 1-bedroom flats on four levels. (69 Sheltered and 40 non-sheltered flats). Each flat is double-glazed and has its own veranda. These maisonette blocks have the highest percentage of home ownership. Some owner occupiers had already undertaken cavity wall insulation observed during the 2008 study. Replacement double glazing was also evident in some of these privately owned maisonettes and some had also removed the storage heaters and installed their own central heating system. Owner occupiers were given the option to connect to the district heating system. The maisonettes have undergone a programme of cavity wall insulation - the 50mm cavity within the construction was filled with Knauf Supafill loose fill insulation. The external appearance has been improved with coloured render in keeping with the overclad high rise blocks.

Energy Consumption (for heating and hot water).

The following data has been provided by SSE and represents a typical year (12 month period from Jan-Dec 2014). Once outliers have been removed (potentially vacant flats), the dataset for the 4 storey maisonette blocks comprises of 194 dwellings.

Table 13- Maisonette block, energy consumption (heat) per block, January - December 2014 (after refurbishment).

Address	Annual Energy consumption (kWh)	Average monthly energy consumption (kWh)
12 Glenfinnan Drive	3,835kWh	320 kWh
2 Kirkhill Place	4,645 kWh	387 kWh
9 Wyndford Drive	3,847 kWh	321 kWh
29 Wyndford Road Road	3,247 kWh	271 kWh
37 Wyndford Road	3,436 kWh	286 kWh

Table 14- Maisonette block, energy consumption (heat) per flat type, January - December 2014.

Housetype **4 storey Maisonette block**	**Before refurbishment** Theoretical annual energy (heat) consumption (kWh)[1.]	**After refurbishment** Recorded annual energy (heat) consumption (kWh)[2.]	**After refurbishment** Average monthly energy (heat) consumption	**Percentage Improvement** Heat energy consumption
1 bedroom 95 dwellings	*	4,035 kWh	336 kWh	*
2 bedroom(62m^2) 47 dwellings	*	6,289 kWh 101kWh/m^2	524kWh	*
3 bedroom(80m^2) 52 dwellings	12,067 kWh 151kWh/m^2	4,425 kWh 63kWh/m^2	369kWh	63%

1. Theoretical figure calculated by MEARU in 2008 using BREDEM calculation.
2. Figures taken from data provided by SSE for Jan- Dec 2014.

The 3 bedroom flat within the maisonette block proved to have the greatest energy improvement of the whole Wyndford estate with 63% percentage improvement in heat energy consumption. The recorded consumption averaged over 52 dwellings (3 bedroom) was 4,425kWh whilst the 2 bedroom flats had higher recorded energy consumption. This is initially a surprising result but a review of the floor plan layouts indicates that the 2 bedroom maisonettes occupy the gable end location in the block therefore experiencing greater heat loss than the 2 bedroom ones located in the middle of the plan with less external wall surfaces.

Table 15- Maisonette block, energy cost (heat) per flat type, January - December 2014

Housetype **Maisonette block**	**Before Refurbishment** Annual energy (heat) cost [1]	**After refurbishment** Recorded Annual energy (heat) cost [2]	**Theoretical annual cost saving**	**Percentage improvement in Cost**
1 bed flat (rented)	*	£361	*	*
1 bed flat (private)	*	£450[3]	*	*
2 bed(62m^2)rented	*	£478	*	*
2 bed(62m^2)private	*	£567[3]	*	*
3 bed(80m^2)rented	£810	£380	£430	53%
3 bed(80m^2)private	£810	£469[3]	£341	42%

1. Based on the previous tariff of 6.17p/kWh and 18p standing charge per day. However this tariff would have varied depending on the energy supplier and method of payment.

2.Tariff- Unit Rate of 5.22 p/kWh for all properties plus a Fixed Charge of 41.3323 p/day.

3. Tariff for privately owned properties as above but also includes their contribution to the Capital Replacement Fund: 24.4800 p/day.

Table 16- Maisonette block, energy cost (heat) per flat type, January - December 2014 (after refurbishment).

Housetype Maisonette block	Annual energy (heat) cost for rented property	Annual energy (heat) cost for private property	Average monthly energy cost	Energy cost for winter month (January).
1 bed	£361 (8.95p/kWh)	£450 (11.15/kWh)	£30 (or £37.5- private property)	£36
2 bed	£478 (7.6p/kWh)	£567 (9.0p/kWh)	£40 (or £47.25- private property)	£42
3 bed	£380 (8.59p/kWh)	£469 (10.6p/kWh)	£32 (or £39.00- private property)	£37

Significant cost savings will be experienced by residents in the 3 bedroom maisonette blocks- up to 53% improvement in energy bills. There is the greatest percentage of private home ownership within the maisonette blocks and these residents will also be making significant savings to their heating costs albeit not as much as those in rented homes due to the standing charge for the capital replacement fund.

5.5 House type 5- A single 9-storey Deck Access Block (Total 52 flats)

This block at 10 Glenfinnan Drive consists of four 1 bedroom flats on the ground floor and 48 2 bedroom maisonettes on the four upper floors, with there being 12 flats on each landing.

March 2008- 9 storey deck access flats prior to refurbishment

June 2015- 9 storey deck access flats after refurbishment

Image 5- 9-storey deck access block, before and after refurbishment

Energy Consumption (for heating and hot water).

The following data has been provided by SSE and represents a typical year (12 month period from Jan-Dec 2014). Once outliers have been removed (potentially vacant flats), the dataset for the 9 storey deck access blocks comprises of 49 dwellings.

Table 17- 9-storey Deck Access Block, Energy Consumption (heat) per flat type, Jan - December 2014

Housetype **9-storey deck access block**	**Before Refurbishment** Theoretical annual energy (heat) consumption (kWh)[1.]	**After Refurbishment** Recorded annual energy (heat) consumption (kWh)[2.]	**After Refurbishment** Average monthly energy (heat) consumption	**Percentage Improvement** Heat energy consumption
1 bedroom 3 dwellings	*	8,040 kWh	670 kWh	*
2 bedroom(62m^2) 46 dwellings	13,375 kWh 215kWh/m^2	6,071 kWh 98kWh/m^2	506kWh	55%

1. Theoretical figure calculated by MEARU in 2008 using BREDEM calculation.
2. Figures taken from data provided by SSE for Jan- Dec 2014.

Table 18- 9-storey Deck Access Block, Energy Cost (heat) per flat type, Jan - December 2014.

Housetype 9-storey deck access block	Before Refurbishment Annual energy (heat) cost [1]	After refurbishment Recorded Annual energy (heat) cost [2]	Theoretical annual cost saving	Percentage improvement in cost
1 bed rented	*	£570	*	*
2 bed(74m^2) rented	£891[3]	£467	£424	48%

1. Based on the previous tariff of 6.17p/kWh and 18p standing charge per day. However this tariff would have varied depending on the energy supplier and method of payment.

2.Tariff- Unit Rate of 5.22 p/kWh for all properties plus a Fixed Charge of 41.3323 p/day

Energy Costs

Table 19- 9-storey Deck Access Block, Energy Consumption Cost per flat type, Jan - December 2014.

Housetype 9 storey deck access block	Annual energy (heat) cost for rented property	Annual energy (heat) cost for private property	Average monthly energy cost	Energy cost for winter month (January).
1 bed	£570 (7.09p/kWh)	£659 (8.19p/kWh)	£47 (or £55- private property)	£88.86
2 bed	£467 (7.69p/kWh)	£556 (9.16p/kWh)	£39 (or £46 private property)	£65.17

6. Conclusions

The upgrading of the Wyndford estate has been very successful as the heat energy consumption is greatly reduced with the average reduction across the estate of 49%- as shown in table 20 below. The 4 storey maisonettes have experienced the greatest improvement in energy performance -the recorded data from SSE indicates a 63% improvement from the theoretical consumption prior to refurbishment works.

Table 20- Comparison of energy and cost savings by percentage.

Housetype	**Percentage Improvement (theoretical)** Heat energy consumption (kWh)	**Percentage Improvement (theoretical)** Cost saving (£)
26 storey block	44%	34%
15 storey block	46%	36%
8 storey	39%	22%
4 storey maisonettes	63%	53%
9 storey deck access	55%	48%
Average	49%	38%

The average heat energy cost savings across the Wyndford estate is 38% based on the theoretical 'before refurbishment' scenario (and associated electricity tariffs at that time). However residents in the 4 storey maisonettes and 9 storey block will see even greater savings in their heat energy costs. For some residents who were paying even higher electricity tariffs and are served by a prepayment meter, the savings will be even greater.

The 'before refurbishment' calculations were based on a theoretical heating regime of 21^{o}C for 16 hours a day. However, the likelihood is that fuel poverty was such that both consumption and achieved temperatures were lower in actuality, with consequent risks to health and well-being. Further to the building upgrade measures many occupants may find that their comfort levels have increased and perhaps now have their heating on for longer periods (than the theoretical 16 hour). They may also keep their thermostat above 21^{O}C and open windows more liberally thereby improving air quality and creating a healthier indoor environment.

The constant-rate payment meter system, introduced by SSE, charges a fixed weekly amount to the household based on estimated heat consumption averaged across a year. Initially this rate was based on SSE's estimate of annual consumption for different types of home, and it is revised periodically to reflect actual consumption patterns- once a more accurate pattern of resident usage this fixed payment may reduce.

Despite the energy consumption being greatly reduced, the energy costs appear to be disproportionate to the flat size. From the recorded energy data from SSE the smaller flats (studio and 1 bedroom) are paying proportionately more for their heat energy than the larger 2 bedroom properties {{{could you briefly recap as to why}}}. Residents in the 1 bedroom flat types in the 26

storey are still paying on average £36.00 a month to heat their flat and above this, the resident will also be paying for their electricity consumption for power usage within the flat.

SSE's tariff unit rate of 5.22p/kWh for all properties is a relatively low rate and is lower than their gas tariff (although it is difficult to make comparisons with other energy companies due to their complex charging structures and variations in rates). However, the fixed charge of 41.3323p/day for a standing meter charge is very high -despite this including a 24 Hour call out service and all repair and maintenance to the Heat Interface Unit and Meter. Of the 380 privately owned homes on the Wyndford estate (factored through Cube HA), 266 opted into the community heating scheme. These residents are required to pay an additional fee of £89 annually.

With the previous levels of standing charge rates residents whose energy consumption was low prior to the upgrade, may find that their energy costs maybe unchanged, while residents whose energy consumption was relatively high will find their energy costs are more affordable than previously. However, Cube HA has taken cognisance of the affordability of this pricing structure and have instituted a two tariff system, which differentiates based on usage. Now householders with low consumption pay less standing charge; although those with higher consumption pay less variable tariff charge; the net effect has resulted in a more equitable share of costs and improved affordability for householders.

SSE also offer a low user tariff to tenants that are using less than 1500kWh a year and are in receipt of certain benefits. This is a unit rate of 8.46 p/kWh with no fixed charges, therefore for an analysis of energy consumption data in the Wyndford estate there are currently between 50 and 60 who have been transferred to this 'low user tariff'. Cube HA Fuel Advisors are actively identifying customers to support moving onto this tariff. If a resident was staying on a short term basis it would difficult to identify their eligibility for this lower tariff rate and they may have moved before sufficient data has been gathered to apply to SSE. Cube have undertaken to review this with SSE, following this report.

It should be highlighted that this paper reports only on heat energy and some residents may still be experiencing high electricity bills due to personal appliances consumption which may alter their perception that heating costs are still high. Some occupant habits such as using electric feature fires will increase their electrical energy and associated costs as they are choosing to heat their home using energy with a higher tariff.

5. Further study work

At this stage data for achieved temperatures and comfort conditions for post-refurbishment properties is not known and this is an important factor. A further phase of study would identify whether residents have increased their levels of thermal comfort and whether they are ventilating their homes more effectively given the enhanced thermal performance of their dwelling. By a programme of indoor environmental monitoring (capturing occupant heating habits during seasonal changes) room temperatures, relative humidity and CO_2 readings can be recorded and analysed from a selection of house types.

During the course of this study Cube HA reviewed their resident's energy payment structure with particular emphasis on the low energy users. In order to show this has been a fair and equitable solution we would recommend a period of monitoring of a sample of homes – including those on the low use tariff and the higher energy consumers. The monitoring would include the following key actions:

1. Take durational temperature readings to ensure that the low energy users are not keeping their temperatures uncomfortably low to minimise energy. This will also highlight if the high energy consumption homes are over heating their homes (or perhaps not using heating timers and thermostats effectively).
2. Monitor RH and CO^2 levels to check that the indoor air quality is not being compromised by a reluctance to ventilate their homes (in order to save heat).
3. Review the size of the property and number of occupants to establish whether their consumption meets expected norms.
4. Take monthly meter readings and review energy bills to ensure they are not being unfairly penalised for exceeding the low energy threshold.

A further study to identify electrical energy consumption through an assessment of resident's electricity bills would allow a comparison of occupants overall energy consumption before and after refurbishment but also whether they experience significant improvements in levels of warmth and control with the new system would need to be evidenced. A more intensive monitoring would also identify whether some residents are continuing with habits of plugging in supplementary fan heaters or feature electric heaters which would be reflected in their electricity bills. In addition to user habits, it would be beneficial to establish tenants understanding of the controls of the new heating system. The new system has time programmers; thermostats and TRV's (which if used effectively) could save the resident money in their energy bill.

APPENDIX 1: WYNDFORD ENERGY EFFICIENCY OPTIONS APPRAISAL

BREDEM Analysis (solar data and degree days for Glasgow from Page & Lebens, 1986)

1.0 26 storey towers (25 storeys flats + ground and roof accommodation) [1964/317]

For all 26-storey towers except Edwards, No. 151 Wyndford Rd: z1 includes k; z2 rest of flat

Specific heat loss 2-apt as existing, assuming 1.5 ac/h is effective rate of air change:

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu windows	10.5	3.20	33.60
gable wall	7.652	1.56	11.94
wall below large windows	3.576	1.55	5.94
k wall and lintol in liv.	3.95	1.55	6.12
TOTAL FABRIC LOSS	25.678	2.23	57.20

VENTILATION LOSS 48.97 m^3 x 0.33 x 1.5 ac/h = 24.24

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 3.83 81.44

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu windows	1.56	3.20	4.99
BR gable wall	7.263	1.56	11.33
BR return wall	3.105	1.64	5.09
Corridor/lift wall (common areas)	19.343	1.37	26.50
TOTAL FABRIC LOSS	31.271	1.53	47.91

VENTILATION LOSS 67.73 m^3 x 0.33 x 1.5 ac/h = 30.56

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 3.28 78.47

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 3.54 159.91

Specific heat loss 2-apt as proposed, with 1.25 ac/h as effective rate of air change:

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu windows	10.5	3.20	33.60
gable wall (cavity not filled)	7.652	0.32 (autoclaved blks)	2.45
wall below large windows	3.576	0.30	1.07
k wall and lintol in liv.	3.95	0.51(cavity ins'n only)	2.015
TOTAL FABRIC LOSS	25.678	1.52	39.135

VENTILATION LOSS 48.97 m^3 x 0.33 x 1.25 ac/h = 20.20

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.79 59.335

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu windows	1.56	3.20	4.99
BR gable wall	7.263	0.32	2.32
BR return wall	3.105	0.30	0.93
Corridor/lift wall (common areas)	19.343	0.47	9.13
TOTAL FABRIC LOSS	31.271	0.56	17.38

VENTILATION LOSS 67.73 m^3 x 0.33 x 1.25 ac/h = 25.46

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.79 42.84

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 2.26 102.175

SOLAR GAIN, 26 storey towers, allowing mean for east/west and north/south orientations

Liv window 6.705 m^2 x 0.8 = 5.364 m^2 net x 0.85 shading x 30.89 W/m^2 = 140.84 W Liv door 1.764 m^2 x 0.7 = 1.235 m^2 net x 0.70 shading x 31.88 W/m^2 = 27.56 W K window 2.012 m^2 x 0.8 = 1.609 m^2 net x 0.70 shading x 30.89 W/m^2 = 34.80 W

Z1 total solar

203.20 W Z2 BR window 1.560 m^2 x 0.8 = 1.609 m^2 net x 0.95 shading x 31.88 W/m^2

= 37.80 W Z1+2 total solar

241.00 W

INCIDENTAL GAINS, 26 storey towers

Z1	50% 2 adults	2 TVs	k appl	ckg.	ltg.	DHW	Total W
	62	54	197	108	7	0	428

Z2	50% 2 adults	1 TV	k appl	ckg.	appl/ltg.	DHW	Total W
	62	27	0	0	21	57	167

SOLAR GAIN + INCIDENTAL GAIN Z1 631 W SOLAR GAIN + INCIDENTAL GAIN Z2 205 W

Z1	54 + 197 + 7 = 258 W x 31.5 = 8,127 MJ = 2,258 kWh + 1,186 ckg =	3,444 kWh
Z2	27 + 21 = 48 W x 31.5 = 1,512 MJ =	420 kWh
Z1+2		3,864 kWh

ELECTRICAL LOAD ESTIMATE (excluding DHW; assume at this stage to be thermally heated)

BREDEM- SPACE HEATING CALCULATION

SPACE HEATING 1: Scenario 1 - as existing; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 3.54; interpolating from mixed heating, Ti z1 = 20.2°C; Ti z2 = 18.36°C

Base temperatures Tb = Ti – ratio of solar + incidental gains (W) to specific heat loss (W/K)

Therefore: Tbz1 = 20.2 - (631/81.44) = 12.45°C Tbz2 = 18.36 – (205/78.47) =

15.75°C DEGREE DAYS Sep Oct Nov Dec Jan Feb Mar Apr

May Yr

Tbz1 = 12.45°C	47.2	103.3	211.3	265.0	277.0	255.6	231.0	158.4	95.6	1644
Tbz2 = 15.75°C	113.1	193.6	309.5	367.3	379.3	348.9	332.4	250.9	179.3	2474

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 1

Qz1 81.44 W/K x 1644 Kdays x 0.024 = 3,213 kWh
Qz2 78.47 W/K x 2474 Kdays x 0.024 = 4,659 kWh

Q^{SH} z1+z2 7,872 kWh (174.2 kWh/m^2) Q^{DHW} 1,664 kWh (36.8 kWh/m^2) Q^{SH} z1+z2 + Q^{DHW} 9,536 kWh
Q^{EL} z1+z2 3,864 kWh (85.5 kWh/m^2) Q^{TOTAL} z1+z2 13,400 kWh (circa 7 t CO_2)