A THERMIE PROGRAMME ACTION

Tools and Techniques for the Design and Evaluation of Energy Efficient Buildings

RUE

The European Commission
Directorate-General for Energy (DGXVII)

THERMIE

This is an important European Community programme designed to promote the greater use of European energy technology. Its aim is to assist the European Union in achieving its fundamental objectives of:

- improving the energy supply prospects of the European Union;
- reducing environmental pollution by decreasing emissions, particularly those of CO_2, SO_2 and NO_3;
- strengthening the competitive position of European industry, above all small and medium-sized enterprises (SMEs);
- promoting the transfer of technology to Third Countries;
- strengthening economic and social cohesion within the European Union.

The majority of the funds of the THERMIE Programme are devoted to financial support of projects which aim to apply new and innovative energy technologies for the production, conversion and use of energy in the following areas:

- rational use of energy in buildings, industry energy industry and transport;
- renewable energy sources such as solar energy, energy from biomass and waste, as well as geothermal, hydroelectric and wind energy;
- solid fuels, in the areas of combustion, conversion (liquifaction and gasificaton), use of wastes and gasification integrated in a combined cycle;
- hydrocarbons, their exploration, production, transport and storage.

The THERMIE Programme (1990-1994) includes a provision for the enhanced dissemination of information to encourage a wider application and use of successful energy technologies. This information is brought together, for example, in publications such as this maxibrochure. Maxibrochures provide an invaluable source of information for those who wish to discover the state of the art of a particular technology or within a particular sector. The information they contain is drawn from all Member States and therefore provides a pan-European assessment.

To guarantee the maximum effectiveness of the funds available, the THERMIE Programme (1990-1994) includes an element for the co-ordination of promotional activities with those of similar programmes carried out in Member States and with other European Community instruments such as ALTENER, SAVE, SYNERGY, JOULE, PHARE and TACIS.

JOULE-THERMIE (1995-1998)

The first THERMIE Programme for the demonstration and promotion of new, clean and efficient technologies in the fields of rational use of energy, renewable energies, solid fuels and hydrocarbons, came to an end in December 1994. In January 1995, the programme was renewed as part of the new Non-Nuclear Energy Programme, better known as JOULE-THERMIE, within the European Community's Fourth Framework Programme for Research, Technological Development and Demonstration. As prescribed in the Treaty on European Union, this programme brings together for the first time the research and development aspects of JOULE (managed by the Directorate-General for Science, Research and Development, DG XII), with the demonstration and promotion activities of THERMIE (managed by the Directorate-General for Energy, DG XVII). A budget of 532 MECU has been allocated to the THERMIE component for the period 1995-1998.

This maxibrochure was produced in the framework of the former THERMIE Programme (1990-1994).

Further information on the material contained in this publication, or on other THERMIE activities, may be obtained from one of the organisations listed inside the back cover.

THERMIE Maxibrochures

A key element of the THERMIE programme is the enhanced dissemination of information relating to proven measures. This information is brought together for example in publications called Maxibrochures. These maxibrochures will provide an in valuable source of information for those wishing to appreciate the current state-of-the-art within particular technologies.

Maxibrochures will draw together relevant information on specific subjects. This information will describe the current state-of-the-art within all Member States and will therefore provide a pan-European assessment.

THERMIE Colour Coding

To enable readers to quickly identify those maxibrochures relating to specific parts of the THERMIE Programme each maxibrochure will be colour coded with a stripe in the lower right hand corner of each document, ie;

- RATIONAL USE OF ENERGY
- RENEWABLE ENERGY
- SOLID FUELS
- HYDROCARBONS

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CIEE Intelligent Facade: Image sequence with varying blinds positions at noon winter solstice. Copyright 1994 by Greg Ward, Saba Rofchaei

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INTERNET

This maxibrochure is available on the THERMIE World Wide Web site (http://erg.ucd.ie/opethermie) in Portable Document Format (pdf). Those interested can download the Acrobat Reader for their specific computer platform and then download the maxibrochure for viewing on screen. Copies of the maxibrochure can then be printed. All World Wide Web links referred to in this maxibrochure can be accessed through viewing the pdf document within the WWW browser Netscape.

Netscape can also be downloaded from the WWW site http://home.netscape.com/comprod/ mirror/index.html. Follow included instructions in each item of software for appropriate setup. These software are available to the user at no cost.

Tools and Techniques for the Design and Evaluation of Energy Efficient Buildings

THERMIE Action No. B184

UCD-OPET

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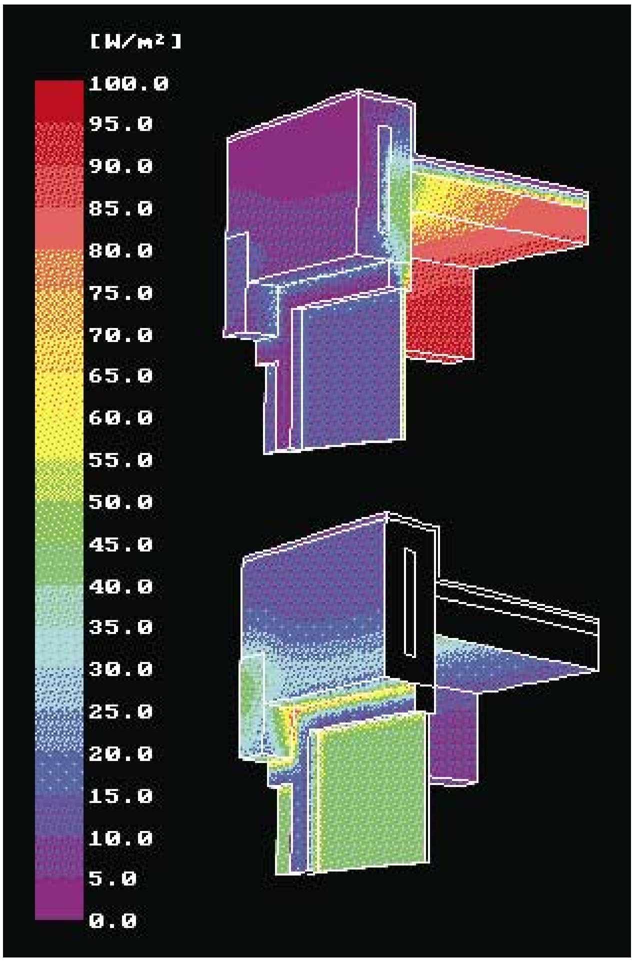
1. INTRODUCTION

Concerns about energy production's associated environmental effects and the high capital cost of new power plants continue to occupy the attention of scientists and policy makers. Twenty years of research efforts have produced a broad understanding of the implications of building energy use, as well as an increasing number of energy-efficient strategies and technologies with significant potential for energy savings.



3D display of thermal condition simulation in new construction element.

However, these strategies and technologies have not been transferred effectively to the building design community. The majority of buildings (whether new, or rehabilitation projects) are still designed without any energy-related considerations beyond those enforced by energy codes. One reason this knowledge gap exists is because building designers do not have the means to assess the impact of new strategies and technologies efficiently and reliably during the building design process.

A dependable energy performance assessment requires the use of complicated algorithms that take into account specific attributes of the building and its context. The algorithms and the lengthy calculations required to estimate year-round energy behaviour have necessitated the development of building energy design tools, both manual and computer based.

From conception to the final construction of a building, issues relating to energy play an important role. The decisions made by architects, engineers and other design team members can have a significant impact on the eventual energy consumption of a building and the quality of its internal environment. Both manual and computer based software tools can be used to assist in that decision-making process.

A wide range of design tools is now available to help architects and engineers in the design of more energy-efficient buildings. They range from quite simple paper-based assessment procedures to advanced computer-based applications. However, which one is best suited to a user's needs? There are many design tools to choose from. There is also the issue, in the case of computer-based design tools, of which operating system and hardware is required to run them. The process of selection can be an arduous task.

The objective of this maxibrochure is to provide guidance to building design professionals in selecting the most appropriate tool or tools for a defined task. The maxibrochure will also, but to a lesser extent, discuss other matters which must be addressed in parallel when choosing a new design tool. These include cost, training, design tool complexity, validation, etc.

Later in the maxibrochure a number of packages are discussed with respect to how they might meet the needs of a user. It is not possible to provide a comprehensive list of such tools. However, a number of resources are provided to help locate the tools required. Please note that the inclusion or omission of a design tool in this section in no way reflects on the quality or otherwise of those included.

2. WHAT IS A DESIGN TOOL?

As used here, the term includes a diversity of tools, from those used to inform the design process by indicating trends in energy use associated with strategic design decisions, to tools to predict the energetic performance of detailed architectural and engineering proposals.

In some cases, design tools have been developed to replace laborious calculation procedures used in the design process. In using the design tool, the 'number crunching' exercise is either carried out by the computer or has been simplified by following a number of pre-defined steps in the case of a manual design tool. They can save considerable time if used correctly, cutting a week’s work on paper to possibly an hour or less in the case of a computer based design tool.

Other tools have been developed to determine the behaviour of physical phenomena which would previously have been too complex to examine by hand. In some cases this extends to assessing interactions between design elements which were previously treated in isolation.

The use of design tools thus makes practical the study of matters not previously considered in many building design processes, either because it is now feasible due to lower time and cost requirements, or because the level of complexity has been reduced. This can help lead to energy related issues being given fuller consideration in the process of design.

Design tools are not always calculation methods. Many other forms of tools have been developed to assist the building designer in arriving at more energy-efficient solutions. Handbooks, tabulated data, etc. have been compiled to assist in energy efficient design. The computerisation of information sources allows designers to locate required information quickly. The introduction of CD-ROM technology over the past few years and the emergence of the Internet are examples of this. However, this maxibrochure focuses on manual and computer-based calculation procedures.

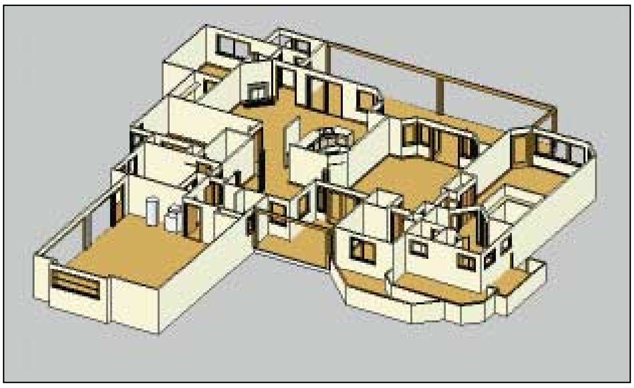
3. WHO SHOULD USE A DESIGN TOOL?

The answer is very much dependent on what is to be studied, analysed or simulated, and at what stage of the design process support is appropriate.

Design tools can greatly assist where specialist or expert knowledge of a topic is not available or where the required study of an issue would be prohibitively complex or time consuming.

Most design tools are based on either mathematical or empirical relationships. However, the user does not necessarily have to understand these formulae in order to use the tool. With an awareness of the limitation of the tool and the help of guidance documentation and/or training, he or she may carry out studies of a particular proposal and the energy consequences for a building or component design.

While architects have begun to use design tools, at present it is the engineer who will be most familiar with their use to assist in the design process. Until recently, the architect has been poorly served with design tools. Computer aided design (CAD) has been one of the very few tools widely taken up in architectural practice. CAD is not a design tool in the sense used here. However, such systems can simplify some of the design functions undertaken by the architect, as well as facilitating the preparation of documentation.

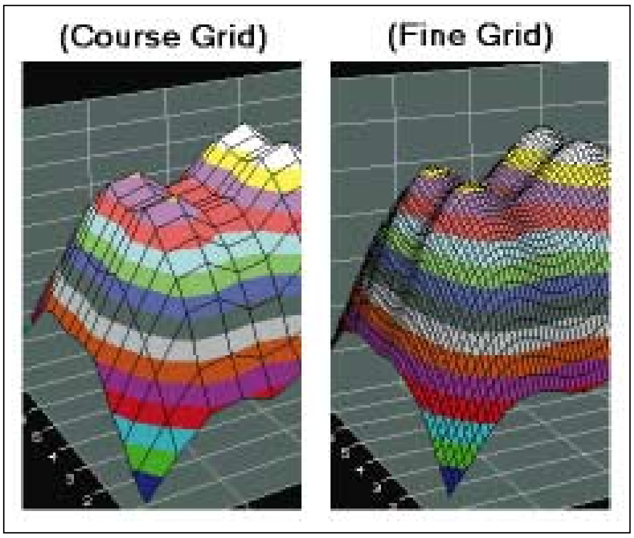


3D solid rendering of building CAD model.

Other applications now available for the architect include tools which indicate the energy related aspects of an emerging design where only an outline of information is available, three dimensional modelling tools which allow the architect to study lighting distribution in spaces, or to predict ventilation in buildings,and so on.

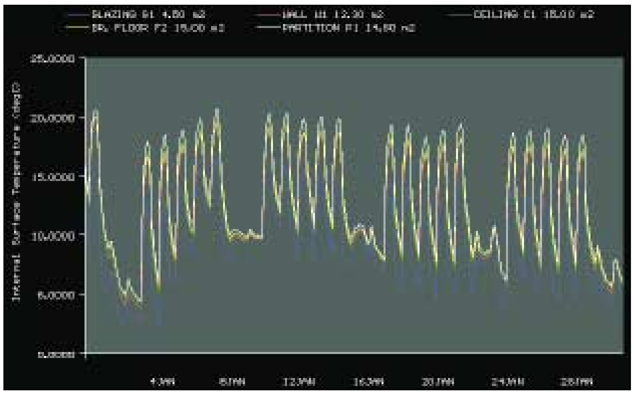
For the engineer, there is a wide selection of software to choose from, making it a task in itself to locate the appropriate design tool to meet specific needs. Since much of the work that an engineer carries out is based on mathematical or empirical models, perhaps the abundance of software available can be explained by the relative ease with which such models can be presented as design tools.

However, tools also have their limitations. They are often mistakenly used with the assumption that they can predict reality. This can be a most misleading assumption and is often the basis for serious misuse of design tools. While some tools can achieve quite accurate predictions, they are based, including assumptions, on approximations which can introuduce errors. Similarly, users will bring to a tool their own assumptions and simplifications of the design problem. For the potential user of a design tool, awareness of the assumptions and simplifications made within the tool's theoretical analysis method is important.



Daylight factor profile (coarse and fine) results.

With simple tools, it is likely that once the use of the tool is understood, re-use at a later date may only require a brief review of the user documentation. However, the more complex the tool the more likely it is that the user will need to remain fully familiar with all aspects of the application or re-training will be required. This is certainly true for the higher level computer-based simulation tools. This means that dedicated staff will be the users of these design tools and that, in practice, they will become part of a design team, or possibly several, with the specific task of carrying out these simulation studies. Often, the smaller practice can not afford to dedicate staff in this way and so consultants can be employed to provide these specialist services. This is discussed in more detail later.



Typical graphical output (internal surface temperatures).

4. DESIGN AND EVALUATION OF ENERGY EFFICIENT BUILDINGS

Many design-related issues can now be analysed through the use of design tools. As stated earlier, this permits prohibitively-complex issues to be addressed in everyday architectural and engineering practice.

The various issues which can be addressed are extensive; they may be broken down into the following groupings:

- building fabric
- thermal performance
- daylighting and electrical lighting
- comfort
- ventilation (mechanical and natural)
- infiltration
- services systems
- energy consumption
- control
- shading/overshadowing

All of these issue are inter-related, in that they can directly or indirectly affect one another and the overall energy performance of a building or services system.

However, less sophisticated tools will often focus on only one or a few of these issues. The more issues taken into account, the more complex the model. Accordingly, to provide design tools which are more suited to early stages of the design process the number of issues considered is kept to a minimum. It is also often the case that more assumptions are made to reduce the information needed as input. The use of more complex tools is then appropriate in later stages of design to ensure all energy related issues are addressed, in greater detail.

Where issues become more complex or critical it is likely that the use of higher level simulation tools will become necessary. These are also used where little or no previous experience exists in matters which may include the design of an innovative component or system. The use of such design tools can provide the confidence necessary to proceed with new ideas and thus move forward in improving building design and innovation.

However, the main aim in the use of tools, in energy efficient design in general, is in achieving the optimum balance between all factors to minimise energy consumption. Unfortunately, no design tool can do this automatically. It is an iterative process involving the expertise of the design team itself, together with appropriate design tools.

There are many software packages available which analyse a specific aspect of one or more building components. For example, PHYSIBEL is a software package developed in Belgium which allows the heat transfer phenomena of construction elements to be analysed in great detail. While this can make a valuable contribution to the overall building design, by itself it is of a specialist nature suited to detailed investigation or research studies.

In supporting the improvement of energy efficiency in buildings, several factors are generally taken into account by all design tools. These are considered in the following sections.

4.1 Location

The location of the project is important as energy performance can be directly affected by such factors as altitude, latitude and longitude, ground topography and surrounding structures, local micro-climate, etc. These factors are not taken into account by some simpler tools, but by almost all intermediate and high level tools. Requirements vary from one tool to another.

Micro-climatic data are an important element in any information input. However, different tools use different data formats. This usually results in considerable time spent inputting the required information. Some efforts have been made to develop standard weather data sets (such as Test Reference Years), but these are not widely used in practice. Temperature of the external environment is a basic requirement of most tools analysing energy-related matters, but can be required as hourly, daily or monthly values. Other climatic data may include wind speed and direction, solar radiation, and humidity.

4.2 Building Geometry

The geometry of the building will play an important part in any analysis of its energy performance. Many simpler tools only accept vertical wall and window elements, horizontal floors and flat, sloping or pitched roofs. However, as the sophistication of the tool increases, the complexity detail of the geometric model accepted by the tool generally increases also. The input of such a model can often be the most time consuming aspect of the data input process. Orientation is important, particularly in respect of the effects of solar irradiation and wind.

Of importance in more detailed studies is zone control. Many simpler tools will only consider single zones, and thus the building model must assume that the whole building is represented as a single room. This is often sufficient for simple and intermediate analyses of domestic buildings, but will be limiting in larger buildings.

Perhaps the most important element of building geometrical data input relating to energy analysis is the building material description. More developed tools will provide built in databases of the properties of typical materials as individual components, or as typical constructional elements such as walls, windows, etc.

4.3 Standard Calculations

For the study of energy use/energy consumption, lighting, daylighting, ventilation and infiltration, running costs, etc. there are many different theoretical calculation methods. It is essential to use a method which is acceptable to national or European standards. The differences between comparative methods are often small. However, some regulatory bodies do require that certain standards be used, particularly when assessing compliance with Building Standards and Regulations.

4.4 Services Systems

The services systems to be included in the building (including space heating, ventilation, air-conditioning, lighting, controls) become important energy issues in the later stages of design. Many intermediate and high level tools offer a wide range of different systems describing services within a building. However, for more detailed study of services systems, design tools developed specifically for such analyses are probably more appropriate.

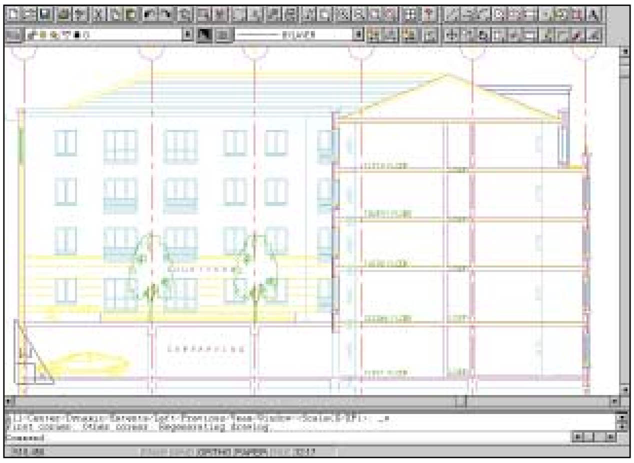
There is an expectation inherent in all design tools that a basic level of information about the building design already exists, albeit perhaps only an outline design. The simpler the design tool the lower the level of information expected. Information on the building geometry, its orientation and the local climate are the starting information requirements for most simplified design tools.

The manner in which design tools are used to improve the energy performance of a building is also important and, unfortunately, can often be unique to a specific design tool. Therefore, it is important that the most appropriate design tool be chosen. It is also important to note that most tools only provide the answers to specific questions. For example, if an architect wants to know how a particular wall construction will perform when compared to another, they must know what materials are to be used, their dimensions and thermo-physical characteristics as a minimum for each wall construction to be considered. Then each wall construction must be input to the design tool and the results calculated. Only then can the two results be compared and the better one selected. If the design tool has a database of materials or constructions matching those to be compared, the input required is substantially reduced. However, this illustrates the extent of information required to carry out a comparatively simple but important exercise.

The data output from tools also varies considerably. As with data input, simpler tools will often only provide an outline of results, which can act as pointers to the designer. As the sophistication of the tool increases the choice of data output increases.

Generally, when considering energy analysis design tools, output in the form of energy requirements or expressed as heat loss or heat gain per unit area are most common. More sophisticated tools may allow the user to customise the format of data output and will provide a range (such as temperatures, comfort indices and light levels) to select from.

More information on data input, calculation procedures and results output is given in Section 11.



Typical CAD user interface (2D).

5. COMPUTER AIDED DESIGN

CAD is now standard in many European building professionals' offices and as previously noted, while not a design tool as discussed in this maxibrochure can greatly assist in the documentation of building geometry. These packages have advanced greatly over the past 10 years and continue to provide enhanced facilities in support of the designer.

In the development of building design tools, efforts are being made to integrate these and CAD systems to produce what would appear to the user as one single design system with built-in CAD facilities -but in reality is a network of tools connected so as to exchange data in a common format. Some of these tools already exist but at present only very simple CAD systems are used. An example of this is the

SCRIBE modeller which has been used by numerous design tools to provide a graphically based geometry input. Other software tools commercially available are succeeding in providing this facility using leading CAD software but at a level where many of the facilities have had to be limited. Typically, a geometrical model will be produced in the CAD package and imported into the energy analysis software when complete in a specified file format (normally dxf for PCs). Often, the user is required to further attribute the geometry to complete the model. Changes to the geometric model have to be made within the CAD software and a new model imported.

Such integration of tools, as well as reducing the time required to design, may also have the effect of bringing design team members and their respective functions closer together. These working relationships may benefit the energy performance of a new building as a result of more closely integrated architectural and engineering design.

CAD systems also provide facilities for the visualisation of three dimensional building models through rendering software and can also be linked to databases and other software through built-in functionality, making them much more than the original simple drawing tools.

6. SOFTWARE OPERATING SYSTEMS AND HARDWARE

Today there are numerous hardware platforms and operating systems available to design professionals. Each has its merits and its pitfalls. While it would not be appropriate to include a full discussion on these matters in this maxibrochure, general comments will be made as guidance with respect to available design tools.

Three operating systems currently share the majority of the world market. These are the Apple Macintosh, Microsoft DOS/Windows and the UNIX operating systems. Generally speaking, each of these operates on one of three hardware platforms; the Apple Macintosh, the IBM compatible PC and the UNIX.

6.1 Macintosh

A significant number of architects today use the Macintosh system. Its main strengths lie in its graphical and generally intuitive user interface. As many of the functions carried out by the user are icon based relatively shorter learning times are required for the inexperienced user. To date, however, few design tools have been made available for the Macintosh operating system. Its use has mainly been in the desktop publishing and graphics fields. This has meant that architects, who generally have moved to Macintosh computers because of the strength of the graphical software available, still have few energy related design tools available. Leading CAD systems are available for the Mac.

Hardware prices are highly competitive with respect to computer power delivered. Minimum specification requirements for the purchase of a new Power Macintosh would include at least 500 Mb of hard disk space and 16 Mb of RAM (Random Access Memory). These requirements, however, increase almost two fold every year, and in particular RAM requirements.

6.2 DOS/Windows

DOS/Windows is the most widely used operating system in personal computers. There is a wide range of software developed for the PC running on both the MS-DOS and the Windows operating systems for the analysis of many energy, ventilation and lighting related aspects of building design. Windows 95 and the Windows NT operating systems will become established in the future and will see the eventual phasing out of the MS-DOS system.

The cost of hardware with respect to power delivered is good. Minimum specification requirements for the purchase of a new Pentium PC (Intel processor) range would include at least 500 Mb of hard disk space and 16 Mb of RAM.

6.3 UNIX

Whereas both the Macintosh and DOS/Windows systems are being developed and sold by individual software developers, the UNIX operating system is available from many companies, each with slight differences but based on the same core system. The hardware used provides considerable power in relatively small computers form moderate to relatively high costs. The use of UNIX as an operating system is more complex, less intuitive and open to incompatibility when trying to run tools on different UNIX operating systems. Graphical user interfaces are available for UNIX computers making them more accessible to less experienced users. A number of useful tools are available for the UNIX system; in the past these tended mainly to be simulation-type tools designed more for the researcher than the building designer, and taking advantage of the high power multitasking environment.

Hardware costs tend to be high for what are very powerful computers. While UNIX computers can be used as stand-alone workstations, they are normally used by numerous users working on terminals connected via a network. Therefore, UNIX power requirements are high.

7. ACCURACY AND VALIDATION

It is often mistakenly assumed that the results obtained from a design tool, whether manual or computer based, will be exact. This is not always the case.

Firstly, the mathematical or empirical model upon which a tool is based incorporates many assumptions and approximations, and to some degree a simplified representation of the building. These are unavoidable , though they may be reduced. Recent research in Europe and other countries has shown that even the most detailed calculation procedures demonstrated varying degrees of error when compared to a physical test environment. This was the case in all simulation models considered.

Secondly, if we take as an example the analysis of building fabric it is rare that actual results will exactly match design calculations. Field measurements have shown that U-values in the built case can be up to three times higher than that designed due to poor construction practise. There is nothing a design tool can do to predict this as it is dependent on construction practice.

Thirdly, users may misuse a tool as a result of inadequate understanding of characteristics, algorithms or practical limitations.

Despite these sources of error, many tools can provide sufficient accuracy to satisfy the needs of the designer. Keeping these factors in mind, the users of design tools should acknowledge that they are looking at a theoretical model where assumptions have been made. By doing so the output of the design tool will be more meaningful and useful.

Validation has also become an important issue in the development of design tools, in particular the higher level computer simulation tools. Validation projects completed in recent years, notably the International Energy Agency (Task 12B/Annex 21C), SERC/BRE and the EU PASSYS projects, have all shown that, at the time of the studies, all models tested showed errors of varying types. For example the energy consumption predictions of the programs varied by 40% (of their mean value) in an opaque room.

As a result of such projects, it is now accepted by most software developers that validation of models must be an integral part of the development of software design tools. For the user of such tools, confidence in the accuracy of the output results is important.

Schemes under which software design tools can be ‘quality certified’ are emerging. However, there is still much debate as to the techniques used for such testing. When choosing a model, particularly one which involves considerable time and financial commitment on the part of a new user and on the basis of which critical decisions may be taken, enquiries should be made as to the results of any testing and validation studies undertaken on the part of the developer. This would apply to all levels of computer based design tools and not only the more advanced simulation packages.

8. TRAINING AND COST

Before selecting a design tool, consideration should be given to the following three issues:

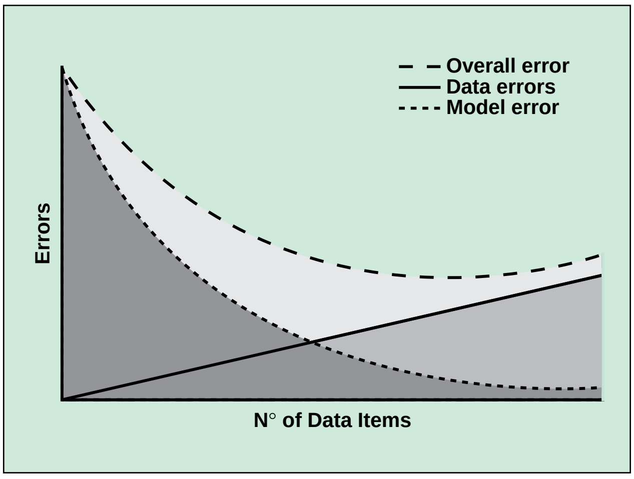
- Will the software run on the user’s existing operating system and hardware platform?
- Is the software of a level of complexity that specialist training is required?

- Will the frequency of use of this software justify dedicating at least one member of staff (part, or perhaps even full time) to the use of this software?

The result of a uninformed decision will be an avoidable cost to the practice. Generally, it is not worth choosing the route of purchasing a complex design tool if the software is only to be used on an infrequent basis and if a consultant is available to supply the service and the computer facilities as required at reasonable cost.

In most cases, simple to intermediate level tools will be capable of providing the analysis procedures required. Again, these range in cost from tools distributed freely to very expensive tools. A review of the market, although time consuming, can be rewarding in the end.

It should also be noted that the level of complexity of a design tool is not proportional to cost. There are many detailed simulation tools available at little or no cost to a user. Many of these are the results of research and are made available in cases where no profit will be made from their use. Training is sometimes available, perhaps with documentation. However, investment in the user interface of the software may not have been adequate and so can be complex to use. Accompanying documentation is usually less developed than in the case of a commercial package, and it may assume that the user already has some experience of similar design tools. Also, the need for a different hardware platform and operating system may still be factors to be addressed.



9. SIMPLE VERSUS SOPHISTICATED

Irrespective of cost, expertise/training and other resource-related issues, complex tools are not always better than simple tools. As the figure above demonstrates, the degree of error introduced is directly related to the number of data items required. Generally, the more complex the tool the more information that is required.

10. SOFTWARE OF THE FUTURE

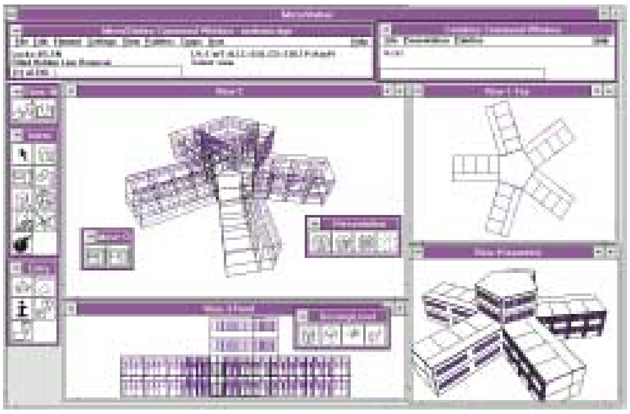
There are many possible directions in which design tool development may advance in the future. However, one factor which must be addressed in all developments is the need to meet the user’s requirements. This has too often been overlooked in the past, with researchers designing tools for researchers’ needs.

With so many building designers now computer-literate, the continued development of manual tools is less likely. Instead, design tool developers will focus on the computer. Increased processor power and reduced computer costs will make these tools more accessible to the ordinary building designer.

However, the issues of complexity remain. With the improvement of graphic user interfaces (GUI), software design tools will become easier to use. In the past, the complexity of some tools has prevented users not accustomed to computer based design tools from exploring the benefits achievable. Improvements in GUI software development will help to overcome this resistance to design tool use, particularly in the case of architects.

Current research and development efforts are also being aimed at closer integration of design tools. It can be seen from the discussions in this maxibrochure that it is often the case that several tools may need to be used in arriving at an overall energy efficient building design. However, if all tools could exchange information in a universal way, without the need to re-input data every time a user needed to use a new tool, and if results could be exchanged so that the consequence of one study could be input to the next it is likely that a more balanced and optimised design could emerge with less effort and reduced time commitment.

The technical barriers to the implementation of such systems are considerable, but are being overcome at an increasing rate thanks to the rapid rate of progress of computer technology, both hardware and software. Achievements to date indicate that such systems could be available soon. Significant advance has already been made, for example in the JOULE programme COMBINE project (EC Directorate General XII for Science, Research and Development). As noted earlier, some commercially available systems now allow, in a limited way, the import of building geometric models from standard CAD tools to design tools.



Module of developed COMBINE user interface.

11. IDENTIFYING FUNCTIONAL REQUIREMENTS

In trying to identify the most appropriate design tool to meet a user's requirements it is useful to first ask what functionality is required from the design tool. Functionality issues include the way in which data is input, the method of calculation, what energy related functions are important and in what output format results are required. By first addressing these issues the search for an appropriate design tool will be made simpler.

When addressing functionality issues it is important to remember that it is not always a case of 'the more functions the better.'

The following table illustrates many options available to the potential users of design tool software. Generally, manual tools are less flexible in that they have a prescribed input and output already defined. This in no way reduces their usefulness, but should be noted when selecting a design tool.

The list of functions given in the tables can serve as a check list to help identify the functional requirements of a design tool.

The Case Studies section describes six design tools. These should enable the reader to identify the most appropriate deisgn tool by providing examples of what is achievable using each tool. Other tools, apart from those described in the case studies, exist. The inclusion or otherwise of a specific design tool should not be taken as a measure of the quality or worth of that tool.

The list on the next page addresses the following questions:

- What are design tools capable of handling in a defined problem?
- For who and what are they intended?
- What results do they provide?
- What input data is required?
- What is the calculation procedure?

As stated earlier, there are many software tools currently available on a commercial, shareware or freeware basis with varying degrees of user support. It is not possible or appropriate to discuss them all here. Sources of information on available design tools can be found in Section 13 of this maxibrochure.

Summary of application and capability

Passive Systems
- ❒ Direct gain
- ❒ Trombe wall
- ❒ Attached sun space
- ❒ Hybrid
- ❒ Cooling
- ❒ Natural ventilation

Zonal Requirements
- ❒ Single zone
- ❒ Multi-zone

Heating
- ❒ Loads
- ❒ Space temperatures
- ❒ Active solar
- ❒ Shading
- ❒ Economics
- ❒ Effect of mass
- ❒ HVAC systems
- ❒ Domestic Hot Water

Cooling
- ❒ Loads
- ❒ Space temperatures
- ❒ Shading
- ❒ Economics
- ❒ Mass
- ❒ Passive cooling

Lighting
- ❒ Daylighting
- ❒ Artifical lighting
- ❒ Glare

Ventilation
- ❒ Ventilation
- ❒ Infiltration
- ❒ Air quality

Summary of intended use and availability

Intended User
- ❒ Architect
- ❒ Engineer
- ❒ Technician
- ❒ Researcher

Uses
- ❒ Pre-design
- ❒ Site analysis
- ❒ Schematics
- ❒ Design development
- ❒ Performance evaluation
- ❒ Research

User Support
- ❒ User documentation
- ❒ Training
- ❒ Telephone/fax/e-mail support
- ❒ Source code
- ❒ Customisation

Summary of results and output

Load Determination
- ❒ Component
- ❒ Zone
- ❒ Building

Loads Output By
- ❒ Sub hour
- ❒ Hour
- ❒ Day
- ❒ Month
- ❒ Season
- ❒ Year

Temperatures
- ❒ Air
- ❒ Surface

Output Format
- ❒ Tabular
- ❒ Graphic
- ❒ Export to other analysis tools

Fuel Use By
- ❒ Consumption (month, year)
- ❒ Peak Demand (month, year)
- ❒ System components
- ❒ Energy system
- ❒ Total Building

Summary of input data

File Type
- ❒ Interactive
- ❒ Built-in graphics
- ❒ Pre-prepared files

Pre-design and Site Analysis Data
- ❒ Location
- ❒ Building type
- ❒ Occupancy
- ❒ Building Area
- ❒ Space temperature
- ❒ Local energy costs
- ❒ Generic building shape
- ❒ Local code requirements
- ❒ Lighting requirements

Schematic Design Data
- ❒ Building surface areas
- ❒ Glazing areas & orientation
- ❒ Zoning
- ❒ Room shapes
- ❒ Operating schedules & profiles

Geometric Design Data
- ❒ Building materials-opaque
- ❒ Building mass
- ❒ Transparent materials
- ❒ Interior finishes

Engineering Design Data
- ❒ Mechanical system
- ❒ Electrical system
- ❒ Lighting system
- ❒ Controls

Weather Data
- ❒ Solar radiation
- ❒ Wind speed
- ❒ Air temperatures
- ❒ Humidity

Summary of calculation procedures

Solution Techniques
- ❒ First principles
- ❒ Response factor
- ❒ Steady state

Solar Orientation
- ❒ Any, including sloped
- ❒ Diffuse, direct, reflected.
- ❒ Total

Shading
- ❒ Any solar obstruction
- ❒ Overhang only
- ❒ Daily switching
- ❒ Seasonal switching

Room Temperatures
- ❒ Surface and/or air
- ❒ Input schedules by user
- ❒ Fixed by tool
- ❒ Varied by tool

U-Values
- ❒ Varation with wind speed
- ❒ Day and night
- ❒ Constant

Infiltration
- ❒ Air change rate per hour
- ❒ Crack method
- ❒ Varied with wind speed

Internal Loads
- ❒ Sensible and latent seperate
- ❒ Sensible and latent total
- ❒ Sensible only

Ventilation
- ❒ Sensible
- ❒ Latent
- ❒ Varies by schedule
- ❒ Calculated as a network

12. CASE STUDIES

The following case studies focus on six design tools, from paper-based methods to detailed simulation tools. Their possible contributions to a typical design procedure are indicated.

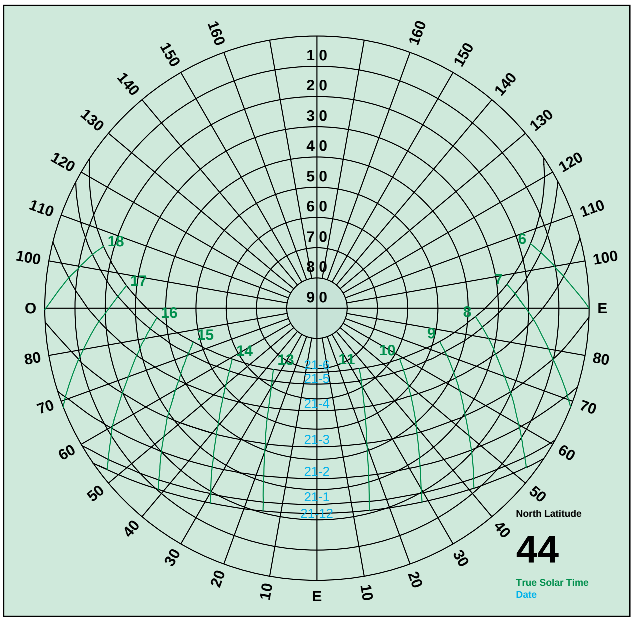
12.1 Sun Charts

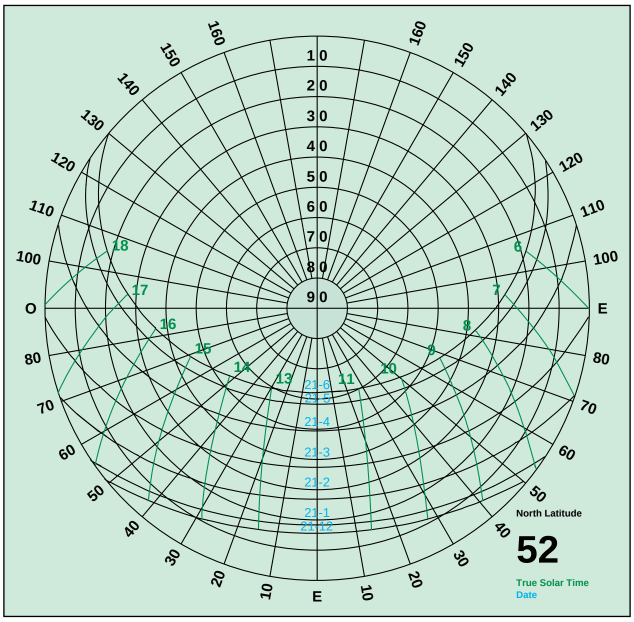
To assess the solar availability on a site, shading from adjacent buildings and vegetation must be determined. For representing the sun's position in the sky, two projections are commonly used: the stereographic projection and the gnomic projection. Here the stereographic projection is discussed.

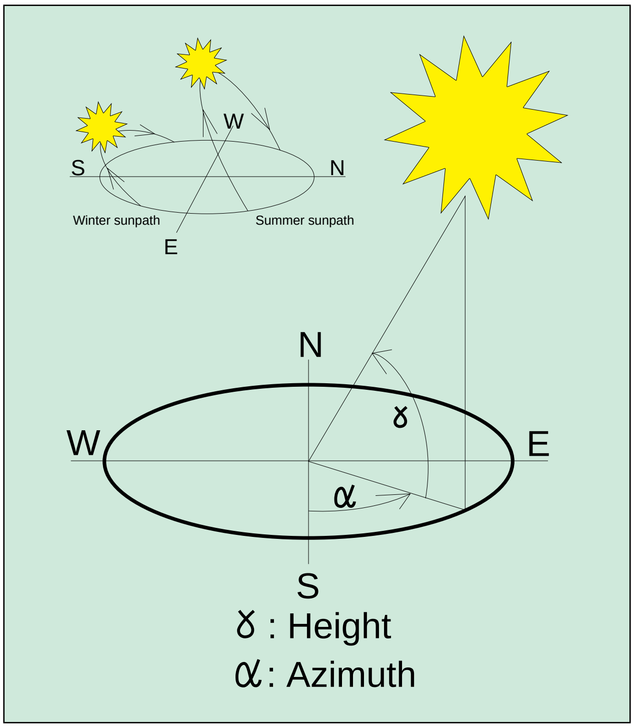
The stereographic chart projects a view of the sky onto a horizontal plane. Radiating lines indicate azimuth and the concentric circles show angular altitude. It can be likened to a photograph where a 180º fish eye lens has been used to take a picture of the sky looking straight up.

For each latitude there is a specific stereographic diagram. Here, 44, 52 and 56 degrees North are provided. These diagrams may be used to indicate which sections of the sky are free of obstructions and, consequently, the relative importance of the periods when solar light will be blocked. The horizon is represented by the outermost circle, at the periphery. The altitude of the sun above the horizon is read on the various concentric circles, from 0º to 90º. The angle of the azimuth (that angle between the vertical plane containing the sun and the south), is written on the periphery. 0º is south, east and west are 90º on either side.

The various trajectories of the sun's movement in the sky are plotted, for the 21st of each month, from December 21 until June 21. The other months are obtained using the following rule of equivalence: July-May; August-April; September -March; Octobe-February; November-January. The other lines, perpendicular to the sun trajectories, provide a way to estimate the position of the sun for a given hour. The hour which is written is the standard time, which is an approximation of the solar time.







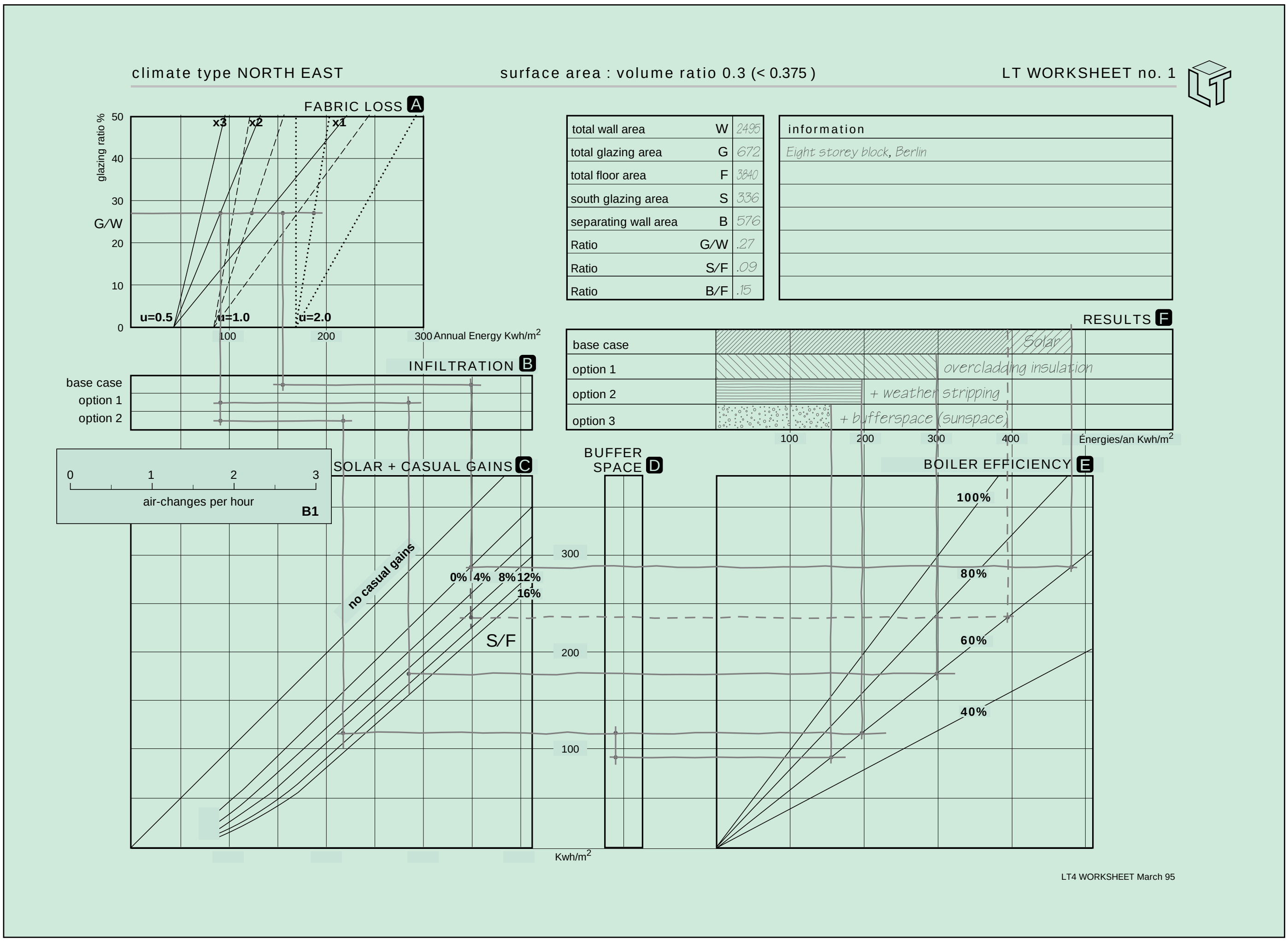
12.2 The LT Method (manual and computer based)

The LT Method uses energy performance curves drawn from a mathematical model, where most parameters have been given assumed values. Only a few key design variables, mainly relating to building form and facade design, are left for the user to manipulate:- glazing ratio, surface to volume ratio, etc.

LT is not to be regarded as a precision model producing an accurate estimate of the performance of an actual building. Rather, the way that LT is intended to be used is to evaluate the energy performance of a number of strategic options and to make comparisons. Furthermore, the energy breakdowns of heating, cooling and lighting, which are evident from carrying out the LT Method analysis will give a picture of the relative importance of various energy components.

The LT Method is available both as a manual method and as a computer-based tool. The manual method requires only the use of pencil and calculator, entering values taken from the drawings and the LT curves, on to the LT Worksheet. The computer method is provided as an Excel spreadsheet (Excel is a Microsoft product available for both PC and the Macintosh). As many offices today also use spreadsheet packages this form of the LT Method will also be useful to many practices without the need for financial investment.

Example of completed LT Method Worksheet.



12.3 New Method 5000

New Method 5000 is a manual and computer based design tool developed to determine quickly and approximately the performance of passive solar buildings. It provides a procedure based on a set of data forms which are filled out in sequence with appropriate calculations.

New Method 5000 is used to predict the auxiliary heating required for any specified month. This is done by subtracting the useful heat gains and heat losses (both in kWh) for a given month.

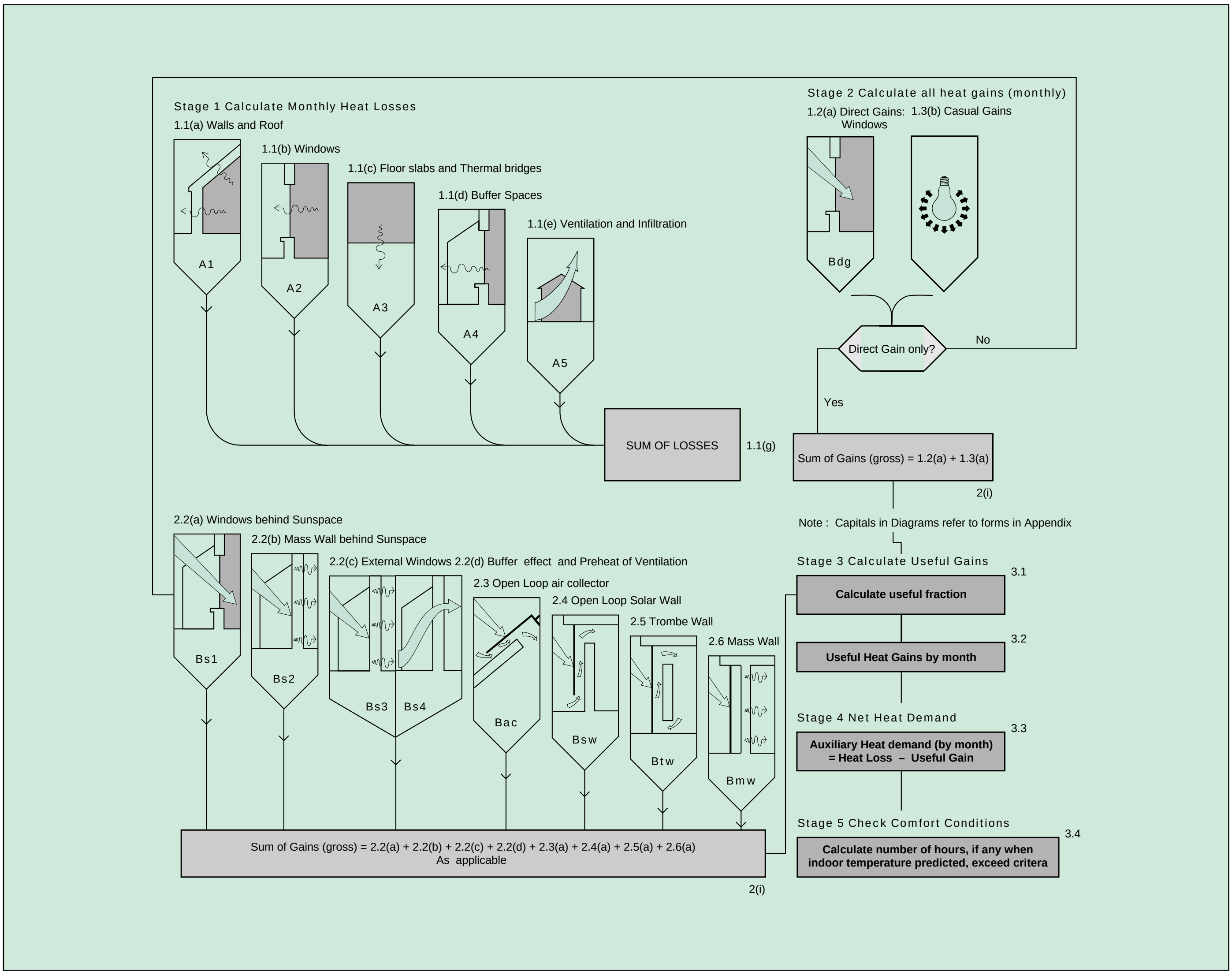
It is convenient to divide passive solar buildings into two subsets:

- those heated by direct gain only (most common)
- and those not relying on direct gain only (numerous types)

For each subset, certain questions may have to be answered: for example, whether the insulation properties of the building are the same by night as by day; whether the thermostat setting is the same by night and by day; whether heating is intermittent, and whether the heated space is comprised of one or more zones (defined by different thermostat settings). Particular to the second category will be the question of which solar-gain devices, singly or in combination, are used, from the wide range of possibilities. It will be rare in practice for a building to use all the possible solar devices. Cost effectiveness will often be the determinant.

The manual version of New Method 5000 is divided into five stages (illustrated below). The computer version, while containing the same procedure appears less fragmented.

By completing the tables a user can determine how much heat is required to meet comfort conditions. Similar results are output from the computer based version (running on a PC under the DOS operating system).



12.4 PASSPORT

PASSPORT is a correlation-based evaluation tool enabling an assessment of the residential building heat requirement.

The PASSPORT tool has a close link to a preliminary European Standard for calculating energy requirements for heating in residential buildings. The development team and a working group of the European Standardisation Committee (CEN TC 89 WG4), having similar concerns, worked in close collaboration in the development of the theoretical basis for the design tool.

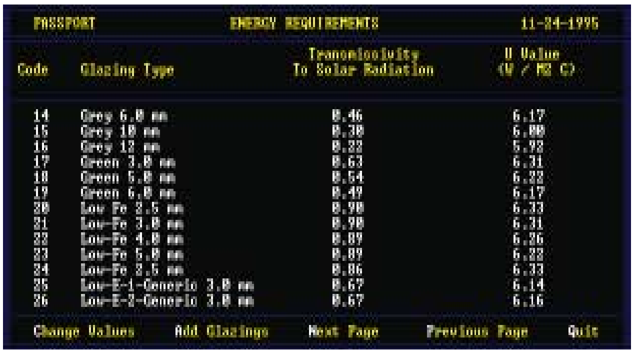
A choice is offered to the user of PASSPORT: either to follow closely the Standard or to call upon some features, intended to improve the accuracy of the results (especially in the case of passive buildings) but not retained by CEN for simplification reasons.

The method is based on a steady state energy balance for the building zone, with an allowance for external temperature variations and a utilisation factor taking account of the dynamic effect of internal and solar gains. Some of the main features of the design tool include:

Free gain utilisation
The gain utilisation factor is given as a function of the gain to load ratio GLR and an inertia parameter t (time constant of the building or of the zone).

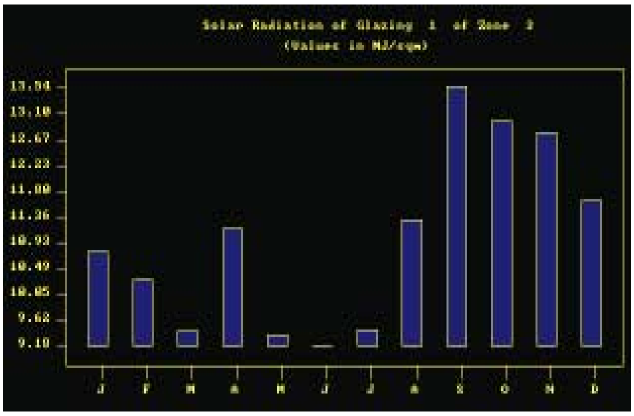
Intermittent heating
The method treats separately two phenomena associated with intermittent heating: decreased losses due to the lower inside temperature and a decrease of the utilised gains due to the fact that these gains may occur when the building is not heated. Two intermittency factors are obtained from formulae taking account of the heating pattern and the time constant of the building.

Multizone
To deal with multizone passive solar buildings, uniform temperature zones are defined; then the calculation method is applied to each zone. To take account of the interaction between the zones an interactive procedure is used to solve the heat balance for all zones.



Glazing material database of PASSPORT.

Zonal data input window.



Typical graphical output (plot) of results.

12.5 ADELINE

The ADELINE software tool provides architects and engineers with detailed information about the behaviour and the performance of indoor lighting systems. Both natural and electrical lighting problems can be solved for rooms of simple and complex geometry.

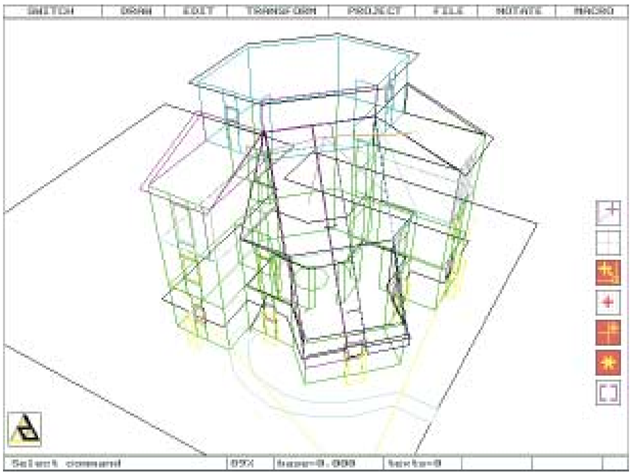
ADELINE predicts lighting performance by processing a variety of data (including geometric, photometric, climatic, optic and human response) to perform light simulations and to produce extensive numeric and graphic information.

The principal aim of developing the design tool was to address the effects of daylighting on the energy performance of a future building from a very early stage of the design process, thereby enabling architects, builders and specialist planners to construct energy-efficient buildings.

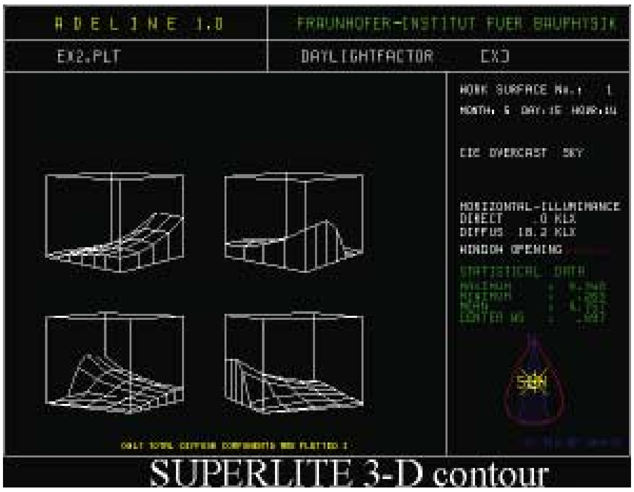
The included features of the design tool allow a detailed study of the daylighting and/or electrical lighting of a room or building design to be carried out by an architect or engineer. Analysis options include the ability to:

- determine lighting conditions in buildings with artificial lighting
- determine daylighting and temperature conditions
- evaluate visual and thermal comfort
- determine the impact of daylighting on lighting in general
- determine the effects of different strategies on heating and air conditioning
- evaluate economic and lighting aspects of many diverse daylighting and energy systems.

The ADELINE design tool is an assembly of a number of tools which includes SCRIBE-MODELLER as a CAD interface, the (day-) lighting tools SUPERLITE and RADIANCE and a link to energy simulation tools (tsbi3, SUNCODE, DOE 2 and TRNSYS) using SUPERLINK. The software can also import standard CAD dxf format files.



Geometric model input using SCRIBE.



Typical output window of SUPERLITE.

RADIANCE rendering of a space with good daylighting characteristics.

12.6 ESP-r

ESP-r is a dynamic thermal simulation environment which may be used to explore a range of issues including building fabric, mass flow, ideal and detailed plant systems -separately or in combination at timesteps ranging from seconds to an hour. It is composed of a number of programs, each contributing certain facilities to the simulation process but the primary interface is provided by way of a project management facility. It attempts to simulate the real world as rigorously as possible at a level which is consistent with current best practice in the international computer simulation community. It combines building, plant, electrical power, with network and/or CFD based air flow simulation.

While such a tool can be used for simple design problems its analysis and descriptive facilities are designed for complex design decision suport. For such simulations, users typically require considerable assistance in the specification of the design hypothesis and its modification in the light of performance indications. These functions are provided within ESP-r by a Project Manager which supports the specification of design problems in terms of:

1. Building geometry including opaque and transparent constructional materials, surface finishes, occupancy, lighting schemes, and small power loads, with superimposed events to represent phenomena such as window opening, shading device positioning and electric light switching.

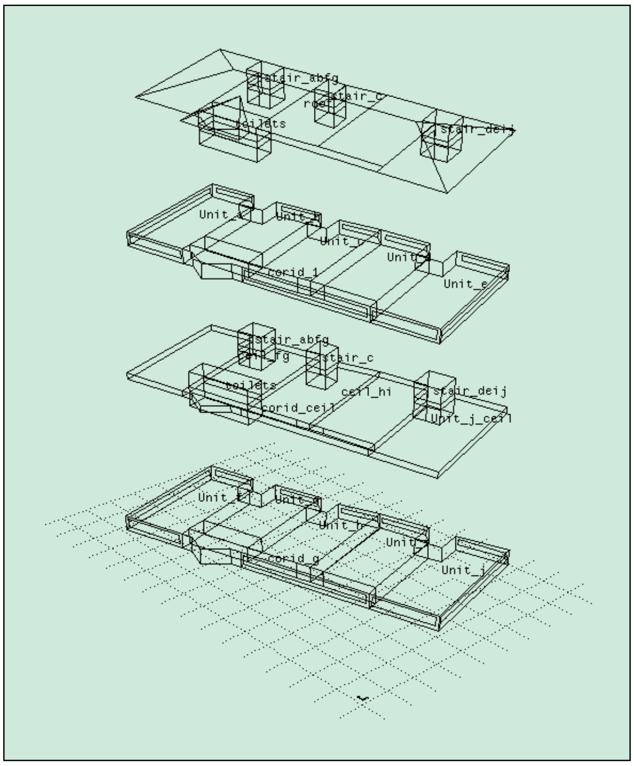
2. A network description of air flow paths (cracks, ducts) and components (fans, dampers) or a 3D grid for CFD based airflow modelling.

3. Environmental systems defined either as "ideal" systems or as networks of dynamic components which may include energy, gas and vapour exchanges or the generation of electricity as in PV cells.

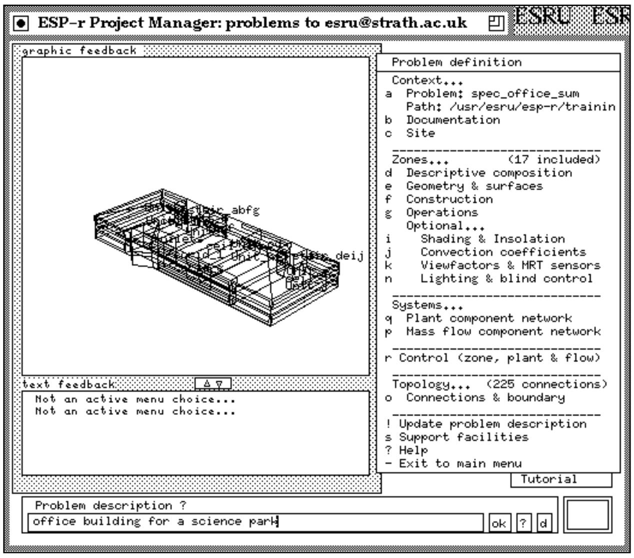
4. Control system specifications for zones, air flow and iplant systems in terms of sensor- action-actuator relationships, each one valid over a given time interval.

When specifying a problem, users are offered access to on-line databases of constructional materials, plant components, profile prototypes, optical properties and climatic sequences. Where possible, inputs are achieved through graphical interaction or by importing data from CAD tools.

Simulation tasks such as the calculation of shading patterns are invoked from the Project Manager as are thermal and visual simulations, results analysis and report generators.



Exploded view of geometric model in ESP-r.



Program manager module of ESP-r from which all other modules are accessed.

13 ENERGY SOFTWARE FURTHER INFORMATION

The following sources of information will provide pointers to the further investigation of design tool selection.

Resource Guide
A European guide to materials potentially useful to building designers has been compiled over several years and is updated bi-annually. It contains numerous references to design tools as well as other energy-related material. It is available on disk (currently for Macintosh only). Further information can be obtained from:

Energy Research Group,
University College Dublin
Richview, Clonskeagh
Dublin 14, Ireland
Fax: +353.1-283 8908
e-mail: jolivetp@richview.ucd.ie
WWW: http://erg.ucd.ie

Info Energie
Liste der Software/Liste des Logiciels
Info Energie is a comprehensive listing (in German and French) of internationally developed software with contact details for each design tool included, in booklet form. It is produced by and available from

Bundesamt für Energiewirtschaft,
CH-3003 Bern, Switzerland
Fax: +41.31-352 7756

Guidance on Selecting Energy Programs
This publication is produced by the Construction Industry and Computing Association and provides detailed information to assist in the selection of energy related software available in the United Kingdom. Further information can be obtained from:

CICA
Guildhall Place,
Cambridge CB2 3QQ
United Kingdom
Fax: +44.1223-62865

BSRIA - Software for Building Services - a selection guide
Provides valuable information on a very wide range of software many of which are concerned with energy. Further information can be obtained from:

The Building Services Research and Information Association
Old Bracknell Lane West
Bracknell, Berkshire RG12 7AH
United Kingdom
Fax: +44.1344-487575

Other Sources
Other sources of information may include national architectural and building services institutes and organisations. It is also recommended that a potential user seek the experienced advice of a professional colleague currently using a similar design tool to the one sought.

International Building Performance Simulation Association
IBPSA's objective is the advancement and promotion of the science of building performance simulation in order to improve the design, construction, operation and maintenance of new and existing buildings worldwide. Further information can be obtained from:

IBPSA
Department of Architecture
Texas A & M University
College Station, TX 77843
United States
Fax 409 845 4491
e-mail larry@archone.tamu.edu
http://www.mae.okstate.edu/ibpsa/IBPSA.html

Building Environmental Performance Analysis Club
The aim of BEPAC is to improve the quality of building performance by encouraging the use and development of environmental analysis and prediction methods in building design and assessment. Further information can be obtained from:

BEPAC Administration
16 Nursery Gardens
Purley on Thames
Reading RG8 8AS
United Kingdom
Fax: +44.1734-842861
e-mail: 100572.3163@compuserve.com
WWW: http://www.iesd.dmu.ac.uk/bepac/

World Wide Web and Internet Information Sources

RADIANCE WWW server
http://radsite.lbl.gov/radiance/

ADELINE
http://www.ibp.fhg.de/wt/adeline/adeline.htm

PASSPORT - Software
http://erg.ucd.ie/passport/passport.html

ESP-r - Energy Systems Research Unit
http://www.strath.ac.uk/Departments/ESRU/esru.html

Catalog - Software
http://solstice.crest.org/efficiency/iris/catalog/software.html

BATMAN, a computer aided learning module for architecture students
http://lesowww.epfl.ch/education/batman.html

Renewable Energy Multimedia System
http://rein.etec.uni-karlsruhe.de/rein/basics/rems/remshome.htm

PASCOOL Passive cooling of buildings
http://lesosun1.epfl.ch/ventil/pascool.html

LESO-PB: Laboratoire d'Énergie Solaire et de Physique du Bâtiment
http://lesowww.epfl.ch/

The World-Wide Web Virtual Library: Energy
http://solstice.crest.org/online/virtual-library/VLib-energy.html

Computer-Based Design Tools
http://eande.lbl.gov/CBS/NEWSLETTER/NL3/EDA.html

Center for Building Science
http://eande.lbl.gov/CBS.html

LBNL Simulation Research Group
http://eande.lbl.gov/BTP/SRG.html

Energy Science and Technology Software Center
http://apollo.osti.gov/html/osti/estsc/estsc.html

Software from the Energy Systems Laboratory
http://loanstar.tamu.edu/software/software.html

Energy Ideas Clearinghouse - Software
http://www.wseo.wa.gov/eic/eicsoft.htm

Energy Software Applications
http://arch.hku.hk/CIA/Energy/soft.html

Building Design Advisor
http://eande.lbl.gov/BTP/BDA/BDA.html

Yahoo - Science:Energy
http://www.yahoo.com/Science/Energy/

Home Page of IVAM Environmental Research
http://www.ivambv.uva.nl/

Rendering
http://www-architecture.uoregon.edu/computing/tools/rendering.html

Blocon Home Page
http://www.blocon.se/

Solar Energy Laboratory
http://www.engr.wisc.edu/centers/sel/sel.html

Integration of CAD and Energy Analysis Software for Building Design
http://www-leland.stanford.edu/~mclayton/cadtoenergy.html

Other servers with similar topics
http://lesosun1.epfl.ch/other_links.html#Building_Physics

14. GLOSSARY OF TERMS AND DEFINITIONS

Building Location

Latitude
Latitude where building is to be sited. The user may also have to specify whether it is in the northern or southern hemisphere. Used in some design tools to assist in the calculation of solar radiation.

Altitude
Altitude above sea level where the building is to be sited.

Climatic Data

Representative days
Conditions based on selected days.

All days
Data for all days of a selected year is used.

Monthly days
Typical day for each month is used.

Design day
Design based on a specified day.

Degree days
Comparison of difference between a base temperature and daily mean outside temperature.

Building Type

The design tool may ask the user to specify the type of building being input (i.e. domestic, office, industrial, etc.) Some programs are limited to analysing only one type of building. Describes the function of the building.

Building Geometry

Orientation
Defined by degree scale or in simplified tools using the Cartesian points.

Dimensions
Detailed dimensional description of the building in three dimensions.

Building Area
Refers, in most cases, to the floor plan area of the building within its external walls.

Zones
Specification of the number of zones in the building (both heated and unheated) and their relativity to one another.

Zonal Control
Control conditions in specified parts of the building.

Limitations

Zonal
Many tools will limit the number of zones the user can input due to the software or memory capabilities. Other characteristics can have maximum and minimum limits.

Theoretical Basis

Admittance
Diurnal swings in temperature established by an admittance value for each surface relating swing in heat input to swing in temperature.

Response factor
Thermal conditions established by response factor and historic data going back at least 12 hours. The factor is the coefficient of a time factor equation from data on surfaces around a space.

Finite difference
Node at points within a structure which perform a heat balance between all interacting regions and solve the resulting equations at each time step.

Degree days
A method of assess energy consumption by comparing the daily difference between a base temperature and the 24 hour mean outside temperature.

External Effects

Obstructions
Specification of external obstructions (trees, other buildings, etc.) which may shade the building and thus reduce solar gain.

Shading
Specification of shading devices to prevent solar penetration, or buildings with complex geometry shading themselves.

Internal Environment

The user will specify the internal design conditions to be achieved including:

- design temperatures
- relative humidity
- light levels
- air change rates, etc.

Building Elements

Solar Absorption
Allows for solar energy through walls and roofs.

Layers
Allows for order of layers in multi-layer elements.

Sloping walls and roofs
Modeling of slopes of complex roofs and walls.

Thermal mass
Considers the mass of the building as a heat or cooling store and analysis the effect of the time lag of the wall.

Windows

User may be asked to input characteristics of the glazing elements in the building including:

- window frame material
- glazing material
- solar protection (film, etc.)
- shades or blinds
- sloping glazing, etc.

Occupancy and Equipment

Occupant gains
Occupants' heat input, split into possibly sensible and latent components.

Load profile
Number of different occupancy periods/levels accommodated.

Occupancy period
Profiles adjusted: daily, weekly or monthly.

Internal Gains

Equipment Gains
Sensible and latent heat gain from equipment

Lighting gains
Can be input as either heat gain per unit area or by the number and type of fittings and heat output per fitting.

Infiltration

Infiltration rate
Air change rate per hour resulting from uncontrolled infiltration of external air:

- estimated and input by user or
- calculated by the program based on wind speed and directional data or,
- simulated using computational fluid dynamics.

Services System Simulation

Time based operation
Set to operate on normal timed on/off schedules.

Night set back
Lower internal temperatures out of hours of use.

Frost protection
System operates when frost is detected (preset minimum temperature normally 5ºC).

Multi-systems
More than one system in operation at any one time.

Part load efficiency
Provision made for part load efficiency of items of plant.

Passive Systems

Direct Gain
Solar radiation gains to a space via glazing or other transparent elements.

Trombe Wall
Externally glazed wall facade with air circulation.

Sun Space
Glazed space attached to the external wall or walls of a building

Operating Conditions

Boiler multiples
Multiple boiler operation can be simulated.

Variable temperatures
Changing temperature needs are simulated.

Refrigeration unit multiples
Multiple refrigeration units can be simulated.

Costs/Fuels

Multiple fuels
Costs of alternative fuels can be calculated.

Multiple tariffs
Varying tariff rates for fuels taken into account.

Combined heat and power
Allows for heat and power generated by single system.

OPET

The Organisation for the Promotion of Energy Technologies (OPETS)
Within all Member States there are a number of organisations recognised by the European Commission as an Organisation for the Promotion of Energy Technologies (OPET). It is the role of these organisations to help to co-ordinate specific promotional activities within Member States. These may include staging of promotional events such as conferences, seminars, workshops or exhibitions as well as the production of publications associated with the THERMIE programme.

Members of the current OPET network are*:

ADEME
27 rue Louis Vicat, 75015 Paris, FRANCE
Tel. 33 1 47 65 20 21/56 Fax. 33 1 46 45 52 36

RARE-APCEDE
6 rue de l'Ancienne Comédie, BP 452, 86021 Poitiers Cédex, FRANCE
Tel. 33 49 50 12 12 Fax. 33 49 41 61 11

RARE-ARE Nord-Pas de Calais
50 rue Gustave Delory, BP 2035, 59800 Lille, FRANCE
Tel. 33 20 88 64 30 Fax. 33 20 88 64 40

ASTER SRL
Agenzia per lo Sviluppo Tecnologico dell'Emilia Romagna
Via Morgagni 4, 40122 Bologna, ITALY
Tel. 39 51 23 62 42 Fax. 39 51 22 78 03

BCEOM
Société Française d'Ingénierie
Place de Frères Montgolfier, 78286 Guyancourt Cédex, FRANCE
Tel. 33 1 30 12 49 90 Fax. 33 1 30 12 10 95

BRECSU
Building Research Establishment
Garston, Watford, Hertfordshire, WD2 7JR, UK
Tel. 44 923 66 47 54 Fax. 44 923 66 40 97

CCE
Centro para a Conservação de Energia Estrada de Alfragide
Praceta 1 - Alfragide, 2700 Amadora, PORTUGAL
Tel. 351 1 471 14 54/82 10/81 10 Fax. 351 1 471 13 16

CEEETA - PARTEX Cps
Centro de Estudos em Economia da Energia,
dos Transportes e doAmbiente-Companhia Portuguesa de Serviços
Rua Gustavo de Matos Sequeira 28-1°DT°, 1200 Lisboa, PORTUGAL
Tel. 351 1 395 56 08 Fax. 351 1 395 24 90

CESEN S.p.A.
Piazza della Vittoria 11A/8, 16121 Genova, ITALY
Tel. 39 10 576 90 11 Fax. 39 10 54 10 54

CORA c/o SEA
Cooperation of Regional Agencies Saarländische
Energie-Agentur GmbH
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