TRANSFERING COMPUTER BASED ENERGY ANALYSIS TOOLS TO PRACTICE: THE WHYs AND WHATs OF SIMPLIFICATION

Ilari Aho
Technical Research Centre of Finland (VTT)
VTT Building Technology
P.O. Box 1804
FIN-02044 VTT, FINLAND
E-mail: Ilari.Aho@vtt.fi

ABSTRACT

The primary purpose of this paper is to discuss the needs and expectations concerning simulation, analysis and evaluation tools from the viewpoint of the design process. The main questions arising from this viewpoint are those considering the nature of energy use in the building sector as a factor of decision making, building design and some of its characteristics as an information process, and the value added to a particular design by the utilisation of simulation tools. Arising from the discussion, it is suggested that for the time being a more appropriate approach for reaching the average desing professional is based on the development of simplified, low cost analysis and evaluation tools. The approach is discussed and described by presenting the concept, development process and implementation , of ETANA, a highly simplified building energy analysis tool, the first version of which is currently being distributed.

INTRODUCTION

The rapid development of computer technology - both in terms of increased performance and decreased prices - has during the recent years provided the basis for major technological leaps in building simulation software. The advances in the simulation field have mainly taken place in increasing the level of detail of the models, development of generic and efficient solver modules and, to some extent, in the introduction of graphical user interfaces. There is also an apparent trend towards object oriented and product model based simulation environments.

The considerable investment and effort put in these developments has primarily been motivated by trust in the penetration of the developed tools in the design market and consequent improvement in energy efficiency, cost and performance of the designs. However, broad application of simulation software in the building and HVAC design industry remains yet to be seen. Consequently, a common attitude (which fortunately is gradually diminishing) among the building simulation community has been to categorize the design profession as not being able to understand the value and benefits of advanced simulation tools.

Sophisticated general purpose design tools have proven their value and usefulness in both research and development work and in the design of individual more complex construction projects. If one looks at the construction arena from either the viewpoint of energy or production quantities, it is however clear that a vast majority of design work and consequently a vast majority of decision making concerning energy use in the built environment is being done in average day-to-day type of projects. Typical for these is a narrow economic operating range for the designer, and a tendency for minimizing investment cost regardless of the operating costs of the building.

BUILDING SECTOR'S POTENTIAL AS A SIMULATION TARGET GROUP

As a sector of economy buildings and construction form a major energy consumer and CO_2-producer [OECD/IEA]. An illustration of the importance of the sector is presented in figure 1. In the OECD countries the building sector accounts for about 30 % of the total final consumption of energy. (It has to be noted, however, that due to statistical and accounting difficulties the sector actually includes both the energy consumed by space conditioning, lighting and other directly building related consumption units and the energy consumed by the activity taking place inside the buildings, for example household and office appliances etc.) This amount of energy results in an annual CO_2 emission of approximately 3500 million tonnes. So, it is clear to see what improved building design by means of, for example, sophisticated computerized analysis tools could accomplish in the environmental sense. This is especially true for retrofit and refurbishment design, where a vast energy saving potential lies untapped.

Appreciating the global importance of energy efficiency in the building sector, it has to be realised that with the present prices of on one hand energy and on the other hand labour and capital, the clients of the buildings and construction sector do not have any economic incentive for paying extra in order to achieve energy efficiency. This is illustrated in figure 2 [Statistics Finland, TEKES]. In the figure it can be seen that for a typical Finnish residential

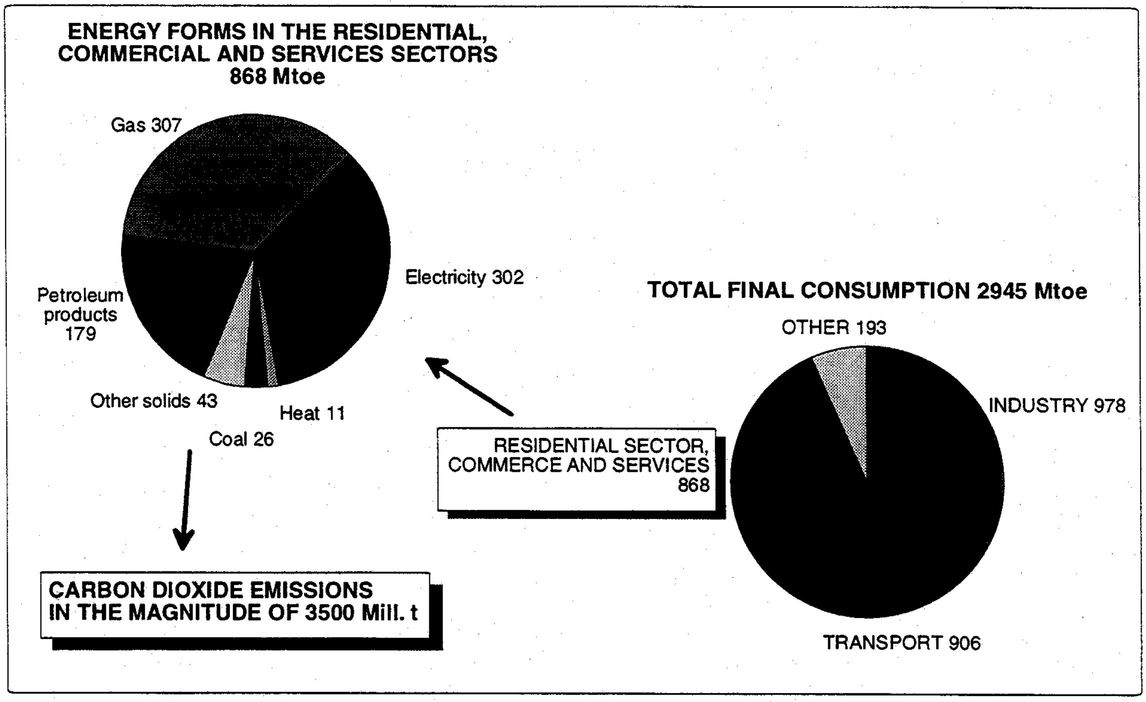

Figure 1. Total final consumption of energy by sector in the OECD countries 1991 and a breakdown of the residential, commercial and services sectors by energy form [OECD/IEA].

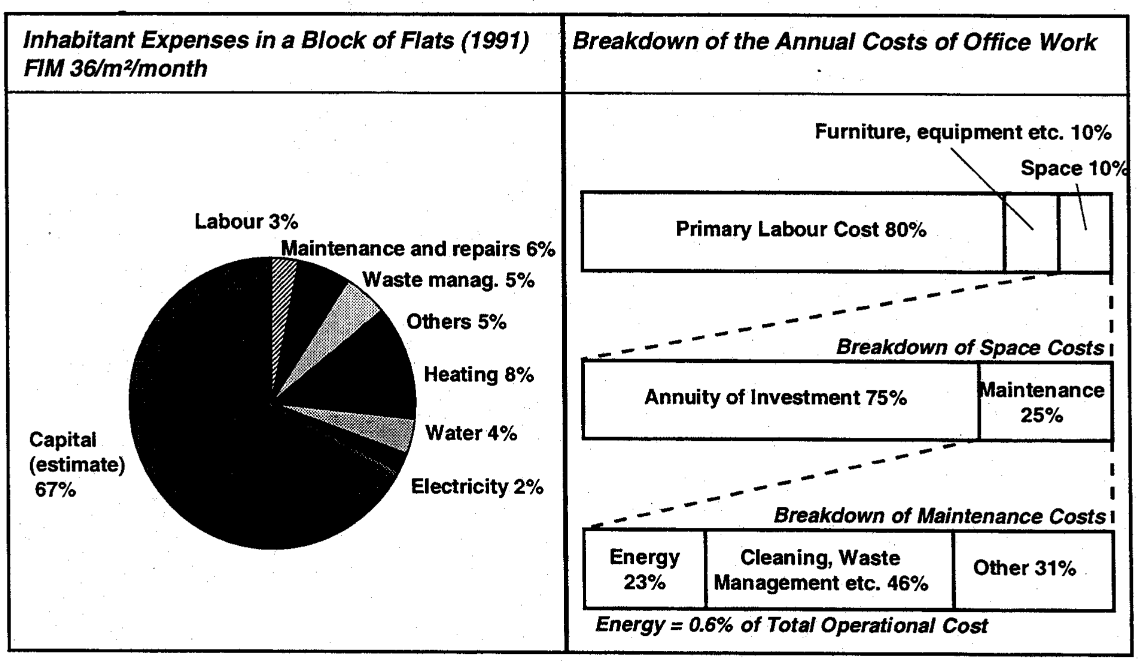

Figure 2. Energy costs from occupants' and building users' point of view [Statistics Finland, TEKES].

building the cost of heating represents about 8 % of the total cost attributable to the acquisition and maintenance of living space. In office buildings, from the organisation's point of view, energy is an even more minor matter. Only about 0.6 % of the total operational cost of an office based organisation is attributable to energy use.

Apparently there is a conflict between the global importance of the building sector from the energy and environment point of view and the relative negligibility of energy as a cost factor in businesses and households. In the case of commercial enterprises there is another point which contradicts extensive energy analysis: investment in energy efficiency does not induce cash flow. This is a viewpoint often forgotten when the reluctance of commercial enterprises towards energy efficiency improvements is being criticised. This fact is, however, clearly demonstrated by the difference in payback requirements that, for example, industry imposes on different investments.

One of the clearest examples of the above can be found in the energy industry. A new power plant is expected to pay itself back in 15 to 25 years, whereas the same utilities criticise private investment in compact fluorescent bulbs as uneconomical, because the payback time for these is somewhere around 3-5 years. (Note for those who disagree: utility driven demand side management programs would not have reached the level they have in North America without governmental requirements.) The same applies for a standard office builder: if one invests in simulation studies and consequent energy efficiency improvements, the results have to pay themselves back in about a year in energy cost savings. Or the measures have to result also in a measurable raise in productivity from, for example, improved working conditions; productivity improvements usually mean increased cash flow.

Technically speaking the building sector offers a huge potential for simulation. The fact that has been left virtually undiscussed by tools developers is the economic aspect. The economics of simulation tools include both the investment required in order to establish productive use of a tool in the design office, and the economic implications of implementing the results of simulation, that is the investment needed and the cost reduction and/or productivity improvement yielded by carrying out improvements in the actual building.

BUILDING DESIGN AS AN INFORMATION PROCESS

Top-down vs. Bottom-up

From the information point of view building design, and systems design in general, is a top-down process (figure 3). The starting point of the process is established by the needs of the prospective user/owner of the building, even though the needs might sometimes be very indistinctly or even confusingly defined and presented. From this starting point a hierarchy of design information is gradually established, leaving the technical implementation details undiscussed until far towards the end of the process.

How does the current generation of building simulation tools match this type of an information process? From the users point of view building simulation software tends to present a highly bottom-up view of the world. In order to be able to produce results, albeit possibly highly valuable ones, one has to be able to specify the solution to be analysed down to a relatively detailed level. This puts the concept of "integrating simulation tools to design practice" in a not-so-optimistic light; it might prove to be highly difficult to integrate two concepts into oneanother if their view of the surrounding world is quite contrary.

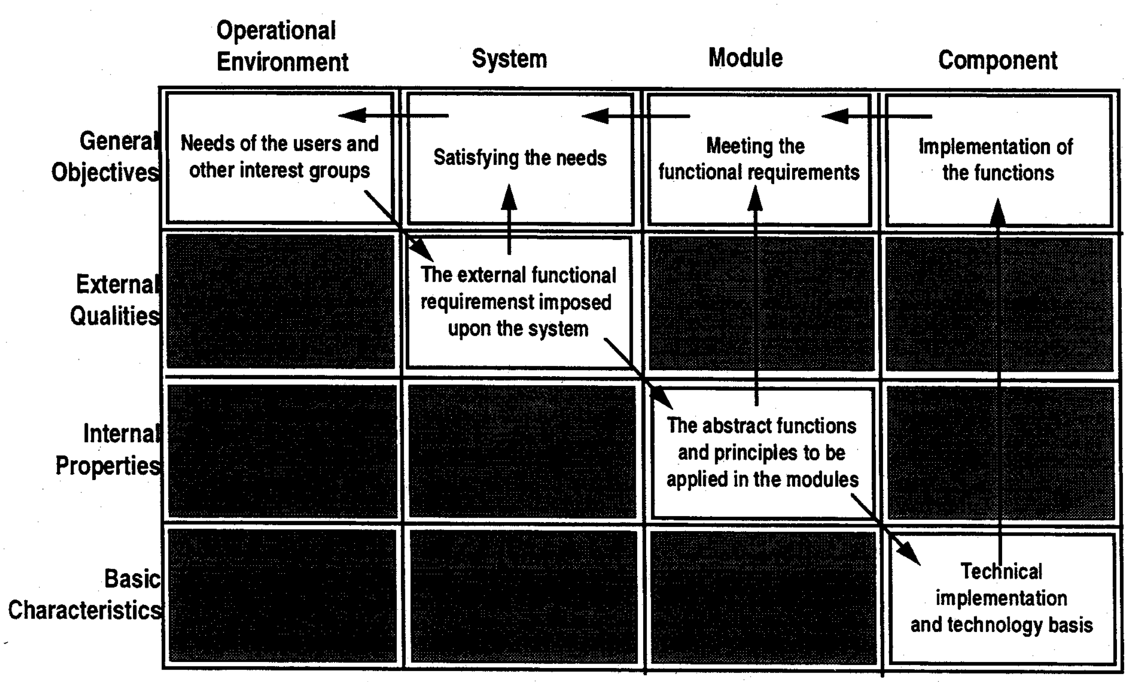

Figure 3. Systems design as a top down information process.

The COMBINE project has concentrated effort in defining a hierarchical information structure for representing building design information [Augenbroe]. The work has been valuable in providing a framework of infrastructure for tool developers. However, the work of developing and establishing a suit of tools that are able to work with only the top levels of the information hierarchy still remains mainly unstarted.

Energy implications of design decisions

The energy economy of a building is mainly affected by decisions made (or not made) during two stages of the life cycle: strategic design (or preliminary and schema design) and use/maintenance of the building. This is illustrated by a hypothetical case in figure 4 [Lassila]. In a normal case the range of influence on energy consumption tends to narrow as design moves on from the strategic decisions towards details. From the simulation point of view an unfortunate fact remains: the more detailed design information is available for performing high quality energy analysis, the less opportunity there is for influencing the design and its overall energy efficiency. In order to effectively steer building design towards energy efficiency, and more importantly, to do it early enough to avoid extensive and expensive redesign or even rebuilding, a strategic design tool should be able to live with the fact that only a very limited number of uncertain design objectives exist at the time when decisions with a high influence on energy consumption are made.

A very interesting and important point considering requirements for the accuracy of early design tools was made by Koen Steemers in the BEPAC conference in 1994 [Steemers]. Combining this idea with experience from the Finnish construction field it can be summarized as follows. It is well known that the influence of the decisions and behaviour of users and maintenance personnel on the energy consumption of a building can be in the order of magnitude of +/-30%. Since the customers of building design tend to compare simulated energy consumption levels with the actually materialized values, it might well be assumed that the confidence interval of simulation results at the early stages of design can be at least in the same order of magnitude as the "design independent" portion of energy consumption, in this case the degree to which user decisions have an impact on energy consumption. It is clear that the actual energy consumption figure arrived at by applying an early design energy analysis tool can not be, nor does it even need to be accurate to the n:th decimal. The

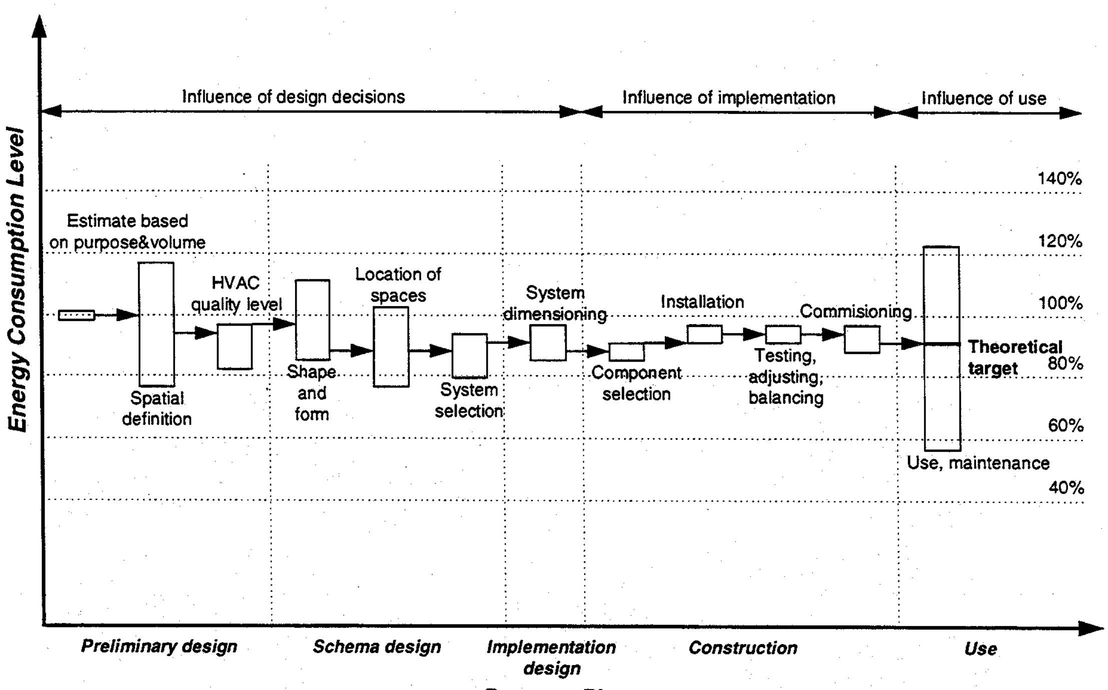

Figure 4. Relative importance of decisions regarding energy efficiency in different stages of the construction process in a hypothetical case study; each box represents the possible range of energy consumption levels resulting from different design decisions made at the process phase in question. The energy consumption level of a building is mainly influenced by decisions made at the strategic design level and during use of the building [Lassila].

value of an early design tool is in providing a means for visualising the large scale energy impacts caused by strategic design decisions, and in giving insight of the interrelationship of these and the resulting energy consumption.

Economic implications to design

The discussion above can be summarised in a basic assumption concerning the applicability and value of design tools. If a design tool, in particular an energy analysis tool, is to be accepted and applied by the design profession, it either has to (1) bring down the cost associated with the construction and use of the building in question or it has to (2) bring down the cost associated with the design work itself while maintaining or even improving the quality of the building being designed. Referring to paragraph 2, due to the role that energy costs play for the customers of the building sector, the first alternative is unlikely to be of high importance in the near future. The second alternative, however, could be considered a competitive advantage for a designer utilising energy analysis tools.

APPROACHES TO ENERGY ANALYSIS TOOL SIMPLIFICATION

Two basic (or even self-evident) approaches to tool simplification can be identified: external and internal simplification. These two approaches are discussed below primarily from the viewpoint of the requirements of early design phases.

External simplification. In this case simplification is taken care of on the interface level. Basically this means that the user of a simulation tool is provided with a mechanism of communicating with the tool in a robust and consistent manner regardless of the phase of design and the amount of information available. External simplification can treat also the possibilities of model and data sharing between different classes and instances of design software, by means of common data transfer mechanisms such as STEP. The main advantage of external simplification is that it is independent of the underlying calculation engine. This means that it can be employed to produce tools with levels of different tailored external appearances combined with a sophisticated general purpose simulation core, thus providing a possibility for applying the same tool consistently throughout the design process. Implementations of this approach include, for example, intelligent front-ends with defaulting capabilities.

Internal simplification. Internal simplification actually refers to the traditional meaning of the word simplification. In this case simplification is represented by compromises made between the accuracy and generic nature of the calculation method employed and the need for small number of input items, methodological simplicity, fast response time, etc. Many of the simplified tools currently being used in consulting companies and design offices are actually computerised versions of former hand calculation routines, and as such their simplified nature is more of an outset than a result of software development. However, these tools are widely used because of their transparent nature: designers are familiar with the methods behind the tools. Of course, internally simplified tools have their limitations, especially in terms of the purposes and cases they can be used for.

CASE: "ETANA" BUILDING ENERGY ANALYSIS TOOL

Background and approach

The need for a highly simplified building energy analysis tool became apparent at the starting point of a project focusing on the systematisation of the energy saving activities of the City of Helsinki [Kosonen and Aho]. At the begining the main focus was on providing the property managers and property personnel of the City with a tool for quickly and easily establishing energy consumption targets for space heating.

After discussions with the personnel of the City it became obvious that a major problem in applying simulation tools for energy targetting is the difficulty of obtaining the required input values. This is especially the case for older buildings, with inadequate and possible out-of-date design documentation. Obviously, for the sake of being able to employ the same method for the whole building stock, it was also required that the tool would enable adjustment of the entered parameters both in terms of accuracy, if additional information would be found, and in terms of the increasing the level of detail of the model to a certain extent when necessary.

The development of the ETANA (acronym for the Finnish translation of "Calculation of energy consumption targets") program adopted an approach with characteristics from both external and internal simplification.

External simplification of the program relies on heavy defaulting. Old building regulations and guidelines and other sources of information were surveyed and heat, electricity and water consumption statistics analysed in order to establish a database of default insulation levels, ventilation rates, appliance loads etc. by building category and age. This database is used in order to allow the user to start work with a minimum number of input items needed for the computation of the first energy estimate.

Internally the software employs a degree-day based simple calculation routine presented in the Finnish building regulations [National Building Code of Finland]. This method was selected mainly because of the fact that it has already been widely used both as a hand calculation routine and as spreadsheet applications in a large number of consulting office. Thus the threshold for acceptance of the software was anticipated to be lowered with a familiar calculation method. Being a steady state monthly or seasonal method it of course has severe limitations. But for normal construction practice with no low energy features or large internal loads that would require dynamic calculations, the method has been found to yield reasonably accurate predictions on monthly or seasonal basis [Kalliomäki and Kohonen].

Structure of the software

The basic structure of ETANA is presented in figure 5. The user starts his/her work by entering nine parameters:

- building category,
- year of construction,
- dimensioning indoor temperature,
- climate zone,
- building volume,
- shape of the building (which can be picked from a number of standard shapes),
- a parameter describing the proportions of the shape (depending on the selected shape),
- number of storeys and
- storey height.

Using these values and the database of default values the program calculates an estimate of the areas of different envelope parts, insulation level, air change rate, water and electricity consumption (which are consequently converted to internal loads) and other parameters required by the calculation procedure. The first estimate of energy consumption can be computed by using these values.

The user than has a choice of modifying the default values established by the program by changing the numeric values of the parameters and/or providing additional information, such as adding individual ventilation units, envelope parts, etc. The possibilities of modification have, however, been kept within certain limits, in order to keep the program as a whole in reasonable dimensions, both in the sense of amount of code, and in the sense of being comprehendable and managable also for people with no experience whatsoever with computer work

The program presents itself as a collection of character based input windows, and a graphical Sankey diagram output of the calculated energy balance. Results and the input data can also be saved as tabulated text files for more detailed examination.

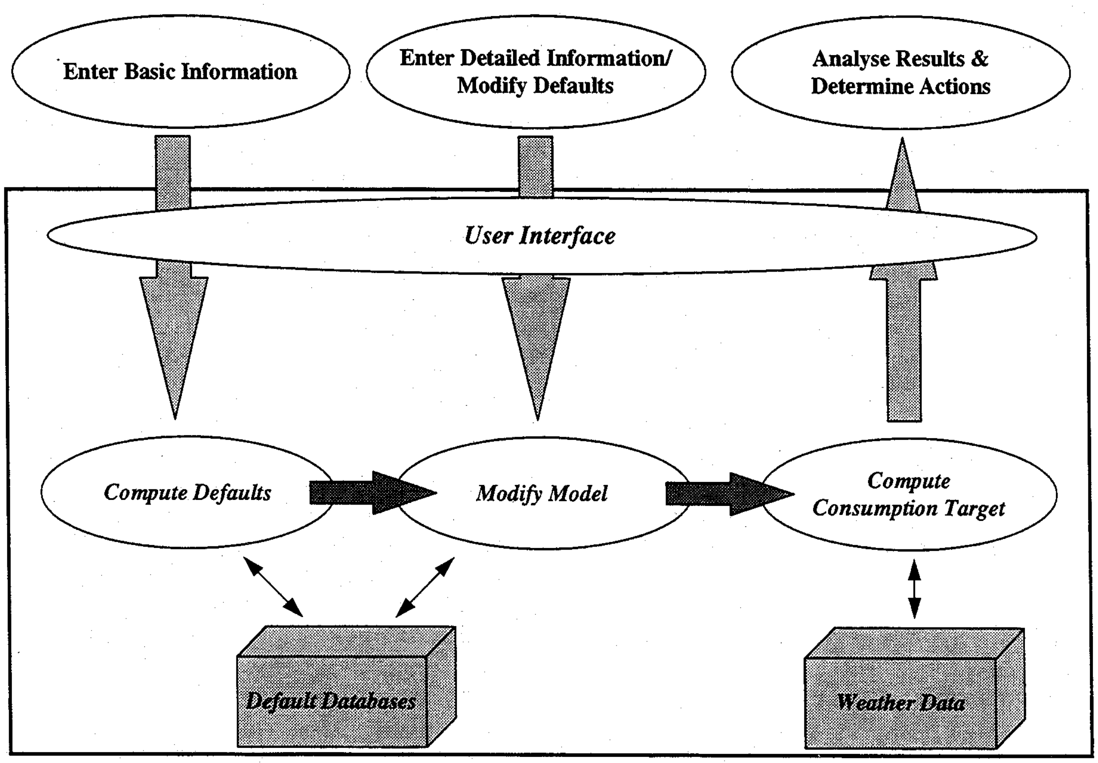

Figure 5. Basic structure of the ETANA energy analysis tool.

Feedback and experience from the field

A first version of the ETANA software has been distributed free of charge by VTT and also via the network of the Finnish Association of the Heating, Piping and Air Conditioning Societies and its member societies. The first release has resulted in some tens of direct contacts from the field with comments and viewpoints on the software.

In addition to bug reports, technical questions and recommendations of features to add in future version, a fair amount of feedback on the approach and implementation in general has been received. Especially the comments have supported the approach of not putting overwhelming emphasis on the accuracy of the software but rather concentrating on solutions which support the user in getting started in work; in the case of ETANA this has mainly been implemented in the form of the defaulting mechanism. It has been found valuable from the users point of view to be able to produce the first results rapidly and without extensive first effort. This seems to have even somewhat lowered the doorstep which for many seems to be hard to cross before applying computerised tools.

Further developments

An improved version of the ETANA software is projected to be published during 1995, with enhanced capabilities of estimating electricity consumption of office, household and HVAC auxiliary equipment. A Windows-version of the tool is also planned.

ACKNOWLEDGEMENTS

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CONCLUSIONS

The building sector as a whole offers a major potential for energy efficiency improvement and consequent reduction of environmental burden. However, in order to facilitate reaching this goal by means of a wider application of computer based design tools attention should be paid to proper segmentation of the market of simulation tools, and consequent development of suitable tools for each designer segment. As majority of building design is performed within strict economic limits and with limited resources for energy analysis more focus should be put on the development of simplified strategic design tools for assisting the design professional in making the right decisions early enough in the design process. Experience gained in Finland in developing and distributing a preliminary version of such a tool support this view.

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