MAINTENANCE OF THE DATABASE OF UK PASSIVE SOLAR BUILDINGS FINAL REPORT

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MAINTENANCE OF DATABASE OF PASSIVE SOLAR BUILDINGS

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(Appendices not complete in electronic version – also figures 1-10 & tables 1-3 missing)

1.0 SUMMARY

In 1996 Altechnica developed a database of passive solar buildings in the UK for the Department of Trade and Industry. That database identified more passive solar buildings than had been expected: the majority of which were passive solar dwellings.

The database has now been expanded to contain over **220** records representing over **1,660** passive solar buildings (though over **1,560** of these are houses) including more than **40** schools and **30** office buildings. This represents an increase in the buildings included in the database of over 220%.

Figure 1 shows a cumulative chart of passive solar buildings constructed to date in the database. As can be seen, the number of passive solar buildings has grown steadily since the 1970s with most of the growth occurring between the 1970s and the early 1990s. Since that time the number of passive solar buildings appears to have grown at a much slower rate - declining from a peak in the 1980s.

The combined floor area of passive solar buildings has grown steadily since the 1970s (see **Figure 2**). In terms of floor area, non domestic buildings utilising passive solar measures for cooling, ventilation and daylighting, are perhaps now becoming more dominant. Fewer new passive solar buildings constructed in the late 1990s were identified and those that were included non-domestic buildings with substantial floor areas.

Figure 3 shows the cumulative totals of passive solar buildings in the residential, educational and office sectors. Each of these sectors has seen some growth in passive solar buildings. Similar trends are indicated in the floor area of passive solar buildings being greatest in the non domestic sector (see **Figure 4**).

Figure 5 shows the distribution by sector of all the passive solar buildings contained in the database. **Figure 6** shows the distribution of floor area of passive solar buildings by sector.

A number of statistics were derived from the database and a series of reports, tables and charts were generated, some of which are included in this report.

A variety of methods were used to estimate the potential energy savings (or *potential passive solar energy credits*) due to passive solar measures. These include the following approaches:

(1) Summing the energy performance data provided by the building designers or owners if known.

(2) In the case of dwellings without accompanying energy performance data but with sufficient information, an estimate of the passive solar credits was made using the Energy Index method developed by Simos Yannas of the Architectural Association.

(3) In the case of non domestic buildings without accompanying energy performance data but with sufficient area and accompanying descriptive information, an estimate of the

passive solar credits was made using a passive solar classification system (PCS), which uses an approximate relationship between a score code for passive solar heating, passive day lighting and passive cooling and ventilation.

Using these techniques an estimate of the passive solar savings was therefore made by first summing the available energy performance data, summing the Energy Index credits for dwellings and schools for which energy performance data was not available and summing PCS credits for non domestic buildings which also did not have energy performance data. This yielded a combined passive solar credit of some **15 GWh per year**.

Based on assumed rates of avoided CO_2 emissions of 370 g/kWh for domestic buildings and 610 g/kWh for non domestic buildings (ETSU, 1994), the potential CO_2 emissions avoided would be of the order of **8.6 million kg per year**.

The potential passive solar credit estimated in this way in the domestic sector is more than 2.6 GWh/year (yielding a CO_2 saving of 968,000 kg/year); in the education sector over 4.2 GWh/year (CO_2 savings 2.5 million kg/year) and in the office sector it is over 6.5 GWh giving a CO_2 saving of 3.9 million kg/year.

2.0 INTRODUCTION

Solar energy has been providing useful energy for centuries and the principal uses have been to provide a source of heat and light. Using solar energy for heat requires either solar collectors - a method known as *Active Solar* - or the careful integrated design of energy efficient buildings which can trap useful solar gains passively - a method known as *Passive Solar* heating design.

Optimum design, sizing and positioning of windows and roof lights combined with light controls can maximise the use of daylight and reduce the requirements for artificial lighting.

Solar energy can also be used to induce convection to ventilate and/or cool a building. This is usually referred to as *Passive Cooling* or *Passive Ventilation*.

All of these uses of solar energy for buildings, if applied effectively, can result in energy savings and reduce CO_2 emissions.

Passive solar design is one of a portfolio measures that can be taken to reduce the energy consumption in buildings together with improved insulation, higher performance windows, high efficiency boilers, simple responsive controls, heat recovery and low energy light bulbs.

2.1 Passive Solar Design in UK

The space heating requirements of individual houses in the UK can be reduced through the adoption of simple passive solar design measures and if the national housing market were to adopt passive solar measures enthusiastically, the total energy and carbon dioxide savings could become significant (ETSU, 1994).

The key aspects of passive solar heating design (PSHD) depend on an integrated design approach which positions the majority of glazing and the most frequently used rooms on the southerly side of the house; specifies high performance windows and includes high thermal mass materials within the insulated envelope. To be effective it requires a highly responsive method of space heating so as to take advantage of passive solar gains. Off peak storage heating systems, for example, are not able to respond to passive solar gains and so energy savings cannot be achieved. Similarly passive solar design does not work well with Aga stoves, wood stoves or open fire space heating methods.

If passive solar heating is to be efficiently exploited in individual houses on a significant scale, PSHD principles must also be applied to the design and layout of whole housing estates to allow for unshaded solar access and correct orientation for as many of the houses as possible. So far only a very small number of projects have taken this approach.

As well as using passive solar design to take advantage of useful solar gains to assist in the space heating of buildings, passive solar gains can be used to induce air movement in order to ventilate buildings. This use of passive solar is beginning to be applied to non domestic buildings and one of the best known is the Queens Building at De Montfort University in

Leicester designed by Short, Ford and Partners.

The solar heat penetrating a building can also be kept to a minimum passively by means of solar shading devices reducing the summer cooling load.

Designing buildings for the optimum use of daylight is another form of passive solar design which has the potential for electricity savings in non-domestic buildings. This entails careful siting of windows, roof lights and atria to increase day light penetration. Light shelves and other devices can also be used to reflect light deeper into a building. The use of daylight is also more effective when combined with automatic light switching and controls so that selected lights can be turned off when sufficient natural light levels are available.

Carefully designed atria for non domestic buildings can be used to induce passive ventilation and enhance daylighting as well as act as buffer spaces to reduce heat loss. However if they are heated or air conditioned then they are no longer energy saving but energy consuming features.

Similarly, carefully designed unheated sunspaces for domestic buildings can utilise passive solar heat gains and act as a buffer space to reduce heat loss from the house. However if they are heated or designed without careful shading or thermal mass or opening vents they can be energy consuming features and become uncomfortable spaces in the summer months.

The passive solar design of domestic and non-domestic buildings has been encouraged principally over the previous two decades in the UK and (once designed and planned) has also been considered a zero or low cost means of reducing energy consumption. The main focus of passive solar design over this period was to maximise its contribution to the space heating of houses. More recently, because of the need to reduce primary energy use (and the amount of carbon dioxide generated by the use of that primary energy) as well as delivered energy use, passive solar design has extended into maximising day lighting and into passive cooling and ventilation. These latter design goals have been particularly focused on non domestic buildings.

3. PASSIVE SOLAR DATABASE

In 1996 Altechnica developed a database of passive solar buildings in the UK for the Department of Trade and Industry. That database identified more passive solar buildings than had been expected, the majority of which were passive solar dwellings.

A number of strategies were used to obtain additional data on passive solar buildings ranging from further literature searches, distribution of publicity flyers, contacting additional known practitioners and a further limited questionnaire survey.

Updating the passive solar database involved tracking down as many passive solar buildings as could be located and then adding information about the identified projects into the database. Additional data was obtained by means of a literature search and from information gleaned from the practitioners via questionnaires. Articles promoting the database accompanied by requests for information were published in a variety of architectural energy, building and solar energy magazines and journals.

3.1 Background

The database *SURVEY4* described in this report is based on a database developed by Altechnica for the DTI in 1995 and developed to run under the database software package *Microsoft Access* for *Windows*.

That database was designed initially as a single database but it evolved into a multi-component database (*PASSIV*) consisting of three main components built up out of two main data sets. The first data set defined as *SURVEY* was based on information about passive solar buildings obtained by using a variety of information gathering techniques including literature survey, personal contacts and a questionnaire survey.

The second data set defined as *NESDATA* was derived from a data bank containing information about dwellings which had been assessed using the National Home Energy Rating (NHER) software program developed by National Energy Services under the auspices of the National Energy Foundation. To combine the data fields common to both data sets (*SURVEY* and *NESDATA*) an additional table (*SUMMDATA*) was incorporated into *PASSIV*.

This present project is concerned only with the SURVEY component of the database.

3.2 Criteria for Identifying Passive Solar Buildings

For a building to be included in the database, there had to have been a deliberate attempt on the part of a building's design team to design the building in order to obtain sufficient passive solar energy to offset the consumption of conventional energy for heating, cooling or lighting purposes.

The appropriate use of passive solar features is also a factor that has influenced the selection of suitable passive solar buildings for the database.

The use of atria or sun spaces is an area of some concern as many are now heated with room heaters or even by central heating radiators. This often negates the benefits of useful solar gains and can even result in an increase in energy consumption. Atria and sunspaces are included in the database if they are an integral part of the design but if there is a suspicion that they may be being heated then this is noted in the data.

4.0 PASSIVE SOLAR BUILDINGS IN THE DATABASE

The database has now been expanded to contain over **220** records representing over **1,660** passive solar buildings (though over **1,560** of these are houses) including over **40** schools and **30** office buildings. This represents an increase of over 220%.

Figure 1 shows a cumulative chart of passive solar buildings (those with date information available) constructed to date (one per record plus the total number of buildings constructed each year) in the database. As can be seen the number of passive solar buildings has grown steadily since the 1970s. Though when the multiplication factor per record is included, the growth in passive solar buildings is much less pronounced with most of the growth occurring between the 1970s and the early 1990s. Since that time the number of passive solar buildings appears to have grown at a much slower rate.

The combined floor area of passive solar buildings has grown steadily since the 1970s (see **Figure 2**). Fewer new passive solar buildings constructed in the late 1990s were identified and those that were included non-domestic buildings with substantial floor areas. This appears to reflect the fact that (in terms of floor area) non domestic buildings utilising passive solar measures for cooling, ventilation and daylighting are perhaps now becoming more dominant. There are however a number of buildings for which the date of construction or the amount of floor area is not known.

Figure 3 shows the cumulative totals of passive solar buildings in the residential, educational and office sectors. Each of these sectors has seen some growth in passive solar buildings. Similar trends are indicated in the floor area of passive solar buildings (see **Figure 4**). If we look now at the break down of the floor area of passive solar buildings by sector, the non domestic sectors have seen the largest growth. The rate of growth in numbers of passive solar dwellings appears to have declined from a peak in the 1980s

Figure 5 shows the distribution by sector of all the passive solar buildings contained in the database and **Figure 6** shows the distribution of floor area of passive solar buildings by sector.

Figure: 1 Cumulative Chart of Passive Solar Buildings in SURVEY4 Database.
(not available electronically)

Figure: 2 Cumulative Chart of Floor Area of Passive Solar Buildings in SURVEY4 Database
(not available electronically)

Figure 3: Cumulative Totals of Passive Solar Buildings in SURVEY4 Database Distributed by Residential, Educational and Office Sectors
(not available electronically)

Figure: 4: Cumulative Totals of Floor Areas Passive Solar Buildings in SURVEY4 Database Distributed by Residential, Educational and Office Sectors
(not available electronically)

Figure 5: Distribution by Sector of Passive Solar Buildings contained in SURVEY4 Database
(not available electronically)

Figure 6: Distribution by Sector of Floor Areas of Passive Solar Buildings contained in SURVEY4 Database
(not available electronically)

5.0 PASSIVE SOLAR ENERGY SAVINGS

5.1 Passive Solar Energy Credit Methods

As well as identifying passive solar buildings in the UK, one of the aims of updating the SURVEY database was to attempt to track the energy saving from passive solar measures in the UK.

Because very little monitoring of the passive solar contribution to building energy performance has been carried out (or is in the public domain) in the UK (35 projects) it is a not an easy task to make an accurate estimate of the passive solar contribution to energy consumption on a national scale and any method employed is inevitably approximate.

Where possible monitored energy performance data has been used, if this has not been possible then calculated or estimated passive solar contribution provided by the designers has been used.

If neither of these were available and if sufficient information about insulation levels, glazing areas and standards, orientation, etc., were available or able to be interpolated from drawings then the passive solar contributions to dwellings (and some schools) were calculated using a computer based calculation method. Ideally it would have been preferable to use a dynamic model to carry out such a task, but it was beyond the resources for this project to include this and in any case it was difficult to obtain sufficient information about buildings for a detailed analysis. After reviewing a number of methods, the Energy Index calculation method seemed to be the most appropriate and was sufficiently straightforward for adaptation for use with the database.

There was no similar standard method available for non domestic buildings which could provide an estimate of the passive solar contribution though several options were examined. A simple passive solar classification method based on assigning a score code was developed which, while tentative, appears as though it might give some indication of the passive solar contribution. However its estimates should be treated with caution.

When information about floor area and types of passive solar features were known, this method was used to estimate the passive solar credits for non domestic buildings for which there was no energy performance data available.

To estimate the potential energy savings (or *potential passive solar energy credit*) due to passive solar measures for buildings in the database the following approaches were included:

(1) Summing the energy performance data on passive solar savings when known.
(2) In the case of dwellings without accompanying energy performance data but with sufficient information on area and insulation standards, an estimate of the passive solar credits was made using the Energy Index method.

(3) In the case of non domestic buildings without accompanying energy performance data but with sufficient area and accompanying descriptive information an estimate of the passive solar credits was made using a passive solar classification system (PCS), which uses an approximate relationship between a score code for passive solar heating, passive day lighting and passive cooling and ventilation.

5.1.1 Energy Performance Data

Some of the information obtained about the buildings identified included energy performance information either in the form of a calculated prediction, an estimate, or in the form of monitored data.

Monitored, calculated or estimated energy performance data about ***71 projects*** (representing **1150** building premises) was provided to the project team. This included energy consumption and energy savings data due to passive solar measures. Of these only **35 projects** provided data about energy savings attributed to passive solar measures (these represented **1051 buildings or premises** (1047 dwellings). The annual energy savings due to passive solar measures for these **35 projects** totals almost ***2,220,000 kWh/year*** (**2.22 GWh/year**) estimated by taking account of multiplication factors per 'site'.

5.1.2 Energy Index

The Energy Index, developed by Simos Yannas (Yannas, 1994), is a method of calculating an estimate of the space heating energy performance and passive solar contributions to houses and which has also been applied to schools. It is a useful aid when applied at the design stage to evaluate alternative design options. It has been validated against the SERI-RES dynamic passive solar energy analysis software model. It is designed to work primarily with direct gain passive solar heated houses so when applied to buildings with other passive solar features such as sunspaces, solar roof spaces and Trombe walls, there will be either an over or under estimate of the passive solar heat contributions so the estimates have to be treated with care. However most of the passive solar dwellings in the database are of the direct gain variety.

The Energy Index has been modified in order to carry out batch processing of those passive solar houses with sufficient parameter information held in the database.

Energy Index analysis was carried out for 1120 residential buildings contained in 74 records in *SURVEY4*. On this basis the total credits from useful passive solar gains for these buildings combined exceeded **3.4 GWh/year**. The Energy Index also calculated credits for four school buildings in the database - this yielded Energy Index Credits of **261,300 kWh** per year.

After the dwellings which had passive solar energy performance data were extracted the passive solar credits were calculated with the Energy Index for the remaining passive solar dwellings. On this basis the passive solar credits for 91 buildings contained in 42 records was over **600,000 kWh/per year**.

Based on the avoided CO_2 rates for passive solar benefits used in ETSU, 1994, the avoided carbon dioxide was estimated. At the rate of 370 g/kWh (assuming gas is the fuel saved) 600,000 kWh/year would avoid the emission of some **228,000 kg of CO_2 per year** (or 228 tonnes per year).

The Energy Index analysis of 1120 dwellings was for approximately 72 % of the dwellings held in the *SURVEY4* database so if we were to extrapolate for 1562 dwellings the passive solar credits calculated on this basis would be in the region of **4.835 GWh/year**. Using the same assumptions the avoided carbon dioxide would be of the order of **1.78 million kg of CO_2** per year (or 1,780 tonnes per year).

5.1.3. Non Domestic Passive Classification System

In the case of non domestic buildings without accompanying energy performance data but with sufficient area and descriptive information, an estimate of the passive solar credits was made using a passive classification system (PCS), which uses an approximate relationship between a score code for passive solar heating, passive day lighting and passive cooling and ventilation. The *PCS* has been incorporated into the *SURVEY4* database. See Appendix 4.

Format of the Non Domestic Passive Classification System

The classification system consists of three sets of codes, one for each of the following:-

- passive heating
- passive ventilation and cooling
- passive lighting (i.e. day lighting)

One of each of these codes is assigned to each non domestic building provided sufficient information about the building is available. Each code is a two-digit alphanumeric string which could potentially be read by the computer database software during automatic sorting and processing. The system also includes an overall "passive score", which is obtained by combining the individual heating, ventilation and cooling plus day lighting codes. The passive solar heating code has been retained even though this is likely to be a less important or may even be a negative factor in the passive solar contribution to non domestic passive solar buildings.

The form of the classification code is shown in the following table:-

Table of Non Domestic Passive Classification System Codes

Definition	Passive Heating	Passive Ventilation & Cooling	Day Lighting
None	H0	V0	L0
Minimal	H1	V1	L1
Small	H2	V2	L2
Medium	H3	V3	L3
Large	H4	V4	L4
Substantial	H5	V5	L5

The overall passive score PX is a code where X is a number which lies between 0 and 15. See Appendix 4 for a description of the criteria used to determine the passive score code.

In order to determine whether or not this procedure was viable, a validating exercise was carried out using the ETSU passive solar design studies to see if the PCS scores corresponded to energy savings.

The results of the PCS for non-domestic buildings (from the ETSU passive solar design studies) were moderately encouraging and there appears to be a loose relationship between estimated "passive solar contribution" and the "overall passive score" achieved in the PCS. This relationship is shown in Appendix 4.
This exercise indicated a relationship of 3.3 times the PCS code value to the passive solar credits per unit of floor area for passive solar offices used in ETSU Passive Solar Design Studies.

Using the PCS scheme of assigning passive solar scores, 72 non domestic buildings in the *SURVEY4* database yielded a total passive solar credit of over **12 GWh/year**. At the rate of 610 g/kWh avoided carbon dioxide (assuming electricity is the energy saved) this would avoid some **7.6 million kg of CO_2 per year** (or 7,700 tonnes per year) (ETSU, 1994).

5.1.4 Passive Solar Energy Credits

Combining these techniques an estimate of the passive solar credits from buildings included in the SURVEY4 database was therefore made by first summing the available energy performance data, summing the Energy Index credits for the dwellings and schools for which energy performance data was not available and summing PCS credits for the non domestic buildings for which energy performance data was also not available. This yielded a combined passive solar credit of some **15 GWh per year**.

Based on the previously described rates for avoided CO_2 emission of 370 g/kWh (domestic buildings) and 610 g/kWh (non domestic buildings) the potential CO_2 emissions avoided would be of the order of **8.6 million kg per year**.

The potential passive solar credits estimated in this way are over **2.6 GWh/year** (yielding a CO_2 saving of **968,000 kg/year**) in the domestic sector; over **4.2 GWh/year** (CO_2 savings **of 2.5 million kg/year**) in the education sector and over **6.5 GWh/year** with a CO_2 saving **of 3.9 million kg/year** in the office sector.

6.0 ANALYSIS OF *SURVEY4* DATABASE

Over 1660 buildings have been entered into the database. These include over 1560 residential buildings and over 40 educational buildings and 30 office buildings - the rest being a mixture of industrial and other buildings. The total floor area of buildings included in *SURVEY4* is over 670,000 square metres, although floor area information of some of the buildings was not provided.

Using the *SURVEY4* database, it is possible very quickly to show totals and distribution of data by sector or on a regional or county basis (see **Tables 1** to **2**) thus providing a speedy method to determine a whole variety of statistics from the data. A further selection is shown in **Appendix 1**. **Figure 7** shows the distribution of passive solar buildings by region. **Figure 8** shows the distribution of floor area of passive solar buildings. **Figure 9** shows the distribution of passive solar buildings in the South East region by county and **Figure 10** shows the distribution of floor area of passive solar buildings in the South East region also by county. Similar distributions can be carried out for other regions or sectors around the country.

Table 3 shows the Energy Index Credit calculation results.

Whilst data on energy use and savings was not complete, a limited amount of data was obtained and if we use the energy data for one site (per record) and simply multiply by the "multiplicity" value for each record we can derive the following estimates: For **921** buildings on **56** sites, total energy use monitored was some **41.8 GWh/year**; for **832** buildings on **57** sites, total heating energy use monitored was **18.56 GWh/year**; and for **1,051** buildings on **35** sites, passive heating savings monitored were some **2,922 MWh/year**. These figures apply to both domestic and non domestic buildings but the same buildings are not necessarily included in each of the totals. The figures should be treated with caution however as in many cases only one example of each building type (i.e. per record) has been monitored.

TABLE 1

(not available electronically)

TABLE 2

(not available electronically)

Figure 7: Distribution of passive solar buildings by region.

(not available electronically)

Figure 8: Distribution of floor area of passive solar buildings by region.

(not available electronically)

Figure 9: Distribution of passive solar buildings in South East region by county.

(not available electronically)

Figure 10: Distribution of floor area of passive solar buildings in South East region by county.

(not available electronically)

Table 3:Energy Index Credit Calculation for Passive Solar Dwellings. (calculated over 23.4kWh/m2 as norm)

(not available electronically)

7.0 CONCLUSIONS

Data about passive solar buildings in the UK has been gathered and entered to update the database of passive solar buildings in the UK.

It has been expanded to include over 220 records of passive solar buildings representing over 1660 buildings around the UK. Whilst it has been possible to identify additional buildings for inclusion into the database this was a much more difficult task as even in spite of growing interest in green issues passive solar design is clearly not part of the mainstream construction industry and represents a very small proportion of buildings.

From the data contained in the *SURVEY4* database it can be seen that the number of passive solar buildings has grown steadily since the 1970s. Though when the multiplication factor per record is included, the growth in passive solar buildings is much less pronounced with most of the growth occurring between the 1970s and the early 1990s. Since that time the number of passive solar buildings appears to have grown at a much slower rate.

In the case of the cumulative growth of passive solar building floor area, a steady continuous growth has occurred since the 1970s. This appears to reflect the fact that non domestic buildings utilising passive solar measures for cooling, ventilation and daylighting are perhaps now becoming more dominant from the point of view of considering the use of passive solar features. Fewer new passive solar buildings constructed in the late 1990s were identified and those that were included a few non-domestic buildings with substantial floor areas.

The cumulative totals of passive solar buildings in the residential, educational and office sectors have seen some growth. Similar trends are indicated in the cumulative total floor area of passive solar buildings. If we look now at the break down of the floor area of passive solar buildings by sector, the non domestic sectors have seen the largest growth.

The rate of growth in numbers of passive solar dwellings appears to have declined from a peak in the 1980s. There may be a variety of reasons for this but could possibly be due to a low level of interest (and / or lack of awareness) from the house building companies. It could also be due to the higher importance given to energy efficiency measures (compared to passive solar design measures) by energy-aware architects and designers as a means of reducing energy consumption in houses. Also, perhaps the benefits of passive solar design are not considered as high a priority in reducing heat consumption because achieving them does involve some constraint on estate layout options.

With relatively low energy prices it may also be difficult to justify the extra design costs required - a successful passive solar heated house involves a good deal more design effort compared to a standard house design. In fact many new reasonably well insulated houses are even designed deliberately to keep the solar gains down because they use a lightweight timber frame construction which does not involve a high level of thermal mass with which to absorb the heat gains.

Whilst passive solar heating design can improve the energy performance of houses, the benefits from classic passive solar measures tend to be of most benefit in spring and autumn, but if the insulation standards are improved, the passive solar benefits tend not to be as useful during these months. Considering the relatively low level of insulation standards in the UK compared to countries such as Denmark, Sweden or Canada, perhaps the priority should be to encourage a large scale improvement in insulation standards rather than encourage passive solar heated houses. The Building Regulations could of course encourage both approaches or preferably an integrated approach.

At the present time, with building heating energy at current levels, improvements in energy efficiency may be of greater benefit, but passive solar heating design should still be encouraged. It can play a useful role in 'next generation' zero energy houses which are sufficiently well insulated and contain sufficient internal thermal mass, together with super windows, to enable them to obtain all of their heat energy needs from passive solar and internal gains even through the winter months - at least in the south of England. As part of the portfolio of energy saving measures for zero energy performance standards, passive solar could help to reduce the energy consumption on new buildings considerably. If not applied to at least a proportion of the 4 million or so houses which are anticipated in the future, then an opportunity to reduce the increased energy demand that these houses will have on the national energy demand and resulting carbon dioxide emissions will have been missed.

Whilst the database almost certainly does not include all passive solar buildings, the number of buildings indicate relatively poor take up of passive solar design measures. It seems unlikely that it will increase without some encouragement, incentives or regulations. The extra design effort involved and the constraints that passive solar imposes on a building's form and appearance is likely to reduce the number of passive solar buildings constructed unless some support is available. Designing effective passive solar buildings is much harder than designing a conventional building - particularly if working to tight deadlines as is increasingly the case.

The issue of heated conservatories and atria needs addressing and the way that they are linked or integrated to the associated buildings requires some guidance.

There does seem to be some interest in incorporating passive solar measures into non domestic buildings if those who occupy the building are also the commissioning clients but there do not appear to be large numbers of such buildings. Some of those that have been built have managed to demonstrate economic benefits by avoiding the capital expenditure on air conditioning plant but clients have to be positive about taking this kind of approach and also should choose a design team with sufficient expertise to realise genuine passive solar performance.

Clients wishing to achieve a so called 'greener' building may be open to the passive solar approach and schemes such as BREEAM have a role to play.

Judging from the information obtained about passive solar building in the UK, there is a wide range of performance and there also appears to be a wide variation in the expertise of architects and designers of passive solar buildings. There often appears to be confusion about passive solar design measures as well as with other solar energy measures or energy efficiency measures particularly with regard to conservatories or atria.

This does appear to be a critical period for passive solar design as there is a danger that if it is not encouraged or if its benefits are neglected, the passive solar expertise which is available will be lost and the benefits of experience will be unavailable so the contribution to energy saving that it could provide in the UK for little extra cost will have been missed.

There does seem to be a need for education and training of practitioners and house builders about passive solar design procedures. In addition there appears to a need for reliable advice about passive solar design and energy efficiency measures to practitioners and others involved in commissioning and constructing buildings - particularly at a very early stage in the design process.

Furthermore there does seem to be a dearth of monitoring of building energy use and even less monitoring of passive solar performance. As long as there is a lack of building energy performance data there is no feed back into design and similar mistakes are repeated as the lessons are not learned effectively or are misinterpreted.

The SURVEY4 database could perhaps play a useful role here. Whilst the SURVEY4 database does not contain a large amount of data on the measured performance of passive solar buildings, the information it does contain about passive solar buildings in the UK could form the core of a CD-ROM type interactive multimedia design guide (or perhaps linked to or based on an interactive web page) and if combined with 3-D walk-throughs, simulations, animations, slide shows, video sequences and tutorials could help to improve both the skills levels and awareness of passive solar design. If the scope was widened to also include building energy efficiency measures and strategies and how they interact and benefit from effective passive solar design then the information obtained for the SURVEY4 database could help in reducing the energy used in buildings and the carbon dioxide emission levels that this entails.

Because of its space heating (or ventilation and lighting) requirement every new building will add to the national energy demand (and to CO_2 emissions), even if it is a so called low energy or green building, unless it is a zero energy building or obtains its energy requirements from renewable energy. It is therefore urgent that new buildings should be designed to make effective use of passive solar and other energy saving measures that can reduce the growth in energy demand.

8.0 REFERENCES

ETSU (1994): *An Assessment of Renewable Energy for the UK*, HMSO.

YANNAS, S. (1994) *Solar Energy and Housing Design, Volume 1: Principles, Objectives, Guidelines* and *Volume 2: Examples* Architectural Association, London.

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APPENDICES

APPENDIX 1 THE *SURVEY4* DATABASE

A1.1 Design of the *SURVEY4* Database
A1.2 Screen forms for use in the Database

APPENDIX 2: REPORTS GENERATED FROM THE *SURVEY4* DATABASE

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Appendix 2.2: Ownership of passive solar buildings by sector
Appendix 2.3: Floor area of passive solar buildings by sector
Appendix 2.4: List of features in passive solar buildings database
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APPENDIX 3: BLANK QUESTIONNAIRE FORM

APPENDIX 4: NON DOMESTIC PASSIVE CLASSIFICATION SYSTEM

APPENDIX 1 THE *SURVEY4* DATABASE

APPENDIX 1 THE *SURVEY4* DATABASE

A1.1 Design and Enhancement of the *SURVEY4* Database

The database, *SURVEY4* is structured such that it contains one main form for inputting or viewing baseline information including location and descriptive information.

Additional linked sub forms are also provided for inputting and displaying data about passive solar features and strategies, fabric insulation standards, energy consumption (and energy saving) data, as well as the consultants and contractors involved with the project. It has a flexible structure so as to allow for the inclusion of the diversity of available information about passive solar buildings.

The *SURVEY4* database is designed to be a tool which permits a whole variety of passive solar statistics (as available) to be extracted from the data. These include numbers of buildings, floor area, date of construction, location, passive solar features, glazing areas and standards, building fabric codes, energy consumption, passive solar credits, distribution by building type, sector, town, county and region.

The *SURVEY* database was designed to:-

- Allow for the variety and complexity of real buildings
- Allow for widely varying amounts of information about each building
- Capture as much information as feasible
- Maximise the use of the available information
- Create a resource that can be used to obtain information on the implementation and benefits of passive solar design
- Be adaptable for ongoing development and enhanced utility

In addition the database follows the same basic structure as the questionnaire and therefore has four main forms which correspond to Parts A, B, C and D of the questionnaire with additional forms dedicated to glazing distribution and feature details. A further component has been included in the *SURVEY4*database for the inclusion of the building fabric information required for carrying out the Energy Index calculation procedure and the facility for calculating the Energy Index Credit for each dwelling with sufficient parameter information.

The SURVEY4 database has also been enhance to have the cabability of inclusion of a single graphic image within the base form of each record. This can be a photograph, drawing or some other form of compatible graphical information.

For each site the *SURVEY4* database can contain the following information:-

Base	- identifiers and location - type and sector - Number of buildings - descriptive information - floor area, Number of floors and building volume - passive classification system (PCS) codes and credits
Fabric Details	- gross and net wall areas and U values by orientation

- gross and net glazing areas and U values by orientation
- type of glazing employed
- gross and net roof areas and U values
- gross and net floor areas and U values
- gross and net areas of doors and U values by orientation
- gross & net areas of sunspaces & U values by orientation

Features - description plus quantitative information on specific passive solar feature and internal surface reflectance

Glazing - glazing areas, percentages, U-values and glazing type
- orientation, eg. N NE E SE S SW W NW (as available)

Energy - modelled and measured energy consumption for buildings (as available),
- SAP data + SAP worksheet, Passive Solar Credits
- Energy Index

Consultants - names, addresses and roles of the building's designers

Data obtained from the literature searches and responses to the questionnaire survey were entered into the database using the screen entry forms corresponding to the questionnaire form.

Appendix A1.2 shows the screen forms of the *SURVEY4* database:

Basedata.qre Form (in five sections)

Fabric Specifications Form

Building Energy Data Form

Glazing Form

Passive & Energy Features Form

Project Consultants Form

(not available electronically)

APPENDIX 2: REPORTS GENERATED FROM THE *SURVEY4* DATABASE

Appendix 2.1: **List of buildings in *SURVEY4* database**

Appendix 2.2: **Ownership of passive solar buildings by sector**

Appendix 2.3: **Floor area of passive solar buildings by sector**

Appendix 2.4: **List of features in passive solar buildings database**
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(not available electronically)

APPENDIX 3: BLANK QUESTIONNAIRE FORMS

(not available electronically)

APPENDIX 4

NON DOMESTIC PASSIVE CLASSIFICATION SYSTEM (PCS)

Derived from previous PCS contributed by Dr Peter Rickaby

NON DOMESTIC PASSIVE CLASSIFICATION SYSTEM (PCS)

Introduction

The passive classification system was previously proposed for both domestic and non domestic buildings but was found not to be appropriate for domestic buildings but appeared to have some potential promise for non domestic buildings when compared to non domestic passive solar building design studies. The estimates are still tentative though and do need to be treated with caution until it is possible to utilise measured performance data of non domestic buildings.

The PCS has been used as a guide in assigning passive solar credits in the database and when energy performance data was not available for the particular non domestic building. This credit was then used in estimating the passive solar credits of non domestic buildings in the database.

The objectives of the classification system are:

1 To identify the nature and approximate extent of the contributions to the annual heating and/or ventilation/cooling demand, and to the reduction of the artificial lighting demand, of buildings which are made by their "passive" (i.e. non-mechanical) features.

2 To provide a system of codes which may be used in conjunction with other data (e.g. floor areas, activity codes, etc.) in order to identify, sort and retrieve records of non domestic passive buildings on the basis of their technical type or the effectiveness of their passive features, and as a starting-point for estimates of "passive contribution".

The format of the classification system

The classification system consists of three sets of codes, one for passive heating, one for passive ventilation and cooling, and one for passive lighting (i.e. day lighting). One of each is assigned to each non domestic building and is to occupy one field in each record in the database. Each code is a two-digit alphanumeric string which may be read by the computer database software during automatic sorting and. The system also includes an overall "passive score", which is obtained by combining the individual heating, ventilation and day lighting codes.

The passive heating classification

The form of the classification code is HX, indicating the degree of passive solar contribution to the heating of the building, on a scale of 0 to 5:

H0 None
H1 Minimal
H2 Small
H3 Medium
H4 Large
H5 Substantial

Points 1 to 5 on the scale representing the degree to which the annual heating demand of a building is satisfied by passive solar features are defined as follows:

H1 *Minimal*

Features: orientation only.

The only passive feature is orientation of a building of an otherwise conventional plan, section and elevation to take advantage of solar gains.

H2 *Small*

Features: orientation and glazing disposition.

The building has appropriate orientation combined with increased south-facing glazing and reduced north-facing glazing, but the plan and section are conventional.

H3 *Medium*

Features: orientation, glazing disposition and internal arrangement.

The building has appropriate orientation combined with appropriately increased south-facing glazing and reduced north-facing glazing, the overall built form is compact, and the internal plan and/or section are arranged to take advantage of solar gains (i.e. by placing occupied spaces on the south side and service spaces with internal gains on the north side, and/or by incorporation of an integrated and unheated sunspace or atrium).

H4 *Large*

Features: orientation, glazing disposition, internal arrangement and responsive heating controls.

The building has appropriate orientation combined with increased south-facing glazing and reduced north-facing glazing, the internal plan and section are arranged to take advantage of solar gains, and there are responsive controls which turn off the heating when solar gains are available.

H5 *Substantial*

Features: orientation, glazing disposition, internal arrangement, responsive heating controls, and thermal mass.

The building has appropriate orientation combined with increased south-facing glazing and reduced north-facing glazing, the internal plan and section are arranged to take advantage of solar gains, there are responsive controls which turn off the heating when solar gains are available, and the building fabric has sufficient thermal capacity inside the insulation to reduce internal temperature swings.

The passive ventilation and cooling classification

The form of the code is VX, indicating the degree of natural ventilation and passive cooling on a scale of 0 to 5:

V0 None
V1 Minimal
V2 Small
V3 Medium
V4 Large
V5 Substantial

Points 1 to 5 on the scale representing the degree to which the building is ventilated by passive means are defined as follows:

V1 *Minimal*

Features: openable windows only.

The building is provided with openable windows in order to permit natural ventilation of occupied rooms but has no special features to promote natural ventilation.

V2 *Small*

Features: openable windows and cross-ventilation.

The building is provided with openable windows in order to provide natural ventilation to occupied rooms, and most spaces have adjustable openable windows on two opposite sides in order to provide cross-ventilation (or ventilation paths are provided between spaces on opposite sides of the building).

V3 *Medium*

Features: openable windows, cross-ventilation and night ventilation.

The building is provided with openable windows in order to provide natural ventilation to occupied rooms, most spaces have adjustable openable windows on two opposite sides in order to provide cross-ventilation, and windows or ventilators may be set to provide secure ventilation at night.

V4 *Large*

Features: openable windows, cross ventilation, night ventilation and induced internal air movement.

The building is provided with openable windows in order to provide natural ventilation to occupied rooms, most spaces have adjustable openable windows on two opposite sides in order to provide cross-ventilation, windows or ventilators may be set to provide secure ventilation at night, and the section of the building is designed to promote internal air movement (e.g. by means of a combination of low-level and high-level openings).

V5 *Substantial*

Features: openable windows, cross ventilation, night ventilation, induced internal air movement and stack ventilation.

The building is provided with openable windows in order to provide natural ventilation to occupied rooms, most spaces have adjustable openable windows (or other ventilation features) on two opposite sides in order to provide cross-ventilation, windows or ventilators may be set to provide secure ventilation at night, and the section of the building is designed to promote internal air movement by means of the stack effect in an atrium and/or in ventilation chimneys.

The passive lighting classification

The form of the code is LX, indicating the degree to which the design of the building uses day lighting to reduce the requirement for artificial lighting, on a scale of 0 to 5:

L0 None
L1 Minimal
L2 Small
L3 Medium
L4 Large
L5 Substantial

Points 1 to 5 on the scale representing the degree to which the requirement for artificial lighting is reduced are defined as follows:

L1 *Minimal*

Features: shallow plan.

The building has a narrow section (12m or less) in order to permit daylight from windows on two sides to penetrate to the centre of the plan.

L2 *Small*

Features: shallow plan and increased heights.

The building has a narrow section (15m or less), average floor-to-ceiling heights of at least 3.5m and increased window heights, in order to permit daylight from windows to penetrate to the centre of the plan.

L3 *Medium*

Features: toplighting.

The building is toplit (if it is single-storey), or toplit via lightwells and/or an atrium (if it has more than one storey), and the width of the plan between the external wall and the lightwells and/or the atrium does not exceed 12m, in order to permit daylight to penetrate throughout the plan on all floors.

L4 *Large*

Features: toplighting and increased floor-to-ceiling and window heights.

The building is toplit via lightwells and/or an atrium, the width of the plan between the external wall and the lightwells and/or the atrium does not exceed 15m, the average floor-to-ceiling heights are at least 3.5m, and the window heights are increased, in order to permit daylight to penetrate throughout the building on all floors.

L5 *Substantial*

Features: narrow building section combined with toplighting and artificial lighting controls.

The building is toplit via lightwells and/or an atrium, the width of the plan between the external wall and the lightwells and/or the atrium does not exceed 15m, the average floor-to-ceiling heights are at least 3.5m, the window heights are increased, and there are controls which reduce the use of artificial lighting (e.g. daylight sensing variable output lighting, or localised reset switching).

The overall passive score

The overall passive score for the building takes the form PXX, where the two final digits XX are the sum of the second digits of the passive heating, passive ventilation and cooling, and passive lighting codes. Thus a building which is coded H1 V2 L3 will achieve an overall passive score of P06. The minimum score is P00 and the theoretical maximum score is P15. However whilst the heating codes have been retained, passive solar heating is not a dominant a factor in non domestic passive solar buildings so it is unlikely to that many buildings will score above 10 in the *PCS*. A building's overall passive score may be calculated automatically by the database software from the individual classifications, and inserted into a field in the appropriate database record.

Example

The following example illustrates the application of the system of coding and classification.

The codes and score for a five-storey university engineering building which is designed to reduce and remove internal heat gains by means of a combination of daylighting, thermal mass and natural ventilation and passive cooling, via a glazed atrium and chimneys in which stack-effect ventilation is induced, are H0 V5 L3 P08.

Validation

PCS codes were scored for a range of non domestic passive solar buildings which were designed as part of ETSU design studies (Baker, 1994; Halcrow Gilbert, 1994; Sluce, 1993) and plotted as in Figure A4.1.

For the majority of the offices there appears to be a consistent relationship between the total PCS score (PX) and the passive contribution per unit of floor area. The mean value is 3.3 x total PCS score (PX). This ratio is plotted in Figure A4.2.

This relationship between PCS total score and floor area was used to estimate the passive solar credits of non domestic buildings in the SURVEY4 database.

References

BAKER, N. V. (1994) *Energy and Environment in Non-Domestic Buildings: a Technical Design Guide* Cambridge Architectural Research Ltd, Cambridge.

HALCROW GILBERT ASSOCIATES (1994) *Non-domestic Building Design Studies (Direct Solar Gain): Final Report* ETSU S/N1/00080/REP, Halcrow Gilbert Associates Ltd, Swindon.

SLUCE, A. et al (1993) *Passive Solar Design Studies of Non-Domestic Buildings Phase II: Atrium Design Studies Final Report* ETSU S/N1/00081/REP/A, Building Design Partnership, London.

SLUCE, A. et al (1993) *Passive Solar Design Studies of Non-Domestic Buildings Phase II: Atrium Design Studies Design Reports* ETSU S/N1/00081/REP/B, Building Design Partnership, London.

YANNAS, S. (1994) *Solar Energy and Housing Design, Volume 1: Principles, Objectives, Guidelines* and *Volume 2: Examples* Architectural Association, London.

(Figures A4.1 & A4.2 not available electronically)