MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

The Wyndford Estate Energy Feasibility Study

COMISSIONED BY CUBE HOUSING ASSOCIATION

Rosalie Menon & Colin Porteous

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WYNDFORD ENERGY EFFICIENCY OPTIONS APPRAISAL for CUBE HOUSING ASSOCIATION

EXECUTIVE SUMMARY

Aims:

i The proposals satisfactorily address fuel poverty - see in particular 0.2.3 c) and 0.4.4 Detailed Summary - partly by means of fabric upgrade and partly by means of new 'wet' heating served by CHP in the case of tower blocks and individual electric boilers for walk-ups - see 0.4.2, 0.4.3 a) and b) Detailed Summary.

ii The proposals improve thermal performance in compliance with SHQS, and with Energy Savings Trust Best Practice Refurbishment Standards where possible; while carbon emissions are significantly reduced, even though space heating demand falls well short of 'Passiv Haus' criteria - see 0.4.1 Detailed Summary.

Iii The issue of further targets is dependent on fundamental and detailed decisions to be made by Cube in light of broad-brush recommendations by MEARU with respect to CHP for tower blocks and individual 'wet' electrical heating systems in walk-ups; and pending detailed development of CHP and detailed life-cycle cost analysis - see 0.4, and in particular 0.4.2, 0.4.3 a) and b) Detailed Summary.

iv The provision of more efficient/effective means of meeting communal lighting and lift loads could comprise a combination of several options: using electricity generated from CHP, depending on the heat to power balance at different times of the year; buying into one or more relatively large and remotely sited wind turbines; on site renewable sources such as building-integrated photovoltaic arrays (BIPV) and/or building-integrated wind generators (BIWG). Other communal options, over and above the CHP and potential buy-in to a wind farm, might be new laundry facilities - not included in present cost schedule by Martin Aitken Associates - see 0.4.5 Detailed Summary.

v The proposals to satisfy aims **i** and **ii** involve providing additional insulation and upgrading windows in a phased manner, as well as upgrading ventilation and heating and exploiting renewable technologies - see relevant parts of 0.4 in Detailed Summary and detailed notes in sections 1.0-5.0.

vi The intrinsic design approach adopted should ensure value for money as per the eight bullet points in the brief; but this view is made pending more in-depth life-cycle cost analysis, recognizing that the detailed approach to CHP represents commitment and risk - see 0.4 and 0.5 Detailed Summary.

vii A monitoring strategy has been briefly outlined (see 6.3), following tried and tested techniques that conform to 'SMART' criteria.

viii Liaison with EST took place at an early stage, with their documentation proving useful in developing proposals for improvements.

ix Liaison with RENEW via Jon Cape has been fruitful, particularly in relation to potential for bio-fuel CHP - see 0.4.3 a) Detailed Summary.

x Many aspects of the proposal contribute to Cube's wider regeneration and investment programme, including recommendations for a general facelift - see 0.4.5 Detailed Summary

Methodology

The methodology adopted conforms to the requirements of the brief in terms of **i** (1 & 2) and **ii** - see 0.2.1 to 0.2.4 Detailed Summary.

Completion of Study and Reporting

MEARU's obligations with regard to completion and reporting of the study, including results of surveys (0.3 Detailed Summary and Appendix D), were completed somewhat ahead of target in mid-June, pending further insights upon receipt of cost schedule by Martin Aitken Associates on 12th August. Relevant comments have now been added to complete the report in terms of recommendations and conclusions in the Executive Summary and the Detailed Summary, as well as notes added throughout the more detailed sections 1.0-5.0 dealing with each housing type under 8 sub-headings.

Recommendations

i Upgrade fabric of each building type (particularly insulation, windows and hygroscopic capacity, but also including external and common area painting); all in accordance with summarized proposals in 0.4, taken together with in-depth appraisals 1.0-5.0 and findings of analysis in Appendices A-C, and all pending further insights or refinements arising from future consultancy and life-cycle cost analysis.

ii Upgrade heating (to 'wet' systems, tower blocks from CHP and walk-ups from individual electric boilers) and ventilation facilities (including solar ventilation preheat by means of glazed buffers, and heat recovery as appropriate) for each building type all in accordance with summarized proposals in 0.4, taken together with in-depth appraisals 1.0-5.0 and findings of analysis in Appendices A-C, and all pending further insights or refinements arising from future consultancy and life-cycle cost analysis.

iii Assuming, communal CHP is adopted for tower blocks, and assuming a favourable business plan for implementation, adopt a non-metered flat-rate charging system based on the number of apartments - see 0.4.4 Detailed Summary and Appendix A.

iv Upgrade communal facilities, such as providing additional laundry facilities to those provided in the 14-storey towers; and considering options for making communal lighting more efficient and meeting loads renewably, pending further insights arising from future consultancy and life-cycle cost analysis; in particular with regard to CHP, remote wind farms and/or scope for building-integrated on-site solar and wind generation.

Conclusions

i The aims have been met using reliable and backed-up analytical methodology.

ii The proposals are practical and capable of implementation within SQHS timescales, offering scope for pragmatic cash-flow phasing within and beyond this point (2015); all subject to insights arising from future consultancy and life-cycle cost analysis, it is assumed including further detailed input by RENEW.

0.0 Detailed Summary - the aims, their context and resolution

0.1 Character and assets relative to MEARU's brief

0.1.1 Essence of the brief: Exploring practical and economic means of upgrading the scheme thermally was paramount (meeting particular minimum standards such as SHQS and EST Best Practice Refurbishment; and, where practical, moving towards German 'Passiv Haus' compliance). Original 1960s drawings have proved a useful tool in this endeavour, supplemented by postal and live surveys, the latter involving a limited number of face-to-face interviews as well as inspections of empty dwellings (voids). The detailed proposals developed in sections 1.0-5.0 below are tailored to suit the variety of layouts and construction conditions found. This includes recommendations for affordably improving the thermal envelope as well as providing new heating systems and enhanced means of ventilation. A key aim is to enhance thermal comfort and affordability, simultaneously improving health and well-being, and minimising, if not eliminating, fuel poverty with attendant risk of mould, dust mite propagation (now with proven causal links to asthma). The scheme is essentially 'all electric' at present, the provision for many dwellings confined to a storage heater in the main living space and another in the hallway. However, there are exceptions to this norm, especially where 'right to buy' sales have been prevalent among the 4-storey walk-up stock. A parallel aim is to reduce carbon emissions with emphasis on exploring opportunities for renewable energy applications - see 0.4 below.

0.1.2 Age and mix: With Dean of Guild applications by Scottish Special Housing Association dating from 1961-1965, this mixed estate of multi-storey flats and maisonettes with lift access, and 3-4 storey walk-up flats and maisonettes, earned a Saltire award in 1968. Most high-rises contain one to three apartment flats (200 1-apt; 792 2-apt; 105 3-apt), but a single nine-storey slab block has 3-apartment maisonettes (48 No. plus 5 2-apt flats). The 4-storey walk-ups contain a mix of 3-apartment (296 No.) and 4-apartment (189 No) maisonettes and 2-apartment flats (164 No). Three-storey sheltered flats are excluded from the study. Since the time of building, although the external appearance of most blocks has become rather shabby, the railway lines to the southwest and southeast have long since disappeared, and the commanding southerly views from many dwellings over the verdant Kelvin valley is a significant asset. There is also a satisfying balance of enclosure, particularly landscaped courts (some in need of 'tlc') bounded by 4-storey walk-ups, and permeability, with a variety of routes from one part of the site to another. Some quite mature trees in some of these spaces add to their quality.

0.1.3 Solar access: this is also generally good, thought to comply with The British Standard Code of Practice (CP 5: 1945, Chapter 1(B)) [Ministry of Housing and Local Government, 1958, Appendix B. 'Daylighting and Sunlighting' in Flats and Houses 1958 Design and Economy, HMSO, London, UK, pp.127-136]. In terms of detail, recessed balconies or verandas provide considerable shading obstruction to some living rooms, which, while limiting summer overheating, also to some extent inhibits sunlight and daylight in winter. On the other hand, the presence of balconies denotes a health related amenity (deemed essential in the 1950s and early 1960s, but increasingly regarded as unaffordable luxuries in the years that followed). Interestingly, access to sunlight, its health-giving properties via vitamin D and its benefits as a natural disinfectant (ultra violet and blue part of visible spectrum) are experiencing a 'back to the future' research resurgence (see Appendix E for references and notes). Over-reliance on antibiotics together with awareness and propaganda regarding skin cancer has tended to occlude the health attributes of sunlight in terms of public perception. However, recent research confirms its essential value both for physical and mental health and well-being. In particular, recent research carried out under MEARU's supervision indicates a relationship between glazed area to living rooms and positive affectivity - a glass to floor area ratio of circa 25-30% seems optimal.

0.1.4 The mix and size of dwelling types: The overall spread relates reasonably well to current expectations of demand, with increasing emphasis on single person accommodation. However, taken together with allocation policy and disposable income trends, there is a relationship to the central issue of fuel poverty. Generally speaking, the larger units within the walk-ups correspond with greater disposable income and 'pride in home', and with a significant proportion of dwellings now owned by the occupants. Younger 'singles' also tend to be placed in the highest towers (25 storeys of flats over a communal ground floor) and more mature singles or couples in the lower ones (8-storey Bison blocks); again, generating a difference in terms of problems and issues.

0.1.5 Environmentally or socially significant communal facilities: Of particular significance are those relating to domestic laundry. The original laundries provided on the ground floor of the 15-storey tower blocks are popular and well used, although modern hygiene and expanded wardrobes still result in a proportion of home washing and drying. The advantage is that this removes water vapour from the flats, thus diminishing risk of excess humidity when construction has become increasingly airtight (e.g. due to window replacement). The walk-ups also have communal drying areas next to stairwells as well as underused communal storage at ground level; and other blocks have a rooftop drying area. Given the model of the 15-storey towers, there is scope for enhancement to fuller communal laundry facilities. There are also other community resources - the old swimming baths on Gairbraid Avenue just to the north of the site is currently undergoing major refurbishment; the primary and nursery schools on the site off the usual scope, as do playing fields, even though presently unfenced; the small set of shop shells are still functioning after a fashion; and Cube's branch office is clearly an asset.

0.2 Methodology

0.2.1 Constructional and dimensional information: Original drawings were located (mainly at the Mitchell Library), providing most of the information required; although full details could not be found for the 26-storey towers and the 8-storey Bisons. Since these were examined in hard copy form along with electronically scanned versions, both in imperial dimensions, they have been redrawn electronically to a design level using metric scales. This also facilitates transport of information to the client and other members of the consultancy team, notably the quantity surveyor (see 0.2.4 below) Changes such as window replacement, internal insulation and cavity insulation were noted from visual inspections - see also 0.2.2 and 0.3 below - augmented by information from Cube HA.

0.2.2 Social and environmental information: This was gleaned from a postal questionnaire (satisfactory response) and partly from face-to face interviews with spot measurements of temperature, humidity and CO_2, the last used as an indicator of air quality. The latter, smaller than originally intended, was carried out in May 2008, and so does not convey winter hardship. However, it did provide useful insights in addition to those of the former, which provided useful data with regard to winter fuel poverty and attendant issues - see 0.3.

0.2.3 Thermal analysis

This had to satisfy the multiple aims of:

a) compliance with SHQS [Guidance on meeting the energy efficiency requirements of the Scottish Housing Quality Standard, Energy Saving Trust, March 2008, which uses SAP 2001 ratings] - in particular achieving a minimum SAP rating of 60 (electrical heating) with 'effective insulation and central heating'; as well as the more routine requirements of being above 'minimum tolerable standard', 'free from serious disrepair', having 'kitchen and bathroom fittings that are in good and safe condition' and being 'safe and secure' with 'smoke detector, secure doors and safe electrical and gas systems' (the last not necessarily applicable in this case);

b) adherence to the principles espoused in Energy-efficient refurbishment of existing housing [Energy Saving Trust C83, 2007 edition & GPG171, 2006 edition], bearing in mind that Cube HA indicated at the outset that insulated over-cladding was generally deemed unaffordable - i.e. emphasis on cavity or internal insulation together with phased window replacement and/or passive solar measures;

c) rendering thermal comfort affordable (total energy costs no greater than 10% disposable income), while minimising risk of condensation and mould, and reducing carbon emissions.

The Standard Assessment Procedure (SAP) and related National Home Energy Rating (NHER) software are descendants of the 2-zone domestic energy model developed by Anderson et al at BRE's Scottish laboratory in East Kilbride in the 1985 (BREDEM). As BREDEM offers some fine-tuning scope (bespoke data for temperature, solar radiation, shading, ventilation etc.), this was used to back up SAP(version 9.70)/NHER software. It should be noted that SAP version 9.70, 2001, which is used in the SHQS documentation by EST [see a) above], is on a scale 1-120, whereas version 9.81, 2005, is from 1-100. The revised SAP scale allows simpler direct comparison with NHER's 1-10 scale. All SAP and NHER ratings should be treated with a degree of caution since they are very sensitive to the specification of the heating system. High improved SAP ratings in excess of 100 (2001) or 75 (2005), for example achievable with biomass communal CHP, are to be welcomed, but perhaps convey a false sense of potential achievement. It is the number of kWh units (Gigajoules divided by 0.0036) and the average cost per kWh unit that will determine affordability. In this regard the BREDEM analysis provides a breakdown of estimated space heating loads, which can be compared with the 'Passiv Haus' standard of no more than 15 kWh/m^2 floor area. It also allows a realistic estimate of power use for lighting and modern appliances. Finally, the BREDEM analysis (Appendices A-B) gives estimates of CO_2 emissions as existing (using published value for grid electricity in the UK), for comparison with the SAP/NHER output (Appendix C). Emissions post-improvement will be very dependant on the particular solutions adopted by Cube, and possible phasing in of major infrastructural work - e.g. associated with combined heat and power (CHP), if this is adopted as a significant component of the upgrade.

0.2.4 Cost analysis

Having decided on viable constructional strategies in terms of a reasonable expectation to meet the above aims, discussions were held with the quantity surveyor, Hugh Aitken of Martin Aitken Associates; followed up by electronic drawings and specification notes. Although specific assumptions had to be made in order to allow the thermal analysis to proceed, there is considerable scope for flexibility in terms of implementation. An affordable 'cash flow' scenario is bound to depend on phasing as well as specification options, available grants etc. Having made this point, caution should be exercised relative to alternatives that could have negative environmental consequences (e.g. internal insulation with low vapour resistance resulting in hidden interstitial condensation). The cost schedule itself (by Martin Aitken Associates) is outwith the scope of this report, but relevant comments and notes relating to it have been added at all stages. A more in-depth life-cycle analysis remains in the future. This could either form part of an advanced 'options appraisal 'stage, or be embedded in the brief once a full consultancy team has been assembled to take the implementation of improvements forward.

0.3 Surveys - key findings

0.3.1 Drawings: Certain key characteristics are worth noting. Ceiling heights are a uniform 7'6" (2.3 m) throughout. All floors, except those in the 9-storey slab block and intermediate floors in walk-up blocks, are tongued and grooved (t&g) boarding on battens, 'floating' over concrete slabs; while floors within walk-up maisonettes are t&g flooring on timber joists, and all floors in the 9-storey slab block are solid concrete with directly applied finishes. Flat roofs on high-rises are concrete, overlaid with insulating screed. Cold or thermal bridges (construction with locally high rate of thermal conductivity) are tackled to some extent (e.g. between bedrooms and balconies; break in thermal continuity between floor slabs and balcony slabs); and opportunities exist for cavity insulation without incurring excessive cold-bridging as a consequence. Both concrete flat roofs on high-rises and timber pitched roofs on walk-ups offer relatively simple opportunities for further insulation to be added. However, ground floors are more problematic in this regard, due to the low ceiling height, this characteristic being most relevant for the lower storey of maisonettes in the walk-up blocks. As floor areas are relatively generous, internal insulation materials and added hygroscopic capacity are feasible, provided adequate steps are taken to avoid interstitial condensation on the, now colder, wall surface behind the insulation - i.e. care should be taken to provide continuous vapour control layers. Net glass areas expressed as a percentage of floor areas are also generous (13-21% for whole dwellings and 19-38% for living zones), constituting an environmental asset provided the thermal efficiency of the glazing is adequate. One can compare this with the 10% minimum at the time of building and the even lower 6.7% (one fifteenth) minimum from 1985 onwards.

0.3.2 Postal questionnaires (see also Appendix D for graphic output): Predictably this yielded many complaints of inadequate, or otherwise unsatisfactory, heating - just over half of the total returned (over 402). Apart from lack of heat emitters, poor control coupled with charge times were key issues, with many resorting to use of additional heating appliances such as oil-filled radiators on the higher direct tariff. For example, a quarter of the respondents had auxiliary appliances in the living room and almost a fifth (18%) in bedrooms. There were also many complaints of discomfort due to cold draughts; some of these probably due to cold surface temperatures rather than infiltration of cold air from outside. Winter electricity bills were also predictably high - a quarter of the sample reporting spending between £20-30 and a third £10-20 per week. Modern appliances of course contribute to this, with nearly a quarter (24%) of respondents using tumble driers. An environmental risk here, if driers are not vented or plumbed in (condensing type), is that occupants are tempted to vent warm moist air into their homes; hence causing condensation. Over 10% also used radiators or clothes-horses, the latter sometimes outside, for drying. However, passive drying was more frequently claimed - e.g. 45% using pulleys, often ones located in semi-outdoor communal areas. In any event, the combination of drying, other hygiene or domestic moisture-generating activity, and fuel poverty resulted in a fairly high incidence of black mould, mildew and water staining (24%), three-quarters of which were black mould or mildew reports.

0.3.3 Visual inspections and face-to-face interviews: Initial inspections in February 2008, mainly of void flats, but also one occupied flat in an 8-storey Bison block, provided some insights as to alterations since the time of building. For example, the Bison blocks had been internally insulated including ceilings on the top floor. Also, flats in one 26-storey tower (Edwards, No. 151 Wyndford Road) had been similarly internally insulated. The 4-storey walk-ups also appeared to have had its cavities insulated (signs of regular drilling in external roughcast). Although Cube HA had no record of this, three long-term tenants in subsequent face-to-face interviews in May had clear recollection of the cavity filling, as well as roof voids having insulation upgraded, either by SSHA or Scottish Homes. However, this would require to be physically confirmed in all these blocks, including checking the slim cavity walls between access decks and kitchens. Partly due to the prevalence of 'right to buy' and partly due to the age profile of residents, the walk-up units lacked consistency with regard to additional heaters for bedrooms and window replacement. New double-glazed windows are interspersed with original single glazing, and, in some cases, former recessed balconies have been glazed and incorporated as part of the living room. Occupants, who still had open balconies, valued them, and were ambivalent about the prospect of these being glazed in as conservatories. Drying washing on balconies also appeared contentious, reportedly banned in tenancy agreements, but an environmentally sensible practice, which should be encouraged. The inspections also revealed that kitchens, as well as bathrooms, had the benefit of being connected to the vertical shunt extract ventilation system in both 26-storey and 8-storey towers; but only bathrooms in the case of the 15-storey towers, their kitchens reliant on the window. The inspections in May further found generally acceptable indoor environmental conditions, corresponding to the ambient weather, although CO_2 levels were on the high side in some cases, indicating lack of adequate ventilation. This is likely to be a more contentious issue in winter, when energy efficiency (e.g. new, well-sealed, double-glazed windows) and desire for a draught-free environment may compromise air quality. Solutions are partly technical and partly social or educational. Recent work carried out by a MEARU-supervised PhD student indicates that the more energy-efficient a home becomes, the more relaxed occupants seem to be about ventilating adequately in winter. The refurbished flats in a tower block in Caledonia Road in the Gorbals were a particularly successful example in this regard. A final observation is the prevalence of curtaining or blinds, which tends to diminish access to light, sunlight and views. This tendency may be attributed to a mix of fashion and a desire for privacy or security. However, the environmental impact is mitigated by the generosity of glazing (0.3.1 above).

0.4 Analysis and Proposals - opportunities and constraints

0.4.1 Thermal upgrading of fabric: A pragmatic approach has been adopted, tailored to the different constructional conditions found for each type (sections 1.0-5.0 below) and to MEARU's brief from Cube HA and subsequent progress meetings. While this does not necessarily come up to the standard recommended by EST (e.g. walls to achieve a U-value of 0.3 and windows 1.5 W/m^2K as per Toby Balson's email of 9th January 2008), the analysis (Appendices A to C) confirms compliance with SHQS and affordable running costs for the user (i.e. estimates of expenditure that are expected to fall within 10% disposable income for low-income households, thus avoiding fuel poverty). Table 1 in Appendix A shows that the mean space heating load for the construction proposed, allowing for realistic rates of ventilation, is 10.9 kWh/m^2 or 24% greater than the Scottish Technical Standard 2007 (TS07) for a benchmark new flat of 80 m^2. The same table shows that the mean total energy load for the construction proposed is 31.1 kWh/m^2 or 12.4% greater than the TS07 benchmark new flat.

0.4.2 Options for heating and SAP/NHER ratings

The point made in 0.2.3 above with regard to the sensitivity of SAP rates with specified heating system is worth emphasizing. For example, the 15-storey tower block flats have SAP 2001/2005 ratings of over 107/76.4 for a bio-fuel CHP system (NHER 9.8), but this reduces to 80/69 for an individual electric CPSU (combined primary storage unit) boiler, and down to below the 60 threshold at 59/57.2 for a normal electric boiler with separate storage unit - with off-peak tariffs applying in each case. With cavity insulation and the existing storage heating system (the status quo, since these blocks have been insulated during the course of this study), the value drops to 51/50.8 (NHER 4.8). The detail of SAP/NHER specification is also such that if a score is just below a critical threshold, it can be moved up taking by relatively simple measures - e.g. increasing DHW tank insulation.

Results of analysis promote confidence comparing the BREDEM-based method (appendices A and B) with the NHER/SAP 2-zone technical output (appendix C), with reasonable correlations between respective energy loads. However, it may be noted that the basic single-zone SAP worksheet output (available, but not included as an appendix) underestimates ventilation loads, significantly overestimates useful solar gains and hence overall significantly underestimates degree-day loads. The conclusion reached through the analysis is that CHP is a viable option that should be pursued for all the high-rise blocks, where vertical distribution to new 'wet' heating systems in each flat would be relatively easy to implement. Ideally, from a low-carbon perspective, this should use a renewable fuel such as wood chips or pellets, at least as the main fuel. However, supposing the choice is thus narrowed, there are several detailed technical options; and even more if the fuel scope is widened. For the 4-storey walk-ups, with a significant presence of owners, and horizontal distribution issues, various alternative options are discussed. One practical solution would be to replace existing storage systems with wet systems supplied by individual electric boilers. In turn, Cube HA could buy into one large, or two medium-sized, wind turbines on a suitable site outside the city centre in order to achieve the same low-carbon level as the CHP served dwellings.

The following table summarizes the NHER results of key simulations:

House Type	NHER Rating As Existing	NHER Rating As Proposed	Additional Scenarios
Type 1- 26 storey	2.5	9.8	
Type 2- 15 storey	3.6	9.8	4.8 Insulated cavities only (existing windows + storage heating)
Type 3- 8 ('Bison') storey	5.2	10	10 'Fallback' scenario
Type 4- 9 storey maisonette block	3.5	9.4	
Type 5- 4 storey maisonettes	2.9 (2.4 without insulation)	7.4 (with electric boiler)	8.3 with CPSU heating system

0.4.3 Estimated total energy loads (Q^{SH+DHW} = space heating + hot water p.a.; Q^{E} = electrical p.a.):

a) CHP for high-rise blocks (note under Type 26/1 = 26 storey block, 1 apartment flat, etc.)

Type	Q^{SH+DHW}(kWh)	No. of units	Total (MWh)	Q^{E} (kWh)	No. of units	Total (MWh)
26/1	3,292	200	658.4	2,561	200	512.2
26/2	4,967	400	1,986.8	3,864	400	1,545.6
15/3	4,605	280	1,289.4	4,161	280	1,165.1
8/2*	3,864	112	432.8	3,864	112	432.8
8/3*	5,025	105	527.6	5,330	105	559.7
9/3**	7,781	53	412.4	4,161	50***	208.1
Total			5,506.6			4,423.5

If it is assumed that 20% is added to 5,506.6 MWh for Q^{SH+DHW} (to allow for distribution/storage losses), this total increases to 6,608.0****, giving an approximately 1.5 heat to power ratio; noting that a variable proportion of hot water may be heated by electric immersion to vary the ratio.

Notes:

* denotes the 'fall-back' version used, rather than 'proposed' with external insulation

** 48 maisonettes and 5 flats – intermediate maisonette value has been multiplied by 53 to include the flats and allow for extra roof/floor/gable losses to some maisonettes

*** 53 reduced to 50 to allow for lower electrical load in small flats

**** 6,608 MWh total for gross Q^{SH+DHW}, allowing for storage/distribution losses, corresponds to a mean value of 5,746 kWh for the 1150 high-rise units as in Table 2 of Appendix A

It is difficult to be precise about the quantity of fuel that would be required to meet such loads; but Jon Cape of Renew has provided some guidance based on predictions for a project in Fife. He estimates: "For Cardenden: 578 homes (2/3 of scheme - the rest is non-domestic) or perhaps 860 home equivalent, estimated annual tonnage of biomass required is 11,300 tonnes per year or say 13 tonnes per home equivalent. On this basis, 1,150 homes (the Wyndford high rise flats) might require 15,000 tonnes, plus more if school etc is included." This may be the factor that tests the validity of such a proposal. Even when rounded down to 280 tonnes/week, it implies two container loads of circa 20 tonnes every day, year round. He also appears to favour a 'combustion', rather than 'gasification' system, with typical heat to power ratio of 1.55 to one; and seems confident that a reliable supply of that order is feasible. The ballpark estimate he gives for network cost is £3 m, plus £6.4 m for the 'energy centre'; the former from a tower block project in Essex and the latter based on a straight extrapolation from Cardenen. Such 'ballpark' figures imply need for liaison with QS, Martin Aitken.

In terms of funding opportunities, Jon Cape reports the following (email 17/06/08):

Based on the work done to date, there appears to be a good case for a biomass CHP community energy scheme to serve the 1150 high rise homes - such a scheme might also serve nearby new build homes (to be developed by Isis) and an adjacent Cube tower block which may be redeveloped.

Development costs: As a community controlled housing association, Cube may be able to seek development cost support from the new Scottish Government Climate Challenge Fund (I am submitting an application for the Cardenden project and have raised Wyndford in principle): funding panels likely to be July (big hurry needed to reach this) or Sept/Oct.

Implementation funding: Renew would wish to mount a proposition to Cube to partner with Cube in the creation of a local SPV, accountable to the community (via Cube's existing structures or otherwise) and to assist that SPV, as a member of Renew, as a co-operative ESCO (Energy Service Company), by structuring implementation finance for the project. Such a structure would be likely to include:

1. Social Landlord (Cube) grant contribution

2. CERT grant contribution (but will need to be quick - CERT partners want schemes which will be operational by Dec 2010.

3. Other grant: Scottish Biomass Support Scheme (hoping to open for bids for 2009 later this year), EST etc

4. Debt: Full modelling will be needed, in dialogue with debt partners to establish the proportion of capital cost which can be met via debt. This will also depend on the detailed project structure, tariff policy and structure etc. In the Cardenden case, 60% debt component is expected, but this could increase if prevailing energy prices (gas and electricity, to which project revenues are linked) increase above biomass cost trends and may be more for Wyndford high rise where unit network costs will be lower than for low rise Cardenden.

5. Risk capital: 1-4 above may prove sufficient, but the funding mix might also include a "quasi equity" social investment just as community wind projects often require a minority risk capital component.

b) thermal and electrical for low-rise blocks (note under Type 4/2 = 4 storey block, 2 apartment flat)

Type	Q^{SH+DHW}(kWh)	No. of units	Total (MWh)	Q^E (kWh)	No. of units	Total (MWh)
4/2	2,938	164	481.8	2,750	164	451.0
4/3	4,525	296	1,339.4	4,161	296	1,231.6
4/4	5,196	189	982.0	4,667	189	882.1
Total			2,803.2			2,564.7

Total thermal (Q^{SH+DHW}) and electrical (Q^E lighting + appliances) demand for walk-ups: 5,368.0

If 5% added for gable conditions, contingencies etc., revised Total = 5,636.0

The analysis in 5.6 below shows that this load could be met with a single 2.2 MW wind turbine.

It is also worth noting that the use of a 0.52 kg CO_2/kWh factor for UK grid electricity (R Godoy, Ch 7, Environmental Design, ed. R Thomas & M Fordham, 3rd edition, 2006) results in estimates of carbon emissions some 20% greater than those of NHER/SAP. For example, the NHER technical output for a 3-apartment flat in the 15 storey tower estimates 5.6 t CO_2 emitted as existing and 1.1 t as proposed, a reduction of 80.3%; while the corresponding value for the BREDEM output using the 0.52 coefficient is almost 7.0 t. If 7.0 is regarded as 100%, 5.6 t is 20% less. Then, accepting the NHER estimate of reduction the proposed BREDEM version would be 1.3 t, 0.2 t higher than predicted by NHER.

0.4.4 Affordability

The mean figure of 57.1 kWh/m^2, in Table 1 of Appendix A, if priced at 5 p/kWh, would average £2.86 per m^2 over the year; which is about £3.50 per week for a flat in the 15-storey tower. The total energy load of 161 kWh/m^2, if also priced at 5 p/kWh, would average £8.06 per m^2 over the year, or just under £10 per week for the same flat. However, CHP raises the issue of how to bill tenants. Heat metering has been problematic with other schemes such as Caledonia Road. The notion of using flat rates based on the number of main rooms in dwelling is appealing in its simplicity. Table 3 of Appendix A shows that this might range from £8.25 to £10.50 for the types of dwellings at Wyndford, again based on a unit tariff of 5 p/kWh. Increments of 20% per unit respectively to 6 p/kWh and 7.2 p/kWh would increase the ranges from £9.90 to £12.60 and £11.90 to £15.10. This indicates some scope for viability for charges that would fall affordably within 10% of disposable income. However, the present situation with regard to fuel prices is volatile and it may be that one would need to look beyond a unit price of 7.2 p/kWh. There is also no avoidance of high initial capital costs for CHP, underlining the need for sophisticated business planning together with life-cycle cost analysis.

0.4.5 Other communal improvements and amenities

At a visual level, it is suggested that a colour facelift would have great benefit for the image of Wyndford. This applies particularly to the exterior of the 26, 15 and 8 storey blocks, and threshold areas such as communal hallways and access decks. Improved external/communal lighting could be a complementary part of this exercise. A new self-cleaning silicon resin paint product has been suggested for the external facades of tower blocks (1.3 below). This has photo-catalytic properties to provide optimal weather protection and long-term value protection. If Cube HA seeks alternative products, care should be taken relative to performance specification (chemical make-up, testing procedures, longevity etc.), noting that many standard masonry paints used in Scotland have relatively poor performance and short life expectancy. On the other hand, it is accepted that alternative specifications will be appropriate for different locations such as semi-enclosed and enclosed spaces.

The electrical load for lighting communal spaces and powering lifts has not been included in the analysis above (0.4.3). Nor has the electrical demand for the communal laundries in the 15-storey tower blocks; and since these are popular, consideration might be given for additional laundry facilities in other blocks. With common lobbies, stairs, access decks, laundries and so forth amounting to some 22,000 m^2, if lighting added 10 W/m^2 and is on all-day and all year, it would add circa 2,000 MWh to the electrical load. With low-energy fittings and smart switching, one might aim for a 20-25% reduction. It is estimated (from formulae in published work) that lifts could add in the region of another 1,650 MWh. Although there is clearly quite a margin for error depending on both usage and motor ratings, the figure has been derived from reliable published formulae ('Lift Power Consumption' by Lufti R. Al-Sharif, Elevator World, 05/01/96; 'Energy Model for Lifts' by Dr Gina Barney).

For the additional electrical load to be met renewably, some, or perhaps all, of it could be added to the CHP, possibly advantageous to some extent in terms of the heat to electricity output ratio. Some could be supplied by photovoltaic (PV) arrays on south facing roofs of the walk-ups, and some by smaller building-integrated turbines on tower blocks. For example, the annual yield for 160 m^2 PV on the 9-storey maisonette block has been quoted to Cube HA as 16.2 MWh (a realistic value). This corresponds to a ballpark estimate for lifts of 108 MWh annually in this block, indicating that the PV array would offset 15% of this load. If annual common lighting of approximately 77 MWh is included, the proportion displaced drops to 8.8%. If four 6 kW wind turbines were added to the same roof, this might produce an additional 24-48 MWh annually, bearing in mind that our current monitoring suggests a value at the lower end is a safer assumption - say 27 MWh. The combined PV and wind contribution might then displace in the order of 40% of the lift load or 23% of the combined lift and lighting load. These estimates are likely to err on the pessimistic side, since the common areas in this instance can be naturally lit during daylight hours; and the maisonette slab configuration, with twelve units only one storey from ground level, is likely to reduce typical lift use compared with taller towers.

The quoted installed price for the PV is £110,000 and would be in the order of £120,000 for the four wind turbines - i.e. a total cost of £115,000 if Cube acquired the full 50% grant. Therefore, even accepting that renewable displacement could be somewhat higher than indicated above, it would appear that the potential for on site renewable contributions is rather modest, and that capital plus maintenance costs would have to be carefully considered relative to the recurring savings. If off-site wind energy were brought into the picture, possibly in combination with CHP, the total sized to meet a proportion of communal loads, potentially all energy loads for the estate could be met renewably, rendering it virtually carbon-neutral. Section 5.6 below indicates that a 2.2 MW turbine running for 2,875 hours and allowing for a further 10% loss would yield 5,700 MWH annually. On the same basis, a 3.3 MW turbine as the newly announced Barrmill wind farm in South Ayrshire would be expected to produce 8,500 MWh - i.e. providing an extra 2,800 MWh. If the total for communal lighting and lifts is of the order of 3,650 MWh, this would leave an extra 850 MWh to come from the CHP or on-site solar or wind installations. The Barrmill capital cost is approximately £1m/MW.

0.4.6 Minimal option

Cube HA could comply with SHQS by upgrading thermally, as summarised in 0.4.1 above and detailed in 1.0-5.0 below, and switching to 'wet' central heating as described in 0.4.2; with the entire scheme remaining grid-connected - at least as an interim measure. However, this would mean investing in individual or communal (block by block) electric boilers that would become redundant if CHP were installed at a later stage. Also this would result in only a modest reduction in carbon emissions, corresponding to the predicted energy savings, unless the electricity were to come from another renewable source such as a wind farm - as suggested for walks-ups and all or some of communal electrical loads as a long-term, low-carbon solution.

0.5 Conclusions

0.5.1 The Aims set out in 0.1.1 can be met in a realistically phased and implemented in an affordable manner. The term 'affordable' is based not so much on actual figures provide by Martin Aitken Associates in their cost schedule (received 12th August), but more on the potential for further refinement of the specification options together with appropriate programming. This will involve the investigation of cost anomalies such as varying rates for balcony enclosure, as well as some savings and some additions to the schedule as it stands; all in accordance with specification notes in 1.0-5.0.

0.5.2 There is a minimal option open to Cube HA, which remains reliant on grid electricity and conforms to SHQS. However, simply upgrading the fabric without renewing the heating will not meet SHQS in terms of SAP/NHER ratings; while upgrading the fabric with grid-connected electric heating will not significantly address carbon reduction. Measures to move towards CO_2 neutrality aided by a major CHP plant, buying into a large off-site wind turbine, and/or other local renewable tactics (PV and building-integrated wind) should be investigated in more depth. Wyndford would become a flagship UK demonstration project.

The following sections 1.0 to 1.5, each with eight sub-sections to cover specific components and services, give a detailed summary of proposals and options for the five different housing types.

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

Fig 1. Image of 26 storey block

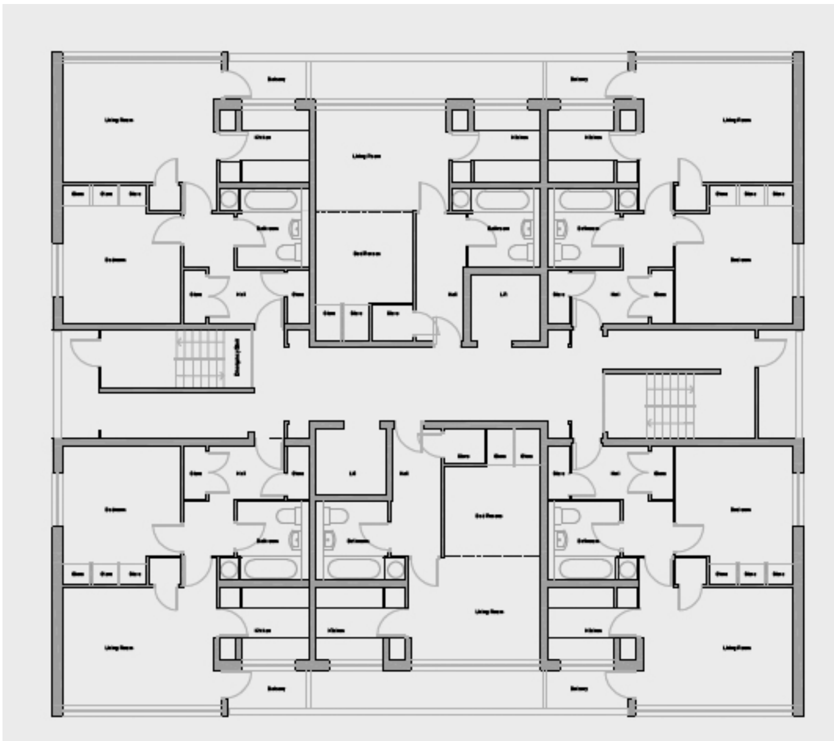

Fig 2. Typical Floor Plan of 26 storey block

1.1 Insulation and hygroscopic capacity - walls and floors

1.1.1 All 26-storey towers except Edwards, No. 151 Wyndford Road

South and north gable walls: The external panels are dense reinforced concrete with a mosaic veneer, dimensioned 7" (176 mm) thick. The existing inner lining is not known with certainty. It is likely to be a 100 mm concrete block making use of an aggregate from industrial waste - foamed slag or clinker. The assumption made for conductivity of the inner leaf errs on the safe side (k = 0.75 W/mK). It is suggested that the inner leaf be lined with 50 mm Foamglas (k = 0.039 W/mK @ 120 kg/m^3); plus 100 mm of a hygroscopic material such as perforated bricks (k = 0.42 W/mK); finished Limelite plaster or clay board (Claytec with Claytec/Tierrafino skim coat). This would increase thermal resistance as follows: 1.57 m^2K/W; new U = 0.45 W/m^2K (assuming existing = 1.56 W/m^2K). If approx. 0.2 m cavity (25% filled with structure) also insulated with mineral wool or equivalent, U drops to approx. 0.15 W/m^2K.

An alternative hygroscopic material to perforated bricks could be autoclaved concrete blocks. (e.g. Airtec XL 2.9N from Thomas Armstrong Concrete Blocks Ltd.). One would need to explore its hygroscopic attributes further compared with perforated bricks, but its lower thermal conductivity is not in doubt (0.09 W/mK). This would lower the U-value to 0.32 W/m^2K without adding insulation to the wide outer cavity (specification used for analysis in Appendices A to C); and to 0.13 W/m^2K including this. The strategy, whether using perforated bricks or autoclaved concrete blocks (latter used in analysis), is to increase hygroscopic capacity on the warm side of an insulating material (Foamglas) that doubles as effective vapour control layer. An additional source of hygroscopic capacity is the existing timber flooring, if accessible - see 2.1 below. The living room, and more importantly the bedroom would then be less susceptible to peaks in humidity; and it is also accepted that such materials enhance air quality at a particular rate of ventilation.

Note: the cost schedule by Martin Aitken Associates, hereafter referred to as QS, does not appear to have included estimates for either Airtec autoclaved blocks or perforated bricks; but have at least included Claytec clay board, with Limelite plaster as a cheaper option.

East/west walls to balcony/veranda and spandrel below window in living: The existing cavity wall to living room is the same as for north and south gables except that the cavity is a normal width of circa 50 mm. The cavity wall at the rear of verandas is slimmer - a total of 10.5" or 267 mm. An existing U-value of 1.55 W/m^2K is assumed in each case. Cavity filling (k = 0.034 W/mK) should lower U-values to 0.51 W/m^2K. Additional internal lining of 50 mm Foamglas and Limelite would reduce this to 0.3 W/m^2K, but is not proposed in kitchens, as it would involve considerable disruption and these are very tight spaces, already made awkward by structural nibs on the window facade.

Note: the QS mentions cavity filling with Foamglas, but has not included it in the costing. In any event Foamglas cannot be used for cavity filing, although it is an excellent material for internal insulated lining due to its high vapour resistance (as noted above). What is intended for cavities, and should be included in the cost, is some form of glass or mineral wool cavity injected insulation - see 2.1. 'Spacetherm' has also been mentioned as an option for internal insulation, but such specification should be treated with caution until more is known about its vapour resistance.

East/west wall of bedroom and hall: Adding 50 mm Foamglas and Limelite will add 1.39 m^2K/W thermal resistance. For the cavity in-shots to bedrooms, assuming cavity also filled, the resultant U value would fall from about 1.64 to just under 0.3 W/m^2K. For the length bounding the unheated stairs, the lining would yield a drop in U from about 2.6 to 0.56 W/m^2K.

1.1.2 Edwards, No. 151 Wyndford Road

This tower differs from the three others in that the window and gable walls in the living room, the gable wall and return section in the bedrooms (2-apartment flats) and a strip of the ceilings in each case has been dry-lined. It was initially assumed that this is 9.5 mm plasterboard lined with 15 mm polyurethane foam on straps, it would add 0.82 m^2K/W thermal resistance to walls. This would then reduce the U-value of all external walls from 1.55-1.56 to 0.68 W/m^2K. Cube HA has now indicated that this is 9.5 mm plasterboard bonded to 30 mm phenolic foam. Since its conductivity is 0.04 W/mK, the added resistance will be the

same as for the slimmer polyurethane foam. This is well above the level that is being proposed for retrofitting the other three blocks, and a risk associated with such dry-lining is that water vapour that passes through, particularly at joints, socket outlets and switches, can condense on the cool surface behind. This is the key difference compared to the suggested specification using 'Foamglas' as the insulating material; but it also does virtually nothing to add hygroscopic capacity. Its only attributes are to increase thermal resistance and speed up thermal response to inputs of heat, the latter not very relevant where storage heating is used. The existing retrofit hence constitutes a dilemma in terms of further upgrades. One solution would be to carry out no further upgrades to this block apart to the change in heating system (1.6 below) and glazing in balconies/verandas (1.2 below).
Cube has also recently indicated that 35 mm polyurethane insulation plus render was applied externally to east/west window walls. If its conductivity is 0.026 W/mK (as per CIBSE guidance), it will have a significant impact, reducing the U-value to the order of 0.35 W/m^{2}K, and approximately 0.38 W/m^{2}K around openings.

1.2 Balconies/verandas

It is suggested that a Vitrol or equal (e.g. Windoor) single-glazed sliding/folding system be attached between the existing balustrade (above existing glazed strip) and r.c. spandrel beams. This would create a valuable thermal buffer (lowering U-values further), enable ventilation preheat to kitchen and living room, and constitute a major enhancement to amenity, including potential use for clothes drying (as could the small external spaces on each floor next to the escape stairs). It may be noted in this regard that there is a continuous 24-hour extract from kitchens as well as bathrooms, which can assist the flow of air from veranda to interior spaces. The issue of sub-division of the veranda into three discrete spaces on each façade should be checked relative to fire escape requirements, such sub-division being very desirable in terms of amenity and added security. It may also be noted that the projecting nibs of the south gable create some asymmetry in terms of solar access. For example, by 12.15 on Monday 11th February, the entire living room window of the south-eastern flat was shaded; as was the entire recessed façade facing the veranda - i.e. only the living room window of the north-eastern flat was in full sun. Also, on the following day, it took until 16.15 for all the windows on the west façade to come fully into sunlight, by which time dusk was rapidly approaching. However, all year round, both verandas do have the daily potential for several hours of morning or evening sunlight.

Note: From the QS cost schedule, a total of £1.8m is allowed for Vitrol/Windoor enclosure. Each balcony is some 11.6 m long and the height from top of existing handrail to lintol is circa 1.2 m, so that each balcony involves an area of approximately 14.0 m^2. There are 200 balconies, making the cost per m^2 is in the region of over £640. This does seem to be on the high side and calls into question the nature of what the company Insutech have included. At any rate, MEARU would suggest a more detailed investigation of the needs and benefits relative to design options (e.g. not all the 7 m run in front of the single apartment flats need open), including alternative products.

1.3 External surfaces

Mosaic on concrete and other surfaces - e.g. walls and soffits in communal balcony/veranda: suggest high performance silicon resin paint such as 'Lucite Silico Therm', a German product. This will also slightly enhance diurnal U-values, and the bright colours available will offer an opportunity to give some aesthetic cheer to these towers.

Note: Contact details for Lucite Silico Therm were provided to enable costs with specification of preparation etc. required. The QS has meantime based costs on two alternative products ('New Decadex' by Liquid Plastics Ltd. and 'Rust –oleum Murfill' by Mathy), which give details of preparation etc., but no indication of technical performance data, chemical make-up, longevity etc. MEARU would recommend a thorough performance-cost investigation before committing to one specification. This should also give details of testing procedures, performance certificates and so forth; as well as citing case studies in Scotland - ideally ones that can be conveniently visited and are some years old.

1.4 Roof

Subject to inspection, by converting to an 'upside-down warm-deck', it should be possible to get the U-value down to 0.2 W/m^2K or less with relative ease (refer to 2.4 below for potential specification). Note: we could not find sectional drawings for this tower. Accordingly the existing layering is not known, but is quite likely to be insulated with a lightweight screed - possibly 'no fines' with foam slag pellets.

Note: The existing waterproof membrane can function as the vapour control layer, hence saving £28k (see QS schedule). However, the rigid foam insulation above it should not be omitted. A sedum roof will help to protect a new outer membrane, if an 'upside-down warm' roof is not acceptable.

1.5 Windows

The original single-glazed windows have been replaced with double-glazed PVCu windows (standard double-glazing according to Cube HA). Further improvement at this stage is therefore not considered to be an economic proposition. However, their U-value is high by today's standards (circa 3.2 W/m^2K), and they are subject to splitting of welded joints, distortion of sashes, impact/heat damage etc.

1.6 Heating and hot water

Analysis indicates pragmatic upgrades to insulation as suggested above in the case of three of the four towers, together with glazing in the verandas of all four, will reduce the thermal load for space heating (SH) together with domestic hot water (DHW) to the point that it is likely to provide reasonable load-matching relative to a combined heat and power (CHP) system. For a 21^{o}C all day (16 h) scenario for the 2-apartment flat, estimated space heating is 3,303 kWh (58% less than existing, hot water 1,664 and electrical appliances, cooking and lighting 3,864 kWh – 8,831 kWh in total (detailed analysis of loads in Appendix B). This means replacing the two electric storage heaters in each flat with a 'wet' system. On the basis that hot water can be distributed vertically in the ducts lining bathrooms, horizontal and vertical pathways for radiators appear relatively simple, provided radiators are placed with some care - e.g. centrally on the gable wall on either side of the storage units for living room and bedrooms in the two-apartment flats; a similar position in the one-apartment flat in the living room on the wall flanked by cylinder cupboard and dry goods; in the hall next to the bathroom in all flats; and a towel-rail radiator in bathrooms.

The provision of CHP will inevitably be a major commitment, but is reflected powerfully in the predicted SAP/NHER ratings - SAP 102 (2001), 76 (2005), NHER 9.8; up from 33 (2001), 35 (2005), NHER 2.5 . A decision would have to be made as to whether it would be done on a block-by-block basis; or on the basis of constructing a single new facility, possibly serving the whole of Wyndford; or somewhere between these two. A decision is also required as to fuel or fuels. With increasingly uncertain fossil fuel (gas and oil) supplies, and increasing emphasis on carbon-neutral energy, bio-fuels such as wood chip, wood pellet and vegetable oils are serious contenders. For example, with a new wood pellet factory under construction in Invergordon, container transport by water to within a few hundred metres of Wyndford on the Forth-Clyde canal is a possibility. Such a venture would involve several players, and paying for the energy supply could be organized in different ways, but it could attract significant external funding. It could also constitute a major renewable energy demonstration project for Scotland, the UK and the EU. Assuming, that such a project might also take longer to set up than the proposed energy conservation measures, continued short-term use of the existing electric storage system would be considerably more economic than at present, even though it falls below the key stipulation of the Scottish Housing Quality Standard (SHQS) of a SAP score no lower than 60 (for electrical heating). However, if the long-term plan were to shift to 'wet' heating in conjunction with CHP, the argument would have to be made not to upgrade to full electric central heating in the meantime.

Note: the QS schedule includes £3m for the four towers or £5,000 per unit. Jon Cape's ballpark estimate for infrastructure and plant for all the tower blocks is £9.4m. - i.e. about £8,175 per unit (l,150 total for high-rises) less what is available in terms of financial help. Clearly, this represents a very significant long-term investment on top of the switch to wet heating systems.

1.7 Ventilation

The existing vertical shunt system extracting air from kitchens and bathrooms should be retained. As well as being essential, at least for bathrooms, this will assist the flow of preheated fresh air into the flats from the newly created veranda buffer. Replacement of the rooftop, extract-only fans with heat recovery units were initially mooted. Pre-warmed fresh air could be supplied to the lift shafts, not only to promote fresh air in the lifts themselves (roofs of which might require modification), but also to help freshen air within the lift halls at each level as people enter and leave. However, the QS estimate of £30k per block suggests that pay-back is off ‘the score-board’!

1.8 Communal facilities

Cube HA has commissioned upgrades to the ground floor of Blaker and Rodgers towers. A meeting with Collective Architecture determined a suitable location for entry of the flow and return from a remote CHP plant, rising immediately to ceiling level, and thereafter suitable horizontal routes to each of the 6 vertical ducts. Facilities at ground level are mainly service and utility, including concierge. Inspection of facilities at roof level were not achieved, and although there may be potential for improved laundry facilities at this level, the proposed buffer spaces for each flat at least will improve the means for drying outside the building envelope in a relatively secure location.

2.0 15 storey towers (14 storeys flats + ground floor accommodation) [1961/177]

Fig 3. Image of 15 storey block

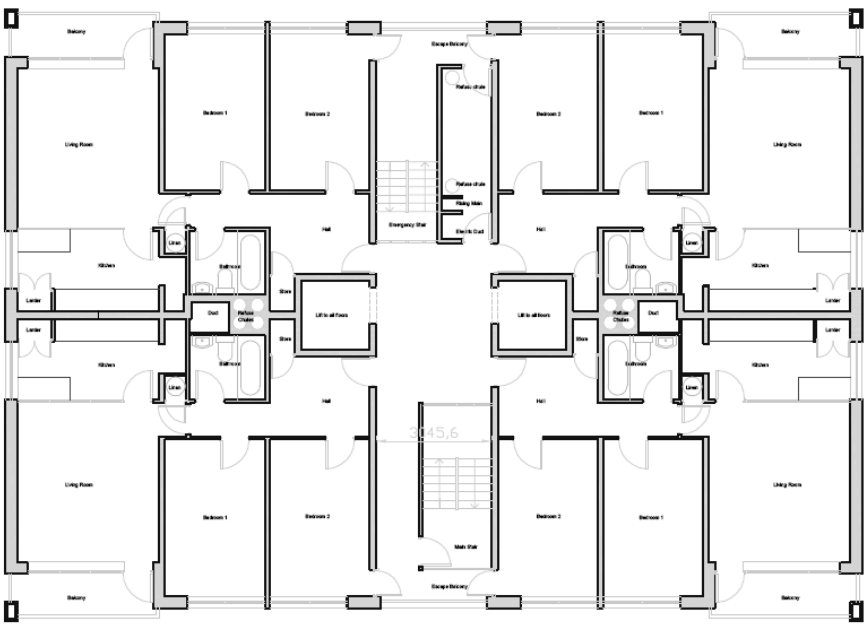

Fig 4. Typical Floor Plan of 15 storey block

2.1 Insulation and hygroscopic capacity - walls and floors

2.1.1 South and north gable walls

Existing construction from outside - 106 mm facing brick (k = 0.84 W/mK assumed), 50 mm cavity, 152 mm dense reinforced concrete (r.c.) spine wall (k = 1.4 W/mK assumed), 18 mm cavity, 9.5 mm foil-backed plasterboard. Suggest blow glass wool or mineral wool into 50 mm cavities (k = 0.034 W/mK. Increase to thermal resistance: 1.47 m^2K/W; new U = 0.44 W/m^2K (cf. existing = 1.025 W/m^2K); but note poor hygroscopic capacity. Note: during the course of preparing this report, the cavities have been filled with Knauf Crown Supafil glass mineral wool with a k-value of 0.04 W/mK - slightly higher than the value given above. However, since nominal 50 mm cavities are usually circa 70 mm wide in reality, the achieved U-value is expected to be at least as low as indicated above and for window wall below.

2.1.2 Cross wall between bedroom and stairs

Existing construction - 178 mm r.c. spine wall, plaster on hard. Suggest line with 80 mm Foamglas and 12 mm Limelite plaster or clay plasterboard, adding 2.125 m^2K/W thermal resistance; new U = 0.4 W/m^2K (cf. existing = 2.5 W/m^2K).

Note: the QS schedule mentions ‘Spacetherm’ as an option for internal insulation, but such specification should be treated with caution until more is known about its vapour resistance.

2.1.3 Window wall

Existing construction from outside - 106 mm facing brick, 50 mm cavity, 0.076 mm foam slag blocks (k = 0.051 W/mK assumed), plaster on hard. Suggest blow glass wool or mineral wool into 50 mm cavities (k = 0.034 W/mK. Increase to thermal resistance: 1.47 m^2K/W; new U = 0.51 W/m^2K (cf. existing = 1.52 W/m^2K), but note again poor hygroscopic capacity. NB: again Knauf Crown Supafil has been inserted.

Notes 2.1.1-2.1.3:

The insertion of cavity insulation will not fully address specific cold-bridge conditions at floor to wall junctions. However, the addition of the insulation is unlikely to result in localized areas of ceiling becoming colder than is presently the case; and the thermal advantage for the walls, added comfort as well as energy efficiency, will be considerable.

In order to increase hygroscopic capacity in living area, originally heated by electric elements in a screed, the cross wall to the adjacent bedroom could be lined with a new material such as Claytec clay board. A new floor finish of cork tiles or real linoleum (linseed oil, cork and hessian) would also be of benefit. In order to increase capacity in bedrooms, existing tongued and grooved flooring could be sanded and sealed, having removed laminate flooring where this exists. This may involve repair or replacement, but should curb desire for laminate flooring; and would achieve a similar visual result suitable for loose rugs if any further soft covering is desired. An alternative would be cork tiles or real linoleum over a plywood substrate screwed to the existing flooring. As with 1.1.1 above, the living room and bedrooms would then be less susceptible to peaks in humidity, with enhanced air quality.

2.2 Balconies/verandas

Glazing in these spaces might be considered as an option. However, the risk in using a Vitrol/Windoor or equal single-glazed sliding/folding system as suggested for the 26-storey towers is that it would buffer the entire living room window, potentially tempting the intervening door to be frequently left ajar between the spaces. This would not matter during sunny conditions, but otherwise it would tend to increase the volume to be heated, and hence can add to, rather than reduce, heating demand. Double-glazing would limit such risk, but it would also limit choice for opening lights and hence converting the space to an open balcony or veranda. Overall, moving to replacement glazing for the present windows may make more economic sense (2.5 below) particularly bearing in mind that balcony slabs were thermally isolated from floor slabs at the time of building. It should also be noted that the recessed nature of the balconies means that the northern pair of flats will be subject to more self-shading than those on the south, thereby decreasing passive solar gain to living rooms.

Note: given the above considerations, the cost allocated by the QS of £3k per unit, a total of £0.84m, could, and perhaps should, represent a saving. In this case, the area of opening to be glazed in for an individual balcony (fixed up to 1.1 m for the main east/west part) is 10.35 m^2, 41.4 m^2/floor, 579.6 m^2 per block, totalling 2,900 m^2. This gives rate of £290/m^2 - i.e. 45% of that for the 26-storey towers!

2.3 External surfaces

Since facing brick has been subject to patching, and the proposed cavity insulation will involve drilling the brickwork at regular intervals as well as raising the issue of need for further weather protection, application of a high performance silicon resin paint such as 'Lucite Silico Therm', is again suggested - with the added bonuses of enhanced diurnal U-values as well as the aesthetic facelift.

Note: See 1.3 note above with regard to alternative specifications for external paint.

2.4 Roof

The original construction with asphalt on a no-fines, foam slag screed, 4.5" (114 mm) reinforced concrete slab and skim plaster on 12.5 mm polystyrene suggests a U-value of approximately 1.44 W/m^2K. Subject to inspection, by converting to an 'upside-down' warm-deck, it should be possible to get U down to 0.2 W/m^2K or less with relative ease. The extra insulation would require to have compressive strength - Foamglas slabs or CFC and HCFC-free EPS slabs are options. These could be weighted down with some form of 'green' (e.g. sedum) or 'brown' (earth) roof. The cold bridges at window heads are already addressed to some extent by use of skim-coated polystyrene on ceilings.

Note: It is now understood that Cube HA has a preferred specification for a traditional warm-deck (not 'upside-down') with 100mm insulation slabs sealed with a Sarnafil membrane. If the insulation has a conductivity of 0.03 W/mK, this indicates a new U-value of 0.25 W/m^2K, somewhat higher than suggested above. The advantages of a 'green' or 'brown' topping (e.g. sedum as indicated by QS) are reduced water run-off, lowered U-value, enhanced microclimate and biodiversity, and prolonged life for the membrane, which is no longer subject to direct solar radiation. See also note for 1.4 above regarding use of existing membrane for vapour control, hence saving £28k per block. There is also mention of integration with PV, but the usable area relative to number of flats on these blocks is small.

2.5 Windows

The original timber double-glazed windows are in rather poor condition, and it is recommended that a programme of replacement with high-performance timber double-glazed windows be put in place. Timber is suggested because analysis has shown that it performs better than PVCu in terms of embodied energy, life expectancy, recycling, and disposal hazards; and also costs more in terms of renewal and maintenance. This would also provide an opportunity to upgrade the U-value to at least the 2007 norm of 1.8 W/m^2K (probably circa 3.0 W/m^2K at present), and it is important to note that this lower (better) value is assumed for analytical purposes relating to demand for space heating.

Note: 'Nordan' as cited by the QS is a reliable make, with better life expectancy (25 cf. 18 years) and lower maintenance costs than uPVC (as noted above). It is assumed the cost is based on 1.8 W/m^2K U-value. It is also stated by the QS that costs are based on uPVC, which should provide a degree of 'padding' compared with more economic high performance timber, especially in life-cycle terms. This assumption is based on analysis by another housing association, which estimated that both the average renewal cost and the combined renewal plus maintenance cost, averaged over respective lifetimes, are over 40%. This may surprise those used to regarding uPVC as maintenance-free.

2.6 Heating and hot water

Analysis again indicates that pragmatic upgrades to insulation as suggested above in the case of all five towers, together with replacement of windows, will reduce the thermal load for space heating (SH) together with domestic hot water (DHW) to the point that it will provide reasonable load-matching relative to a combined heat and power (CHP) system. For a 21°C all day (16 h) scenario for the 3-apartment flat, estimated space heating is 2,005 kWh (69.5% less than existing), hot water 2,600 and electrical appliances, cooking and lighting 4,161 kWh – 8,766 kWh in total (detailed analysis of loads in Appendix B and summary in 0.4.3 above). This corresponds to SAP 107(2001), 76 (2005) and NHER 9.8, up from 41 (2001), 42 (2005), NHER 3.6 prior to installation of cavity insulation. It again means replacing the two electric storage heaters in each flat with a 'wet' system. On the basis that hot water can be distributed vertically in the ducts between bathrooms, horizontal and vertical pathways for radiators again appear relatively simple. Within flats, this can be high level with drops, or low level with some disruption to flooring, both initially from main riser duct via cylinder and linen cupboards to the circulation zone. Radiators could flank concrete cross walls close to the circulation zone in living room and bedrooms, thus enhancing stored heat since dense concrete has high thermal capacity. In round terms, a 1.5 m width of 0.15 m thick concrete, 2.3 m high, will store 0.5 kWh of heat when its temperature is raised by 2 K. Incidental gains and linkage with the living room should obviate need for a radiator in the kitchen; a variety of locations are possible in the hall; and a heated towel rail would be useful in the bathrooms.

Note: The same comments as for 1.6 above apply with respect to planning for CHP relative to relatively short-term retention of the existing electric storage heating; and the relationship of this tactic to the criteria for SHQS. At present, without new CH, but with added cavity insulation, the predicted SAP is 51 (2001), 50.8 (2005) and NHER 4.8 - i.e. below the SHQS threshold. The QS schedule includes £1.4m for the four towers or £5,000 per unit. And the same comments as in 1.6 above apply here.

2.7 Ventilation

The existing vertical shunt system extracting air from bathrooms should be retained; and kitchens linked to it via the cylinder cupboard. As well as being essential, this will assist cross ventilation of fresh air through rooms, whether via trickle vents in cold weather or through open windows in warm weather. To further inhibit presence of stagnant air in hallways and provide some 'ventilation preheat', it is proposed to glaze in existing escape balconies, designing for controlled ingress of fresh air into the buffer spaces thus formed, and deliver it by low pressure fans to hallways. This would involve careful detailed design, and mitigation of the ventilation load has been assumed for calculation purposes. Again, replacement of the existing extract-only fans with heat recovery units at roof level should be explored with a view to utilizing lift shafts and lifts as transport media.

Note: Although, as noted in 1.7 above, the cost for roof-lift-lobby heat recovery does not look viable, the proposed ventilation preheat to individual hallways, by glazing in escape balconies does not appear in the QS cost schedule. The area per floor is about 15.77 m^2, 221 m^2 per block and 1,105 m^2 for all five blocks. If the cost/m were contained within £250/m^2, the total cost would be £276,250 - i.e. £563,750 less than the total allowed for glazing balconies. Neither is the proposed link from kitchens to the vertical extract from bathrooms currently included in the costs. Both these are advised and should be affordable given other suggested savings.

2.8 Communal laundry

This original 1960s amenity is still in full use - located on the ground floor. An important environmental benefit is that it reduces risk of high humidity, and hence high populations of dust mites, within flats; and also reduces the temptation to use radiators as a means of drying at times when the need for space heating is minimal or absent. Its popularity is significant as there is a belief, among some housing providers at least, that communal facilities such as this are old-fashioned, and would become 'white elephants'.

3.0 8 storey Bison towers (7 storeys x 4 flats + gr'd fl. x 2 flats + roof) [1963/497]

Fig 5. Image of 8 storey 'Bison' block

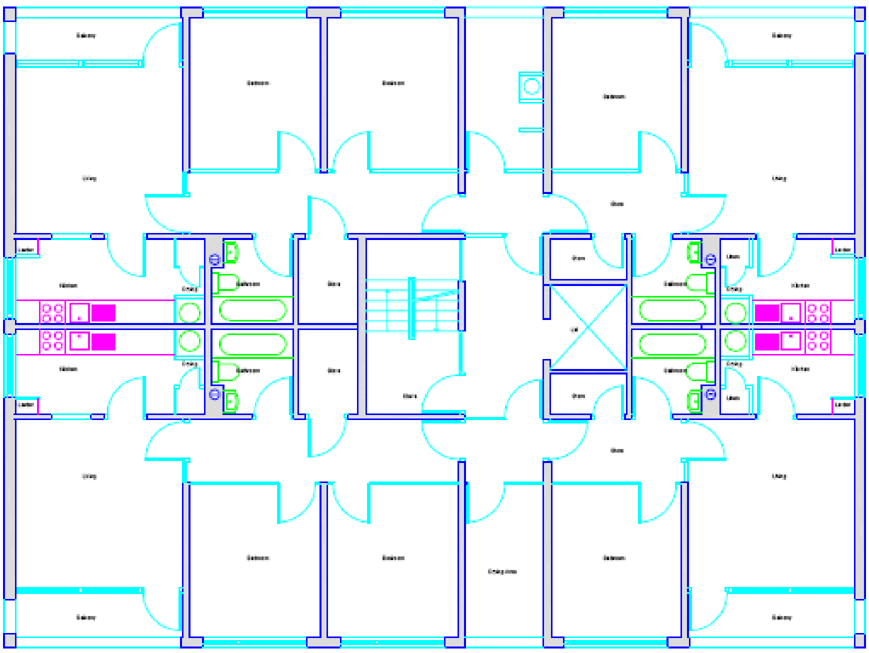

Fig 6. Typical Floor Plan of 8 storey 'Bison' block

3.1 Insulation and hygroscopic capacity - walls and floors

3.1.1 South and north gable walls

Existing pre-cast sandwich from outside - 76 mm reinforced concrete (k = 1.4 W/mK assumed), 25 mm open cell EPS (expanded polystyrene), 152 mm reinforced concrete (k = 1.4 W/mK assumed), plaster on hard, post-construction dry lining (assumed to be 15 mm polyurethane backing to 9.5 mm plasterboard fixed to existing surface via battens; and also assumed to have been applied to all six Bison towers). The original wall without dry lining is estimated to have a U-value of 0.935 W/m^2K, assuming there is no prolonged interstitial condensation within the EPS. With the assumed specification of dry lining, the present U-value should be in the order of 0.53 W/m^2K.

3.1.2 Window wall

Existing pre-cast sandwich from outside - 76 mm reinforced concrete, 25 mm open cell EPS, 102 mm reinforced concrete, plaster on hard, post-construction dry lining. The original wall without dry lining is estimated to have a U-value of 0.97 W/m^2K and 0.54 W/m^2K with dry lining. In terms of further upgrading, this presents a dilemma. The dry lining is limited in the same way as the Edwards 26 storey tower and the present U-values are poorer (higher values of heat loss) than upgrades suggested elsewhere. This is especially the case between bedrooms and external spaces via cross walls.

3.1.3 Wall between bedroom and balcony

This is originally 6" dense concrete, with an external lining of wood-wool shown on structural drawings, the U-value without dry lining is estimated to be 1.93 W/m^2K, and 0.75 W/m^2K after dry lining. The cross wall between the bedrooms and communal outdoor 'slot', which does not appear to have had any wood-wool lining, is even higher; respectively 2.65 W/m^2K before and 0.84 W/m^2K after dry-lining.

3.1.1-3.1.3 Proposal

There is a case to be made for complete encapsulation of the existing rectangular form of the block - say an extra 100 mm insulation (k = 0.034 W/mK) over opaque surfaces, glazing in the balconies and 'slots' (see 3.2 below) and replacing windows (see 3.5 below). This would reduce thermal transmittance (U-value) through the main outer walls to 0.21 W/m^2K.

Although it would mean three layers of insulation at various points through the construction, risk of interstitial condensation would be slight. The main area of risk would be close to the inside, as at present, but the relatively higher temperature of the nearest concrete to the inside (due to the extra layer of insulation externally) would mitigate this. Such encapsulation would also permit thermal enclosure of the 8th utility floor, and some thermal upgrading on top of the final occupied floor - i.e. roof to topmost flats (see 3.8 below). Finally, suitable edge insulation could be carried down into the ground in order to limit floor losses from the two ground floor flats.

Note and caveat: The QS schedule has included for external insulation - a cost of £123,200 per unit, totalling £0.98m for seven blocks. However, the detailed analysis in Appendices B and C indicate that this is a potential saving; one which should be seen in conjunction with 3.5 and 3.7 below. Enclosure of the 8th utility floor as suggested does not appear to be included in the cost schedule at present.

Adding hygroscopic capacity is also not straightforward. Since both living rooms and bedrooms have tongued and grooved boarding, it is again suggested that this could be sanded and sealed, also again having removed laminate flooring where this exists and carried out essential repairs or replacement. Similarly, cork tiles or linoleum on plywood sheeting is another option.

3.2 Balconies and 'slots'

Glazing in these spaces should be considered together with external insulation. However, it is suggested that double-glazed horizontal sliding windows are specified to counter frequent opening up of the balcony to the living room (the issue highlighted in 2.2 above). Similarly, it should also be noted that the recessed nature of the balconies means that the northern pair of flats will be subject to more self-shading than those on the south.

Note: At present QS has included Vitra/Windoor system as for 1.2, rather than system recommended above. The 'slot' glazing appears to be included under 'glazing to drying area' - see also 3.7 below. However, the cost per m^2, like the 26-storey tower but in contrast to that for the 15-storey towers, seems high. The area of balcony glazing required per apartment is short of 5 m^2, totalling 1,075 m^2 for all 217 apartments. This gives a figure of approximately £605/m^2 - i.e. in the same ballpark as 1.2.

3.3 External surfaces

A reliable proprietary system of external insulation and render should be specified, bearing in mind the 'breathability' of the render coating as well as its longevity in a harsh climate. The opportunity can again be taken to add some colour to replace the grey.

Note: See comment in 1.3 and 2.3 regarding alternative specifications for masonry paint relative to performance should the external insulation not go ahead (see note in 3.1 above)

3.4 Roof

Subject to inspection, and final use of the 8th floor, it should be possible to lower the effective U-value for the 7th floor flats to the same order as the encapsulated walls.

Note: There does not appear to be a cost set against this in the QS schedule.

3.5 Windows

The original timber double-glazed windows are in poor condition, and it is recommended that a programme of replacement with high-performance timber double-glazed windows be put in place. However, in this case, should the decision for external insulation go ahead, including double-glazing to balconies, this would make a case for prolonging the life of the largest area of existing fenestration to the living room (with repair/maintenance as required). Then, replacing bedroom and kitchen windows will, as for 2.5 above, provide an opportunity to upgrade the U-value to at least the 2007 norm of 1.8 W/m^2K, and this better value is assumed for analytical purposes relating to demand for space heating.

Note: It is assumed, as for 2.5, that the Nordan specification by QS is for this U-value and for all windows except the living room; and that the small sum has been included in the cost for its repair.

3.6 Heating and hot water

For this set of six tower blocks, analysis shows that significant upgrades to insulation as suggested above, together with replacement and addition of windows, will reduce the thermal load for space heating (SH) together with domestic hot water (DHW) to a level of viability for a CHP system, but one that might indicate a need for further integrated electrical generation. In other words, the improvement to thermal efficiency will be such that a typical CHP 'heat to power' ratio, using the need for heat as the criterion, could leave electricity under-funded; and roof-integrated wind turbines could in this case supply such a shortfall (all subject to later analysis). For a 21^{o}C all day (16 h) scenario for the externally insulated 2-apartment flat (as per 3.1 above), estimated space heating is 1,173 kWh (72% less than existing), hot water 1,664 and electrical appliances, cooking and lighting 3864 kWh – 6,701 kWh in total. This corresponds to SAP 117(2001), 78 (2005) and NHER 10.0, up from 53 (2001), 52 (2005), NHER 5.2 as existing. However, detailed analysis of loads in Appendix B goes on to examine a 'fall-back' position where the balconies and 'slots' are glazed in but external insulation is omitted. For this 'fall-back' scenario, space heating is 2,200 kWh (48% less than existing), hot water etc as before – 7,728 kWh in total. This corresponds to SAP 112 (2001), 77 (2005) and NHER 10.0, noting that the influence of the CHP together with the existing level of insulation and double-glazing is such that the lack of external insulation only marginally affects the ratings. This again means replacing the two electric storage heaters in each flat with a 'wet' system; but in this case, it may be advisable to split the routes for distribution of domestic hot water and space heating. The former could be sited in the bathroom duct, feeding directly into the cylinder cupboard in the kitchen. The vertical rise for the latter might be better located in the store within each flat, with horizontal flow and return to radiators in each room below the flooring in the hallway. Radiators could then again advantageously flank concrete cross walls close to this circulation zone.

Note: See 1.6 and 2.6 above for comment relating to cost of CHP.

3.7 Ventilation

The existing vertical shunt system extracting air from bathrooms and kitchens should be retained. As well as being essential, this will assist cross ventilation of fresh air through rooms, whether via trickle vents in cold weather or through open windows in warm weather. As for the 15-storey towers (2.7 above), to further inhibit presence of stagnant air in hallways and provide 'ventilation preheat', it is proposed to glaze in existing east/west 'slots', designing for controlled ingress of fresh air into the buffer spaces thus formed, and deliver it by low pressure fans via ducts in the top of store cupboards into hallways. Again, replacement of the existing extract-only fans with heat recovery units at roof level should be explored with a view to utilizing lift shafts and lifts as transport media.

Note: see 2.7 for comment relating to heat recovery versus preheat from the 'slots" (similar to escape balcony set-up in 2.7), where it is accepted that the former is probably not good value (at £30k in this case). In these blocks the QS has also included a cost for the glazing for the latter, but as with 3.2 above, it appears unreasonably high - there are 14 'slots' per block, excluding the final uninhabited level and the ground floor, giving an total area for the 7 blocks of 188 m^2 and a rate of £750/m^2 (£141,050/188). At any rate, it looks as if there is also scope for the suggested preheated ventilation to hallways without incurring cost over and above that in the schedule.

3.8 Communal drying/laundry/amenity/facility

The timber roof structure and vertical openings (corresponding to windows in flats below) provides scope for an attractive top-lit penthouse for amenity use as well as utility - both laundry (as 2.8) and passive, as well as machine, drying.

Note: This is not currently included in the QS cost schedule, and affects the roof - see 3.4 above. There are clearly cost 'swings and roundabouts' in relation to these blocks, which offer a range of choices - the significant variables, other than the communal rooftop facility, being heat recovery, external insulation and current high rates for glazing in balconies and 'slot' openings.

4.0 9 storey Maisonette Blocks (8 storeys + ground floor flats etc.) [1965/194]

Fig 7. Image of 9 storey maisonette block

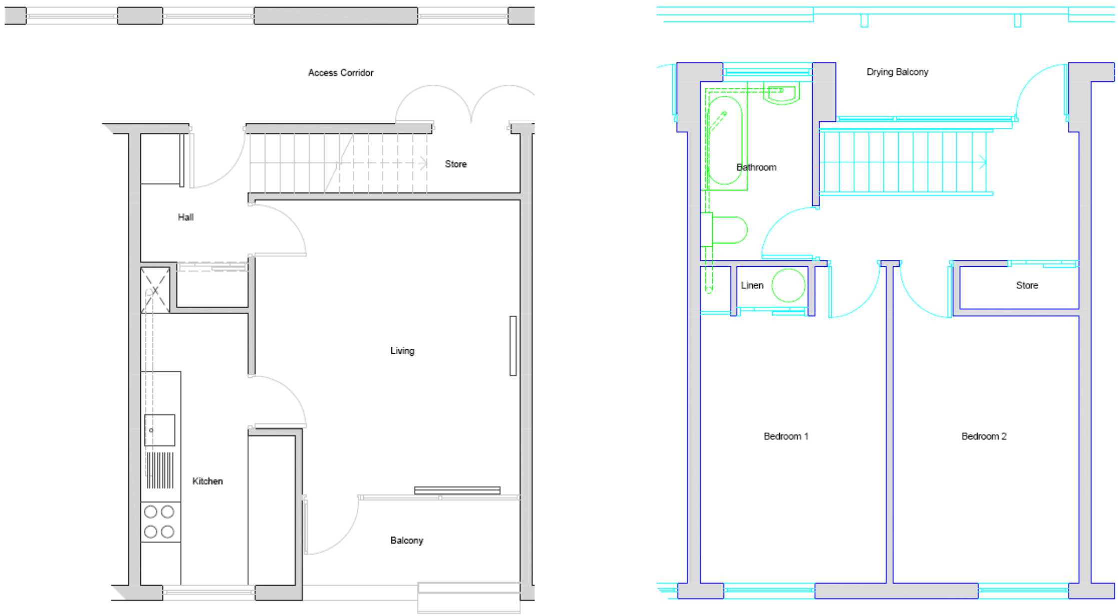

Fig 8. Typical Floor Plan of 9 storey maisonette block

4.1 Insulation and hygroscopic capacity - walls and floors

4.1.1 South and north gable walls

Existing construction from outside - 106 mm facing brick (k = 0.84 W/mK assumed), 76 mm cavity, 178 mm reinforced concrete (k = 1.4 W/mK assumed), plaster on hard (no information of any change internally). The as-built wall is estimated to have a U-value of 1.57 W/m^{2}K. If the cavity were insulated with blown glass wool or mineral wool (k = 0.034 W/mK), the U-value would improve to 0.37 W/m^{2}K.

4.1.2 East window wall

Existing construction from outside below sill level - 106 mm facing brick (k = 0.84 W/mK), 67.4 mm cavity, 106 mm common brick (k = 0.62 W/mK), 12.5 mm plaster on hard (k = 0.5 W/mK) - estimated to have a U-value of 1.47 W/m^{2}K, which, if insulated as above would fall to 0.4 W/m^{2}K. Existing construction from outside above sill level - 6 mm 'Granitone' mineral board (k = 0.25 W/mK), 38 mm cavity, 9.5 mm 'Timberit' fibreboard (k = 0.057 W/mK), 25.4 mm cavity, 106 mm common brick - estimated to have a U-value of 1.08 W/m^{2}K. If insulated with mineral wool slabs between new Eternit (or similar mineral board) cladding and the brickwork, the U-value could achieve a similar value - circa 0.4 W/m^{2}K. There are other variants - e.g. the return wall between kitchens and next-door balcony, where 7" (178 mm) dense concrete replaces the brick - estimated as-built U-value 1.13 W/m^{2}K, but with potential to a U-value of 0.25 W/m^{2}K.

4.1.3 West access façade

The outer skin of the unheated access deck is the same as the opaque parts of the east façade. Its mean thermal resistance, including single-glazed timber windows, is estimated to be 0.625 m^{2}K/W, with the resistance of the inside air taken as 0.125 m^{2}K/W.
The construction between the hall, stairs and store is a combination of 7" concrete (assumed medium density) and solid timber doors, frames etc. The mean resistance of this is estimated to be 0.41 m^{2}K/W, including the internal surface resistance. Adding these two values together gives a total mean average thermal resistance of 1.035 m^{2}K/W - i.e. an average U-value of 0.97 W/m^{2}K. If the opaque parts of the outer skin are upgraded to a U-value of 0.4 W/m^{2}K as above, it is estimated that the new mean average

resistance for the combined access deck construction now increases to 2.32 m^2K/W, giving an overall mean U-value of 0.43 W/m^2K.

4.1.4 West upper floor façade

At this level there are four variants of cavity construction, estimated to have U-values of 1.57, 1.47, 1.52 and 1.23 W/m^2K. With cavity filling, it is expected that these could respectively be upgraded to 0.53, 0.4, 0.52 and 0.48 W/m^2K.

Note: The cost of cavity insulation is not included in QS schedule - assume this is because full grant is available?

4.1.5 Exposed sections of upper floor

In these sections, the 7" concrete slabs are reduced to 6" and 1" of polystyrene inserted, giving a U-value of approximately 0.94 W/m^2K.

4.1.6 Exposed sections of first floor

These are potentially problematic. Although parts of the first floor are above flats and a concierge office, a significant proportion of it is above unheated accommodation or open. Allowing for the cork floor finish as per original drawings, it is estimated that the U-value is as high as 1.8 W/m^2K.

Note: There does not appear to be a cost allowed in the QS schedule to address this issue.

4.1.1-4.1.6 Overall comment

Overall, although much of the construction can be relatively easily and economically upgraded, the expectation for resultant U-values is still generally on the high side relative to what is proposed for high-rise types 1-3 above; and some relatively acute cold bridges are likely to remain. There is also very little scope for hygroscopic capacity without adding some. There are no timber floating floors (implying potential noise nuisance) and even the intermediate floors within maisonettes are reinforced concrete slabs. Accordingly, it is worth considering hygroscopic linings to the structural cross walls. Even Claytec clay board on dabs would help in this regard and the decision will require to be made in conjunction with a strategy for ventilation - see 4.7 below.

4.2 Balconies/verandas

This block is unique in the Wyndford portfolio in that it has two private outdoor balconies per maisonette - a west-facing drying space, which should help to reduce moisture loads within the dwellings, and an east-facing space off the living room. Both of these could be tempting for outdoor relaxation, depending on weather, time of year and time of day, but to capitalize on this potential, the utility spaces could benefit from a 'face-lift'. The solar access and aspects to both west and east are quite good - open landscaped areas.

4.3 External surfaces

The brickwork in this block is in reasonable condition, if somewhat austere. On the assumption that the 'Granitone' panelling will be replaced in order to upgrade insulation, the opportunity can be taken to introduce some cheerful colours. Access decks would also benefit greatly with some freshly and brightly painted surfaces. The partial mesh screens on the drying balconies are also uninspiring visually.

Note: See notes for 1.3, 2.3 and 3.3 above concerning technical performance of specified alternatives to recommended Lucite Silico Therm for external surfaces. The QS schedule has a note 'excludes balcony areas'. It is assumed this means individual amenity and utility balconies, but not access decks, which would greatly benefit from a facelift. However, since these are enclosed, an alternative to Lucite would not only be acceptable but also perhaps desirable - e.g. a specification similar to that which might be used in lift lobbies, where the main criterion is vandal-resistance rather than weather resistance and breathability.

4.4 Roof:

The original construction with three layers of bituminous felt over a vermiculite screed, 7" reinforced concrete slab and foil-backed plasterboard on battens suggest a U-value of approximately 1.27 W/m^{2}K. Subject to inspection, it should be possible to lower the U-value to circa 0.2 W/m^{2}K using the same upside-down warm roof concept suggested elsewhere.

Note: Refer to comments for 1.4 and 2.4 for potential saving of additional vapour control layer.

4.5 Windows

It appears that the original timber single-glazed windows have been replaced with uPVC double-glazed units apart from the windows on the west façade to the access corridor. Therefore, it may not be economic to carry out more upgrading in the near future (no change assumed in analysis).

4.6 Heating and hot water

It is assumed that the original electric radiant and convector heaters in the living rooms have now been replaced with partial central heating with storage units as elsewhere - i.e. one unit in the living room and one in the hallway. Once again, analysis supports the upgrades to insulation suggested above, reducing the thermal load for space heating (SH) together with domestic hot water (DHW) to a satisfactory point for a CHP system. However, partly due to the form and construction of the maisonette and partly due to it being uneconomic to replace existing double-glazed windows, the resultant space heating load remains on the high side. For a 21^{o}C all day (16 h) scenario for the 3-apartment intermediate-location maisonette, estimated space heating is 5,181 kWh (41% less than existing), hot water 2,600 and electrical appliances, cooking and lighting 4,161 kWh – 11,942 kWh in total (detailed analysis of loads in Appendix B). This corresponds to SAP 103 (2001), 76 (2005) and NHER 9.4, up from 40 (2001), 41 (2005), NHER 3.5 as existing. Central ducts on the kitchen/bathroom side of plans facilitate vertical distribution, with storage cupboards aligned in such a way as to assist with further horizontal distribution within dwellings to radiators. NB: it is not clear from drawings how the vertical ducts are fireproofed/sound-proofed (to be checked).

It may be noted at this point that if a new biomass CHP gasification plant (using either wood chips or wood pellets) were to be sized to serve all the high-rises at Wyndford, it would probably be of considerable interest as a demonstration project. It is worth emphasizing that significant variations have been predicted for the heat to electricity ratios in such plants. At the BedZED project to the south of London, Arups estimated this to be 1.39; while for Bowhill and Cardenden in Fife, (including social housing owned by Ore Valley HA) RD Energy Solutions estimated the ratios to be considerably less, at 1.14 and 1.15 respectively. All three studies were for woodchips, with weekly consumption predicted as follows; BedZED 20 tonnes; Bowhill 55 tonnes; Cardenden 156 tonnes. The tripling of consumption and more than doubling of thermal output comparing Bowhill to Cardenden (2.5 MW cf. 6.1 MW) has not significantly affected the ratio of heat to electricity. Hence the cause of the significantly higher ratio predicted for BedZED is not immediately apparent. In any event, if wood chips were used and calculations showed a surplus of heat relative to demand in the upgraded dwellings, this might be useful for drying the woodchips (although it is best for the supplier to guarantee maximum moisture content). There is also bound to be more surplus heat in summer than winter, and seasonal thermal storage may be advisable to avoid wasting heat. On the other hand hot water tanks with an immersion element can be used to mediate between electrical and thermal outputs.

4.7 Ventilation

In this instance the planning has achieved natural ventilation throughout, including kitchens and bathrooms. However, this raises the question of how to make ventilation more energy efficient. The simplest solution may be to provide humidistat-controlled, variable speed extracts in both kitchen and bathroom. Also, on the basis that warm air is likely to stratify up to the first floor, there might be a case to use a low-powered fan to re-circulate air back down to the living room. The landing cupboard could facilitate this. A full heat recovery system in each flat appears to be more problematic, but nevertheless should be investigated.

Note: Extract fans, as suggested above, are currently not included in the QS schedule.

4.8 Communal amenities

The current use of the ground floor, over and above flats and concierge, has not yet been fully established, but could offer potential in this regard. From the point of view of mitigating heat loss from some of the maisonettes above, there is a case for as much of the ground floor to be heated as possible.

Note: There is nothing included in the QS schedule for this at present.

5.0 4 storey Maisonette Blocks (+ flats in corner locations) [1962/233]

Fig 9. Image of 4 storey maisonette block

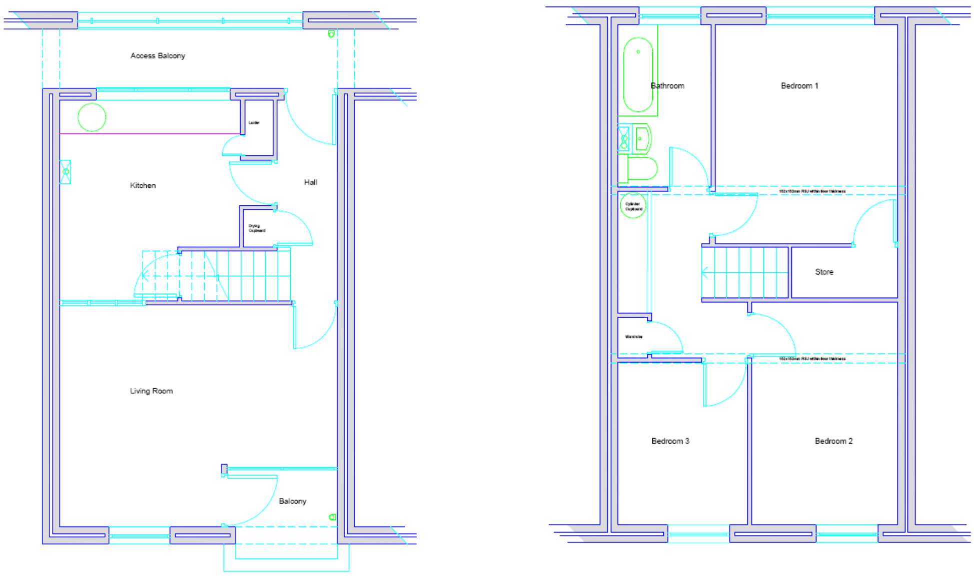

Fig 10. Typical Floor Plan of 4 storey maisonette block

5.1 Insulation and hygroscopic capacity - walls and floors

5.1.1 Main walls

Existing construction from outside - roughcast (18 mm and k = 0.675 W/mK assumed),106 mm common brick (k = 0.84 W/mK assumed), 75 mm cavity, 106 mm common brick (k = 0.62 W/mK assumed), plaster on hard (12. 5 mm and k = 0.5 W/mK assumed). The as-built wall is estimated to have a U-value of 1.41 W/m^2K (rising slightly to 1.47 in any sections with facing brick in lieu of commons roughcast). If the cavity were to be, or has been, insulated with blown glass wool or mineral wool (k = 0.034 W/mK), the U-value would improve to 0.37 W/m^2K (noting that there were signs of this in block inspected, and several tenants had clear recollection of these measures being carried out by SSHA or Scottish Homes). It may also be noted that the cavity width of 75 mm has been estimated from the overall dimension of thickness on original drawings - 12.5". converting to 317.5 mm; and further that although the nominal width of cavities in such walls is often given as 2" or 50 mm, the measured thicknesses are often circa 75 mm.

5.1.2 Window wall to access decks

Existing construction is shown on drawings to have an overall thickness of 210 mm, including finishes, and to be of some form of concrete block cavity construction. The following is assumed from outside - 18 mm cement render (k = 0.5 W/mK), 80 mm medium density concrete block (k = 0.51 W/mK assumed), 50 mm cavity, 50 mm medium density concrete block (k = 0.51 W/mK assumed), 12 mm plaster on hard (k = 0.5 W/mK) - estimated to have a U-value of 1.48 W/m^2K; which, if insulated as above, would fall to 0.52 W/m^2K.

Note: The QS schedule does not include a sum for insulating these walls, although it is unlikely that they have been insulated (as opposed to the cavity brick walls).

5.1.3 Exposed sections of intermediate floors

Existing construction from outside - 12.5 mm asbestos wood soffits (probably Asbestolux, with assumed k = 0.16), 50 mm fibreglass quilt between timber joists (k = 0.034 W/mK assumed), air cavity between timber joists; timber flooring (21 mm and k = 0.14 W/mK assumed) - estimated to have a U-value of 0.49 W/m^2K.

Note: Again the QS schedule does not appear include a sum for insulating these sections of exposed floor, although it is unlikely that they have been insulated to a greater degree than as built.

5.1.4 Ground floor

From CIBSE A3, U-value predicted to be generally 0.34 W/m^2K, although corner locations may be somewhat higher. (Note: most corners occupied with pram stores etc.)

5.1.1-5.1.4 Overall comment

Much of the construction can be relatively easily and economically upgraded with cavity insulation, if this has not already happened. The intermediate timber floors and timber staircase in maisonettes also provide some embedded hygroscopic capacity to complement the thermal capacity of inner leafs of plastered brickwork. But the more timber is exposed by reconditioning, or covered with another hygroscopic material, the better. Plasterboard lining to internal partitions will also help to some extent, but could possibly be supplemented by Claytec clay board (included in QS schedule).

5.2 Balconies/verandas

All dwellings have a recessed or semi-recessed private outdoor balcony. It is suggested that consideration be given to glazing in these spaces. This would thermally buffer the large windows to living rooms, but still leave a smaller window opening directly to the outside. The detailed specification would of course be cost dependent, but it is recommended that either the single-glazed Vitrol/Windoor system (as for 1.2) or some form of double-glazed horizontal sliding windows (as for 3.2) be used in order to allow the space to open up and close down according to weather.

Note: Unlike the 26-storey and 8-storey tower blocks, but like the 15-storey towers, these balconies do not have solid balustrades. Hence, if glazed in, there would need to be a section of fixed toughened glass up to 1.1 m, with Vitral (or equivalent) opening sections above. There are also slight variants in size/design among the 4-storey walk-ups, with some balconies only slightly projecting beyond the wall face and others projecting significantly. Since the balconies are on alternate floors, this raises the need for roofs if they are to be enclosed. An estimate of the mean area, including glass roofs is 8.1 m^2 per unit, giving a total of some 2,340 m^2. In this case, the indicative m^2 cost given by the QS looks significant cheaper than either the two very expensive towers (26 and 8 storey) or the 15 storey towers - at circa £185/m^2. The other issue is that the number of units given in the cost schedule is 289 - assumed to be the number that are rented out of the total 649 in 4.storey blocks. Half of the maisonettes are on the ground floor, and some (including some that are rented?) are already glazed in. At any rate, it is possible that 289 is in excess of the number that might be required to be glazed.

Overall, although it is MEARU's understanding that Insutech visited the site in order to evaluate need with respect to such installations, the wide scope of the costs relative to the varying housing types suggests a need to reinvestigate and double-check areas required.

5.3 External surfaces

The brickwork and roughcast in these blocks are in reasonable condition. However, threshold spaces in the stair 'close' and on access decks are dismal. As for 4.3, the opportunity can be taken to introduce some cheerful colours in durable paints.

Note: Although these are external in that access decks have large unglazed 'window' openings, the surfaces are much more sheltered compared with the external surfaces of the tower blocks. Therefore, in this instance a different specification of paint to that of Lucite Silco Therm could be appropriate.

5.4 Roof

This is a traditional tiled pitched roof with timber trusses. The original slim fibreglass quilt is likely to have been upgraded (similar to the cavity insulation several long-term tenants recalled that roof insulation had been upgraded by SSHA or Scottish Homes), possibly under the auspices of Heatwise Glasgow. If 52 mm Pavatex Isolair fibreboard (k = 0.045 W/mK) is placed across the top of 100 mm deep ties, with cellulose fill (or mineral wool quilt) between joists (k = 0.034 W/mK), it is estimated that the U-value will be a respectable 0.21 W/m^{2}K. (Note: OSB or equivalent could be laid on top of the Pavatex to provide robust crawl-ways.)

Note: The QS schedule does not currently include a cost for upgrading the roof insulation.

5.5 Windows

Due to the 'right to buy' sales, it is difficult to tell whether all rented dwellings still have timber single-glazed windows. In any event, the opportunity should be taken to schedule a programme to upgrade windows to high performance timber types, conforming to the current standard of 1.8 W/m^{2}K if not lower. The exception might be the large living room window and French door, assuming that balconies are glazed.

Note: The comments made for 2.5 and 3.5 apply here in relation to relative timber/uPVC costs and performance. Due to the piecemeal status quo, it may be that this item is more than adequately covered in the QS costs, even though only rented dwellings are included in the total - i.e. decisions would require to be made on a house-by-house basis as to which windows should be renewed.

5.6 Heating and hot water

The current status is partial central heating with storage units as elsewhere - i.e. one unit in the living room and one in the hallway. However, the case for a CHP system here is weakened by the proportion of flats now in private ownership - now in excess of 50%. Even though the Scottish Government has called a halt to 'right to buy' for new housing, and may extend the scope of proscription, the present situation is dynamic in this regard and strengthens the case for individual solutions for heating. Distribution for any kind of district heating would also be inherently awkward. The options for horizontal distribution are limited. Access to roof spaces over privately owned flats would cause problems, suggesting the access decks as the best option, with insulated pipe-work fixed externally below soffits. However, windows facing on to the deck go right up to the ceiling, and there is no route into maisonettes for individual pipe distribution other than within the intermediate timber first floors. Overall, it seems worth considering options for heating systems that can be installed on a home-by-home basis and do not rely on a major distributive infrastructure.

The cheapest solution would be to stay all-electric, adding fixed appliances to bedrooms, bathrooms and perhaps kitchens. However, this sidesteps the issue of carbon emissions, apart from modest reductions attributable to increased energy efficiency. Conversion to 'wet' systems with individual condensing combi-boilers would reduce carbon emissions further - by circa 0.3 kg/kWh delivered, corresponding to a 58% reduction. However, there is currently no gas supply to the scheme. An electric 'wet' system is another option (see next paragraphs), which would give the same advantage of increased responsiveness as gas. The carbon emissions for such a system could be mitigated by solar thermal arrays on the roofs, but distribution from a communal pre-heat tank to individual cylinders and boilers would encounter the same issues as for CHP. The same would apply if communal ground source heat pumps were to be located in the former pram stores at the corners of blocks on ground floors; or if a combination of solar thermal and heat pumps were employed, as by Shettlestone Housing Association. However, this last suggestion might be worth exploring in parallel to a competing option with individual boilers. It would in any case be of value to establish the degree of difficulty and disruption that distribution via the underside of access decks would in fact constitute.

A more radical solution would be to consider hydrogen as a viable alternative fuel, associated with individual fuel cells, and with on-site generation of electricity by wind turbine funding on-site electrolysis of water. In broad-brush terms, one might expect each 5 kWh to produce 1m^3 hydrogen, including energy needed for cleaning, drying and compressing the gas. This amount of hydrogen could then be expected to yield circa 1 kWh of electricity and 1 kWh of heat. Berwick Housing Association is soon to trial just such a proton exchange membrane (PEM) fuel cell set-up in the rural Borders area of Scotland. However, it poses the question of whether it would not make more sense to connect the turbine to the grid and use electricity directly. Also, the efficiency of a fuel cell and net AC power output will vary with the flow rate of fuel; and the heat recovered will also vary with both fuel input and flow and return temperatures adopted - the lower the temperatures, the greater the capture and the steeper the increase relative to energy input. This in turn suggests a low-temperature wet system, either by replacing existing flooring or embedded in plaster on walls - perhaps desirable, but all adding to cost. If electricity were used directly, as opposed to a means of producing hydrogen, this could be either in the present storage-heating mode or with heating changed to a wet system with an electric boiler (and ideally more hot water storage and insulation).

The analysis (appendices A-C and summary in 0.4.3 b above) indicates that a single wind tower of adequate diameter and height could meet the entire load for the walk-up maisonettes and flats, improved as proposed. For a 21^{o}C all day (16 h) scenario for the 4-apartment maisonette, estimated space heating is 2,140 kWh (76% less than existing), hot water 3,056 and electrical appliances, cooking and lighting 4,667 kWh – 9,863 kWh in total (detailed analysis of loads in Appendix B). This corresponds to SAP 69 (2001), 63 (2005) and NHER 7.4 for a standard electric boiler, up from 31 (2001), 33 (2005), NHER 2.4 as built with no cavity insulation; and SAP 79 (2001), 68 (2005) and NHER 8.3 for a CPSU. Total annual loads on this basis for all 353 units is estimated as 5,368 MWh. Theoretically a turbine tower of the equivalent height to the 26-storey flats might be located centrally within the triad of Bisons at the north-west end of the scheme. The wind velocity at such a height should average some 8.4 m/s (using an exponent of 0.3 on a standard power-law formula at a hub height of 80 m). However, large turbines are notoriously sensitive to urban texture, so that the best solution might be to buy into one on a suitable rural site in the vicinity of Glasgow.

The swept area of a turbine blade is proportional to the power output. The UK's first wind farm at Delabole in Cornwall had blades of 34 m diameter, a swept area of 908 m^2 and a power output of 0.4 kW per turbine (mean wind velocity of 7.6 m/s at hub height). Therefore a turbine of 80 m diameter would have a swept area of 5,027 m^2 and a power output of 2.2 MW. (Note: although this is according to the proportional relationship, the Delabole website is rather more optimistic, predicting 2.3 MW from a 70 m diameter blade.) A 2.2 MW turbine should yield approximately 6,325 MWh annually (2.2 x 2,875 hours) and, allowing for a further 10% loss, this gives an annual working output of approximately 5,700 MWh - closely matching the estimate give above and elaborated in Appendices A and B.

5.7 Ventilation

As for 4.7 above, the planning has achieved natural ventilation throughout, including kitchens and bathrooms. In addition each dwelling has a small drying cupboard with its own system of natural ventilation to the outside (varying according to plan type). All kitchens were originally fitted with a pulley. These may not have survived in many cases, but the communal drying areas adjacent to each staircase do seem to be well used (see 5.8 below). Mechanical ventilation with heat recovery (MVHR) should also be considered.

Such a unit could be located within bathrooms (e.g. above WC cisterns), exhausting from both kitchen and bathroom (horizontally to the outside from the latter from lower maisonettes; and through the roof for upper ones); and supplying to the top landing, which would function as a distribution plenum - especially for bedrooms.

Note: The QS schedule has not included a cost for MVHR.

5.8 Communal amenities

Acknowledging the success of the communal laundry in the 14-storey tower blocks, it is suggested that consideration be given for a similar facility in the ground floor pram stores (no longer used for this purpose) of these 4-storey walk-ups, possibly still leaving some space for communal storage of large items. Alternatively, upgrading the communal drying rooms to small laundries (4.8) would again have the benefit of reducing dependency on the dwellings themselves for drying, albeit that the small drying cupboards within dwellings could still be used for this purpose.

Note: The QS schedule has not currently included a cost for such a facility.

6.0 Concluding comments

6.1 Specification options

The favoured options relative to the above five sections have been discussed with Hugh Aitken of Martin Aitken Associates; and drawings and additional specification notes provided thereafter. The premise is that the construction proposals are practical as well as near-minimal in terms of achieving the key aims - SHQS compliance, affordable comfort etc. The room for cash-flow manoeuvre lies mainly with the timing of window replacement and glazed buffer spaces where these have been recommended. However, there is also scope for cost refinement in terms of detailed design and specification - particularly for items such as:

window replacement (e.g. comparing capital cost, maintenance cost and longevity of uPVC with high performance timber);

glazing in of balconies (proportion of fixed to movable glazing and mechanism for opening);

appropriately different specification of paint for various communal situations - e.g. external walls of towers, semi-open access decks, enclosed access decks, stairs and lift lobbies.

In terms of services, the radical proposal lies with the intended heating upgrades - the move to 'wet' systems, coupled with major infrastructural commitment such as CHP and wind generation. Initially for CHP there are fundamental decisions to be made with respect to type and location of plant, as well as type and supply of fuel. It is also new territory for housing associations to enter into financial arrangements with the owners of major wind farms, as tentatively mooted. Moreover, both the phasing and the extent of financial aid will be critical to outcome, with the status quo of grid-connected electric storage heating mediating in the interim period (at least up until 2015 by which time compliance with SHQS NHER/SAP ratings should have been achieved).

At a more minor level, improvements to the ventilation, in two cases linked to the glazing in of outdoor communal spaces and in most cases including some potential for heat recovery, are not critical to the basic upgrade to fabric, and would provide further scope for phasing. From the indicative costs it looks as if heat recovery from shunt ventilation shafts in tower blocks to lift lobbies would not be good value for money. On the other hand, it is considered that the pre-heated supply to individual hallways from enclosed fire balconies and slots (15-storey and 8-storey towers) would be worthwhile, especially since these measures simultaneously tackle 'cold bridge' sections of external wall. So also would individual MVHR systems for the walk-ups (supply to stairwells only); and mechanical extract from kitchens and bathrooms in the 9-storey maisonette slab.

6.2 Cost benefit assessment, including life-cycle analysis

The main steer for this lies in the brief conclusions in 6.1 above, with justification of benefit in respect of detailed proposals provided by the detailed thermal analysis in the following 3 appendices, taken together with summarised comments in 0.2.3, 0.3 and 0.4. At the time of writing, the initial cost appraisal by Martin Aitken Associates does not include life-cycle analysis, which precludes the provision of more definitive techno-financial conclusions. However, the present cost spreadsheets do indicate scope for savings in some areas that could possible permit additional expenditure in others. The detailed notes inserted at appropriate points in sections 1.0-5.0 above provide a basis for further consideration of detailed design and specification beyond this initial 'options appraisal' stage - i.e. once a consultancy team incorporating full architectural services is in place. Discussions have also taken place with Jon Cape of RENEW, and clearly he will be involved in potential funding opportunities with regard to renewable CHP - possibly wind power as well. There have also been ongoing discussions between Willie Croft, Maureen Hannigan and Colin Porteous during the preparation of this report concerning options and opportunities for cavity and internal insulation building-integrated PV etc. As stated above, opportunities for more detailed performance specification and phasing works are embedded in the various stages of this report and decisions would require to be made by Cube once in possession of more advanced technical and cost reports for specific elements and components.

6.3 Outline Monitoring Strategy

6.3.1 Overall Comment

The strategy adopted would depend to some extent on the final decisions regarding upgrading and its phasing; and the aim would be to provide a thorough post-occupancy evaluation as follows:

6.3.2 Post Occupancy Evaluation (POE) - occupants

Postal and doorstep surveys similar to those carried out as part of this Options Appraisal would form one strand of post-improvement monitoring.

6.3.3 Post Occupancy Evaluation (POE) - measured data in dwellings

A second strand would be more in-depth and longer term instrumented measurement and data collection, possibly including meter reading and/or monitoring appliance use.

6.3.4 Post Occupancy Evaluation (POE) - performance of plant and infrastructure

A third strand would include detailed monitoring of CHP, wind generators and other renewable plant, including infrastructure and the ease of installation and maintenance.

6.3.5 Post Occupancy Evaluation (POE) - performance in terms of cost and benefit

6.3.6 Who does what?

MEARU would be pleased to have the chance to bid for 6.3.2 and 6.3.3. However, 6.3.4 would require more specialist engineering knowledge and expertise - i.e. the realm of a mechanical and engineering services engineer, with experience of renewable technologies. 6.3.5 requires quantity surveying expertise, ideally with experience in the environmental architecture field.

APPENDIX A: WYNDFORD ENERGY EFFICIENCY OPTIONS APPRAISAL

Paper for WREC 2008 Conference, Glasgow, summarising BREDEM thermal analysis

Opportunities and Constraints for Upgrading 1960s Housing to Low-Carbon Status

Prof Colin Porteous[1] & Rosalie Menon[2]

[1] Co-director/Senior Researcher Mackintosh Environmental Architecture Research Unit (MEARU), Glasgow School of Art, Glasgow, UK, Tel: 44-141-353-4657, Email: <c.porteous@gsa.ac.uk>
[2] Lecturer, Mackintosh Environmental Architecture Research Unit (MEARU), Glasgow School of Art, Glasgow, UK, Tel: 44-141-353-4657, Email: <r.menon@gsa.ac.uk>

1 Introduction

MEARU is currently engaged in an options appraisal for Cube Housing Association (CHA), its fundamental purpose to explore economic means of alleviating fuel poverty through improved thermal performance in its large 1960s scheme in northern Glasgow. This is a mixed high-rise and low-rise development, original drawings by the Scottish Special Housing Association dating from 1961-65. The aim of this paper is to identify opportunities and constraints for low-carbon solutions to the brief; recognizing that this is not the same as new-build low-energy, low-carbon solutions.

2 Context and Methodological Approach

The high-rises accommodate 1,150 dwellings, 64% of the total. Of the remaining 36% of walk-up flats and maisonettes, a large number are now in private ownership. A different energy strategy is therefore required for this typology, and this paper will concentrate on options for the high rises - 26, 15 and 8 storey flats in sixteen towers and a 9 storey block with four sets of maisonettes over flats. These vary both in terms of initial construction and subsequent changes such as replacement of windows and addition of insulated linings internally. Therefore a uniform constructional solution is not feasible. MEARU's client, CHA, has also made it clear that solutions must be economically pragmatic and capable of phased implementation. For example, their initial cost analysis had ruled out over-cladding all the high-rises. However, a minimum requirement is that all housing is brought up to Scottish Housing Quality Standard (SQHS). This means achieving a minimum Standard Assessment Procedure or SAP rating of 50 with full central heating with appropriate insulation and energy efficiency. CHA also expressed interest in CHP as a solution.

The present partial heating system in all units is all-electric (no mains gas distribution on site), with one storage unit in the living room and one in the hallway. Full central heating (CH) enabled by combined heat and power or CHP implies a shift to a more responsive 'wet' method of heat delivery. Due to the existing vertical servicing in all the high-rises, this seems feasible, without significant disruption to existing internal fabric. For CHP to be viable, the following are key criteria: a) a suitable annual balance between thermal and electrical demand; b) avoidance of dumping heat at times of low demand; and c) a means of accessing adequate heat at times of high demand. A solution to b) and c) would be to provide seasonal thermal storage and heat pumps; domestic hot water (DHW) mediating between electrical and thermal loads since water can be heated by electric immersion or surplus heat from the CHP engine.

Since the economic and practical constraints of upgrades imply 'living with' a relatively high overall energy demand, albeit significantly less than at present, CHP by means of biomass gasification is an attractive option. The potential also exists for either wood chips or pellets to be transported on water to within a few hundred meters of the site, the final stage on the Forth-Clyde Canal. However, with respect to criterion a), there is considerable divergence in estimates as to what the ratio of heat to electricity would be from such a plant. Ove Arup and Partners estimated this at 1.39 for the BedZED project south of London; 949 MWh heat, 683 MWh electricity (Beddington Zero Energy

Development, 1999). But for Bowhill and Cardenden in Fife, (including social housing) RD Energy Solutions (2008) estimated the ratios to be considerably less, at 1.14 and 1.15 respectively. All three studies were for woodchips, with weekly consumption predicted as follows; BedZED 20 t; Bowhill 55 t; Cardenden 156 t. Tripling of consumption and more than doubling of thermal output comparing Bowhill to Cardenden (2.5 MW cf. 6.1 MW) has not significantly affected the ratio of heat to electricity. Hence the cause of the higher ratio predicted for BedZED is not immediately apparent. The moisture content of woodchips is critical for effective combustion. Although BedZED's ratio implies a surplus of thermal energy to be dumped (its space heating load is minimal) and it was intended to use some of this to dry the chips, a guaranteed supply within recommended moisture limits is desirable (e.g. as achieved by the Forestry Commission at its new Inverness HQ).

A CHP plant of the scale envisaged for CHA, together with distributive infrastructure and seasonal storage, implies a sustainable financial model. Although this lies outside the scope of MEARU's remit, CHA have involved an organization called RENEW; and there are useful precedents such as that used by Gigha Renewable Energy Ltd (Porteous, 2006).

Having assumed such a model is attainable, the objective of analysis is to test its viability based on rational technical proposals. In summary: a) 26-storey towers to be internally insulated, with balconies glazed as buffers, but no new glazing (existing PVCu double-glazed units too new); b) 15 storey towers to be cavity insulated, and windows replaced to 2007 norm of 1.8 W/m^2K, and ventilation improved; c.i) 8 storey blocks (already insulated internally) to be insulated externally, windows replaced to 2007 norm and have balconies glazed in plus improved ventilation; c.ii) 8-storey blocks 'fallback' omitting external insulation, but replacing windows, glazing in balconies and improving ventilation; d) 9-storey block to be part cavity insulated, part externally insulated (existing dry cladding replaced) and improved ventilation, but no new glazing (existing PVCu double-glazed units too new).

To obtain realistic broad-brush values, steady-state BREDEM methodology is used (Anderson et al, 1985) with estimated solar gain and degree-days localized to Glasgow (Page and Lebens, 1986). This method also allows realistic estimates for air change rates, based on monitored studies and reflects occupants' habits and the intensity of occupancy within tight space standards more than the air-tightness of construction (Porteous and Ho, 1997; Porteous and Menon, 2006). Based on such work, the analysis assumes a heating season from September to May; and also assumes that demand for hot water and electricity for cooking, lighting and appliances will remain unchanged in the 'now' and 'proposed' scenarios - see Table 1 below.

3 Analysis and discussion of results

In deriving heat to electricity (H/E) ratios from Table 1, hot water is pragmatically allocated as thermal and/or electrical (see Table 2 next page). It should also be noted that the mean in the penultimate row, Table 1, is based on the 'fallback' scenario for the 8-storey flats. This is because, although desirable, and technically readily attainable, the proposed insulated over-cladding may be unaffordable. The row with mean average values is based on the estimated value for a typical unit in each case a-d) multiplied by the number of units of respective types; the summation then divided by the total number of units, 1,150. The final row gives values for a notional flat of 80 m^2, conforming to Scottish Technical Standards 2007 (TS07) (Scottish Building Standards Agency, 2007); together with the upper limit for space heating in a dwelling to German Passiv Haus standard. It may be noted that the mean saving for the four types asterisked, taking the fallback value in the third case, is 47.4%; while the range is from just over 40% to nearly 70% - partly attributable to type and shape, and partly to construction potential and constraint.

Table 1. Predicted annual demand (kWh/m^2)

High-rise type/storeys	Space heating	DHW	Electrical load
26-st: Now	174.2	36.8	85.5
Proposed*	73.1	36.8	85.5
15-st: Now	102.7	40.6	64.9
Proposed*	31.3	40.6	64.9
8-st: Now	87.7	34.7	84.5
Proposed	24.4	34.7	84.5
Fallback*	45.8	34.7	84.5
9-st: Now	118.3	35.1	56.1
Proposed*	69.9	35.1	56.1
Mean: Now	135.8	36.7	67.3
roposed*	57.1	36.7	67.3
SO7 80m^2 flat	46.2	32.5	52.0
Passiv Haus	15.0		

Regarding 'now' and 'proposed' predictions, it should be noted that both are based on an 'all day' (total 16 hour) demand on a 21^{o}C setting in the living room; but 'now' is calculated for mixed response (storage plus direct electric), while 'proposed' is responsive (wet system, perhaps with direct electric top-up).

Table 2 below summarizes the predictive data in terms of the delivered heat to electrical ratio (H/E), where thermal demands have been multiplied by a factor of 1.2 in order to allow provisionally for 20% losses in distribution and storage. A further stage of detailed design and analysis would be required to come to a more accurate difference between thermal demand and heat requiring to be delivered by the CHP plant. As with Table 1, the fifth row of mean averages takes into account different flat types, the 26 storey towers having four two and two single apartment flats per floor, and the 8 storey blocks a mix of two and three apartment flats. Fortunately there is a single block of the maisonettes (4th row). Its high thermal loads are due to factors such as its two-storey form and generous glazed areas with fairly new PVCu double-glazing (U-value 3.2 W/m^{2}K) - not economic to replace at present. The first two columns of values take the H/E ratio over an entire year; while the third looks at January in isolation. Within this set-up, the first assumes that the CHP must deliver 100% space heating and hot water (DHW); the second that 50% of DHW will come from heat and 50% from electric immersion; and the third column, investigating peak space heating demand in January, assumes that all DHW will be heated by electricity.

Table 2. kWh Heating/Electric (H/L) ratios

High-rise type/storeys	H/E p.a. H 100% Thermal	H/E p.a. H 50% DHW	H/E Jan. H 0% DHW
26-st: Proposed	5960/3864 = 1.54	4962/4696 = 1.06	685/464 = 1.48
15-st: Proposed	5526/4161 = 1.33	3305/5461 = 0.61	431/563 = 0.76
8-st: Fallback	4637/3864 = 1.2	3638/4696 = 0.77	377/391 = 0.96
9-st: Proposed	9337/4161 = 2.24	7777/5461 = 1.42	880/563 = 1.56
Mean: Proposed	5746/3864 = 1.49	4263/4850 = 0.88	559/481 = 1.16
SO7 80m^2 flat	7555/4161 = 1.82	5995/5460 = 1.10	759/563 = 1.35

The last two columns of Table 2 shows that, if heat to electrical output ratios from a Fife to BedZED range of 1.14-1.39, in some cases more of the DHW could be met by the CHP's thermal output. This is particularly significant for peak January loads. It implies that seasonal thermal storage may not be a prerequisite, provided there can be intelligent balancing between heat and electricity for DHW.

Table 2 also suggests an irony. All four high-rises, and the benchmark TS07 80 m^2 flat, appear viable for bio-fuel CHP that is notionally carbon neutral. However, if thermal efficiency increases to the point where the space heating is negligible, while loads for hot water, lighting and appliances maintain a status quo, the H/E ratio for CHP becomes less favourable. If enough electricity is generated to meet demand, there will be surplus heat. Options then narrow for on-site generation in compliance with UK government definitions of carbon neutrality (Cutland, 2007) - Department for Communities and Local Government (DCLG) and HM Revenue and Customs (HMRC). Building integrated photovoltaic arrays are unlikely to meet more than 30-40% of such loads (Porteous and Menon, 2007); while micro-wind generation is a generally suspect technique in urban locations. It is possible that on this particular site, the roofs of tower blocks could provide scope for some wind generation; but, in general, it would seem that housing at 'Passiv Haus' standard as in Table 1, would find carbon-neutrality more difficult to attain than a project such as this, where large-scale biomass CHP looks possible - in this case a delivered thermal output of just over 2 GWh annually for the high-rises alone.

A key objective was to mitigate fuel poverty. For the CHP proposal to work, it must be affordable for tenants. The accepted yardstick is not to spend more than 10% of disposable income on heat and power. Since reliable knowledge of income is not obtainable, it is proposed that £10/week is used as a benchmark. Adopting a 'what if?' scenario of charging 5 p/kWh delivered, Table 3 gives theoretical costs (based on Table 2 H+E) with predicted mean temperatures, all within comfort norms, in the living-kitchen zone (Z1) and rest of dwelling (Z2). The first column values in parenthesis and the last set in this column attempt a viable flat weekly charge for single, two and three apartment (room) dwellings. The only one coming above the £10 benchmark is the 3-apartment maisonette (3+), identified on Table 2 as a high consumer. The validity of this proposal would depend on three key variables: real cost per delivered kWh relative to 5 p; variability above or below 20% for distribution and storage; margins for tenants above and below predictions. However, it is a useful basis from which to start detailed design and business planning.

Table 3. Affordable energy and comfort

High-rise type/storeys	Weekly H + E cost	Mean Ti Z 1 (°C)	Mean Ti Z2 (°C)
26-storey: Proposed	£9.45 (9.00/8.25)	19.8	18.2
15-storey: Proposed	£9.31 (9.75)	20.1	18.8
8-st:orey Fallback	£8.17 (9.75/9.00)	20.4	18.8
9-storey: Proposed	£12.98 (10.50)	19.9	18.4
Mean: Proposed	£9.16	20.0	18.5
Charge/No. of rooms (3+ is a maisonette)	1 = £8.25 2 = £9.00 3 = £9.75 3+ = £10.5		

Having set out a uniform CHP strategy for the high-rises, optimum options for the 4-storey walk-up flats and maisonettes are more elusive. The current status is partial central heating with storage units as elsewhere - i.e. one unit in the living room and one in the hallway. However, the case for a CHP system here is weakened by the proportion of flats now in private ownership - now in excess of 50%. Even though the Scottish Government has called a halt to 'right to buy' for new housing, and may extend the scope of proscription, the present situation is dynamic in this regard and strengthens the case for individual solutions for heating. Distribution for any kind of district heating would also be inherently awkward. The options for horizontal distribution are limited. Access to roof spaces over privately owned flats would cause problems, suggesting the access decks as the best option, with insulated pipe-work fixed externally below soffits. However, windows facing on to the deck go right up to the ceiling, and there is no route into maisonettes for individual pipe distribution other than within the intermediate timber first floors. Overall, it seems worth considering options for heating systems that can be installed on a home-by-home basis and do not rely on major distributive infrastructure. Similarly windows can be replaced for rented homes only; while a financial arrangement can be made with home-owners regarding cavity and loft insulation.

The cheapest heating solution would be to stay all-electric, adding fixed appliances to bedrooms, bathrooms and perhaps kitchens. However, this sidesteps the issue of carbon emissions, apart from modest reductions attributable to increased energy efficiency. Conversion to 'wet' systems with individual condensing combi-boilers would reduce carbon emissions further - by circa 0.3 kg/kWh delivered, corresponding to a 58% reduction. However, there is currently no gas supply to the scheme. An electric 'wet' system is another option (see next paragraphs), which would give the same advantage of increased responsiveness as gas. The carbon emissions for such a system could be mitigated by solar thermal arrays on the roofs, but distribution from a communal pre-heat tank to individual cylinders and boilers would encounter the same issues as for CHP. The same would apply if communal ground source heat pumps were to be located in the former pram stores at the corners of blocks on ground floors; or if a combination of solar thermal and heat pumps were employed, as by Shettlestone Housing Association (Porteous and MacGregor, 2005). This last suggestion might be worth exploring in parallel to a competing option with individual boilers. It would in any case be of value to establish the degree of difficulty and disruption that distribution via the underside of access decks would in fact constitute.

A more radical solution would be to consider hydrogen as a viable alternative fuel, associated with individual fuel cells, and with on-site generation of electricity by wind turbine funding on-site electrolysis of water. In broad-brush terms, one might expect each 5 kWh to produce 1m^3 hydrogen, including energy needed for cleaning, drying and compressing the gas. This amount of hydrogen could then be expected to yield circa 1 kWh of electricity and 1 kWh of heat (Pritchard, 2001). Berwick Housing Association is soon to trial just such a proton exchange membrane (PEM) fuel cell set-up in the rural Borders area of Scotland. However, it poses the question of whether it would not make more sense to connect the turbine to the grid and use electricity directly. Also, the efficiency of a fuel cell and net AC power output will vary with the flow rate of fuel; and the heat recovered will also vary with both fuel input and flow and return temperatures adopted - the lower the temperatures, the greater the capture and the steeper the increase relative to energy input (Gray et al, 2003). This in turn suggests a low-temperature wet system, either by replacing existing flooring or embedded in plaster on walls - perhaps desirable, but all adding to cost. If electricity were used directly, as opposed to a means of producing hydrogen, this could be either in the present storage-heating mode or with heating changed to a wet system with an electric boiler (and ideally more hot water storage and insulation).

Pending further analysis, it would also appear that a single wind tower of adequate diameter and height could meet the entire load for the walk-up maisonettes and flats. Theoretically a turbine tower of the equivalent height to the 26-storey flats might be located centrally within the triad of 8-storey towers at the north-west end of the scheme. The wind velocity at such a height should average some 8.4 m/s (using an exponent of 0.3 on a standard power-law formula at a hub height of 80 m). However, large turbines are notoriously sensitive to urban texture, so that the best solution might be to buy into one on a suitable rural site in the vicinity of Glasgow.

The swept area of a turbine blade is proportional to the power output. The UK's first wind farm at Delabole in Cornwall had blades of 34 m diameter, a swept area of 908 m^2 and a power output of 0.4 kW per turbine (mean wind velocity of 7.6 m/s at hub height). Therefore a turbine of 80 m diameter would have a swept area of 5,027 m^2 and a power output of 2.2 MW. (Note: although this is according to the proportional relationship, the Delabole website is rather more optimistic, predicting 2.3 MW from a 70 m diameter blade.) A 2.2 MW turbine should yield approximately 6,325 MWh annually (2.2 x 2,875 hours) and, allowing for a further 10% loss, this gives an annual working output of approximately 5,700 MWh. It is anticipated that this figure should be adequate for space heating, water heating, cooking, lighting and appliances for 485 maisonettes and 164 flats.

4 Conclusions

Although not yet cost-planned, the range of remedial measures proposed for the high-rises are likely to be affordable, given appropriate phasing. These include internal, cavity and (possibly) external insulation, new windows (if justified), glazed-in balconies and improved ventilation, Note also that there are sources of grant and other financial aid mechanisms for CHP and some energy efficiency measures (cavity insulation to proceed on this basis for 15-storey tower blocks).

Assuming capital affordability, there is a viable case for biomass gasification CHP for the high-rises, based on the steady-state predictions for heat and electricity demand. Analysis also indicates that DHW is a useful mediator between electricity and heat, thus downgrading the role of seasonal thermal storage. Further dynamic analysis is to be carried out to give confidence in this position. However, this is predicated on a business plan that keeps delivered unit costs to users within an affordable level that also provides comfort.

Such a system would take all the high-rises close to carbon neutrality; ironically easier to achieve than for a low-energy new-build equivalent. However, although proposals for the high-rises achieve significant energy savings in all cases, the affordability to both housing association and tenants (as indicated above) is likely to be the decisive factor.

There are a number of options for the low-rise, walk-up dwellings, including solar thermal and ground source heat pumps. However, an attractive alternative may be to buy into a large (2.2 to 2.3 MW) wind turbine on a wind farm local to Glasgow; with the added advantage of flexibility of supply relative to a CHP system. Again, this is predicated on affordable energy efficiency measures such as cavity insulation and window replacement, and would take the entire scheme close to a carbon-neutrality.

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APPENDIX B: 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

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

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

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)

SPACE HEATING 1: Scenario 2 - as proposed; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 2.26; interpolating from responsive heating, Ti z1 = 19.81°C; Ti z2 = 18.24°C

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

Therefore: Tbz1 = 20.2 - (631/59.34) = 9.18°C Tbz2 = 18.24 - (205/42.84) = 13.45°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 9.81°C	16.9	45.2	124.7	169.3	178.6	165.3	136.3	81.00	39.6	957
Tbz2 = 13.45°C	63.2	128.3	240.8	296.0	308.0	283.6	262.0	185.9	119.1	1887

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 2

Qz1	59.34 W/K x 957 Kdays x 0.024 =	1,363 kWh
Qz2	42.84 W/K x 1887 Kdays x 0.024 =	1,940 kWh

Q^{SH} z1+z2 now 58% less than Scenario 1 as existing	3,303 kWh (73.1 kWh/m^2)
Q^{DHW}	1,664 kWh (36.8 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}	4,967 kWh
Q^{EL} z1+z2	3,864 kWh (85.5 kWh/m^2)
Q^{TOTAL} z1+z2	8,831 kWh (circa 1.1 t CO_2 if CHP)

SPACE HEATING 1: Scenario 3 - as proposed; whole-flat demand @ 25°C; 2xday (2 + 7 h)

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 2.26; interpolating from responsive heating, Ti z1 = 22.02°C; Ti z2 = 19.95°C

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

Therefore: Tbz1 = 22.02 - (631/59.34) = 11.39°C Tbz2 = 19.95 - (205/42.84) = 15.16°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 11.39°C	34.2	80.7	181.5	232.7	244.4	225.9	199.0	131.1	74.0	1404
Tbz2 = 15.16°C	99.3	176.2	291.8	349.0	361.0	332.1	314.4	234.1	163.3	2321

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 3 (case study 1 - 26 storey towers)

Qz1	59.34 W/K x 1404 Kdays x 0.024 =	2,000 kWh
Qz2	42.84 W/K x 2321 Kdays x 0.024 =	2,386 kWh

Q^{SH} z1+z2 now 44% less than Scenario 1 as existing	4,386 kWh (97.0 kWh/m^2)
Q^{DHW}	1,664 kWh
Q^{SH} z1+z2 + Q^{DHW}	6,050 kWh
Q^{EL} z1+z2	3,864 kWh
Q^{TOTAL} z1+z2	9,914 kWh

26 storey Scenario 2 and CHP

a) All thermal loads met by waste heat from CHP and 20% distribution/storage losses

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	4,967 kWh x 1.2 =	5,960 kWh
Q^{EL} z1+z2		3,864 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.54 - probably realistic working ratio	

b) All SH & 50% DHW met by waste heat from CHP and 20% distribution/storage losses

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	4,135 kWh x 1.2 =	4,962 kWh
Q^{EL} z1+z2		4,696 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.06 - possibly realistic working ratio	

26 storey Scenario 3 and CHP

a) All thermal loads met by waste heat from CHP and 20% distribution/storage losses

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	6,050 kWh x 1.2 =	7,260 kWh
Q^{EL} z1+z2		3,864 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.88 - dubious realistic working ratio	

b) All SH & 50% DHW met by waste heat from CHP and 20% distribution/storage losses

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	5,218 kWh x 1.2 =	6,262 kWh
Q^{EL} z1+z2		4,696 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.33 - probably realistic working ratio	

2 15 storey towers (14 storeys flats + ground floor accommodation) [1961/177]

Note: 'as existing' denotes condition when inspected by MEARU prior to cavity insulation

Specific heat loss 3-apt as existing, assuming 1.25 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. timber K window	2.065	3.20	6.61
20% frame d.g. timber L window	5.393	3.20	17.26
gable wall (dry-lined f.b. pl'bd)	12.87	1.025	13.19
wall below large windows	3.193	1.52	4.71
TOTAL FABRIC LOSS	23.521	1.78	41.77

VENTILATION LOSS 56.07 m^3 x 0.33 x 1.25 ac/h = 23.13

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.65 64.90

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. timber Br window	4.956	3.20	15.86
BR return wall to balcony	2.09	1.025	2.14
BR window wall	6.017	1.52	9.15
Stair wall (escape areas)	10.98	1.65	18.12
Landing door (entrance)	2.26	1.13	2.55
Escape balcony door	2.09	1.97	4.11
TOTAL FABRIC LOSS	28.393	1.83	51.93

VENTILATION LOSS 90.40 m^3 x 0.33 x 1.25 ac/h = 37.29

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.26 89.22

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 2.41 154.12

Specific heat loss 3-apt as proposed, with 1.00 ac/h as effective rate of air change:

Proposal involves cavity insulation and glazing in escape balconies only (to provide a source of preheated air for ventilation entering flats in hallways); and new d.g to all rooms (2007 norm)

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. new K window	2.065	1.80	3.72
20% frame d.g. new L window	5.393	1.80	9.71
gable wall (dry-lined f.b. pl'bd)	12.87	0.44	5.66
wall below large windows	3.193	0.47	1.50
TOTAL FABRIC LOSS	23.521	0.88	20.59

VENTILATION LOSS 56.07 m^3 x 0.33 x 1.00 ac/h = 18.50

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.59 39.09

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. new Br window	4.956	1.80	8.92
BR return wall to balcony	2.09	0.44	0.92
BR window wall	6.017	0.47	2.83

Stair wall (escape areas)	10.98	0.37	4.06
Landing door (entrance)	2.26	0.84	1.90
Escape balcony door	2.09	0.82	1.71
TOTAL FABRIC LOSS	28.393	2.23	20.34

VENTILATION LOSS 90.40 m^3 x 0.33 x 1.00 ac/h = 29.83

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.27 50.17

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 1.39 89.26

SOLAR GAIN (15 storey towers), allowing mean for east/west and north/south orientations

Liv window e/w	5.393 m^2 x 0.75 = 4.045 m^2 net x 0.7 shading x 30.89 W/m^2 =	87.46 W
K window n/s	2.065 m^2 x 0.8 = 1.652 m^2 net x 0.95 shading x 31.88 W/m^2 =	50.03 W
Z1 total solar		137.50 W
Z2 BR window	4.956 m^2 x 0.8 = 3.965 m^2 net x 0.95 shading x 30.89 W/m^2 =	116.30 W
Z1+2 total solar		254.00 W

INCIDENTAL GAINS (15 storey towers)

Z1	50% 4 adults	2 TVs	k appl	ckg.	ltg.	DHW	Total W
	124	54	197	108	10	30	523
Z2	50% 2 adults	2 TVs	k appl	ckg.	appl/ltg.	DHW	Total W
	124	54	0	0	25	27	230

SOLAR GAIN + INCIDENTAL GAIN Z1 660 W
SOLAR GAIN + INCIDENTAL GAIN Z2 346 W

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

Z1	54 + 197 + 10 = 261 W x 31.5 = 8,222 MJ = 2,284 kWh + 1,186 ckg =	3,470 kWh
Z2	54 + 25 = 79 W x 31.5 = 2,489 MJ =	691 kWh
Z1+2		4,161 kWh

SPACE HEATING 2: Scenario 1 - as existing; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 2.41; interpolating from mixed heating, Ti z1 = 20.34°C; Ti z2 = 18.74°C

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

Therefore: Tbz1 = 20.34 - (660/64.9) = 10.17°C Tbz2 = 18.74 – (346/89.22) = 14.86°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 10.17°C	22.6	58.1	148.6	196.1	207.2	191.8	163.0	101.2	52.1	1141
Tbz2 = 14.86°C	92.2	167.4	282.8	339.7	351.7	323.5	305.2	225.5	155.2	2243

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 1 (case study 2 - 15 storey towers)

Qz1	64.9 W/K x 1141 Kdays x 0.024 =	1,777 kWh
Qz2	89.22 W/K x 2243 Kdays x 0.024 =	4,803 kWh
Q^{SH} z1+z2		6,580 kWh (102.7 kWh/m^2)
Q^{DHW}		2,600 kWh (40.6 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}		9,180 kWh
Q^{EL} z1+z2		4,161 kWh (64.9 kWh/m^2)
Q^{TOTAL} z1+z2		13,341 kWh (circa 7.0 t CO_2 if CHP)

SPACE HEATING 2: Scenario 2 - as proposed; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES - typical flats in 14+1 storey towers

Whole-flat HLP = 1.39; extrapolating from responsive heating, Ti z1 = 20.11°C; Ti z2 = 18.77°C

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

Therefore: Tbz1 = 20.11 - (660/39.09) = 3.23°C Tbz2 = 18.77 – (346/50.17) = 11.87°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 3.23°C	1.6	6.1	28.5	47.8	50.4	42.8	24.5	12.5	4.5	219
Tbz2 = 11.87°C	38.8	89.6	194.5	247.1	259.0	239.4	213.2	130.7	82.7	1495

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 2 (case study 2 - 15 storey towers)

Qz1	39.09 W/K x 219 Kdays x 0.024 =	205 kWh
Qz2	50.17 W/K x 1495 Kdays x 0.024 =	1,800 kWh
Q^{SH} z1+z2 now 69.5% less than Scenario 1 as existing		2,005 kWh (31.3 kWh/m^2)
Q^{DHW}		2,600 kWh (40.6 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}		4,605 kWh
Q^{EL} z1+z2		4,161 kWh (64.9 kWh/m^2)
Q^{TOTAL} z1+z2		8,766 kWh (circa 1.3 t CO_2 if CHP)

15 storey Scenario 2 and CHP

All thermal loads met by waste heat from CHP and 20% distribution/storage losses assumed

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	4,605 kWh x 1.2 =	5,526 kWh
Q^{EL} z1+z2		4,161 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.33 - probably realistic working ratio	

3.0 8 storey Bison towers (7 storeys x 4 flats + gr'd fl. x 2 flats + roof) [1963/497]

Specific heat loss 2-apt as existing, assuming 1.25 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. timber windows	5.69	3.20	18.21
door to balcony (solid)	2.45	1.97	4.83
gable wall (liv + k)	13.04	0.53 (dry lined)	11.94
TOTAL FABRIC LOSS	21.18	1.65	34.98

VENTILATION LOSS 55.9 m^3 x 0.33 x 1.25 ac/h = 23.06

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.39 58.04

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. timber window	2.415	3.20	7.73
BR gable wall to common zone	8.76	0.84 (dry lined)	7.36
BR gable wall to balcony	2.80	0.75 "	2.10
BR window wall	4.95	0.54 "	2.67
Entrance screen (common area)	3.68	1.19	4.38
TOTAL FABRIC LOSS	22.605	1.07	24.24

VENTILATION LOSS 54.465 m^3 x 0.33 x 1.25 ac/h = 22.47

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.97 46.71

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 2.18 104.75

Specific heat loss 2-apt as proposed, assuming 1.00 ac/h is effective rate of air change:

Proposal involves external insulation and glazing in balconies (with total resistance taken as twice the value when completely open to allow for regular opening of inner and outer windows during heating periods) and 'slots' (standard d.g. in each case); new d.g to K and BR (2007 norm); and using slots as preheat spaces, air fed into entrance halls of flats.

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. liv windows	4.18	1.60 (R 2 x open value)	6.69
new door to balcony (d.g.)	2.45	1.60 (R 2 x open value)	3.92
20% frame k window (new)	1.51	1.80	2.72
gable wall (liv + k)	13.04	0.21 (dry lined + ins'n)	2.74
TOTAL FABRIC LOSS	21.18	0.76	16.07

VENTILATION LOSS 55.9 m^3 x 0.33 x 1.00 ac/h = 18.45

SPECIFIC HEAT LOSS z1, with Heat Loss Parameter (HLP) of 1.42 34.52

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. new window	2.415	1.8	4.35
BR gable wall to common zone	8.76	0.34 (+ d.g. + ins'n)	2.98
BR gable wall to balcony	2.80	0.32 " "	0.50
BR window wall	4.95	0.21 " "	1.04
Entrance screen (common area)	3.68	0.38 " "	1.40
TOTAL FABRIC LOSS	22.605	0.45	10.27

VENTILATION LOSS 54.465 m^3 x 0.33 x 1.00 ac/h = 17.97

SPECIFIC HEAT LOSS z2, with Heat Loss Parameter (HLP) of 1.19 28.24

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 1.31 62.76

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

Liv window 4.180 m^2 x 0.8 = 3.344 m^2 net x 0.70 shading x 30.89 W/m^2 = 72.30 W
K window 1.510 m^2 x 0.8 = 1.208 m^2 net x 0.95 shading x 31.88 W/m^2 = 36.59 W

Z1 total solar 108.88 W

Z2 BR window 2.415 m^2 x 0.8 = 1.932 m^2 net x 0.95 shading x 30.89 W/m^2 = 56.70 W

Z1+2 total solar 166.00 W

INCIDENTAL GAINS

Z1	50% 2 adults	2 TVs	k appl	ckg.	ltg.	DHW	Total W
	62	54	197	108	7	57	485
Z2	50% 2 adults	1 TV	k appl	ckg.	appl/ltg.	DHW	Total W
	62	27	0	0	21	0	110

SOLAR GAIN + INCIDENTAL GAIN Z1 594 W
SOLAR GAIN + INCIDENTAL GAIN Z2 167 W

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

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

SPACE HEATING 3: Scenario 1 - as existing; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 2.18; interpolating from mixed heating, Ti z1 = 20.37°C; Ti z2 = 18.83°C

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

Therefore: Tbz1 = 20.37 - (594/58.04) = 10.14°C Tbz2 = 18.83 – (167/46.71) = 15.25°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 10.14°C	22.3	57.6	147.8	195.2	206.3	190.9	162.1	100.4	51.5	1134
Tbz2 = 15.25°C	101.4	178.9	294.5	351.8	363.8	334.6	317.1	236.6	165.8	2345

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 1 (case study 3 - Bison towers)

Qz1	58.04 W/K x 1134 Kdays x 0.024 =	1,580 kWh
Qz2	46.71 W/K x 2345 Kdays x 0.024 =	2,629 kWh

Q^{SH} z1+z2	4,209 kWh (87.7 kWh/m^2)
Q^{DHW}	1,664 kWh (34.7 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}	5,873 kWh
Q^{EL} z1+z2	3,864 kWh (80.5 kWh/m^2)
Q^{TOTAL} z1+z2	9,737 kWh (circa 5.1 t CO_2 if CHP)

SPACE HEATING 3: Scenario 2 - as proposed; whole-flat demand @ 21°C; all-day (16 h)

Note: direct solar gain to Z1 is reduced; indirect gain is increased - assume useful gain same

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 1.31; extrapolating from responsive heating, Ti z1 = 20.14°C; Ti z2 = 18.81°C

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

Therefore: Tbz1 = 20.14 - (594/34.52) = 2.93°C Tbz2 = 18.81 - (167/28.24) = 12.9°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 2.93°C	1.5	5.3	25.9	44.2	46.6	39.2	21.9	11.2	3.9	200
Tbz2 = 12.90°C	54.4	117.0	224.6	278.9	229.5	212.2	184.6	119.1	65.2	1486

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 2

Qz1	34.52 W/K x 200 Kdays x 0.024 =	166 kWh
Qz2	28.24 W/K x 1,486 Kdays x 0.024 =	1,007 kWh

Q^{SH} z1+z2 now 72% less than Scenario 1 as existing	1,173 kWh (24.4 kWh/m^2)
Q^{DHW}	1,664 kWh (34.7 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}	2,837 kWh
Q^{EL} z1+z2	3,864 kWh (80.5 kWh/m^2)
Q^{TOTAL} z1+z2	6,701 kWh (circa 1.0 t CO_2 if CHP)

Note that compared with the 26 storey towers, the Bisons started only slightly worse than the 26-storey finishing point in terms of space heating load. This is due to the existence of the internal dry-lining (false walls). However, the existing condition also carries risk of interstitial condensation and mould behind the false walls, especially where the continuity of vapour control (the insulation itself) is broken at panel junctions, and power or switch points. The proposed over-cladding, which simultaneously tackles the appearance of these blocks, together with window renewal, also takes the improvement further than proposed for the 26 storey towers - 78% cf. 58%. The additional 20% gain is also partly due to the proposal to take advantage of solar ventilation preheating (also a passive form of heat recovery) by glazing in balconies and 'slots' (with standard d.g.). The saving would be reduced by thinning down the new layer of insulation; but since a large part of the cost of over-cladding can be attributed to plant (mast climbers etc.) rather than materials, and labour costs would be the same in each case, the choice seems to boil down to whether to over-clad at all. Having made this point, it will be inherently costly. The only feasible fall-back position short of the proposal would seem to be to re-glaze as proposed, including glazing in balconies and slots, but to deal with appearance by means of painting as proposed for the 26-storey towers.

Specific heat loss 2-apt as 'fallback', assuming 1.00 ac/h is effective rate of air change:

The proposal involves exterior paint and glazing in balconies (total resistance taken as mean between completely open and closed values to allow for regular opening of inner and outer windows during heating periods) and 'slots' (standard d.g. in each case); new d.g to K and BR (2007 norm); and using slots as preheat spaces, air fed into entrance halls of flats.

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. liv windows	4.18	2.16	9.03
new door to balcony (d.g.)	2.45	2.16	5.29
20% frame k window (new)	1.51	1.80	2.72
gable wall (liv + k)	13.04	0.53 (existing + paint)	6.91
TOTAL FABRIC LOSS	21.18	1.13	23.95
VENTILATION LOSS	55.9 m^3 x 0.33 x 1.00 ac/h =		18.45
SPECIFIC HEAT LOSS z1, with Heat Loss Parameter (HLP) of 1.76			42.40

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. new window	2.415	1.8	4.35
BR gable wall to common zone	8.76	0.67 (+ glass only)	5.87
BR gable wall to balcony	2.80	0.61 "	1.71
BR window wall	4.95	0.54 "	2.67
Entrance screen (common area)	3.68	0.87 "	3.20
TOTAL FABRIC LOSS	22.605	0.79	17.80
VENTILATION LOSS	54.465 m^3 x 0.33 x 1.00 ac/h =		17.97
SPECIFIC HEAT LOSS z2, with Heat Loss Parameter (HLP) of 1.51			35.77
SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 1.63			78.17

SPACE HEATING 3: Scenario 3 - fallback; whole-flat demand @ 21°C; all-day (16 h)

Note: assume useful gain same as scenarios 1 and 2

INTERNAL BASE TEMPERATURES

Whole-flat HLP = 1.63; interpolating from responsive heating, Ti z1 = 20.37°C; Ti z2 = 18.83°C

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

Therefore: Tbz1 = 20.37 - (594/42.4) = 6.02°C Tbz2 = 18.83 – (167/35.77) = 13.95°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 6.02°C	5.1	16.2	60.4	93.5	97.5	88.5	61.4	32.3	13.1	468
Tbz2 = 13.95°C	71.2	140.8	255.5	311.5	323.5	297.6	277.5	199.6	130.8	2008

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 3 (case study 3 - Bison towers)

Qz1 42.40 W/K x 468 Kdays x 0.024 =	476 kWh
Qz2 35.77 W/K x 2,008 Kdays x 0.024 =	1,724 kWh
Q^{SH} z1+z2 now 48% less than Scenario 1 as existing	2,200 kWh (45.8 kWh/m²)
Q^{DHW}	1,664 kWh (34.7 kWh/m²)
Q^{SH} z1+z2 + Q^{DHW}	3,864 kWh
Q^{EL} z1+z2	3,864 kWh (84.5 kWh/m²)
Q^{TOTAL} z1+z2	7,728 kWh (circa 1.15 t CO_2 if CHP)

8 storey Bison Scenario 2 and CHP

All thermal loads met by waste heat from CHP and 20% distribution/storage losses assumed

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	2,837 kWh x 1.2 =	3,404 kWh
Q^{EL} z1+z2		3,864 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	0.88 - surplus of heat if Q^{EL} met	

8 storey Bison Scenario 3 and CHP

All thermal loads met by waste heat from CHP and 20% distribution/storage losses

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	3,864 kWh x 1.2 =	4,637 kWh
Q^{EL} z1+z2		3,864 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.2 - probably realistic working ratio	

4 8 storey Maisonette Blocks (8 storeys + ground floor flats etc.) [1965/194]

Specific heat loss 3-apt as existing, assuming 1.25 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 screen	7.665	3.20	24.53
Kitchen window - PVCu	1.62	3.20	5.18
Kitchen cavity wall	2.70	1.47	1.17
Kitchen panel + half-brick wall	1.08	1.08	3.97
Kitchen balcony timber/glass	2.787	2.04	5.69
Kitchen balcony spine + panel	2.96	1.13	3.34
TOTAL FABRIC LOSS	18.812	2.33	43.88
VENTILATION LOSS	58.32 m^3 x 0.33 x 1.25 ac/h =		24.06
SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.65			69.94

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu BR w'w	3.135	3.20	10.03
ditto Bathrm window	1.627	3.20	5.21
ditto landing window & door	5.36	3.20	17.15
Composite access-deck/façade	12.89	0.97	12.50
Bedroom cavity wall	6.88	1.47	10.11
Bedroom panel + half-brick wall	2.88	1.08	3.11
Bathroom cavity wall	2.20	1.47	3.23
Bathroom return cavity wall	1.74	1.23	2.14
Bathroom r.c. spine cavity wall	1.74	1.57	2.73
Landing/stairs cavity wall	3.13	1.52	4.76
Bathroom floor over access-deck	1.405	0.97	1.36
Bedroom floor over balcony	4.39	0.966	4.24
TOTAL FABRIC LOSS	43.377	1.62	76.57
VENTILATION LOSS	110.97 m^3 x 0.33 x 1.25 ac/h =		45.78
SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.52			122.35
SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 2.59			192.29

Specific heat loss 3-apt as proposed, assuming 1.10 ac/h is effective rate of air change:

The proposal involves upgrading insulation - cavity fill where possible, plus re-cladding half-brick and concrete spine sections with additional insulation and adding 25 mm 'Foamglas' to soffit of balcony; and improved ventilation control for kitchens and bathrooms.

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu screen	7.665	3.20	24.53
Kitchen window - PVCu	1.62	3.20	5.18
Kitchen cavity wall	2.70	0.40	1.08
Kitchen panel + half-brick wall	1.08	0.40	0.43
Kitchen balcony timber/glass	2.787	2.04	5.69
Kitchen balcony spine + panel	2.96	0.25	0.74
TOTAL FABRIC LOSS	18.812	2.00	37.65
VENTILATION LOSS	58.32 m^3 x 0.33 x 1.1 ac/h =		21.17
SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.30			58.82

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. PVCu BR w'w	3.135	3.20	10.03
ditto Bathrm window	1.627	3.20	5.21
ditto landing window & door	5.36	3.20	17.15
Composite access-deck/façade	12.89	0.43	5.54
Bedroom cavity wall	6.88	0.40	2.75
Bedroom panel + half-brick wall	2.88	0.40	1.15
Bathroom cavity wall	2.20	0.40	0.88
Bathroom return cavity wall	1.74	0.48	0.84
Bathroom r.c. spine cavity wall	1.74	0.53	0.92
Landing/stairs cavity wall	3.13	0.52	1.63
Bathroom floor over access-deck	1.405	0.43	0.60
Bedroom floor over balcony	4.39	0.59	2.59
TOTAL FABRIC LOSS	43.377	1.14	49.29

VENTILATION LOSS 110.97 m^3 x 0.33 x 1.10 ac/h = 40.28

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.84 89.57

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 2.00 148.39

SOLAR GAIN (9 storey slab), allowing mean for east/west and north/south orientations

Z1 Liv window e	7.665 m^2 x 0.8 = 6.132 m^2 net x 0.7 shading x 30.89 W/m^2 =	132.60 W
Z1 K window e	1.62 m^2 x 0.8 = 1.296 m^2 net x 0.95 shading x 30.89 W/m^2 =	38.03 W
Z1 total solar		170.63 W
Z2 BR window e	3.135 m^2 x 0.8 = 2.508 m^2 net x 0.95 shading x 30.89 W/m^2 =	73.61 W
Z2 stairs etc w	5.36 m^2 x 0.8 = 4.288 m^2 net x 0.7 shading x 30.89 W/m^2 =	92.72 W
Z2 Bathroom w	1.627 m^2 x 0.8 = 1.302 m^2 net x 0.8 shading x 30.89 W/m^2 =	32.17 W
Z2 total solar		198.50 W
Z1+2 total solar		369.00 W

INCIDENTAL GAINS (9 storey slab)

Z1	50% 4 adults	2 TVs	k appl	ckg.	ltg.	DHW	Total W
	124	54	197	108	10	0	493
Z2	50% 2 adults	2 TVs	k appl	ckg.	appl/ltg.	DHW	Total W
	124	54	0	0	25	57	260

SOLAR GAIN + INCIDENTAL GAIN Z1 664 W
SOLAR GAIN + INCIDENTAL GAIN Z2 459 W

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

Z1 54 + 197 + 10 = 261 W x 31.5 = 8,222 MJ = 2,284 kWh + 1,186 ckg = 3,470 kWh
Z2 54 + 25 = 79 W x 31.5 = 2,489 MJ = 691 kWh
Z1+2 4,161 kWh

SPACE HEATING 4: Scenario 1 - as existing; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES - typical intermediate maisonettes in 8+1 storey slabs

Whole-flat HLP = 2.59; interpolating from mixed heating, Ti z1 = 20.34°C; Ti z2 = 18.74°C

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

Therefore: Tbz1 = 20.31 - (664/69.94) = 10.82°C   Tbz2 = 18.66 – (459/122.35) = 14.91°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 10.82°C	28.8	70.2	166.1	215.6	227.0	210.0	182.2	117.1	63.8	1281
Tbz2 = 14.91°C	93.4	168.8	284.3	341.2	353.2	324.9	306.8	226.9	156.6	2256

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 1 (case study 4 - 8 storey maisonettes)

Qz1	69.94 W/K x 1281 Kdays x 0.024 =	2,150 kWh
Qz2	122.35 W/K x 2256 Kdays x 0.024 =	6,625 kWh

Q^{SH} z1+z2	8,775 kWh (118.3 kWh/m^2)
Q^{DHW}	2,600 kWh (35.1 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}	13,375 kWh
Q^{EL} z1+z2	4,161 kWh (56.1 kWh/m^2)
Q^{TOTAL} z1+z2	15,536 kWh (circa 8.1 t CO_2 if CHP)

SPACE HEATING 4: Scenario 2 - as proposed; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES - typical intermediate maisonettes in 8+1 storey slabs

Whole-flat HLP = 2.00; extrapolating from responsive heating, Ti z1 = 19.9°C; Ti z2 = 18.4°C

Base temperatures Tb = Ti – ratio of solar + incidental gains (W) to specific heat loss (W/K)
Therefore: Tbz1 = 19.9 - (664/58.82) = 8.61°C   Tbz2 = 18.4 – (459/89.57) = 13.28°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 8.61°C	14.1	38.3	111.3	154.2	162.4	150.2	121.2	69.9	37.0	859
Tbz2 = 13.28°C	60.5	124.0	235.8	290.7	302.7	278.8	256.7	181.2	115.1	1846

ANNUAL SPACE HEATING LOAD 'Q^{SH}' for Scenario 2 (case study 4 - 9 storey slab)

Qz1	58.82 W/K x 859 Kdays x 0.024 =	1,213 kWh
Qz2	89.57 W/K x 1846 Kdays x 0.024 =	3,968 kWh
Q^{SH} z1+z2 now 41% less than Scenario 1 as existing		5,181 kWh (69.9 kWh/m^2)
Q^{DHW}		2,600 kWh
Q^{SH} z1+z2 + Q^{DHW}		7,781 kWh
Q^{EL} z1+z2		4,161 kWh
Q^{TOTAL} z1+z2		11,942 kWh (circa 1.5 t CO_2 if CHP)

8+1 storey Scenario 2 and CHP

a) All SH & 50% DHW met by waste heat from CHP and 20% distribution/storage losses

Q^{SH} z1+z2 + Q^{DHW} + 20% = thermal demand Q^{TH}	6,481 kWh x 1.2 =	7,777 kWh
Q^{EL} z1+z2		5,461 kWh
Q^{TH} divided by Q^{EL} (ratio of heat to electricity)	1.42 - probably realistic working ratio	

5 4 storey Walk-up Maisonette Blocks (4 storeys, with corner flats etc.) [1962/233]

Specific heat loss 4-apt as existing, assuming 1.25 ac/h is effective rate of air change:

Note: since kitchens are accessed off halls, they are taken in zone 2 in this analysis; blocks are either north-south (living room facing south) or east-west (living room facing east/west); an intermediate location on plan at the upper level (below roof) is taken in this analysis.

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame s.g. timber screen	4.44	4.50	19.98
20% frame s.g. timber window	1.85	5.00	9.25
Flush balcony door	2.44	1.97	4.81
Cavity wall	4.94	1.41	6.97
TOTAL FABRIC LOSS	13.67	3.00	41.00
VENTILATION LOSS	39.7 m^3 x 0.33 x 1.25 ac/h =		16.38
SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 3.30			57.38

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame s.g. timber BR n'th w.	2.09	5.00	10.45
ditto Bathrm window	1.28	5.00	6.40
ditto BR s'th windows	3.69	5.00	18.45
ditto Kitchen n'th deck window	3.39	4.50	15.26
Front door to deck	1.97	1.97	3.88
Slim cavity wall to deck	5.96	1.48	8.82
Normal cavity wall upper floor	15.59	1.41	21.98
Bedroom/bathrm. floor over deck	5.28	0.46	2.43
Ceiling over upper floor	44.29	0.74	32.77
TOTAL FABRIC LOSS	83.54	1.44	120.44
VENTILATION LOSS	143.26 m^3 x 0.33 x 1.25 ac/h =		59.09
SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 2.86			179.53
SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 2.96			236.91

Specific heat loss 4-apt as proposed, assuming 1.00 ac/h is effective rate of air change:

Note: analysis as per existing apart from insulation improvements (cavity fill and loft insulation); window replacement to 2007 norm and enclosing balconies with s.g. Vitrol or equal system; and improved ventilation control, ideally MVHR.

Z1 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. timber screen	4.44	1.40	6.22
20% frame d.g. timber window	1.85	1.80	3.33
Glazed balcony door	2.44	1.60	3.90
Cavity wall	4.94	0.41	2.03
TOTAL FABRIC LOSS	13.67	2.09	15.48
VENTILATION LOSS	39.7 m^3 x 0.33 x 1.00 ac/h =		13.10
SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.65			28.58

Z2 construction element	Area (m^2)	U-value (W/m^2K)	Rate of loss (W/K)
20% frame d.g. timber BR n'th w.	2.09	1.80	3.76
ditto Bathrm window	1.28	1.80	2.30
ditto BR s'th windows	3.69	1.80	6.64
ditto Kitchen n'th deck window	3.39	1.80	6.10
Front door to deck	1.97	1.97	3.88
Slim cavity wall to deck	5.96	0.52	3.10
Normal cavity wall upper floor	15.59	0.41	6.56
Bedroom/bathrm. floor over deck	5.28	0.20	1.06
Ceiling over upper floor	44.29	0.21	9.30
TOTAL FABRIC LOSS	83.54	0.51	42.70

VENTILATION LOSS 143.26 m^3 x 0.33 x 1.00 ac/h = 47.28

SPECIFIC HEAT LOSS, with Heat Loss Parameter (HLP) of 1.44 89.98

SPECIFIC HEAT LOSS z1+2, Heat Loss Parameter (HLP) of 1.48 118.56

SOLAR GAIN, 4 storey walk-ups, assuming north/south orientation

Liv window s.g	1.85 m^2 x 0.8 = 1.48 m^2 net x 0.95 shading x 56.96 W/m^2 =	80.09 W
Liv screen s.g	4.44 m^2 x 0.8 = 3.552 m^2 net x 0.70 shading x 56.96 W/m^2 =	141.63 W
Z1 total solar as existing		221.72 W
Z2 BR w'w1 s.g.	2.09 m^2 x 0.8 = 1.672 m^2 net x 0.95 shading x 21.91 W/m^2 =	36.63 W
Z2 BR w'w2 s.g.	3.69 m^2 x 0.8 = 2.952 m^2 net x 0.95 shading x 56.96 W/m^2 =	159.74 W
Z2 Bath w'w s.g.	1.28 m^2 x 0.8 = 1.024 m^2 net x 0.50 shading x 21.91 W/m^2 =	11.22 W
Z2 K'n w'w s.g.	3.39 m^2 x 0.8 = 2.712 m^2 net x 0.70 shading x 21.91 W/m^2 =	41.59 W
Z2 total solar as existing		249.18 W
Z1+2 total solar as existing		470.90 W
Liv window d.g	1.85 m^2 x 0.8 = 1.48 m^2 net x 0.95 shading x 37.95 W/m^2 =	53.36 W
Liv screen t.g	4.44 m^2 x 0.8 = 3.552 m^2 net x 0.70 shading x 46.49 W/m^2 =	115.59 W
Liv door t.g	2.44 m^2 x 0.7 = 1.708 m^2 net x 0.75 shading x 24.88 W/m^2 =	31.87 W
Z1 total solar as proposed		200.82 W
Z2 BR w'w1 d.g.	2.09 m^2 x 0.8 = 1.672 m^2 net x 0.95 shading x 17.27 W/m^2 =	27.43 W
Z2 BR w'w2 d.g.	3.69 m^2 x 0.8 = 2.952 m^2 net x 0.95 shading x 46.49 W/m^2 =	130.38 W
Z2 Bath w'w d.g.	1.28 m^2 x 0.8 = 1.024 m^2 net x 0.50 shading x 17.27 W/m^2 =	8.84 W
Z2 K'n w'w d.g.	3.39 m^2 x 0.8 = 2.712 m^2 net x 0.70 shading x 17.27 W/m^2 =	32.79 W
Z2 total solar as proposed		199.44 W
Z1+2 total solar as proposed		400.26 W

INCIDENTAL GAINS (4 storey walk-up maisonettes; 4-apt)

Z1	50% 5 adults	2 TVs	k appl	ckg.	ltg.	DHW	Total W
	155	54	0	0	10	0	219
Z2	50% 5 adults	4 TVs	k appl	ckg.	appl/ltg.	DHW	Total W
	155	108	197	108	30	78	676

SOLAR GAIN + INCIDENTAL GAIN Z1 as existing	441 W
SOLAR GAIN + INCIDENTAL GAIN Z2 as existing	925 W
SOLAR GAIN + INCIDENTAL GAIN Z1 as proposed	418 W
SOLAR GAIN + INCIDENTAL GAIN Z2 as proposed	875 W

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

Z1	54 + 10 = 64 W x 31.5 = 2,016 MJ =	560 kWh
Z2	108 + 197 + 30 = 335 W x 31.5 = 10,553MJ = 2,931kWh + 1,186 ckg =	4,117 kWh
Z1+2		4,677 kWh

SPACE HEATING 5: Scenario 1 - as existing; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES - typical intermediate maisonettes in 4 storey walk-ups

Whole-flat HLP = 2.96; interpolating from mixed heating, Ti z1 = 20.26°C; Ti z2 = 18.52°C

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

Therefore: Tbz1 = 20.26 - (441/57.38) = 7.69°C Tbz2 = 18.52 – (925/179.53) = 13.37°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 7.69°C	10.1	28.7	91.3	131.0	137.6	126.9	98.2	54.0	24.0	702
Tbz2 = 13.37°C	61.9	126.3	238.4	293.5	305.5	281.4	259.5	183.7	117.2	1867

ANNUAL SPACE HEATING LOAD ‘Q^{SH}’ for Scenario 1 (case study 5 - 4 storey maisonettes)

Qz1	57.38 W/K x 702 Kdays x 0.024 =	967 kWh
Qz2	179.53 W/K x 1867 Kdays x 0.024 =	8,044 kWh
Q^{SH} z1+z2		9,011 kWh (112.6 kWh/m^2)
Q^{DHW}		3,056 kWh (38.2 kWh/m^2)
Q^{SH} z1+z2 + Q^{DHW}		12,067 kWh
Q^{EL} z1+z2		4,677 kWh (58.4 kWh/m^2)
Q^{TOTAL} z1+z2		16,744 kWh (circa 8.7 t CO_2 if CHP)

SPACE HEATING 5: Scenario 2 - as proposed; whole-flat demand @ 21°C; all-day (16 h)

INTERNAL BASE TEMPERATURES - typical intermediate maisonettes in 4 storey walk-ups

Whole-flat HLP = 1.48; extrapolating from responsive heating, Ti z1 = 20.08°C; Ti z2 = 18.71°C

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

Therefore: Tbz1 = 20.08 - (418/25.38) = 3.61°C Tbz2 = 18.71 – (875/89.98) = 8.99°C

DEGREE DAYS	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
Tbz1 = 3.61°C	1.8	7.0	31.7	52.3	58.1	47.3	27.7	14.2	5.2	242
Tbz2 = 8.99°C	16.0	42.9	120.3	164.2	173.2	160.2	131.2	77.3	37.4	923

ANNUAL SPACE HEATING LOAD ‘Q^{SH}’ for Scenario 2 (case study 5 - 4 storey maisonettes)

Qz1	25.38 W/K x 242 Kdays x 0.024 =	147 kWh
Qz2	89.98 W/K x 923 Kdays x 0.024 =	1,993 kWh

Q^{SH} z1+z2 now 76% less than Scenario 1 as existing	2,140 kWh (26.7 kWh/m^2)
Q^{DHW}	3,056 kWh
Q^{SH} z1+z2 + Q^{DHW}	5,196 kWh
Q^{EL} z1+z2	4,667 kWh
Q^{TOTAL} z1+z2	9,863 kWh (circa 1.5 t CO_2 if wind)

Note: this is the largest of the house types in this 4-storey walk-up set. The 3-apartment maisonettes and 2-apartment flats would have a proportionately lower load, while gable-end locations would be respectively somewhat higher in each case. At this stage it looks likely that the mean average would fall comfortably within the figure of 8,783 kWh/unit that was used relative to the wind turbine analysis, with a total of 5,700 MWh output.

4-apt maisonettes	9,863 x 189 units =	1,864 MWh
3-apt maisonettes, pro rata space heating 1,925 kWh pro rata DHW = 2,600 kWh, and electricity 4,161 kWh	8,686 x 296 units =	2,571 MWh
2-apt flats, pro rata space heating 1,274 kWh pro rata DHW = 1,664 kWh, and electricity 2,750 kWh	5,688 x 164 units =	933 MWh
Total for all walk-ups		5,368 MWh
Add 5% to allow for gable conditions, contingencies etc		5,636 MWh

APPENDIX C: WYNDFORD ENERGY EFFICIENCY OPTIONS APPRAISAL

NHER/SAP Analysis - See attached CD ROM for PDF versions of NHER technical summaries

APPENDIX D: WYNDFORD ENERGY EFFICIENCY OPTIONS APPRAISAL

Appendix D- Survey Results

Appendix Di- Survey Analysis

Postal Survey- April 2008

A detailed questionnaire was sent out to approx. 2000 residents on the Wyndford estate. The questionnaire asked residents a range of questions relating to fuel expenditure, use of heating system/controls and evidence of moisture problems. A copy of the postal questionnaire is attached for reference (Appendix Dii).

There was a very good response rate from the survey with over 400 residents returning the completed survey. This has been collated into an Excel spreadsheet as attached in CD Rom version (Appendix Diii). A full analysis of the survey results is included in sections 0.3.2 and 0.3.3 of the main report.

Dampness

28% of overall respondents experience dampness in their residence. This took a variety of forms including mould, mildew, water staining and smells. Of those residents reporting dampness the highest percentage is experienced in 15 storey block and 4 storey maisonettes.

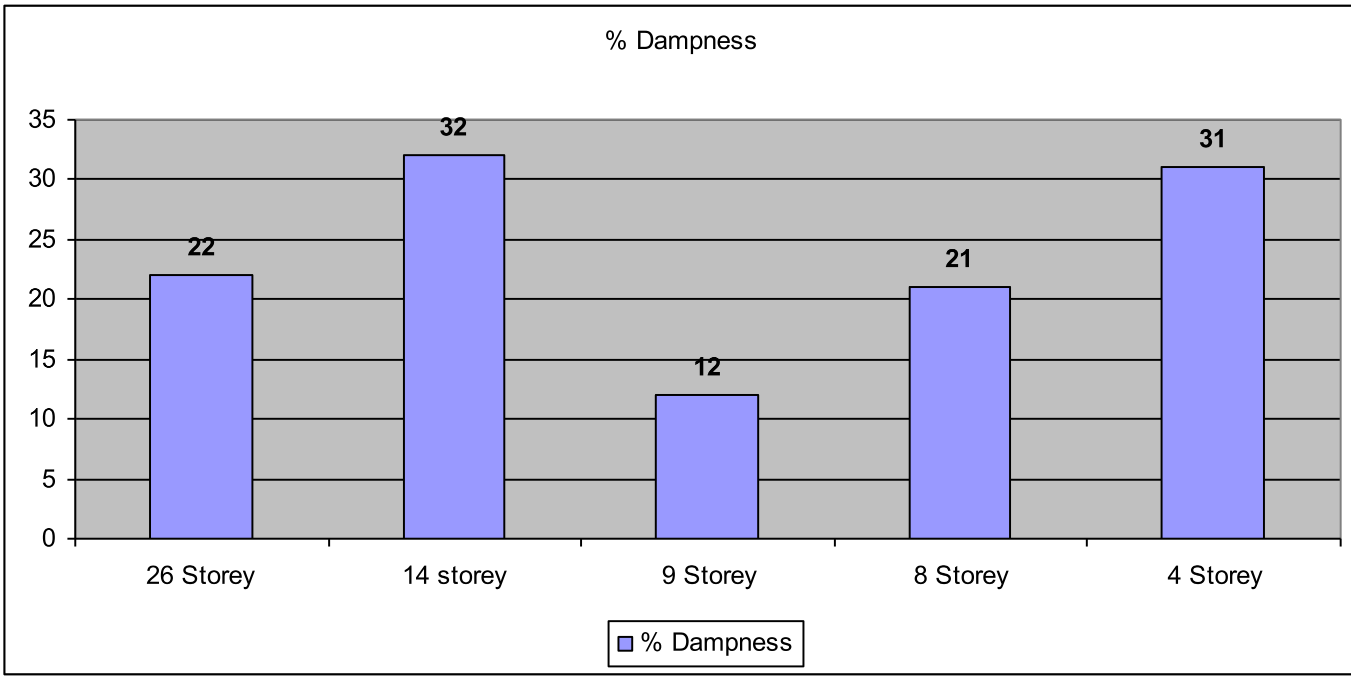

Fig 1. House types of those experiencing dampness.

Heating System and Controls

A series of questions related to how residents use the controls on their heating and hot water systems. The results indicate whilst many residents change their radiator controls on a regular basis, the majority of residents do not use the timer on heating and hot water systems.

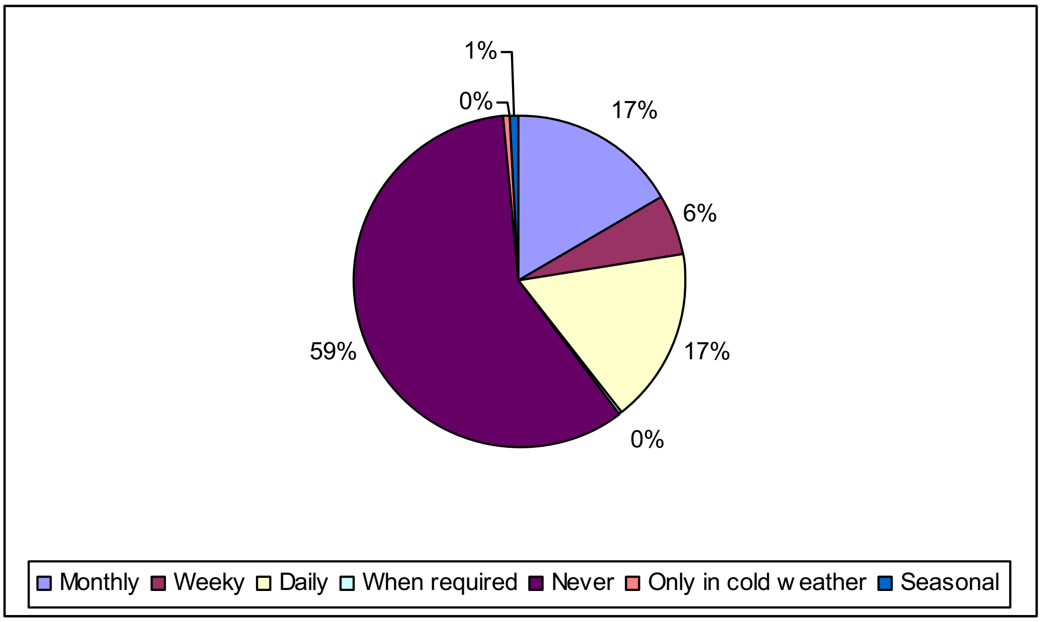

Fig 2. Percentage of residents who change controls on radiators

Percentage of residents who use their heating on a timer	
Yes	35.82%
No	47.51%

Percentage of residents who use their hot water on a timer	
Yes	48.51%
No	39.05%

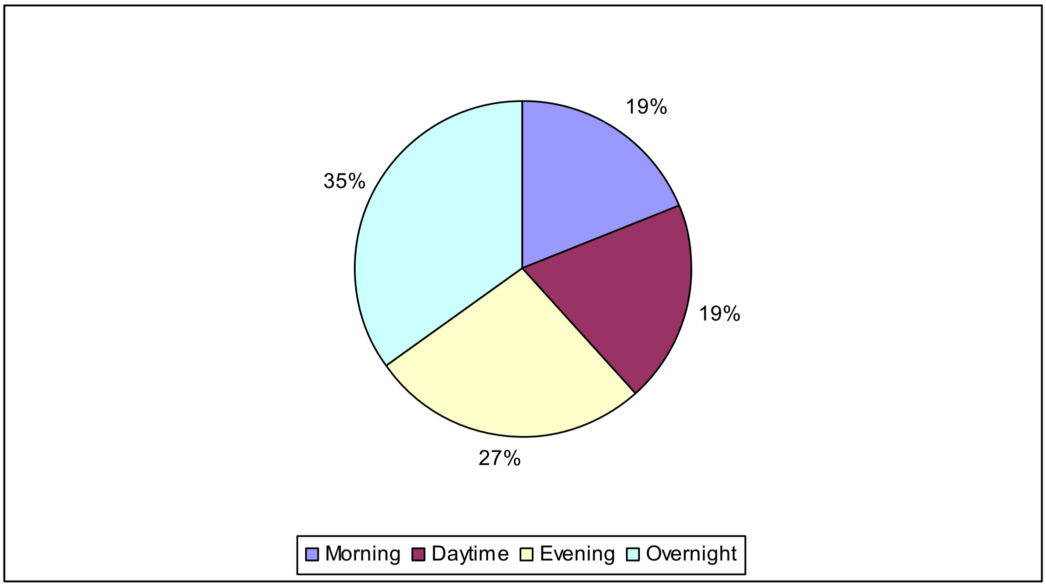

Fig 3. Percentage of residents who use storage heaters at various times of day.

Given that most apartments have storage heaters only in the hall and living room, many residents heat bedrooms by way of convector fan heaters and oil filled radiators. Many residents also supplement the living room heater with oil filled heaters and feature electric fires.

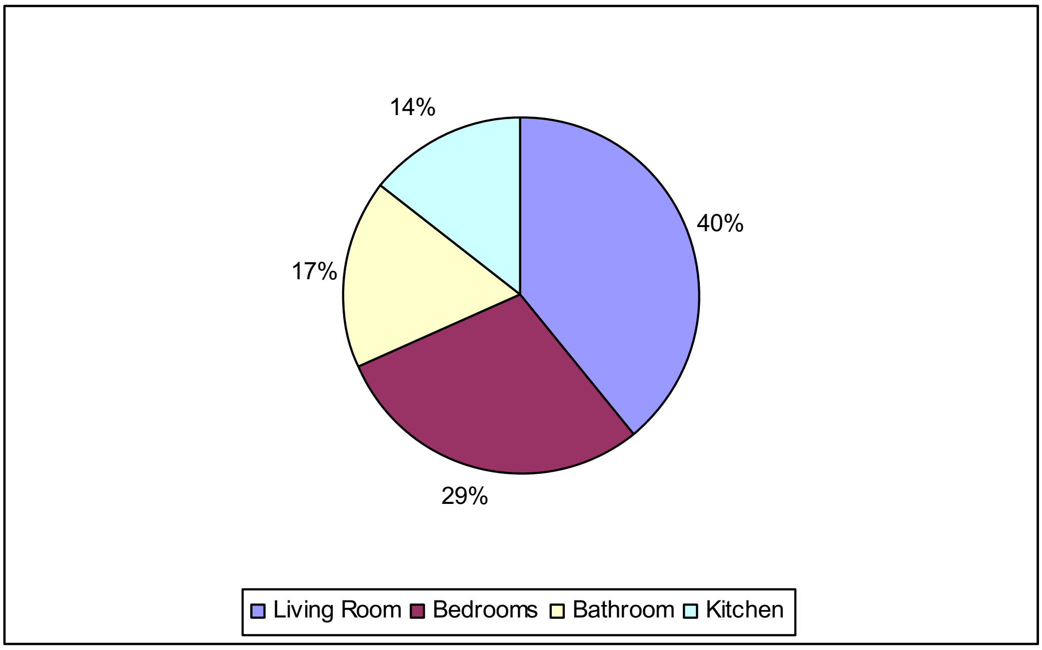

Fig 4. Percentage of residents who use additional radiators in rooms.

Energy Costs and Methods of Payment

A high percentage of residents noted that they pay for their energy by means of token, card or key. It is most likely that the energy supplier will charge at a higher rate for this method of payment rather than Direct Debit or quarterly bills.

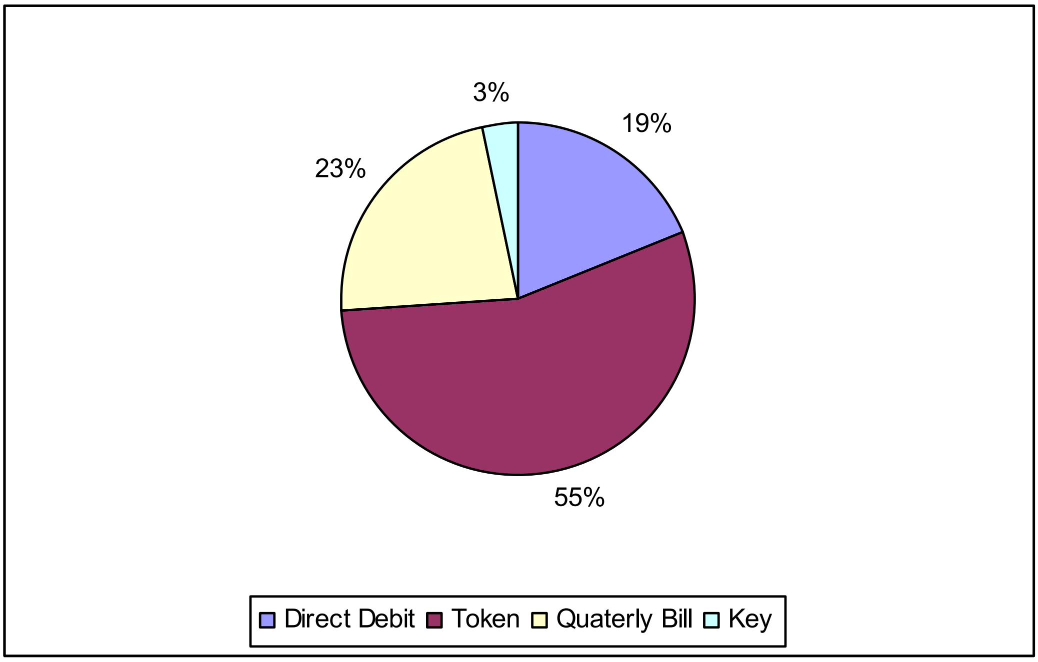

Fig 5. Percentage of residents who pay by token, Direct Debit, quaterly bill for their energy.

33% of residents reported spending between £10-20 a week on fuel costs however 25% reported spending between £20-30 a week (or approx £1300per year).

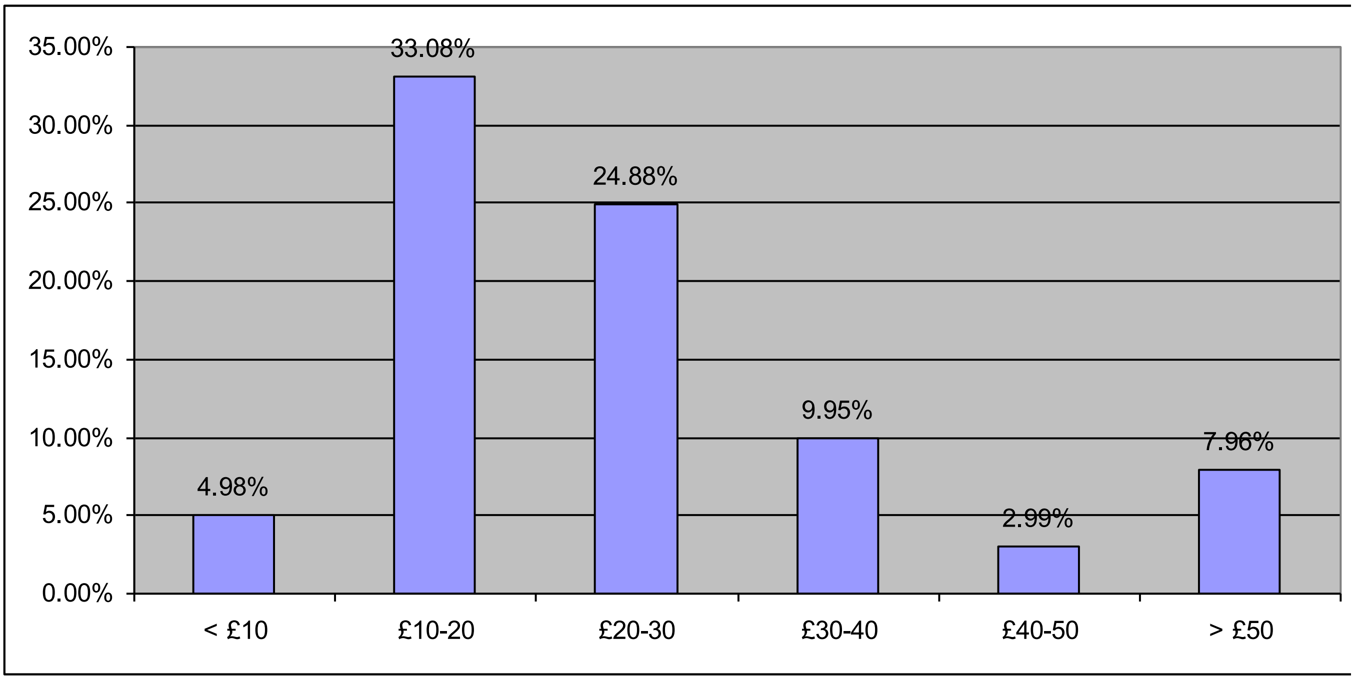

Fig 6. Expenditure on energy bills per week (average over 1 year).

The diagram below indicates the percentage of residents spending over £25 a week relative to the house type. Whilst this could be compared with the theoretical fuel costs as calculated in the 'as existing' house type scenarios in the SAP calculations this is unlikely to have a direct relationship since the expenditure is most likely linked to affordability and such factors. A possible reason for relatively low expenditure in the 9-storey block relative to the 15-storey towers, and also to the 4 storey walk-ups, may be the stratification of warm air from living rooms to bedrooms. Taken together with allocation policy, age profiles and disposable income trends, this could account for apparently anomalous disparities as well as logical differences, such that between the 26-storey towers and all the others.

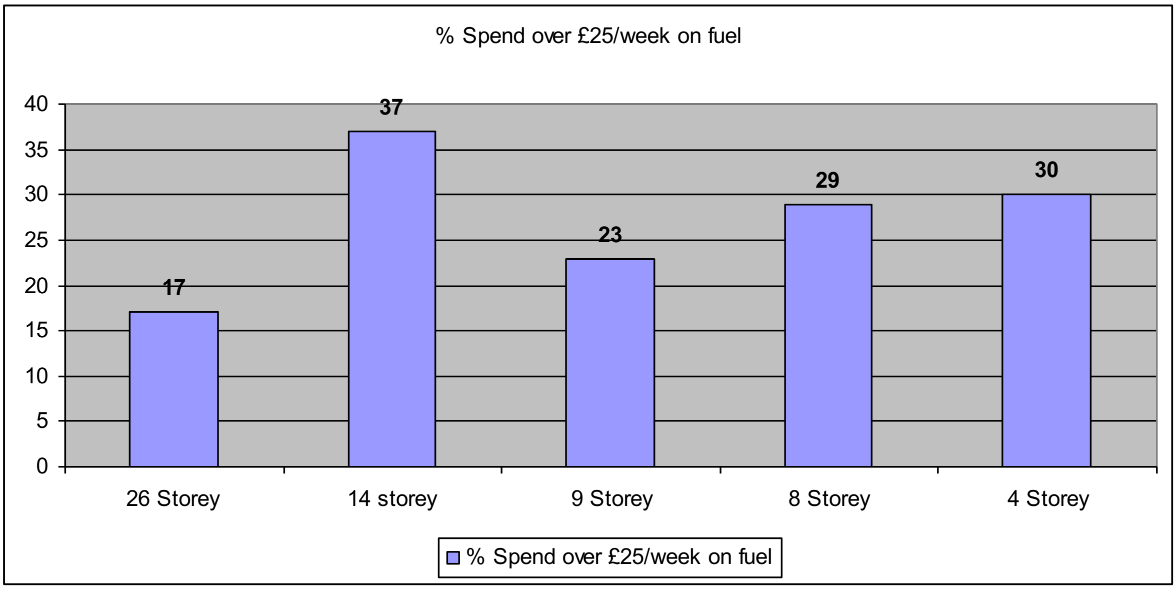

Fig 7. Percentage of residents spending over £25 a week (relative to house type).

As part of the analysis residents were also questioned about their clothes drying habits in order to establish whether this was related to increased fuel consumption. The drying of clothes on an indoor pulley was a very popular option whilst many chose to dry outside either on their balcony or communal drying spaces.

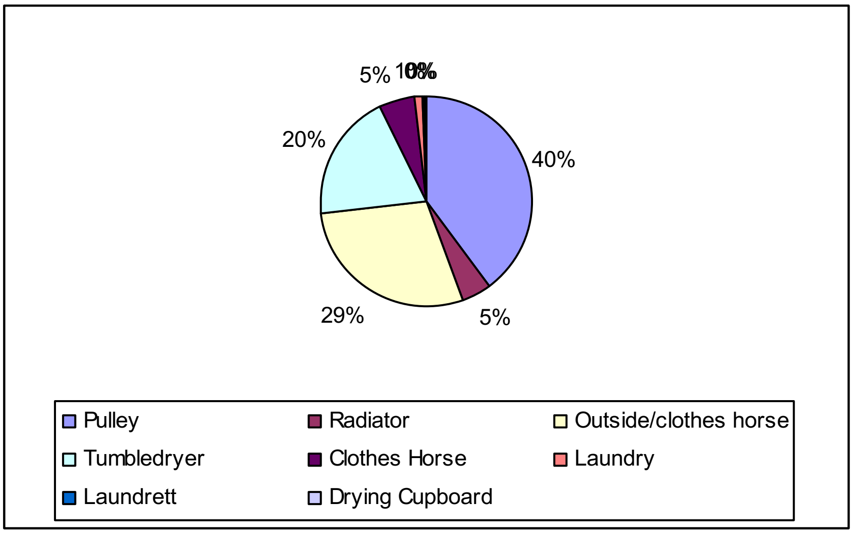

Fig 8. Method of clothes drying by residents.

Appendix Dii- Copy of postal questionnaire
Appendix Diii- Excel spreadsheet of postal questionnaire responses (enclosed CD ROM)

Wyndford Resident Survey

This survey is being conducted by researchers from the Mackintosh Environmental Architecture Research Unit (MEARU) to help the your Housing Association get a better understanding of how your homes are heated and used. It will be used to help design more energy efficient home improvements in the future.
All your responses will be kept anonymous and information about individuals will not be made public.
If you have any questions or concerns about this please contact MEARU on 0141 353 4657.

Name	
Address (including flat position)	

Please write the number of bedrooms you have in the flat [ ]

How many **adults** (over 18) live in the flat? [ ]

How many **children** live in the flat? [ ]

Please write the ages of the **adults**

	Adult 1	Adult 2	Adult 3	Adult 4	Adult 5
Age					

Please write the ages of the **children**

	Child 1	Child 2	Child 3	Child 4	Child 5
Age					

How many people (both adults and children) are there in the flat at the following times?
During the week

	morning	afternoon	evening
Number of people			

How many people (both adults **and** children) are there in the flat at the following times?
During the weekend

	morning	afternoon	evening	overnight
Number of people				

How many heaters there are in each room?

	Living Room	Bedrooms	Kitchen	Bathroom	Hall
Radiators					
Storage heaters					
Other heaters					

Do you have problems with dampness? Please circle [Yes] [No]

What form does this take? Circle **ALL** that apply.

Water stains	Black mould	Mildew	Smells

User Control

Please circle how often you change the controls on your radiators or storage heaters

Every day	Every week	Monthly	Never

Do you have/use timer on heating system? Please circle Yes No

When is your heating normally on? Circle **ALL** that apply.

Morning	Daytime	Evening	Overnight

Do you use timer on hot water immersion? Please circle Yes No

When is your hot water immersion usually on. Circle **ALL** that apply.

Morning	Daytime	Evening	Overnight

How do you normally dry clothes? Please circle **ALL** that apply

Tumble drier	On radiators	Pulley	Outside

Is the cylinder insulated? Please circle Yes No

How do you pay for your fuel Please circle: Token Card Quarterly bill

What is the name of power supplier?

How much do you spend on fuel?

Typical winter week	£
Typical spring week	£
Typical summer week	£
Typical autumn week	£

Do you have any comments about how your flat is heated?

Would you be willing to take part in a further survey to help us with this project? This would involve an interview lasting less than half an hour in your home. Please circle Yes No

Div- Copy of doorstep questionnaire

Wyndford Energy Feasibility Study

Survey carried out by MEARU (Mackintosh Environmental Architecture Research Unit) on behalf of CUBE Housing Association
This survey will be used to help design more energy efficient home improvements in the future. All your responses will be kept anonymous and information about individuals will not be made public. If you have any questions or concerns about this please contact MEARU on 0141 353 4657.

Survey

Name……..

Address…………………………………

Flat Position……………………………

House type (ie.26 storey block)…………………………………

Energy Use/ Cost
What do you think about your current heating system?..................................

Are the controls or timers easy to use? YES/ NO

Are you worried about fuel bills? YES/ NO

Do you use the heating system as much as you would like? YES/ NO

What do you think about energy being produced on the Wyndford Estate?

What do you think about a communal heating system?

Would you want heating to be metered or as standard charge in rent?

How important is having a choice of energy supplier? HIGH / MEDIUM/ LOW

Would you prefer your electricity to come from renewable sources? YES/ NO

Building Fabric
Do you use your balcony? YES/ NO

Would you use it more or less if it was enclosed? YES/ NO

How often do you use communal laundry space? (if applicable) OFTEN/ SOMETIMES/ NEVER

If upgrades were undertaken what would say is a priority?
…………………………………………………..

Health
Does anyone living in flat suffer from respiratory diseases, eg.asthma? YES/ NO

Observations
Does flat feel cold, damp, overheated etc;

How clear clear are the windows (proportion covered by blinds, curtains etc)

Are there fan heaters in main living spaces?

Windows/vents sealed

CO2
readings………………………temperature………………………humidity…………………………….

Appendix Dv- Excel spreadsheet of doorstep questionnaire responses (enclosed CD ROM)

Doorstep resident survey on 12th and 13th May 2008

Out of the 402 residents who participated in the postal survey a selection were then contacted in order to undertake a further more detailed survey.

Appendix Dvi- Photographic documentation of interiors
Doorstep resident survey on 12th and 13th May 2008

	
Oil filled radiators replacing storage heaters	Residents use of balcony space
	
Oil filled radiators supplementing heating system	Mechanical extract in Kitchen (Bison block)

	
Residents drying clothes on balcony	Relationship between kitchen and living room in 15 storey block
	
Radiators used to dry clothes	Windows obscured
	
Large existing storage heater	Electric feature fire supplementing heating system

APPENDIX E: WYNDFORD ENERGY EFFICIENCY OPTIONS APPRAISAL

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