The Design Process for Energy Efficient New and Refurbished Housing

for EC Thermie SUNH and SHINE Projects

M. WILSON, J.H. WALKER, M. SANTAMOURIS, S. JAURÉ

Low Energy Architecture Research Unit (LEARN)
University of North London
Spring House
6-40 Holloway Road
London N7 8JL
http://www.unl.ac.uk/LEARN/

Abstract

A team of specialist advisors, the authors of this paper, provided design advice to the architects and engineers of the EC Thermie target projects SUNH (Solar Urban Hew Housing) and SHINE (refurbished housing) during the design phase, which is still ongoing. M. Wilson is the co-ordinator of this task of advisors dealing with the 'Specific Innovative Technologies' (SIT) of: Daylighting (M. Wilson), passive design, energy management and heating (J.H. Walker) and passive cooling and active systems (M. Santamouris). Overall technical and financial co-ordination is provided by S.Jauré. The projects covered a wide climatic range, comprising 16 projects in 8 countries, from Finland, to southern Spain. General guidance was provided at an initial meeting and then specific advice was given as the projects developed, at regular meetings at approximately three monthly intervals. It is clearly not possible to review the advice given in all the projects but this paper will review some common issues for the range of projects. In particular this paper will:

1. Discuss some key issues relating to the design and procurement process, including issues relating to national differences of construction technique and building form.
2. Contrast those projects where intervention was at an early stage, with those where intervention was later in the design process.
3. Provide a small selection of case studies where intervention gave rise to improved design solutions.

INTRODUCTION

Although the design for many of the projects is still evolving, it may be said with some confidence that the design advice of the Specific Innovative Technologies (SIT) task has already made a significant improvement on the designs of most buildings within the project.

This has been achieved through a co-ordinated and systematic approach to providing design support, comprising (for SUNH and SHINE separately):

1. Some general guidance given at the first meetings on some of the key design issues.
2. Each project completing standard pro-forma 'Project Evaluation Sheets' describing the projects key points and evolution over time.
3. Projects making detailed presentations at technical design meetings held about every three months.
4. Specific comments being made immediately afterward, in an interactive way with the designers and their technical advisers. These comments are then noted and sent to each of the projects for action/reaction.
5. Response to comments fed back and noted in updated Project Evaluation Sheets. Loop 2. to 5. then repeated.

It should also be noted that a key aspect of this integrated project is the exchange of ideas and experience between each of the projects themselves. A number of projects have energy aware architects or have their own energy consultants appointed and are able to make valuable comments on other projects, from a new and objective standpoint. Furthermore the other 'tasks' providing guidance on the project (Environmental and Materials Assessment, Architecture and Urban Integration, Comparative Simulation and Dissemination) also have a valuable contribution to make. This is especially true as an 'integrated design approach' is being strongly recommended, taking into account the full range of aesthetic, energy and environmental concerns. Of these other tasks the Comparative Simulation is one with a high degree of overlap with the SIT task, providing as it does (when adequately done by the project) some quantification of both the key design issues (e.g. summer overheating) and the effects of proposed solutions (e.g. shading, ventilation, thermal mass). This latter point is very important as the SIT task is not funded to carry out detailed design, simulation or analyse specific solutions, which is the ultimate responsibility of each project.

Clearly with such a wide range of regional climates, both the design problems and solutions are going to be quite varied between projects. However in all cases the overall objectives were much the same - to provide a comfortable internal environment, whilst rationally and economically making use of energy and material resources.

General Guidance and Tools Provided

At an early meeting some overall design advice was provided. This included:

1. The need to consider good daylighting design and in particular achieving simple minimum standards for average daylight factors in principle rooms; 2% in kitchens, 1.5% in living rooms and 1% in bathrooms. All projects were asked to calculate average daylight

factors using the following simple formula:

$$DFavg. = T\,Aw \quad / \; A\,(1 - R^2)$$

Where, T is the diffuse glass transmission factor,
Aw is the total glazed area of windows and skylights,
 is the angle of visible sky in degrees,
A is the total area of room surfaces,
R is the average reflection factor,

Other simple criteria suggested were to limit the ‘no sky line’ to less than 50% of the room and maintain a maximum ‘limiting depth’ for single sided glazing, given by:

$$L/H + L/W \quad 2/(1-Rb)$$

Where, L is the room length, W the room width,
H is the window head height, Rb is the average weighted reflectance at rooms rear half.

Furthermore, all projects were encouraged to use the ‘Daylight’ software, which enables average daylight factors and daylight distribution to be easily calculated and quickly optimised.

2. Natural ventilation and passive cooling guidelines were provided, with particular attention to solar pre-heating, and the use of night time ventilation as a strategy in the more southerly countries. All projects were also encouraged to make use of simple software called ‘SummerII’ to help design natural ventilation systems in conjunction with a heating and cooling load calculation.

3. A strategic approach to energy management was recommended to ensure good control of the internal environment, with low energy consumption. This was highlighted at this early stage to promote good integration with the building design and heating system, but also to emphasise the role of controls in realising the predicted savings in use, with the actual occupants.

After these initial briefings, all issues were dealt with in relation to specific projects at the regular design meetings.

DESIGN AND PROCUREMENT ISSUES

One interesting factor which had an impact on the outcomes, was the different approaches to planning, design, built form, use of materials, and procurement in each of the different countries involved - albeit from a small non scientific sample. This is an interesting factor as it sets each project in it’s own context, which has a bearing on what may be considered innovative, and the affects the likely hood of replication within the dynamic, social and professional, context of the country involved.

For example in the UK housing association sector, the ‘Design and Build’ procurement method has been widely adopted, as a means of providing low cost mass housing for low income households (as opposed architect designed and tendered over most of Europe). As a result the primary design responsibility has been passed to the volume house builders, who are building to a price, within a minimum quality standard. This has led to a disincentive to innovation in this sector and in consequence a lower expectation of what would be innovative. In response to this, all SUNH and SHINE projects have therefore appointed their own architects (and in many cases energy consultants) to provide innovative and workable designs with considerable replication potential within the social housing sector.

Under the general heading of planning, there are a range of associated factors which affect the applicability of designs for each country. For example, despite being relatively dense in population terms, there is still a preponderance of traditionally constructed houses, or low rise flats, being built in the UK, as these are preferred by both the planners and occupants following problems with the high rise flats of the 1960’s. However, high rise flats are still being built in volume, quite cheaply, in many other countries, which given their dense ‘massing’ can be inherently energy efficient, minimising wall areas for winter heat loss and summer heat gain; but detracting from opportunities for natural ventilation and daylighting. Hence the design solutions proposed need to take account of these local circumstances.

Similarly the availability of land and planning restrictions can limit the extent to which optimal passive solar design can be implemented as may be seen in the two examples in Figure 1 and Figure 2 below.

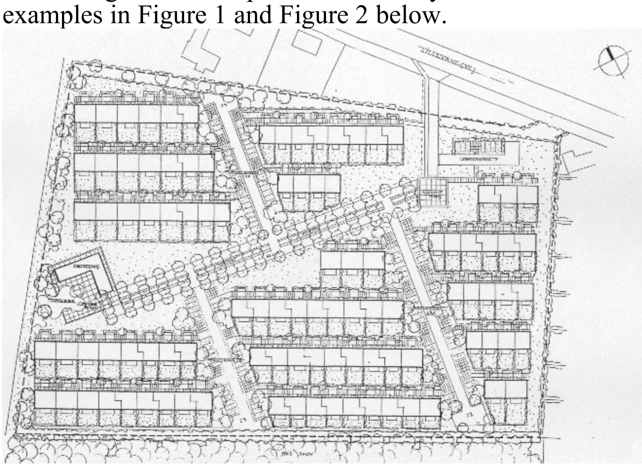

Figure 1. Proposed Site Plan, Farum Sodal, Denmark.

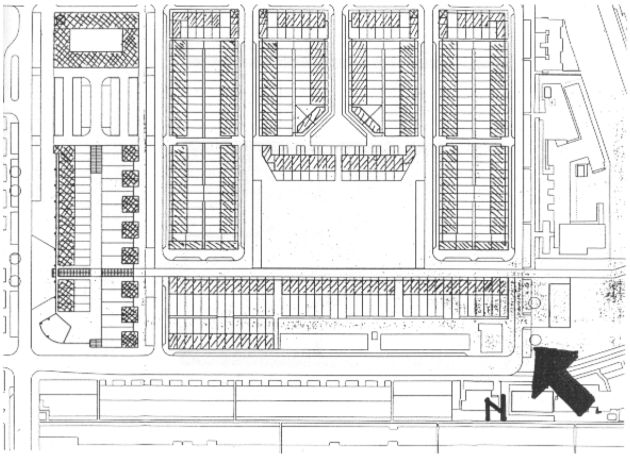

Figure 2. Proposed Site Plan, Schaakwijk, Netherlands.

In these two cases local planning restrictions have lead to different site layouts and design solutions. In the former, local planners have required no more than 1 ½ storey high construction on the site, but have not dictated orientation; leading to an ideal opportunity for passive solar designed and oriented bungalows. By contrast, in the latter case the site is squeezed into a tight city grid plan, 45 degrees off north-south into which the houses must conform; also due to commercial reasons, the housing density is high and heights up to three storeys are allowed. However the latter project has within these constraints, managed to develop passive solar designs which have maximised solar gain on the SE/SW facades, with alternate designs for ‘street facing’ and ‘garden facing’ southern aspects. This is an important principle to establish and replicate to overcome the common practice of standard house type construction, without reference to orientation.

Another contrasting area is that of predominant construction techniques, where traditional brick cavity wall houses and low rise flats are very predominant in the UK. Custom and practice has also led many architects to only partially fill these cavities with insulation, thereby avoiding a low cost opportunity for additional insulation. This is therefore an area where the design advice aimed to promote better insulated wall construction, by not only fully filling cavity walls but also considering highly insulated timber frame, or solid externally insulated walls. Over much of Europe a far wider range of non traditional building techniques are acceptable, with external wall insulation very widespread in northern Europe. However there still appear to barriers to external insulation in some more southerly countries, where the use of concrete frame and hollow clay brick is common. Again this is an area where the design advice has attempted to highlight the benefits of external insulation in combination with high internal thermal mass (with night cooling) as a strategy against overheating.

Financial and commercial pressures are also involved, which for rented social housing is generally a downward pressure on costs, which can compromise innovation. In housing for sale cost is important, but more subtly, involving market forces and the perceived value of the finished dwelling. This can be a problem for integrated passive solar designs, because much of the value is in the skill of the design to work without the need for visible 'bolt on technology'. A good example would be in the Qualitat Promocions project in Sitges, Spain where flats for sale are being developed. Despite having developed a design strategy to minimise summer overheating, it was originally proposed to provide centralised air conditioning for the whole apartment block, in response to a perceived marketing need for the 'reassurance' and status this would provide. Following SIT task intervention a compromise solution has now been agreed that air conditioning will not be provided as standard (although still an option) and marketing literature will highlight that these homes are designed such that air conditioning should not be needed and would be a poor choice environmentally and financially.

In summary, projects should be judged within an appropriate regional context, taking into account local circumstances and not just be applicable to an ideal 'green field' south facing site, with low replication potential. The SIT task has tried to deal with the realities which each design team has had to deal with and in each case 'add value' to the design, thus ensuring the project has a better outcome than would have been the case without intervention. In all cases national standards are thus far exceeded, albeit to different absolute standards.

Innovative Design and the Pareto Principle

The Pareto principle (also known as the '80/20' rule) applies very well to the design process for innovative buildings. That is to say with an free choice of site, building layout, construction technique etc. 80% of an innovative low energy design could be developed at the sketch design stage, for 20% of the total effort. On the other hand, projects which have reached an advanced stage of their design (or site planning), have the least opportunity to consider suggested design improvements and changes may be time consuming and expensive to implement. Given the nature of Thermie projects, many of principle design parameters were established prior to the project starting, such that the opportunity for fundamental change is often limited. The SIT task therefore is about the fine tuning of projects, to extract that additional 20% of potential saving, to ensure the design is well integrated, practical and widely replicable.

For SHINE which concerns the renovation of buildings, the options are to an extent even more limited, because the buildings already exist, with given orientations, window sizes and site layouts. However everything else is open to improvement and the potential for both energy saving and replication is far greater.

CASE STUDIES FROM SUNH AND SHINE

With 16 projects a huge amount of case study material is available, all of which cannot be covered in a short paper such as this. Therefore a number of key topics are discussed with reference to the appropriate projects concerned.

Sunspaces and Glazed Balconies

A number of projects have included some sort of sunspace or glazed balcony, as a means of enhancing the solar aperture of the building, providing a thermal buffer space and as a means of providing pre-heated ventilation air. The glazed balcony is often a favoured solution in refurbishment, having a number of secondary aesthetic and maintenance benefits associated with it.

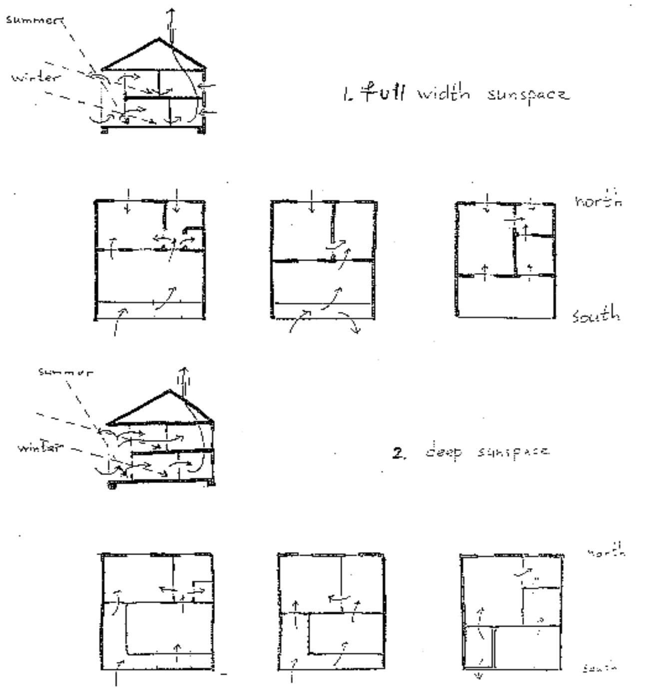

Figure 3. Working Design Sketch of Two Storey Sunspaces at Schaakwijk, Netherlands - Full Width and Deep Plan.

The design sketches in Figure 3 demonstrate how the design team have considered a range of alternative design options, and presented these for discussion at a SUNH design meeting. The deep sunspace option was discouraged on grounds of energy performance (greater heat loss perimeter) and higher cost, despite certain advantages in terms of improved daylighting and ventilation opportunities.

One of the key performance factors discussed was in terms of the risk of 'misuse', which is a topic relevant to all projects with sunspaces and glazed balconies. This applies to the heating of sunspaces, which often takes place in practice, and leads to increased rather than decreased energy consumption. In the case of a double height conservatory the possible benefit and risk are both increased. A number of possible solutions were discussed ranging from; providing 'external style' finishes and furniture to the sunspaces to discourage heating; through to providing an electronic alarm system to warn occupants of misuse.

A more robust solution would be to make the space uninhabitable, for example by making it extremely small. In affect this is what the twin solar wall achieves, in Figure 4.

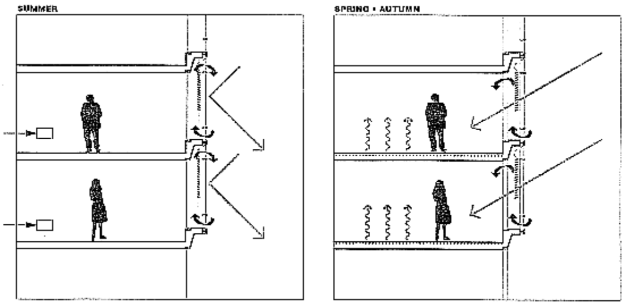

Figure 4. Cross Section of Solar Wall, USBL, Oslo, Norway

By accepting that the space will not be habitable there is no risk of occupant heating, summer overheating is permissible, and the space can be used effectively as a buffer zone, either rejecting or admitting available solar gains. The drawback is that no amenity space is provided, unlike a conservatory.

Improved amenity space and energy efficiency are two main reasons for glazing in balconies on existing flats, such as with the projects shown in Figures 5 and Figure 6.

Figure 5. Design Sketch Showing Proposed Glazed Balconies, BIG Heimbau, Engelsby, Germany.

One of the key factors which distinguishes these two projects is in the choice of glazing to the balcony, which is single in Goteborg, but is double with low-E in Englesby. In many ways the single glazed option is preferable, in that it is lower cost, discourages use of the balcony in the winter and allows more daylight into the flats. However, thermal simulation of the Engelsby flats has indicated that the risk of 'misuse' associated with heating the balconies is that energy consumption in flats may actually be increased by 220%, rather than decrease. Thus only a few flats extending their living space into the balconies (or simply leaving separating doors open) will offset any benefit from flats which don't heat the balconies at all.

This contrasts with typical saving for glazed balconies, quoted by IEA Task 20 [1], of 10-25%, where not misused. Thus in the case of Englesby double glazing with low-E coating is proposed to 'insure' against misuse. At Goteborg it is hoped that tenant education and prohibitive running costs will prevent misuse. More behavioural research data is required to assess the risks of misuse.

One of the problems with enclosed balconies, with multiple glazing elements (e.g. 4 layers), is that the light

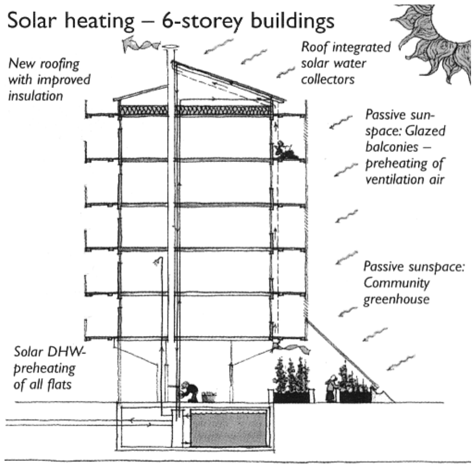

Figure 6. Design Sketch, Gardsten, Goteborg, Sweden.

Natural Daylighting Solutions

transmission drops below 50% and daylight levels can become too low, leading to increased electric lighting use and poor internal environments. At Engelsby, this problem was overcome by providing an additional small window to the rear of the room. If this can't be arranged, then glazing in balconies may only be a practical solution where the original windows were oversized; and double glazing only where original windows were very oversized.

In new build there is more scope for adjusting window size and details, in conjunction with the choice of glazing material. One example is shown in Figure 4, where an originally flat floor slab detail has been articulated, following SIT advice, to improve daylight penetration by increasing the sky view at window head level.

A key area for daylighting is the kitchen, which requires good daylighting conditions, especially over work surfaces, where visually demanding tasks take place. Hence the advice given to the designers at Farum Sodal for the kitchen shown in Figure 7. It was suggested that either the window could be moved closer to the work surface, widened (with same area) or a separate small window specified above the work surface, for good lighting for right handed people.

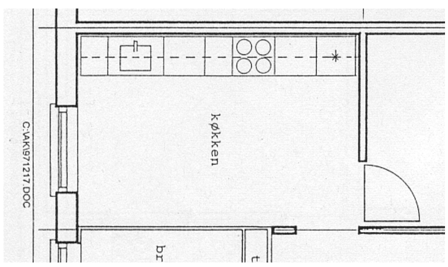

Figure 7. Original Kitchen Plan at Farum Sodal, Denmark.

Other Issues and Summary

The preceding examples show a small selection of the design issues and some of the design advice provided by the SIT task. Other key topics have included: Integration of passive and mechanical ventilation, passive cooling, solar shading, active solar, PV's, appropriate heating and control systems and much more. Please contact the authors for further information, including dissemination literature.

REFERENCES

1. IEA Solar Heating and Cooling (SHC) Programme, Task 20, 'Solar Energy in Building Renovation' (pub. James & James, London, ISBN 1-873936-74-5, 1997).