Cost effective solutions to social housing – comparing the differences between certification by annual heat demand and by peak load

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Figure 1: Larch House, south façade

1 Introduction

For passivhaus to be adopted by social housing providers, homes designed to the standard must be economical to build. Capital cost reduction has become a major issue in the UK with its government-led 'Comprehensive Spending Review'. No matter how attractive the carbon savings and the pay-back benefits achieved by spending a little more money, Housing Associations (who are the main UK providers of low cost homes on a 'not-for-profit' basis) mostly require low energy homes to be delivered without a cost premium. The two certified passivhaus social housing prototypes that bere:architects designed for Ebbw Vale in Wales, were won in an open competition and represent our first attempt at building low cost housing and also one of our first attempts at achieving passivhaus certification. The successfully completed houses have been open to visitors for the last nine months with hundreds of people, from the UK and overseas, coming to see low cost, low energy housing working in tough winter conditions.

The building site is one of the toughest locations in the UK. It is a relatively high and exposed site, so it remains misty and cold for much of the winter. Whilst the competition organisers required us to deliver low cost housing, they were also acutely aware of the tough local weather conditions. So they decided to take a precautionary approach to this important early UK example of a certified passivhaus, by insisting that we adopt 'extreme worst-case' weather data. This was prepared for the precise location, by the Building Research Establishment, using Meteonorm software. In this paper we explain why we designed one house using certification by annual heat demand and the other house using certification by peak heat load. We also investigate the relationship between the choice of weather data and the build cost of a passivhaus and consider whether the lessons learnt would now enable us to safely use average weather data for future projects.

2 The design brief

Figure 2: Larch House and Lime House, street view of north façades

To deliver two small detached passivhaus homes, less than 100sq.m each, meeting all the standard housing association design quality requirements and built as far as possible to match the cost of ordinary social housing. Due to concerns about whether a house really could be 'passive' in the exposed and relatively cold conditions of the site compared to much of the UK, and under the relatively dense winter cloud cover compared to Central

Europe, the brief required us to design the prototype houses using the precaution of extreme 10 year worst-case weather data which was prepared for the project by the BRE using Meteonorm software.

3 The Larch House, our first prototype

Larch House, our first Welsh Passivhaus Social Housing prototype, is certified by the Passivhaus Institute and also achieves Zero Carbon, Code 6 of the Code for Sustainable Homes. This is a 3 bedroom house designed to minimize Annual Heat Demand (13kW/m2/yr) with a peak heat load of 11W/m2. It is located 1000ft up in the top of a valley, with particularly cold and cloudy winters and relatively little winter sun. To meet the 'worst-case' local climatic conditions, our specification included 425mm of insulation in the walls, 480mm under the ground floor slab, and 560mm in the roof. The windows occupy 55% of the south elevation to maximize the potential for solar gains during the winter. The house is designed to ensure excellent comfort and minimal energy bills even in extreme weather conditions, together with bright and airy interior spaces. However the high quality windows are very large and therefore expensive, when compared to most UK low-cost social housing and these large windows require shading in summer. Both these factors adversely affect the build cost of the house when compared to the cost of average UK social housing.

4 The Lime House, our second prototype

So for our second Welsh Passivhaus Social Housing prototype, the Lime House, we wanted to find a way to overcome the costs associated with large windows and retractable blinds.

Lime House is also a certified Passivhaus, also using extreme 10 year 'worst-case' weather data, but it uses a different method of achieving Passivhaus certification, based on the peak heat load. When there is a shortage of sun, solar gains become less significant and the internal heat gains become more important. To ensure the peak heat load remained below 10W/m2 in an extreme weather event, we were encouraged by the PHPP software to reduce the amount of glazing, assuming the same fabric specification as the Larch House. We found that reducing the south facing glazing to 20% of the elevation enabled us to keep the peak heat load below the limit of 10W/m2 in the event of a 10 year peak load weather scenario while at the same time maintaining an acceptable annual heat demand (17kWh/m2/a). This approach enabled us to rely primarily on post air heating to meet the peak load.

A design optimization graph produced by Robert McLeod (BRE) and Carine Oberweis (bere:architects) helped us understand the building physics that determined the glazing areas. This graph clearly shows two discrete optimisation points with respect to glazing areas depending on whether Annual Energy Demand or Peak Load is being optimised.

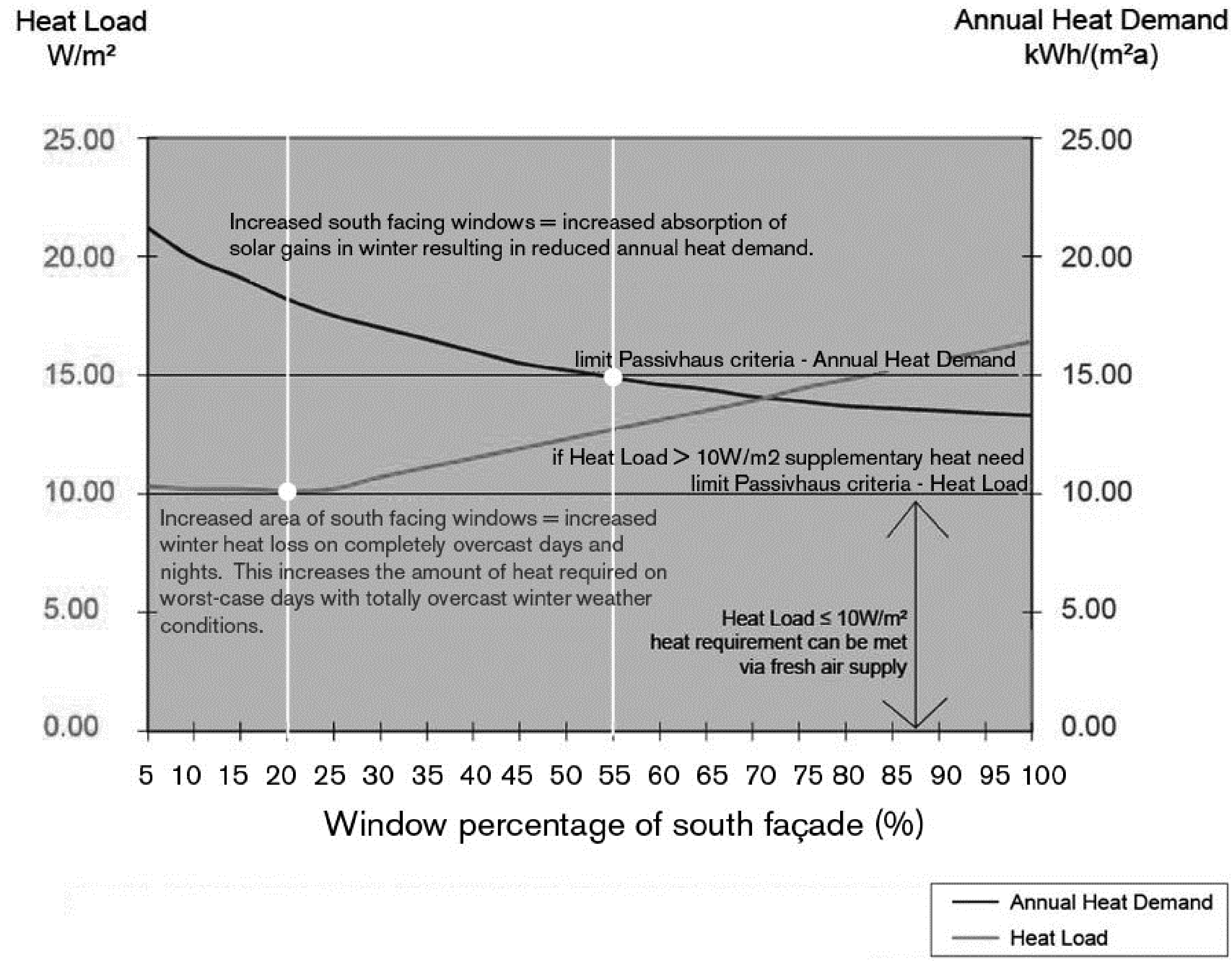

Figure 3: Lime House, design optimisation graph

5 Results

The worst-case weather data for Ebbw Vale, produced by the BRE, is almost twice as demanding as either Manchester or Innsbruck mean data. It also resulted in two very different design outcomes; the annual heat demand method seemed to prioritise solar heat gains and the peak heat load method seemed to prioritise internal heat gains and the reduction of fabric transmission losses. The peak heat-load method of design resulted in the cheapest building, mainly because smaller windows save window costs and, if the smaller windows do not require summer shading, the cost of blinds can be eliminated.

However, even in the Lime House, using extreme worst-case weather data resulted in costs that are proving prohibitive to the uptake of low energy housing by social housing providers in a period of reduced government expenditure. Since both houses proved very successful in maintaining comfortable conditions by air-heating in an unusually cold winter, we decided to investigate the savings that we could achieve in future if we use average weather data for Wales or the North of England. We also decided to check for any associated risks.

Figure 4: (left) Larch House 55% south glazing and (right) Lime House 20% south glazing; as built using extreme 10 year worst case Ebbw Vale weather data

When we re-designed the two houses with average (Manchester) weather data we found that this significantly reduced or even eliminated the difference between using 'annual heat demand' and 'peak load' certification. Both certification methods allowed us to use 33% south facing glazing and an identical (reduced) fabric specification compared to the built houses. PHPP indicates that internal blinds will be sufficient to maintain comfort in summer.

Figure 5: (left) Larch House 33% south glazing and (right) Lime House 33% south glazing; redesigned using only Manchester mean weather data which also allows a cheaper fabric specification

Our cost consultant then re-analysed the cost of our re-designed Larch House compared to the Royal Institute of Chartered Surveyors 'BCIS' database for a one-off detached house built in the previous 10 years.

- **Larch House with worst-case weather data (as built):** 55% glazing to south elevation; external solar blinds; 425mm mineral wool in walls in 3 layers; 560mm mineral wool in roof; 480mm XPS under ground slab. (due to the extreme 10 year worst-case weather data, the house cost 22% more than typical low cost housing).

- **Larch House with mean weather data:** 33% glazing to south elevation; no solar blinds; 240mm mineral wool in walls in only 2 layers; 420mm mineral wool in roof; 240mm XPS under ground slab (cost reduced to just 9% more than typical low cost housing).

Clearly using average weather data saves a lot of money, but what about the risk of being unable to meet the heating requirement in extreme worst case weather conditions? To check this, we put the 10 year worst-case weather data back into option (2) with its reduced fabric specification. The peak heat load went up to 11W/m2. This is just 1W/m2 above the capacity of the air supply, and in a 100m2 house equates to just 100watts. This is a very small additional heating demand that can be supplied by just 4 tea lights! Or we could provide one emergency fan heater, or supply a towel radiator in a bathroom which would supply the additional heat needed in an extreme 10 year worst case weather scenario.

6 Conclusions

- When mean weather data is used, it seems to us that there is little difference between the fabric specification needed for ‘annual heat demand’ and that needed for ‘peak load’ methods of certification in the UK climate zones that we tested.
- If extreme 10 year worst-case weather data is used, the ‘peak load’ optimised method of design and certification was found to result in the cheapest outcome
- Because a passivhaus has a very low energy demand and a high thermal inertia, we conclude that, even in the event of unusually cold weather conditions, using average weather data typically presents only a small risk to maintaining the complete comfort and satisfaction of the occupants during winter months.
- Detached dwellings are more costly to build and heat than row-housing. Row-housing or multi-residence dwellings will achieve further capital and operational cost savings.
- We suggest that the precautionary decision to use worst-case weather data is probably no longer necessary in the UK. If vulnerable tenants are likely to occupy the property, the small risk to complete comfort that is caused by an extreme 10 year worst case weather scenario could be eliminated, for example, by including one heated towel rail in the house, but even this may not be necessary. So in future we suggest that the use of accurate mean local weather data is likely to be sufficient in the UK. Significantly lower build-costs will result from this decision, which is an important factor in reducing one of the UK’s key barriers to the uptake of seriously low-energy, low cost passivhaus housing.

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