Energy Modeling Tools Assessment
For Early Design Phase

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prepared for

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Energy Modeling Tools Assessment for Early Design Phase

1. Introduction

This report documents the findings of the project on Energy Modeling Tools Assessment for Early Design Phase, commissioned by the Northwest Energy Efficiency Alliance. This project falls under the Advanced Design Tools and Guidelines category of the Product and Service Development component of the Commercial Sector Initiative in the Alliance.

2. Project Overview

Nearly all energy use in the commercial sector takes place in, or is associated with, the buildings that house commercial activities. The total number of commercial buildings in the USA has increased from 3.8 million to about 4.7 million and total commercial floor space has increased even more significantly from 51.1 to 67.3 billion square feet of commercial floor space from 1979 to 1999. Energy consumed in commercial buildings (amounting to 5 to 6 quadrillion Btu annually, between 1979 and 1999) is a significant fraction of that consumed in all end-use sectors. In 2000, about 17 percent of total energy was consumed in the commercial sector (EIA 2000).

The design and evaluation of commercial buildings has become increasing complex over the years. Such complexity arises from the changing perception and demands of building owners, facility managers and tenants with regard to green/sustainable developments and life-cycle operating costs (concerning energy use, in particular) as well as a growing awareness of the potential impact of buildings on human productivity, health and security.

It is well recognized that the key to influencing the building costs and its performance standards (including energy performance) lie at the early stages of a building project's life cycle (Augenbroe 1992, Mahdavi and Lam 1991). Given the complexity involved, there is a need for effective and efficient tools to assess energy impacts early in the conceptual design phase of a new commercial building design process. Some tools currently exist in various stages of development and targeted for different types of applications and users. There is a need to assess what are currently available and where necessary, make recommendations for improvements to the tools to facilitate their use in the industry.

3. Project Goals

This project seeks to identify, study and evaluate existing energy simulation software in the construction industry that are suitable for the early stages of architectural design, i.e., during the conceptual or early schematic design phases. There are multiple aspects to consider concerning energy use in building, including geographical and climatic context, occupancy functions and schedules, building enclosure and HVAC system design, energy conservation techniques, peak load management, utility rates, etc. The goals of the project are to:

(a) define what constitutes the early design phase in contractual terms with respect to professional practice in the building delivery process;

(b) develop a classification scheme for comparing and ranking the current range of energy simulation software based on a matrix of criteria;

(c) evaluate the performance of FIVE selected tools through their application and testing in "simulated" architectural practice scenarios by graduate students and selected practicing architects under controlled conditions.

4. Application of Energy Modeling Tools in Industry

An industry survey by Wong et al. (2000) of the use of performance-based simulation tools for building design and evaluation concluded that usage of tools remain very limited due to several factors: (1) inherent technical limitation of the software, (2) emphasis on initial or capital cost by clients, (3) a fragmented building delivery process that does not routinely include quantifiable assessments of design options by the design team, and (4) the prescriptive nature of current building codes and design guidelines do not promote analytical use of these tools. The paper also provides a comprehensive list of the well-known simulation tools for energy and HVAC system analyses available in the building industry, providing brief descriptions of the program features and results output. However, commonly deployed energy related software tools in industry have been dominated by those used for the analysis of energy consumption, selection and sizing of HVAC equipment by the HVAC designers. Most of these tools are developed for the purpose of design verification and to meet building code requirements at the end of the design phase. They do not necessarily provide "active support" particularly for the "early" design process.

These points are also echoed in an internal study by the Public Works and Government Services Canada (Ma, 2001). The study included eight building energy simulation tools (namely, Energy-10, RETScreen, EE4 CBIP, Visual-DOE, BLAST, DOE-2, EnergyPlus and ESP-r) which focused mainly on their functionalities. The purpose was "to contribute to an increased understanding of energy techniques and consequently, to more rational decision-making in building design" amongst the designers and engineers at PWGSC.

With the increasing consciousness and demand for sustainable building design solutions, the U.S. Green Building Council has provided a national standard for what constitutes a "green building" - the Leadership in Energy and Environmental Design (LEED™) Green Building Rating System. It contains a prerequisite requirement of minimum energy performance for new construction and major renovations. Recommended potential technologies and strategies include "the use of a computer simulation model to assess the energy performance and identify the most cost effective energy measure. Quantify energy performance compared to the baseline building" (LEED-NC 2003). This is a major impetus in promoting the use of energy modeling tools in design.

5. Definition of Early Design Phase and Application of Tools

Whilst the term "early design phase" is very commonly used in discussing the building design process, it invariably refers to the stage of work where initial design ideas are being conceptualized in tandem with the formulation of the building project requirements. It is generally recognized that this is an adaptive-iterative process (Mahdavi and Lam 1993). However, it is often not clear in practice when this phase ends and the next begins.

One essential reference to establish a professional practice definition of early design is the American Institute of Architects Contract Documents. The AIA standard form of contract (see Appendix 1) includes the provision for *Energy Studies and Report* under the category of planning and evaluation services. The description of supplementary services further describe *Energy Studies* consisting of special analyses of mechanical systems, fuel costs, on-site energy generation and energy conservation options for the Owner's consideration. The description of *Schematic Design Document* also includes electronic modeling.

There are also considerations of copyright of electronic documents associated with computational modeling work. These are covered in the Owner-Architect Agreement shown in Appendix 1.

Given these contractual provisions and the drive towards greener designs, it is envisaged that the use of energy modeling tools will become more pervasive in due course. The critical challenge then is to ensure the available tools are indeed effective in supporting the design process.

Many energy modeling tools have been developed over the years by research and development teams in academia, public agencies as well as the private sectors around the world. The conceptual approaches adopted and technical implementation of these tools varies significantly. Some tools employ “simplified” methods that address specific perceived needs of the early design phase while others adopt complex first-principle based engineering algorithms that can meet detailed design requirements. The potential for continuous development of any of these tools depends largely on the software engineering paradigm adopted, which should consider both data modeling and activity modeling for the entire design process.

In building performance modeling, the fundamental data required may be categorized as contextual (e.g., geographical and climatic), formal (e.g., geometric configuration and orientation), semantic or attributive (e.g., dynamic material properties), and performance indices (e.g., energy consumption targets and code requirements). Activity modeling should recognize the growing necessity to support multi-disciplinary collaborative design as building projects become more complex (Lam and Mahdavi 1995). With increasingly affordable computing power, it is argued that energy modeling tools should adopt rigorous physics and engineering-based algorithmic principles in the computational prediction of energy performance to ensure acceptable results.

The different functions within a particular design phase can be met through the user interface design which could progressively reveal different levels of pertinent information input demands with associated library support, and generate appropriate output information to assist in decision making at that particular stage. For example, at the early design phase, the architect may explore various building geometries, orientations and fenestration configurations, and be provided with recommended input parameters derived from an extensive contextual case-based library support in terms of materials, construction, performance targets, etc. The output required at this phase may just be building loads without detailed considerations of mechanical systems and actual energy consumption. As the design progresses, the design team can then be exposed to greater degrees of freedom, with commensurate application support, in modifying the input parameters, not only in terms of the data model but also in computational algorithmic options that aim towards increasing levels of accuracy and resolution as well as performance details in the results output.

6. Literature survey of existing energy modeling tools

A literature review was conducted on the more well-known energy modeling tools that exist. These tools vary tremendously in many respects. A comparison of the 22 tools was made based on the following criteria:

User interface
CAD interface
Ease of use
Manuals
Computer Platform
Expertise required
Input Flexibility
Output capability
Functionality
Technical approach
Validation
Audience

Customer support
Price
Usage

Details, including contact information for the respective tools are given in Appendix 2a. The definitions of the items in the evaluation matrix are given in Appendix 2b.

In discussion with the Project Manager at the Northwest Energy Efficiency Alliance, five tools were selected for conducting detailed evaluation of their use in the context of early design support. These are (1) Green Building Studio, (2) eQUEST, (3) Energy Scheming, (4) Ecotect and (5) TAS. These tools were selected because they were relatively known and considered to hold particular promise for use in schematic design. This selection may be regarded as representative of the broad categories of tools that exist in industry. The same information contained in Appendix 2 has been extracted and tabulated for these five tools for convenient comparison in Appendix 3.

7. Evaluation of selected tools for the early design phase

The evaluation of the five selected tools is structured to address the following themes in computational design modeling and analysis:

Usability

System requirements
Interoperability with other tools, import/export capabilities
User interface
Learning and training time required
Effort required in updating model / conducting parametric studies
Processing time

Functionality

Comprehensiveness of geometric and system modeling
Types of energy calculations (e.g., load estimation, HVAC systems performance, etc.)
Types of data analysis and presentation
Availability of other environmental domain simulations (e.g., lighting)

Reliability

Consistency of results
Accuracy of results

Prevalence

Compliance with industry standards
Documentation
User support
Pricing and licensing

The exercise involves two major tasks: (1) development of a comprehensive classification schema for comparing the five selected tools, and (2) application and experimental testing of the tools in “simulated” architectural practice scenarios conducted by graduate students and selected practicing architects under controlled conditions.

7.1 Comparison of features of selected tools

A detailed matrix of features is developed to enable a comprehensive comparison of the five selected tools according to the major themes stated above, and represented by the following specific criteria:

I. System
II. Extension
III. Functionality
IV. User
V. Modeling
    a. Project Information
    b. Building Modeling
    c. HVAC Modeling
VI. Result Output

Detailed description of these features is given in Appendix 4. The following provides a summary of the strengths and limitations of each tool.

Green Building Studio (GBS)

Strength:

- Web service for energy modeling instead of stand-alone simulation program, less maintenance required on upgrades and reference data files.
- Direct geometry capture from Autodesk Architectural Desktop (ADT), ArchiCAD, Revit, Autodesk Building System CAD programs to GBS, no need for remodeling
- Utilizes well-established DOE-2 hourly simulation engine
- Whole building energy analysis with annual as well as life-cycle energy consumption and cost
- Easy to use, user only specifies the building type and geographical location as input
- Built-in library for various simulation parameters (building construction, shading, internal heat gain, infiltration, schedule, HVAC system and equipment, and utility rates) based on statistical data
- Fast at calculating energy consumption for buildings with uniform floor height and function
- The model in GBS can be exported as DOE-2 or gbxml file format for detailed energy analysis using other simulation programs

Limitations:

- Requires expertise in Autodesk Architectural Desktop (ADT), ArchiCAD, Revit, Autodesk Building System CAD programs
- Lack of documentation explaining the various assumptions made in the model (under development)
- Assumptions (building construction, shading, internal heat gain, infiltration, schedule, HVAC system and equipment, and utility rates) not visible to or editable by the user during input (under development)
- Assumptions (shading, infiltration, schedule, HVAC system and equipment, and utility rates) not reported in the output
- Difficult to model buildings with multiple spatial functions
- Can not perform parametric studies of design alternatives (under development)
- View of the association between plan and space type list limited to uppermost floor of the building
- Building elements with error messages cannot be directly identified in the drawing.

Ecotect

Strengths

- Complete package (modeling, simulation, post processing) developed to support conceptual building design
- Short turnaround time allows quick, relative comparisons useful for early design
- Support export to EnergyPlus, ESP-r for detailed validations
- Multiple domain simulations from same model
    - Thermal (Energy) Loads
    - Cost Analysis (Building and Energy)
    - Shadows and Shading
    - Solar Analysis
    - Lighting Design Support
    - UK Part-L Regulation Analysis
    - CFD plug-in under development
    - Acoustic Analysis
- Modeler easy to learn, possible to model slopes and different heights
- Online tutorials and forums
- Well designed Graphic User Interface (GUI)
- Imports 3D geometry
- Material Libraries
- Includes discomfort analysis

Limitations

- Exception errors when working with multiple projects during single session. Program should be restarted when closing one project and opening another project
- Admittance method might only give rough results (low confidence)
- Single state undo/redo
- Difficult to manage complex building geometry
- Material Thermal Properties not linked to construction layers, difficult to estimate
- No hierarchy of spaces and zones (each space is 1 zone)
- No HVAC system definitions (only present / not present states)
- No detailed building energy calculations (only simple conversion from load to energy use via single coefficient)
- Lack of engineering documentation explaining the various assumptions
- Limited post processing timescales
- Limited data export for post processing

Energy Scheming

Strengths:

- Helpful in understanding the heat gain and loss through different building elements in different seasons
- Energy-efficiency guidance in the context of specific building design
- User-friendly graphic data input
- Possibility of using building images from any pixel-based or object-based graphics application as underlay for plan take-off
- Visualization, animation and sound effect for output results

Limitations:

- Calculation of heat gain and loss instead of modeling of building energy consumption
- Calculation of four evaluation days instead of annual simulation
- Steady-state heat transfer analysis
- Moisture transfer and humidity analysis are not considered
- Capture of geometry from the underlay is not accurate (snap function not available)
- Model is displayed in 2D, as pasted or drawn

- No consideration of heat flow between different floors and spaces in the building
- Non-common units required for some of the input data

eQUEST

Strengths:

- Building creation wizards make the creation of the building model easier
- Good visualization of output results
- Batch processing function
- Operating cost estimation
- Code compliance for CA-Title 24
- Use bin weather data, which is easier to obtain
- Can import DOE-2 input file
- Can import .dwg file as underlay for building geometry specification
- Well established DOE-2 simulation engine
- Recommendations for building construction, internal heat gain, HVAC system and scheduling, according to building type

Limitations:

- Experience with DOE-2 required in order to use the detailed data edit mode
- Graphic result output not available for projects not originally created in eQUEST
- Building construction and scheduling not editable in wizard data edit mode
- Library is not editable
- No indication of which zone the specific activity area type and window are assigned to in wizard data edit mode
- Lack of tutorial for detailed data edit mode
- Lack of example files
- Metric unit system not available
- Only provides code compliance for California

TAS

Strengths

- Suite of simulation software, purchase as required (HVAC systems and CFD simulators available separately)
- Building Energy Simulation (requires additional packages) includes
    - Natural Ventilation simulation (with automatic aperture control functions)
    - Building and systems energy
    - Carbon emissions/ running costs in Part L macro
- Video tutorials
- Imports popular DWG and DXF as plan overlay
- Exports building geometry to Lightscape (Lighting design) and Cymap (HVAC & Electrical design)
- Allows voids in constructing multi storey complex spaces
- Hierarchy of spaces and zones allows easy management
    - Constructions and Internal Conditions can be assigned to all zones within a group
- Separate input interfaces for zones and internal conditions allow flexible model management
- Extensive database for weather, schedules, constructions and internal conditions
- Output can be copied to external spreadsheet applications for post processing

Limitations

- Separation into multiple applications can be confusing
- No engineering documentation
- Content of specific help files associated with individual interfaces is incomplete at present.
- Modeling Technique limited (Snap function not easy to use)
- Unable to import 3D geometry
- Export of building geometry to Lightscape which is a legacy product
- Cannot model sloped floors (e.g., a sloping floor in auditorium)
- Interface in Building Simulator not easy to use
    - Internal conditions must be dragged within structure view and cannot be modified in the information window
    - Conditions assigned wrongly to group has to be deleted individually
    - Method to add new material not intuitive
    - The only way to add items from database is by dragging between windows
- Cannot create project specific local libraries from the given global libraries
- Lack of engineering documentation explaining the various assumptions
- Building energy calculations requires separate HVAC package

7.2 Experimental testing of the application of selected tools

7.2.1 Context of early conceptual design phase

The experiments for evaluating the energy modeling tools are formulated in the context of the nature of informational demand the architect would have in the early conceptual or schematic design stage, as well as the expected level of technical expertise the architect would possess.

7.2.1.1 Scope

The scope of the evaluation reflects contractual provisions in the AIA standard form of contract (see Appendix 1).

7.2.1.2 Availability of Information

With respect to the details required for energy modeling, it is expected that sufficient information should be available during conceptual or early schematic design. The AIA standard form of contract states that preliminary selections of major building systems and construction materials shall be noted on the drawings or described in writing within the *Schematic Design Document*.

7.2.2 Knowledge base of architects

The Architectural Registration Examination (ARE) requires candidates to consider environmental and energy related issues in the pre-design stage. The requirements, similar to those stipulated by NCARB and NAAB, prepare the architect with an insight on the scope and tasks of environmental concerns, but not methodologies by which an architect can investigate such concerns.

7.2.2.1 Geometry Semantics

One of the main challenges in successfully conducting an energy simulation is to be able to describe the design accurately. The semantic differences between CAD and simulation geometric modeling are significant. The experiments take into account scenarios where such differences occur and investigate how each of the 5 selected energy simulation tools (see Appendix 3) assists the architect in building an accurate model efficiently.

7.2.2.2 Usability

The usability of the tools is a major concern for architects. The amount of time and effort required to produce desired results has to be tracked, which will inevitably affect the likelihood of applying a particular tool in the design process.

7.2.2.3 Informational needs

Considering the information that the architect needs to be able to evaluate a design or even formulate alternatives, assessment of the post-processing capabilities of each tool in presenting relevant information has to be made.

7.2.3 Industry practices

As the energy simulation tool is used within a design process that involves other software (e.g., CAD, spreadsheets, presentation, etc.), an assessment of the compatibility and interoperability of each of the 5 selected tools with other typical software used in the industry has to be conducted as well.

7.2.4 Experimental setup

The experiment setup attempts to simulate the scenario of an early conceptual design in a typical architectural practice that presents details that would test the capabilities of the tools according to the computational design modeling themes mentioned above. A hypothetical building of 3 stories and multiple zones, with moderate complexity in geometry and construction (see Figures 1- 5 in Appendix 5) is provided for energy simulation using each of the five selected tools.

The digital drawings of the building are initially prepared in 2-D in AutoCAD 2000 and serve as a common starting point for using each tool. This allows assessment of the usability of each tool from a neutral standpoint. Each tool will then take this basic input information for further development into a 3-D model for energy simulation. Similarly, the weather files, construction, material properties, HVAC systems, space gains and occupancy schedules are pre-determined and not taken from any of the tool's "libraries". This ensures an objective assessment of the time and effort required when using each tool.

Except for GBS, the energy modeling tools have proprietary methods and corresponding dedicated CAD interfaces for defining building geometry and zoning. These CAD interfaces allow the simple import of the 2-D AutoCAD drawings as a drawing overlay but the geometry basically has to be remodeled from scratch. Non-cubic forms generally require much effort to achieve in these CAD interfaces. Theses tools also assume certain level of user knowledge and experience in defining thermal zones. GBS can accept input file from ArchiCAD 8 or ADT 3.3, Revit and Autodesk Building System formats.

The different tools allow different levels of HVAC specifications. Energy Scheming only calculates space loads; Ecotect allows only the specification of the presence or absence of a heating/cooling system; TAS and eQUEST allow detailed specification of the type of HVAC system to be used.

The next stage in testing the energy modeling tools is the assessment of their parametric functionalities. A series of permutations on the base case such as decreasing the size of windows, adding sun shades and altering building construction types will be conducted to evaluate the effort required in updating the model when conducting parametric studies.

Given the plethora of data presentation methods and potential for information overload, an assessment the effectiveness of each tool in communicating operative information to the architect will be conducted. Of particular interest is the ability to compare results between parametric iterations.

The information for the base case and parametric studies was organized into a 3-part task for the external participants.

Provide one day briefing/familiarization of the tasks and ONE tool.
Allow two days for the experiment which is phased:
Part 1 – preparing the geometric input file (CAD import, or direct input in the tool)
Part 2 – material specification
Part 3 – specifying the indoor environmental conditions and some basic HVAC system configurations.

The degree of completeness of each part achieved by each architect was recorded.
A pre-processed completed file of each part was then given to the participant to start the next part.

This approach allows each participant to experience most of the functionalities of each energy modeling tool within two days. This also enables comparisons of the architect's achievements in each part and derives observations on the relative difficulty of the tasks.

To better assess and objectify the experience of the participants, a user survey questionnaire was developed with focus on how the tools would fit in or complement actual architectural practice (see Appendix 7a).

8. Results of the experimental testing of application of tools

8.1 Comparative analysis of selected tools by graduate students

All the five selected tools operate on the Windows platform on which the tests were conducted. Except for GBS, the tools operate with moderate stability with eQUEST and Energy Scheming crashing occasionally. GBS and Energy Scheming can operate directly on the Macintosh platform while the other tools require a Windows emulator but we did not test the Macintosh configuration. The findings on program stability reveal the differences between the stand alone program and the web-based service approaches.

The web-based service approach adopted by GBS has 3 main advantages. First, the client software that has to be installed on user workstations places less burden on the user workstations as compared to entire programs in the case of stand alone tools. This approach has a direct effect on program stability. Second, the burden of program maintenance, fixes and updates is minimized for the user. Though technology for automatic software updates is prevalent, none of the selected tools offer this feature. Furthermore, the user may decide not to use automatic updates for various reasons. In the case of web-based services, since the main program resides on the developer's end, any program maintenance, fixes or updates are timely and transparent to the user. Third, since energy simulations are by nature computationally intensive, the speed of the simulation depends on the processing power of the computer the program resides on. In the case of web-based services, users are no longer limited by the computer resources they own or can afford but can take advantage of the processing power of the developer's equipment, which are typically more advanced.

An important factor in the usability of the selected tools is the quality of user interfaces. The main difference between the tools reflects the two main approaches toward energy modeling in the early design phase. One approach is to simplify the process to the extent that it is transparent to the user and thus easy and feasible to deploy. To this end, GBS uses highly automated processes and mostly default values that take most parameter selections out, leaving a simple user interface. The other approach allows highly configurable tools to empower informed users. This gives the user more control but requires more comprehensive input. Consequently, the user interfaces are much more detailed and complex, though still well designed as in the case of Ecotect by appropriate categorization and hierarchical organization of menus.

Interestingly, TAS also has a comprehensive interface but segments the tool into different packages rather than adopting the typical hierarchical program organization. The claim that this improves usability is arguable although it reflects the intended marketing strategy of selling the tool in modules. Users can purchase only those that are useful to them.

eQUEST offers both approaches by having two sets user interfaces for a “wizard” mode and a “detailed” mode where the former is simplified and the later allows the user to access all possible parameters. This flexibility allows eQUEST to remain appropriate and useful to a larger base of users.

The availability of technical support also affects the usability of the selected tools. Ecotect has notably comprehensive help files, tutorials and discussion forums, while GBS and TAS offer video tutorials to facilitate learning of the tool.

As established by Bazjanac (2001), up to 80% of the effort in preparing a simulation input file goes into the geometric description of building geometry. Given that most simulation engines utilize geometry semantics that are different from typical CAD tools, the user has to spend time duplicating already existing data in the selected energy modeling tool. This process is often tedious and error prone. In this regard, a well designed interface in each selected tool to input building geometry with ease is considered very important. This includes functionalities such as object and point snaps, node modifiers, dimension queries and direct numerical input. Features that allow efficient and concise import of existing CAD data will be beneficial.

Depending on the technical approach adopted, issues with complex spatial definitions have to be addressed. Non-convex spaces have been known to pose issues when calculating shading and shadowing solar radiation effects. While the user should not be burdened overtly with the intricacies of semantic differences, there should be some form of guide and feedback as to the “correct” modeling approach within each tool. In our test model, the building represents a typical commercial building that includes multiple level spaces, a variety of constructions, uses, loads and schedules, sloped ceilings and floors (e.g., in auditoriums) as well as non-rectangular walls. This set up aims to test the various tools exhaustively.

Except for GBS, the selected tools have built in CAD modelers for building geometry input. While many energy modeling tools are typically restricted to describing simple orthogonal spaces with uniform height on each level of the building, Ecotect, TAS and eQUEST are able to describe complex geometries satisfactorily. Ecotect in particular has a well designed interface and comprehensive functionalities that ease the process, including the feature of importing 3D models albeit zoning definitions still have to be defined manually. Ecotect also has the feature of flexible axis checking that computes volumes of non-convex spaces as well as a comprehensive error log that allow users to check the model easily, though this should be extended to allow confirmation of correct models. None of the other selected tools offer such checking functionalities. eQUEST and TAS report errors detailing specific problem areas.

Of particular interest is GBS since it accepts geometry information from Autocad ADT models directly. GBS purports to accept ArchiCad models as well but we have not been successful in demonstrating this feature. Nonetheless, this is a significant achievement by potentially eliminating one of the most arduous processes in energy modeling. However, there is still no feedback or confirmation that the model is correctly represented for energy simulations. While the integration of GBS and Autocad ADT improves its usability drastically, the same integration would also limit the base of users since the latter would have to model in strictly "proper" CAD semantics particular to AutoCad.

In preparing the building model, the user has to specify the building materials, construction, internal loads, HVAC types and schedules. Particularly in the early design phase where it is an adaptive-iterative process, the user may desire to study the effects of different strategies by varying these parameters. As such, it is important that the user can specify, edit and manage these parameters with ease.

To assist the user in the initial specification, all the selected tools except GBS have accessible built in libraries of typical materials and constructions and corresponding values. As a form of feedback to allow users to decide whether appropriate materials have been chosen, Ecotect, TAS and eQUEST shows the user the U-Value equivalent of the construction specified. In the case of GBS, the materials and constructions are chosen automatically based on some assumptions related to building type and building location, in keeping with the simplified approach. As these assumed parameter inputs are not visible to the user, they cannot be manipulated to represent a desired design and to conduct parametric studies. In the same line of providing libraries of typical values, TAS and eQUEST include libraries of schedules.

In our test model representing a building of moderate size with a floor area of $4355m^2$, there are 15 materials in 8 constructions, forming 19 zones with 225 surfaces. 6 schedules are used to describe the occupancy, equipment loads and HVAC operating hours. To efficiently manage these parameters, the organization and design of the user interfaces play an important role. Ecotect has a well designed zone management layout that allows easy understanding while eQUEST and TAS use a well structured hierarchy, including the functionality to group various zones, to facilitate good management of the parameters.

Bazjanac (2001) also established that significant effort in conducting simulations is spent on analyzing the results. In this regard, the selected tools generate various simple reports such as temperature profiles, heat gains and losses and building loads, but do not include extensive post processing functionalities. TAS and Ecotect allow the simulation results to be subsequently exported to spreadsheets for further analysis though the latter limits the amount of data that can be exported at any one time.

Ecotect, GBS and Energy Scheming allow model export to more detailed modeling tools such as DOE-2, EnergyPlus or ESP-r when a detailed analysis is required, though we have identified several issues with this feature, e.g., inconsistent surface representation.

Appendix 6 tabulates the simulation results of the test model using the five selected tools, as well as two extra sets of results by using EnergyPlus as a benchmark. Comparing the annual heating and cooling loads where available, Ecotect and TAS achieve satisfactory accuracy. Since GBS reports annual building energy in terms of fuel and electricity consumption, the heating and cooling loads were obtained by exporting the GBS model into DOE2 format, and using eQUEST to conduct the simulation. With regard to the large difference in the cooling loads between the GBS and benchmark models, we noted that the defaulted assumptions such as schedules and thermostat setpoints in the GBS model varied significantly from the parameters specified in our test model. Energy Scheming reports the total net heat flow in the building graphically but the usefulness of this format is arguable.

With respect to the early design phase as an adaptive-iterative process, energy modeling tools should ideally be able to support parametric studies. Whilst none of the selected tools include features to manage and conduct such studies, Ecotect does allow a graph plot of results to be saved and compared to the next set of simulation results, and eQUEST can provide a comparison report for multiple simulation runs.

8.2 Feedback from architects on application of tools

It has proven to be a challenge to solicit participation from practicing architects in the experimental application of the tools. Every effort was made to offer flexibility in scheduling the exercise, allowing the use of “live projects” from their own offices as test cases, provide incentives in the form of free license of the software tools (generously agreed upon by some of the tool developers) as well as technical support from the research team for up to one year upon completion of the exercise.

This situation should cause us to reconsider whether architects will indeed use energy simulation tools in the early design phase as part of their work under current professional practice conditions, regardless of the tool capabilities.

Eventually, six people participated in the exercise – one architect from a firm in Pittsburgh (subject A) , an architect who is a full-time faculty but continues to be involved in practice (subject B) , a senior architectural researcher (subject C), an architectural assistant who is current pursuing a graduate program (subject D), an intern architect (subject E) and an intern engineer (subject F).

	Subject A	Subject B	Subject C	Subject D	Subject E	Subject F
GBS	√	√	√			√
Ecotect		√		√	√	
Energy Scheming						√
eQUEST				√		√
TAS					√	

Subject B has over ten years of experience with energy modeling and currently uses Energy-10. Subject E and subject F have three and six years of experience respectively with energy modeling, both of them currently use EnergyPlus. Subject D has limited experience of less than a year with Energy-10 and EnergyPlus software. Subject A and C have no prior experience with energy modeling. There is unanimous indication of interest in building geometry and material selection in design exploration. Most of the participants were also interested in using energy modeling for design verification as part of LEED certification. Only one subject was interested in HVAC system design.

Detailed responses to the post experiment survey questionnaire are given in Appendix 7b. While the findings are by no means statistically significant, the following are some main observations gathered from the survey.

Under the category of *general impression of the energy simulation tool*, Ecotect ranked consistently higher in several aspects pertaining to ease of learning and use of the tool as well as modeling functionalities and user support, followed by eQUEST. GBS does not provide any direct modeling/editing function within the simulation platform and the result report is not rated as highly compared to Ecotect and eQUEST.

Interoperability in terms of import/export of files between CAD and simulation tools is seen to be an important feature in the tool specification. However, this feature is still not commonly provided in the tools. The low rating of GBS by one subject is due to the inability to import an ArchiCad model created using an education version of the tool.

Parametric analysis is regarded as an important function of energy modeling tools. Ecotect performs very well in this aspect. With the exception of real-time network collaborative function which no tool offers, eQUEST and Ecotect both provide good coverage of the functionalities indicated in the questionnaire compared to GBS.

The three tools provide reasonable documentation support which is deemed important by the subjects. However, it is noted that no documentation or tutorial is provided in the “detailed mode” in eQUEST. These tools also provide good user interface for model display.

eQUEST is the only tool that provides zone management, building type and space type definitions. The subjects believe that these modeling features are important.

GBS does not offer any direct building modeling function (geometry and construction). Geometry information is expected to be obtained from the CAD file while construction is assumed by the tool based on location and building type. Ecotect seems to provide better geometry modeling capabilities than eQUEST, while the construction library in Ecotect is limited in comparison. One subject commented that the predefined construction in Ecotect is not likely to be used in the USA.

In defining internal environmental conditions, GBS provides default assumptions based on building type and space type. The other two tools offer detailed input flexibility even though the libraries of schedules are limited.

There is an erroneous observation by one subject that the utility rate can be defined in GBS, where in fact the rate is pre-defined based on the location of the project.

Only eQUEST provides flexible and detailed modeling of HVAC systems while GBS offers detailed simulation of pre-defined systems which cannot be edited. However, no subject seems to be aware of this functionality since there is no response. It is interesting to note that one subject indicted that it is “easy” to define HVAC system in Ecotect when the fact is that the only option is to select the “availability” of air conditioning.

eQUEST and Ecotect provide a comparable level of details of result output. Ecotect has superior graphical representation of the information compared to the others. It may not be fair to directly compare the post-processing effort required amongst the three tools as the information content provided varies significantly.

As for the warning message function, Ecotect is comparable to eQUEST in informing the user of the “location” of the input error. GBS only provides a general error message.

The subjects felt that the time required for modeling their buildings using the three tools is reasonable. GBS does not seem to instill a high level of confidence in the results provided because of the largely unknown internal assumptions.

eQUEST seems to require a higher level of background knowledge and expertise to conduct the modeling exercise.

Subject A did not complete the questionnaire but provided the following written comments on the experiment with GBS:

a. The automatic generation of a building model from Autocad objects is a very useful and important step.
b. Even more useful would be if the tool were able to follow xref paths to build the model, as multi-story buildings are typically drawn into multiple files.
c. Some tools for performing limit analysis on building components are needed to make the tool very useful in design.

(i) Establish "baseline" conditions to approximate ASHRAE minimum standards (this would coincide with LEED practice)
(ii) Allow for seeing variations if building orientation were adjusted (perhaps by 15 degree intervals)
(iii) Allow for seeing variations if insulation were increased by factors of 50% (i.e. 150% of base, 200% of base, etc.)
(iv) Allow for seeing variations for glazing system changes (heat gain, transparency, insulation)
(v) Allow for seeing variations for glazing shading systems (basic assumptions such as 25% shaded, 50% shaded, etc.)

d. Also, some way to indicate and develop a model based on differing wall types is needed. For example, a building might have areas of brick wall, stone faced wall and metal panel, not all having the same mass and insulation properties. These could likely be easily made into different wall types within AutoCAD, if there was a way to easily key and control them within GBS.
e. The area of window orientation, shading and mechanical system impact still needs a good useful tool.

9. Conclusion and recommendations

Research by Lam et al. (2002) has demonstrated the web-based service approach to energy modeling tool design has distinct advantages of being platform independent, allowing distributed collaborations, ease of maintenance and updates, better resource support and availability and arguably lower costs. The development of GBS as a web-based service has shown the same benefits.

The user interface should be designed such that it is familiar, cognitive and compliments the concepts and processes of architectural design and energy modeling. With respect to operation within the Windows environment, Ecotect has been exemplary in providing a well designed user interface that is easy to use.

Technical help, guidance and documentation are important to the usability of software. Ecotect has comprehensive help files, tutorials and the user forum was very useful. TAS and GBS have taken a new approach to providing guidance by providing videos. Only eQUEST provides detailed technical documentation, which we consider to be important given the nature of energy modeling, but may not be a dominant issue during the early design phase.

Geometric acquisition for energy modeling has traditionally been a tedious and error prone process. The advances of Ecotect in allowing 3D CAD model import and fully automatic geometric acquisition from imported CAD files by GBS is heartening.

Different technical approaches have different semantic and spatial limitations. It is important that the user receives timely and detailed feedback on the correctness of the geometry that he/she has defined. This should be the case even if the geometry acquisition is totally automated.

In general, extensive library support and appropriate recommendations for constructions and materials are important for the designers, especially in the early design phase. Comprehensive weather data should also be made available.

The post processing functionalities in the selected tools are limited to conventional numerical and graphical reports of values such as loads and temperatures. It would be desirable to develop visualizations that would better facilitate a qualitative understanding of the design performance to the user and provide appropriate guidance in the context of early design decision making.

With respect to the early design phase as an adaptive-iterative process, energy modeling tools should ideally be able to support parametric studies. This is generally lacking in contemporary energy modeling tools.

The information content provided by the various tools varies tremendously. There is a need to clarify the information needs of the early design phase and to match the provisions accordingly.

For a tool to be beneficial and remain relevant throughout the building delivery process, it would be advantageous if it is developed based on comprehensive and fundamental principles in modeling the building-environment interactions. The tendency to adopt abstraction and rule-of-thumb approaches in an attempt to meet the time and resource constraints encountered in early design should be avoided. By offering different sets of user interfaces that automate and reveal parameters on different levels of granularity, it is possible for a tool to support various design phases effectively.

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Appendix 1. Summary of contractual provisions in the AIA contract document for conducting energy studies in architectural practice

Architect's Services

B141 - 1997 (Owner-Architect Agreement)

Identifying the services needed for the project: Under the Categories of Planning and Evaluation Services *Energy Studies and Report.*
Design Service Articles 2.4.2.1 (p.896): Schematic Design Document may include study models, perspective sketches, *electronic modeling* or combination of these media. Preliminary selections of major building systems and construction materials shall be noted on the drawings or described in writing.

B163 - Part2 (Description of Designated Services for Owner-Architect Agreement)

Article 2.3 – Description of Designated Services:

Project Administration and Management Services - .01 Project Administration – *02 – Research*
Design Services - .23 Architectural Design/Documentation - *.07 Study model(s)*
Design Services - .25 Mechanical Design/Documentation - .01 (Schematic Design Phase) - *.01 Energy sources, .02 Energy conservation* and .02 (Design Development Phase) - *.07 Energy conservation measures*
Design Services - .31 Materials Research/Documentation -.01 (Schematic Design Phase) - .02 Investigation of availability and suitability of alternative *architectural materials, systems and equipment.*

Article 2.4 – Description of Supplemental Services:

Supplemental Services - .54 Special Studies consisting of investigation, research and analysis of the Owner's special requirements for the Project and documentation of findings, conclusions and recommendations for: - .01 Master planning *to provide design services relative to future facilities, systems and equipment* which are not intended to be constructed as part of the Project during the Construction Phase. .02 Providing special studies for the project such as *analyzing acoustical or lighting requirements,* record retention, communications and security systems.

Supplemental Services - *.68 Energy Studies* consisting of special analyses of mechanical systems, fuel costs, *on-site energy generation and energy conservation* options for the Owner's consideration.
Supplemental Services - *.78 Computer Applications* consisting of computer program development and/or computer program search and acquisition, plus on-line computer time charges, for: *.08 Architectural analysis and design ; .10 Mechanical analysis and design; .11 Electrical analysis and design.*

Copyright of Electronic Document

B141-1997 (Owner-Architect Agreement)

(P.2) Terms and Conditions
Articles 1.3 contain the “ground rules” of B141, and embodies a number of notable changes from earlier editions. *One such change involves the architect’s drawings, specifications and other documents, now defined as “Instruments of Service”, which specifically includes documents in electronic form. The owner’s right to the use of such documents (and architect’s consultant’s rights in documents they have prepared) have been clarified by means of nonexclusive licenses.* In place of “basic” and “additional” services, circumstances are identified that may give rise to change in the architect’s services, thereby entitling the architects to additional compensation or additional time for performance. Provisions for dispute resolution now include mediation. Provisions for dispute avoidance include a wavier of consequential damages. The waiver is intended to prevent the escalation of dispute by limiting parties to direct damages resulting from a breach. Finally, grounds for termination are clarified, and the owner is given the right to terminate for convenience.

(P.18) Technological advances, such as computer-aided design, have and will continue to have an impact on the architect’s services and the manner in which they are provides. *The architect’s services are reflected in instruments of service*, such as drawings, specifications, *electronic data* and interpretive sketches which help the owner to reach the final result, a building project. *Because the use or misuse of the architect’s instruments of service affects specific rights and obligations of the owner, the construction team and the public, the architect as a licensed professional retains ownership of, control over and responsibility for these documents.*

(P.19) 1.3.2 Instrument of Service: 1.3.2.1 Drawings, specifications and other documents, including those in electronic form, prepared by the Architect and the Architect’s consultants are Instruments of Service for use solely with respect to this Project. The Architect and the Architect’s consultants shall be deemed the authors and owners of their respective *Instruments of Service and shall retain all common law, statutory and other reserved rights, including copyrights.*

(P.20) *Given the rapid pace of technological changes, it is not practical to address all the varieties of electronic documentation in a standard form document. The parties may wish to develop a separate, written agreement on how to deal with the electronic formats they may use.*

(P.21) 1.3.2.4 Prior the Architect providing to the Owner any Instruments of Service in electronic form or the Owner providing to the Architect any electronic data for incorporation into the Instruments of Service, the Owner and Architect shall by *separate written agreement* set forth the specific conditions governing the format of such *Instrument of Service or electronic data, including any special limitations or licenses not otherwise provided in this Agreement.*

Appendix 2. Summary of a survey of existing energy modeling tools

	ApacheSim (part of VE of IES)	BDA	BSim2002	COMFIE
User interface	Graphical user interface	Graphical schematic editor, building browser and decision desktop	SimView graphical user interface and model editor	Graphical user interface (PLEIADES)
CAD interface	yes	no	yes	no
Ease of use	2 days training is recommended for the basic modules	Easy (according to the developer)	courses available	Easy (according to the developer)
Manuals		User's guide, online help	User's guide	User's manual
Computer Platform	Windows 95/98/2000/ME/NT	Windows 95/98/NT/2000	Windows 98/2000//NT/XP	PC or Macintosh
Expertise required	2 days training is recommended for the basic modules, with additional courses available for specific applications	Knowledge of Windows applications	General knowledge of building design and thermal performance is required	General knowledge of building design
Input Flexibility	Certain energy systems such as PCM and roof ponds not covered,	Complex 3-D geometry and sloping roofs not covered	Unlimited rooms and zones	Multi-zone model
Output capability	Presents a wide range of data outputs in tabular and graphical form	User-selected output parameters displayed in graphic form, including 2-D and 3-D distributions	Tabular or graphic output of any of the calculated parameters on hourly, weekly, monthly, or periodical basis, numeric output is also available	Heating and cooling load, system sizing information, hourly indoor temperature profile and temperature histogram
Functionality	Hourly simulation of solar shading and penetration, HVAC systems and control, natural ventilation and mixed mode systems	Daylighting analysis and electric lighting computation, thermal and energy analysis, comparison of multiple design alternatives,	Simultaneous thermal and moisture simulation, dynamic solar and shadow simulation, daylighting calculation, building integrated PV system calculation	Heating and cooling load calculation, system sizing, hourly temperature profile, comfort evaluation
Technical approach	Detailed finite difference technique for building envelope, CIBSE Admittance Method for load calculation and system sizing	Simplified daylighting analysis and electric lighting computation, DOE-2 energy simulation engine	Finite time step, finite difference on building envelope	Finite volume method for building simulation, simplified mechanical system modeling
Validation	Independent testing by other companies and institutions shows good results	DOE-2 is subject to BESTEST validation procedure	Thermal simulation engine tsbi3 is subject to BESTEST validation procedure	Empirical validation and inter-model comparison with ESP-r
Audience	Mechanical engineers, building design consultants, architects	Architects and engineers	Mechanical engineers, building design consultants, architects	Architectural engineers, energy consultants, architects
Customer support	Available from the developer	Available from LBNL	Available from the developer	Available from the developer , users' club
Price	Depends on retailers	free	20000+ DKK, depending on number of licenses	Around $1000 for new installation
Usage	Many throughout Europe	800+ as of 06/2001	About 125 licenses	100+
Contact	Don McLean IES Limited 141 St James Road Glasgow, Scotland G4 0LT UK Tel: +44 (141) 226 3662 Fax: +44 (141) 226 3747 Email: drdon@ies4d.com Web: http://www.ies4d.com	Konstantinos Papamichael Lawrence Berkeley National Laboratory Mail Stop 90-3111 1 Cyclotron Road Berkeley, California 94720 Tel: (510) 486-6854 Fax: (510) 486-4089 Email: K_Papamichael@lbl.gov Web: http://gaia.lbl.gov/BDA	Kim B. Wittchen Danish Building and Urban Research P.O.Box 115 Hoersholm, DK-2970 Denmark Tel: +45 (45) 86 5533 Fax: +45 (42) 86 7535 Email: bsim-support@dbur.dk Web: http://www.bsim.dk	Bruno Peuportier Ecole des Mines de Paris Centre for Energy Studies - Paris 60 Boulevard Saint-Michel - 75272 Paris Cedex 06 Tel: +33 1 40 51 9151 Fax: +33 1 46 34 24 91 Email: peuportier@cenerg.ensmp.fr Web: http://www-cenerg.ensmp.fr/

	DEROB-LTH	DOE-2	ECOTECT	EnerCAD (Switzerland)
User interface	Graphical interface	Text input file	Intuitive 3D modeling interface	Graphical interface
Cad interface	no	no	yes	no
Ease of use	Easy (according to the developer)	Requires training or extensive use to become proficient	Easy (according to the developer)	Input assistants make the program easy to use
Manuals		User's manual, reference manual, engineer's manual	Tutorials, online help	User's guide
Computer Platform	Windows 95/NT	Windows 95/98/ME/2000/NT, UNIX, DOS, VMS	Windows 95/98/NT/2000/XP or Macintosh	Windows all versions and virtual PC for MAC
Expertise required	General knowledge of performance parameters in building design is required	3-day training recommended	CAD and environmental design experience useful but not essential	none
Input Flexibility	Up to 8 rooms	Up to 200 zones, 512 interior walls, fixed system configurations	Can deal with highly complex 3D models	
Output capability	Simple diagrams for space temperatures, space heating- and cooling demand and solar parameters , diagrams for the distribution of the comfort indices PMV and PPD for one space	Numerical output of input verification report, performance summaries, design day summaries and hourly report for building thermal performance, energy consumption and cost	Graphic output of thermal, lighting, acoustic and cost results, export to RADIANCE, EnergyPlus, ESP-r etc.	Table of monthly values, Annual heat demand, Monthly histogram, Flux diagram
Functionality	Hourly calculation of temperature and comfort level, detailed window and shading modeling, flexible modeling of building	Numerical output of detailed, hourly, whole building energy analysis of multiple zones in buildings of complex design, operational energy cost calculation, daylighting analysis included	Hourly simulation of lighting, thermal and acoustic performance, discomfort level, resource management, daylighting analysis included	Monthly calculation of cooling and heating load, U-value calculator, shading calculator, window calculator
Technical approach	RC-network building thermal model, simplified mechanical system modeling	Hour-by-hour, response factors for walls, weighting factors for zones, rectilinear surface model for daylighting	CIBSE Admittance Method for load calculation, hour-by-hour building and system thermal performance simulation	Monthly heat balance method
Validation		Subject to BESTEST validation procedure	Undergoing	Based on Swiss 'recommendation SIA 380/1' and the European 'thermal performance of buildings EN 832'
Audience	Researchers, energy consultants	Architects, engineers, energy consultants, researchers	Architects, engineers, environmental consultants	Architects and building engineers
Customer support		LBNL help line, commercial sources	Support forum maintained by the developer	
Price		$300-$2000	$650 for first professional license, $350 for education and $90 for student	CHF 550 for version 2004
Usage	150	Widespread through out utility and consulting company	2000+ as of 09/2002	500+
Contact	Department of Construction and Architecture Lund Institute of Technology Lund University Box 118 Lund, 221 00 Sweden Tel: +46 (46) 222 9662 Fax: +46 (46) 222 4719 Email: Maria.Wall@Ebd.Lth.Se	Fred Winkelmann Lawrence Berkeley National Laboratory Mail Stop 90-3147 1 Cyclotron Road Berkeley, California 94720 Tel: (510) 486-5711 Fax: (510) 486-4089 Email: FCWinkelmann@lbl.gov Web: http://simulationresearch.lbl.gov	Square One Research Pty Ltd c/o Center for Research in the Built Environment Cardiff University, Bute Building, Cardiff, Wales CF10 2NB, UK Tel: +44 (29) 2087 5977 Fax: +44 (29) 2087 4623 Email: sales@squ1.com Web: http://www.squ1.com	CUEPE University of Geneva Battelle bat. A 1, rte de Drize Carouge/Gevera, 1227 Switzerland Fax: +41 (22) 705 96 39 Email: info@enercad.ch Web: http://www.enercad.ch

	Energy-10	Energy Scheming	ENER-WIN	eQUEST
User interface	Menu-driven input system	Graphical interface	Graphical interface (zone sketch interface)	Graphical interface, schematic design wizard, design development wizard
CAD interface	no	no	no	yes
Ease of use	Autobuild feature makes the tool easy to use	Predefined building elements make the tool easy to use	Easy to use	knowledge-based default values make the tool easy to use
Manuals	User's manual and help system	User's manual	Users manual	Tutorials, online help
Computer Platform	Windows 3.1/95/98/2000/NT	Macintosh or Windows	Windows ME/2000/XP	Windows 95/98/ME/NT/2000/XP
Expertise required	Novice, 2 days training recommended	Understanding of basic concepts of energy design	Experience with Windows applications. Knowledge of building thermal properties and energy concepts	Understanding of basic concepts of building and HVAC system design
Input Flexibility	Building size less than 10,000 sf, up to 2 zones, 10 surfaces per zone, limited HVAC system types	Single zone, do not have HVAC systems, do not intend to be a building simulation program	25 zones per floor, up to 98 zones in total, 200 walls and 400 surfaces	Up to 3 floors
Output capability	Comparison of various EEMs between reference and base case building, annual energy cost, cost-effectiveness ranking of EEMs	Graphic and numeric reports showing heat gain and loss by hour for each of the calculation days	Graphical and numerical output of monthly and annual energy consumption and utility bill by end use, annual electric and cost savings from the use of daylighting	Graphic output of monthly and annual energy consumption by end use, graphic comparison of alternative designs, detailed numeric load, system, plant and economics reports
Functionality	Automatic generation of base cases and energy-efficient alternative case, rank-ordering of EEMs, annual operation cost calculation, daylighting analysis included	Loads analysis for 24 hours for each of 4 seasonal evaluation days, daylighting analysis included	Peak cooling and heating load calculation and zone sizing, hourly calculation of energy performance, Simplified HVAC system simulation	Hourly simulation of thermal and energy performance as well as energy cost, parametric runs, comparison of alternative designs
Technical approach	CNE thermal network thermal simulation engine, 15-minute time step, rectilinear surface model for daylighting (split flux method)	Hourly calculation of 4 evaluation days	transient modeling based on sol-air temperature, time lag, decrement factor, ETD; zone loads and temperatures based on a heat balance methodology; and daylighting algorithms based on a modified Daylight Factor methodology	DOE-2.2 simulation engine
Validation	Subject to BESTEST validation procedure			DOE-2 is subject to BESTEST validation procedure
Audience	Building designers, HVAC engineers, utility companies	Architects	Architects, engineers, energy analysts	Architects, architectural engineers
Customer support	Commercially available from SBIC		Available from the developer	
Price	$250	$250	$250 for professional license	free
Usage	2000+ as of 04/2002	600+ as of 03/1999	100+	unknown
Contact	Sustainable Buildings Industry Council Suite 1000 1331 H Street, NW Washington DC 20004 Tel: (202) 628-7400 ext 210 Fax: (202) 393-5043 Email: SBIC@SBICouncil.org Web: http://www.sbicouncil.org/	G. Z. Brown Energy Studies in Buildings Laboratory Department of Architecture University of Oregon Eugene, Oregon 97403 Tel: (541) 346-5647 Fax: (541) 346-3626 Email: GZBrown@aaa.uoregon.edu	Larry O. Degelman College of Architecture Texas A&M University College Station, Texas 77843 Tel: 409-845-1891 Fax: 409-862-1571 Email: larry@archone.tamu.edu Web: http://www.cox-internet.com/larryd/enerwin/	James J. Hirsch & Associates Email: Jeff.Hirsch@doe2.com Web: www.doe2.com

	EZDOE	FTIDOE	Green Building Studio	HAP
User interface	Text input file	Manu-driven input	Web-based	Windows-based graphical interface
CAD interface	no	no	yes	no
Ease of use				Requires training or extensive use to be proficient
Manuals	Online help	Basics manual	Online help, tutorials	User's manual and reference guide, online help
Computer Platform	MS DOS	Windows		Windows 95/98/ME./NT2000/XP
Expertise required	Basic familiarity with building geometry and HVAC systems is recommended			General knowledge of HVAC engineering principles
Input Flexibility	Up to 22 different air handling systems			100 plants, 250 systems, 1200 spaces, unlimited building elements fixed system configurations
Output capability	Numerical and graphical output of hourly or annual energy consumption and operation cost	Numerical and tabular output of the simulation results		Graphical and numerical output of design reports and hourly, daily, monthly or annual simulation reports
Functionality	Hourly calculation of energy consumption and operation cost, daylighting simulation included	Load calculation and system sizing, hourly building and system performance simulation as well as operating cost calculation		Load calculation, system sizing, hourly thermal and energy performance simulation, operating energy cost calculation
Technical approach	DOE-2.1D thermal simulation engine	DOE-2 simulation engine	DOE-2 thermal simulation engine	ASHRAE-endorsed transfer function methodology for load calculation, hour-by-hour thermal and energy simulation
Validation	DOE-2 is subject to BESTEST validation procedure	DOE-2 is subject to BESTEST validation procedure	DOE-2 is subject to BESTEST validation procedure	Comparison studies with DOE-2.1 yielded good correlation
Audience	Architects and architectural engineers	Architects and architectural engineers		architectural engineers, facility engineers, energy service consultants
Customer support		Available from the developer	Available from GeoPraxis, Inc.	Carrier factory support and training available
Price	$1250	$999	free	$1195 for first year and $240 thereafter
Usage	unknown	unknown	unknown	Approx. 5000 worldwide as of 07/2002
Contact	Elite Software P.O. Drawer 1194 Bryan, Texas 77806 Tel: 409-846-2340 Fax: 409-846-4367 Email: info@elitesoft.com Web: http://www.elitesoft.com	Finite Technologies Incorporated Tel: 907.337.2860 Fax: 907.333.4482 info@finite-tech.com http://www.finite-tech.com	John F. Kennedy GeoPraxis, Inc. Tel: 707.766.7010 Fax: 707.766.7014 Email: jfk@geopraxis.com Web: www.geopraxis.com	Software Systems Carrier Corporation Bldg TR-4 P.O. Box 4808 Syracuse, New York 13221 Tel: (315) 432-6838 Fax: (315) 432-6844 Email: software.systems@carrier.utc.com Web: http://www.carrier-commercial.com/software

	HBLC	PowerDOE	RIUSKA	TAS
User interface	Windows-based graphical interface	Graphical interface	Windows-based graphical interface	Windows-based graphical interface
CAD interface	no	yes	yes	yes
Ease of use		training is highly recommended by developer	default data libraries	Easy to use, No training courses are required
Manuals	Users manual, online help	Quick start guide, tutorial, online help		Users manual
Computer Platform	Windows 95/NT	DOS, UNIX, Windows	Windows 95/98/NT	Windows NT
Expertise required	Engineering background useful for analysis portions	training is highly recommended	Engineering background required to analyze calculation results.	General knowledge of architectural engineering and building design
Input Flexibility	Up to 50 thermal zones		The flexibility associated with DOE-2.1E	Unlimited number of zones, rooms and surfaces
Output capability	Heating and cooling load, sizing information, hourly energy consumption	Graphical and numeric outputs of schedules, peak loads, monthly and annual energy consumption	Numerical output of hourly and annual heating and cooling loads, energy consumption and temperature profile	Numerical and graphical output of any simulation parameter over any period of time
Functionality	Hourly simulation of building and system energy performance	Hourly simulation of thermal and energy performance	Hourly calculation of building and system energy performance	System sizing, Hourly simulation of heating and cooling demand, CFD, daylighting
Technical approach	BLAST simulation engine	DOE-2.2 simulation engine	DOE-2.1E thermal simulation engine	Hourly simulation of dynamic building and system performance
Validation	BLAST is subject to BESTEST validation procedure	DOE-2 is subject to BESTEST validation procedure	DOE-2 is subject to BESTEST validation procedure	Empirical validation using IEA test data
Audience	Mechanical and architectural engineers, researchers	engineers, energy consultants, and utility staff	architectural engineers	Building services engineers and architects
Customer support	Available from the developer	Available from the developer		Available from the developer
Price	$1500 for new installation	$278 for non-expiration license		UK$1600+
Usage	500+	unknown	About 20 in Finland	200+
Contact	Building Systems Laboratory University of Illinois 1206 West Green Street Urbana, Illinois 61801 Tel: 217-333-3977 Fax: 217-244-6534 Email: support@blast.bsouiuc.edu Web: http://www.bso.uiuc.edu	James J. Hirsch & Associates Email: Jeff.Hirsch@doe2.com Web: www.doe2.com	Tuomas Laine Olof Granlund Oy Malminkaari 21 P.O. Box 59 Helsinki, FIN-00701 Tel: +358 (9) 351031 Fax: +358 (9) 35103421 Email: Tuomas.Laine@granlund.fi	Alan M. Jones EDSL Ltd 13/14 Cofferidge Close Stony Stratford Milton Keynes, Mk11 1BY United Kingdom +44 (1908) 261 461 +44 (1908) 566 553 Email: info_edsl@csi.com Web: http://ourworld.compuserve.com/homepages/edsl

	TRACE 700	VisualDOE
User interface	Windows-based graphical interface	Graphical interface
Cad interface	no	yes
Ease of use	Formal training recommended for new users	Not as easy as eQUEST or Energy-10 (according to 21CR)
Manuals	Engineer's manual, online help, modeling guide	User's manual
Computer Platform	Windows 95/98/ME/NT/2000	Windows 95/98/NT/ME/2000/XP
Expertise required	Industry knowledge of HVAC equipment and systems	Basic experience with Windows software. Familiarity with building systems is recommended. One to two days of training also recommended
Input Flexibility	Unlimited rooms, systems, and building elements, fixed system configurations	Up to 1024 zones and 256 systems, analysis of up to 99 alternatives
Output capability	Graphical and numerical output of design parameters, hourly building temperature profiles and energy consumption, comparison of various alternatives	graphical comparison of design alternatives or selected parameters, standard DOE-2.1E numeric output, LEED style end-use report Life cycle cost analysis of design alternatives
Functionality	Load calculation, system sizing, comparison of up to 4 system design alternatives through hour-by-hour simulation, life-cycle cost calculation, daylighting analysis included, ASHRAE 90 analysis	Hour-by-hour simulation of thermal and energy performance as well as energy cost, daylighting analysis included, comparison of alternative designs 95% of DOE-2.1E's functions
Technical approach	Choose from 7 different ASHRAE load methodologies, Hourly calculation available, rectilinear surface model for daylighting	DOE-2.1E simulation engine
Validation	Comparison studies with DOE-2.1 yielded good correlation	DOE-2 is subject to BESTEST validation procedure
Audience	Engineers, architects, energy consultants and utility companies	architectural engineers and architects
Customer support	Free technical support from Trane factory, training available	Available from the developer
Price	$1995 for single license, $3990 for site/LAN license	$800 for single professional license
Usage	Approx. 1200 worldwide as of 05/2001	1000+ as of 08/2002
Contact	Trane C.D.S. Support Center Trane Company 3600 Pammel Creek Road La Crosse, Wisconsin 54601 Tel: (608) 787-3926 Fax: (608) 787-3005 Email: CDSHelp@trane.com Web: http://www.trane.com/commercial/software	Eley Associates 142 Minna Street, Second Floor San Francisco, California 94105 Tel: (415) 957-1977 Fax: (415) 957-1381 Email: support@eley.com Web: http://www.eley.com

Appendix 3. List of selected energy modeling tools for experimental evaluation

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
User interface	Intuitive 3D modeling interface	Windows-based graphical interface	Web-based	Graphical interface, schematic design wizard, design development wizard	Graphical interface
Cad interface	yes	yes	yes	yes	no
Ease of use	Easy (according to the developer)	Easy to use, No training courses are required		Easy (according to the developer)	Predefined building elements make the tool easy to use
Manuals	Tutorials, online help	Users manual	Online help, tutorials	Tutorials, online help	User's manual
Computer Platform	Windows 95/98/NT/2000/XP or Macintosh	Windows NT		Windows 95/98/ME/NT/2000/XP	Macintosh or Windows
Expertise required	CAD and environmental design experience useful but not essential	General knowledge of architectural engineering and building design		Understanding of basic concepts of building and HVAC system design	Understanding of basic concepts of energy design
Input Flexibility	Can deal with highly complex 3D models	Unlimited number of zones, rooms and surfaces		Only 3 floors could be defined (according to Charli_and_Mahabir_Overview_simulation_model.ppt)	Single zone, do not have HVAC systems, do not intend to be a building simulation program
Output capability	Graphic output of thermal, lighting, acoustic and cost results, export to RADIANCE, EnergyPlus, ESP-r etc.	Numerical and graphical output of any simulation parameter over any period of time		Graphic output of monthly and annual energy consumption by end use, graphic comparison of alternative designs, detailed numeric load, system, plant and economics reports	Graphic and numeric reports showing heat gain and loss by hour for each of the calculation days
Functionality	Hourly simulation of lighting, thermal and acoustic performance, discomfort level, resource management, daylighting analysis included	System sizing, hour-by-hour simulation of heating and cooling demand, CFD, daylighting		Hour-by-hour simulation of thermal and energy performance as well as energy cost, parametric runs, comparison of alternative designs	Loads analysis for 24 hours for each of 4 seasonal evaluation days, daylighting analysis included

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Technical approach	CIBSE Admittance Method for load calculation, hour-by-hour building and system thermal performance simulation	Hour-by-hour simulation of dynamic building and system performance	DOE-2 thermal simulation engine	DOE-2.2 simulation engine	Hourly calculation of 4 evaluation days
Validation	Undergoing	Empirical validation using IEA test data	DOE-2 is subject to BESTEST validation procedure	DOE-2 is subject to BESTEST validation procedure	
Audience	Architects, engineers, environmental consultants	Building services engineers and architects		Architects, architectural engineers	Architects
Customer support	Support forum maintained by the developer	Available from the developer	Available from GeoPraxis, Inc.		
Price	$650 for first professional license, $350 for education and $90 for student	UK$1600+	free	free	$250
Usage	2000+ as of 09/2002	200+	unknown	unknown	600+ as of 03/1999
Contact	Square One Research Pty Ltd c/o Center for Research in the Built Environment Cardiff University, Bute Building, Cardiff, Wales CF10 2NB, UK Tel: +44 (29) 2087 5977 Fax: +44 (29) 2087 4623 Email: sales@squ1.com Web: http://www.squ1.com	Alan M. Jones EDSL Ltd 13/14 Cofferidge Close Stony Stratford Milton Keynes, Mk11 1BY United Kingdom +44 (1908) 261 461 +44 (1908) 566 553 Email: info_edsl@csi.com Web: http://ourworld.compuserve.com /homepages/edsl	John F. Kennedy GeoPraxis, Inc. Tel: 707.766.7010 Fax: 707.766.7014 Email: jfk@geopraxis.com Web: www.geopraxis.com	James J. Hirsch & Associates Email: Jeff.Hirsch@doe2.com Web: www.doe2.com	G. Z. Brown Energy Studies in Buildings Laboratory Department of Architecture University of Oregon Eugene, Oregon 97403 Tel: (541) 346-5647 Fax: (541) 346-3626 Email: GZBrown@aaa.uoregon.edu

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming

Appendix 4a. Selected energy modeling tools: Matrix of features

I. SYSTEM					
Operating platform					
Windows	Yes	Yes	Yes	Yes	Yes (emulated Mac)
Mac OS	No	No	Yes	No	Yes
Unit system	SI and English	SI	SI and English	English	SI and English
Energy design guidance	No	No	No	Yes (general guidance available in tutorial)	Yes (specific advice in context of the building design, in text or audio format)
Built-in library*					
Weather data	Yes	Yes	Yes	Yes	Yes
Material	Yes	Yes	Yes	Yes	Yes
Construction	Yes	Yes	Yes	Yes	Yes
Schedule	No	Yes	Yes	Yes	Yes
Internal heat gain	No	Yes	Yes	Yes	Yes
Infiltration	No	Yes	Yes	Yes	Yes
HVAC system type	No	No (available in separate plug-in)	Yes	Yes	No
HVAC equipment	No	Yes	Yes	Yes	No
Simulation application					
Stand-alone	Yes	Yes	No	Yes	Yes
Web-powered	No	No	Yes (via Internet)	No	No

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Program stability	Moderate (Exception errors when working with multiple projects during single session. Program should be restarted when closing one project and opening another project)	Moderate (120MB file size limitation. Program unstable when a larger number of reports are requested)	Stable	Crash occasionally	Crash occasionally (beta version evaluated)
Weather file	Library and user definable	Library and user definable	According to zip code	According to geographical location (can be downloaded from doe-2.com ftp site by eQUEST)	No separate weather file, weather data is specified in input interface
Types of weather files	.wea (weather tool data)	.twd (TAS weather database)	Unsure	.bin file	N/A
History Tracking					
Undo/redo	Yes (single state undo/redo only)	Yes	No (available in CAD tool)	No	No
Error logging	Yes	Yes	Yes (runtime error message)	Yes (separate error log file)	Yes (runtime error message)

II. EXTENSION					
Interoperability					
IFC compliance	No	No	No	No	No
File exchange with other energy simulation tools	Yes (export of EnergyPlus, ESP-r file)	No	Yes (export of .inp and gbxml file, import of gbxml file is not visible to the user)	Yes (import of .inp file)	Yes (export of .doe2 file)
File exchange with CAD tools	Yes (Autodesk Architectural Desktop and 3D studio file)	No	Yes (.dwg from Autodesk Architectural Desktop, .pne from ArchiCAD, .rvt from Revit, unsure from Autodesk Building System. All CAD information is imported into GBS through SOAP and a gbXML file.)	No	No

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Drawing data input					
Import as underlay	Yes (AutoCad DXF, ASCII model, 3D studio, Stereo Lithography, Radiant Scene, HPGL plot, Ray, Analysis Grid files)	Yes (AutoCAD .dwg and dxf files)	No	Yes (AutoCAD .dwg files)	No (copy and paste drawings from other programs as underlay)
Building element import	Yes (AutoCad DXF, ASCII model, 3D studio, Stereo Lithography, Radiant Scene, HPGL plot, Ray, Analysis Grid files) - Element information not included)	No	Yes	No	No

III. FUNCTIONALITY					
Technical approach	CIBSE admittance method	TBD (Dynamic Simulation)	DOE-2.2 simulation engine	DOE 2.2 simulation engine	Hourly calculation of building load for 4 evaluation days
Types of energy calculation					
Building load calculation	Yes	Yes	Not visible in GBS result output. Available in gbxml file exported from GBS.	Not visible in eQUEST graphic result output. Available in detailed simulation output file.	Yes
Building energy simulation	No	No	Yes	Yes	No
Parametric operation					
Single run/single input and output	Yes	Yes	Yes	Yes	Yes
Batch Processing	No	Yes	No	Yes	No
Code compliance	Yes (UK Part-L)	Yes (UK Part-L)	No	Yes	No
Cost estimation	Yes (material cost and resource consumptions, energy cost not included)	No	Yes (annual energy cost and lifecycle operating cost)	Yes (monthly and annual energy cost, lifecycle cost)	No

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
IV. USER					
Documentation					
Tutorial/manuals/ wizard	Tutorial, some background of thermal analysis in help file and in html file and example/tutorial files	Separate help file and video tutorial	Tutorial for installation and basic usage in pdf and video format	Tutorial in pdf format, schematic design and design development wizards	User's manual in hard copy and pdf format
Engineering documentation	No	No	No	Yes (combined in tutorial)	Yes (combined in user's manual)
Help function	Yes (help menu, help topic, FAQ, balloon help)	No (in manager, menu list only in modeler in simulator)	Yes (help menu)	Yes (help menu and on-screen help)	No
User support	Yes (homepages, helpdesk, forum, online courses)	Yes (helpdesk, training)	Yes (inquiry and issues submission through website)	Unsure	Yes (by phone or email)
File save interval	Anytime	Anytime	Anytime	Anytime with the exception when the building creation wizard window is open	Anytime with the exceptioni of when a specification window is opened, in which case the user is prompted to close it
Navigation between windows	Flexible random	Flexible random	Flexible random	Flexible random	Flexible random
Clarity of menu and tool bars	Yes	Yes	Yes	Yes	Yes
Model view	Yes (2D and 3D)	Yes (2D and 3D)	No (view in VRML in external application)	Yes (2D and 3D)	Yes (2D)
Model display	Wireframe, Shaded, OpenGL and VRML	Wireframe and Shaded	VRML	Shaded	As pasted or drawn
Expertise required	General knowledge about building energy simulation and thermal analysis.	General knowledge about building energy simulation and thermal analysis.	Experience of 3D CAD tool (Autodesk Architectural Desktop, ArchiCAD, Revit, Autodesk Building System)	General knowledge about building energy simulation and thermal analysis. DOE-2 experience required in detailed data edit mode	General knowledge about building thermal analysis

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
V. MODELING					
Zone management	By zone management dialog	By zones and zone groups	By space list table	By activity area allocation, no information about the specific location in the building in schematic design wizard	By occupancy, lighting and equipment zones
a. PROJECT INFORMATION					
Building type definition	Yes (Domestic Dwelling, Commercial Residential, Office/Shop/Assembly, Industrial or Storage, Other) only used in the UK Part-L analysis	No (for project labeling only)	Yes (see appendix, links to default values)	Yes (see appendix, links to default values)	Yes (links to default values)
Space type definition	No (conventionally specified in zone management dialog as zone name)	No	Yes (see appendix, links to default values)	Yes (see appendix, links to default values)	No
b. BUILDING MODELING					
Geometry					
Space composition					
Build-up by spaces	Yes	Yes	No (done in CAD tool)	Yes	Yes
Subdivision of floor plate	Yes	Yes	No (done in CAD tool)	Yes	Yes
Direct drawing input					
Primitive shapes	No	No	No (done in CAD tool)	No	No
Extrusion based on closed curve	Yes	Yes	No (done in CAD tool)	Yes	No
Surfaces	Yes	No	No (done in CAD tool)	No	Yes

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Building element definition	Yes (void, roof, floor, ceiling, wall, partition, window, panel, door, point, speaker, light, appliance, solar collector, camera, line)	Yes (floor, building element and window)	No (Defined in the CAD input file)	No	Yes
Different heights within floor	Yes	Yes	Yes	Not available in wizard data edit mode, flexible in detailed data edit mode	Yes
Sloped roof	Yes	Yes	No (done in CAD tool)	Yes	Yes
Sloped floor	Yes	No	No (done in CAD tool)	No (except in detailed data edit mode)	No
Building orientation	Yes	Yes	Yes	Yes	Orientation of elevations and roof surfaces available
Accessible coordinate data	Yes (Cartesian coordinate and polar coordinate)	No	Not shown in the user interface, available in CAD tool and gbxml file exported from GBS	Yes	No
Snap function	Yes (snap to grid or object)	Yes (snap to overlay only)	No (available in CAD tool)	Yes (to overlay and grid)	No
Modification	Yes (transform(move, rotate, scale, mirror, extrude, revolve, spin), morph, link/unlink, group/ungroup)	Yes (delete, change alignment)	No (done in CAD tool)	Yes	Yes
Geometry checking	Yes	No	Yes	Unsure	No
Building construction					
Material	Selectable from the library and user definable	Selectable from the library and user definable	Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.	Selectable from the library, not editable and definable except in detailed data edit mode	Selectable from the library and user definable

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Layer	User definable	User definable	Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.	Selectable from the library, not editable and definable except in detailed data edit mode	Selectable from the library and user definable
Construction	Selectable from the library and user definable	Selectable from the library and user definable	Not visible, editable and definable by user. Visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.	Selectable from the library, not editable and definable except in detailed data edit mode	Selectable from the library and user definable
Shades	User definable	User definable	Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.	Selectable from the library, editable but not definable except in detailed data edit mode	Selectable from the library and user definable
Default values	No	No	Yes	Yes	Yes
Recommendation	No	No	Yes (according to building type and geographical location)	Yes (according to building type)	Yes (according to building type)
Internal loads					
Occupant					
Load					
Density	Yes (user definable)	Yes (user definable)	No	Yes (editable)	Yes (selectable from the library and user definable)

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Total Number of occupants	Yes	Yes	Yes (Not visible, editable and definable by user except in ABS. Visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes	No
Schedule	Yes (User definable)	Yes (Selectable from the library and user definable)	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (selectable from the library, not editable and definable except in detailed data edit mode)	Yes (user editable, occupied/unoccupied only, one schedule per day for all occupancy zones)
Lighting					
Load					
Density	Yes (User definable combined with Equipment Load)	Yes (User definable)	Yes (Not visible, editable and definable by user. Visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable)	Yes(selectable from the library and user definable)
Individual appliance	Yes (User definable)	Yes	Yes (Not visible, editable and definable by user except in ABS)	No	No
Schedule	Yes (User definable)	Yes (Selectable from the library and user definable)	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (selectable from the library, not editable and definable except in detailed data edit mode)	Yes (user editable, on/off only, one schedule per day for all lighting zones

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Equipment					
Load					
Density	Yes (User definable combined with Lighting Load)	Yes (User definable)	Yes (Not visible, editable and definable by user. Visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable)	Yes (selectable from the library and user definable)
Individual appliance	Yes	Yes	Yes (Not visible, editable and definable by user except in ABS)	No	Yes (selectable from the library and user definable)
Schedule	Yes (User definable)	Yes (Selectable from the library and user definable)	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (Selectable from the library, not editable and definable except in detailed data edit mode)	Yes (user editable, on/off only, one schedule per day for all equipment zones)
Default values	No	No	Yes	Yes	Yes
Recommendation	No	No	Yes (according to building type, location, floor area and ratio of surface to floor area)	Yes (according to building type and activity area type)	Yes (according to building type)
Infiltration					
Rate	Yes (User definable)	Yes (User definable)	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable)	Yes (selectable from the library and user definable)

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Schedule	Yes (User definable)	Yes (Selectable from the library and user definable)	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes	Yes (follows occupant schedule)
Default values	No	No	Yes	Yes	Yes
Recommendation	No	No	Yes (according to building type)	Yes	Unavailable in input process, available in design guidance advice
Utility					
Rate	Yes (for equipment only)	No	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (selectable from the library, and user definable)	No
Schedule	Yes (User definable)	No	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (selectable from the library, and user definable)	No
Default values	No	No	Yes	Yes (for California only)	No
Recommendation	No	No	Yes (according to building location)	Yes (according to climate zone and estimated peak electrical demand)	No

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
c. HVAC MODELING					
Thermostat setpoint	Yes	Yes	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable)	Yes
HVAC zoning	Yes (multi zones)	Yes (multi zones)	Yes (multi zones)	Yes (multi zones)	No
Relationship between HVAC zone and building space	HVAC zone same as the building space	One HVAC zone can have multiple spaces	HVAC zone same as the building space	HVAC zone different from building space	N/A
Zone Grouping	No	Yes	No	Yes	No
HVAC schedule	Yes (Fixed on/off timing for entire year)	Yes	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable)	No
Default values	No	No	Yes	Yes	No
Recommendation	No	No	Yes (according to building type)	Yes (according to building type)	No
Outside air requirement	No	No	Yes (Not visible, editable and definable by user except in ABS. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable)	Yes (selectable from the library and user definable)
Default values	N/A	N/A	Yes	Yes	Yes

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Recommendation			Yes (according to space type)	Yes (according to activity area type)	Unavailable in input process, available in design guidance advice
HVAC system	No	No	Yes (Not visible, editable and definable by user. Not visible to user in GBS result output. Accessible and editable in gbxml and DOE-2 files exported from GBS. Gbxml and DOE-2 files can not be imported into GBS by user.)	Yes (editable and user definable)	No
Default system	No	No	Yes	Yes	No
Recommendation	No	No	Yes (according to building type and floor area)	Yes (according to building type and heating/cooling source)	No
System sizing	No	No	Yes (Not visible in GBS result output)	Yes (Autosize available. Sizing info not visible in eQUEST report output)	No
VI. RESULT OUTPUT					
Output export	Yes (text, bitmap output)	Yes	No	No	No
Format of Report					
Numeric	Yes	Yes	Yes	Yes	Yes (total net heat flow and breakdown by building element)
Graphic	Yes	Yes	Yes	Yes	Yes (total net heat flow, breakdown of heat gains and losses by building element)
Tabulated data	Yes	Yes	Yes	Yes	Yes
Spreadsheet	No	No	No	No	No
Data visualization	Yes	Yes	No	No	Yes (with animation and sound effect)
Types of Report					
Single runs report	Yes	Yes	Yes	Yes	Yes

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Comparative runs report	No	No	No	Yes	No
Content of Report					
Parameter					
Temperature profile	Yes	Yes	No	No	No
Heat gain/loss	Yes (fabric, indirect solar, direct solar, ventilation, internal, inter-zonal gains)	Yes	Not visible in GBS result output. Available in gbxml file exported from GBS.	Not visible in eQUEST graphic result output. Available in detailed simulation output file.	Yes
Zone load	Yes	Yes	Not visible in GBS result output. Available in gbxml file exported from GBS.	Not visible in eQUEST graphic result output. Available in detailed simulation output file.	No
Building load	Yes	Yes	Not visible in GBS result output. Available in gbxml file exported from GBS.	Not visible in eQUEST graphic result output. Available in detailed simulation output file.	No
Building energy use	No	No	Yes	Yes	No
Breakdown of building energy use	No	No	Yes	Yes	No
Utility bills	Yes (equipment only)	No	Yes	Yes	No
Frequency					
Building lifecycle value	Yes	No	Yes (30 years)	Yes	No
Annual value	Yes	Yes	Yes	Yes	No
Monthly values	Yes	Yes	No	Yes	No
Daily values	Yes	Yes	No	No	Yes
Hourly values	Yes	Yes	No	No	Yes

	ECOTECT	TAS	Green Building Studio	eQUEST	Energy Scheming
Summary					
Total	Yes	Yes	Yes	Yes	Yes
Average	No	No	No	Yes	No
Peak	Yes	Yes	Yes	Yes	Yes

* Definition of *Built in Library* as a selection of specific cases with complete and realistic description of relevant input parameter

Building Types in GBS	**Space Types in GBS**		
Automotive facility	Active storage	Electrical or mechanical	Other televised playing area sports arena
Convention center	Active storage hospital or healthcare	Elevator lobbies	Parking area attendant only parking garage
Courthouse	Air or train or bus baggage area	Emergency hospital or healthcare	Parking area pedestrian parking garage
Dining bar lounge or leisure	Airport concourse	Equipment room manufacturing facility	Patient room hospital or healthcare
Dining cafeteria fast food	Atrium each additional floor	Exam or treatment hospital or healthcare	Personal services sales area retail
Dining family	Atrium first three floors	Exercise area exercise center	Pharmacy hospital or healthcare
Dormitory	Audience or seating area penitentiary	Exercise area gymnasium	Physical therapy hospital or healthcare
Exercise center	Audience or seating area exercise center	Exhibit space convention center	Playing area gymnasium
Fire station	Audience or seating area gymnasium	Fellowship hall religious buildings	Police station laboratory police or fire station
Gymnasium	Audience or seating area sports arena	Fine material warehouse	Public and staff lounge hospital or healthcare
Hospital or healthcare	Audience or seating area convention center	Fine merchandise sales area retail	Reading area library
Hotel	Audience or seating area motion picture theatre	Fire station engine room police or fire station	Reception or waiting transportation
Library	Audience or seating area performing arts theatre	Food preparation	Reception or waiting motel
Manufacturing	Audience or seating area religious	Garage service or repair automotive facility	Reception or waiting hotel
Motel	Audience or seating area police or fire stations	General high bay manufacturing facility	Recovery hospital or healthcare
Motion picture theatre	Audience or seating area courthouse	General low bay manufacturing facility	Restoration museum
Multi family	Audience or seating area auditorium	General exhibition museum	Restrooms
Museum	Bank customer area	Hospital nursery hospital or healthcare	Ring sports area sport arena
Office	Banking activity area office	Hospital or medical supplies hospital or healthcare	Sleeping quarters police or fire station
Parking garage	Barber and beauty parlor	Hospital or radiology hospital or healthcare	Sorting area post office
Penitentiary	Card file and cataloguing library	Hotel or conference center conference or meeting	Specialty store sales area retail
Performing arts theatre	Classroom or lecture or training penitentiary	Inactive storage	Stacks library
Police station	Classroom or lecture or training	Judges chambers court house	Stairs inactive
Post office	Confinement cells penitentiary	Laboratory office	Stairway
Religious building	Confinement cells court house	Laundry ironing and sorting	Supermarket sales area retail
Retail	Conference meeting or multipurpose	Laundry washing hospital or healthcare	Terminal ticket counter transportation
School or university	Corridor or transition	Library audio visual library audio visual	Workshop workshop
Sports arena	Corridor or transition manufacturing	Living quarters dormitory	Worship pulpit choir religious
Town hall	Corridors with patient waiting exam hospital or healthcare	Living quarters motel	
Transportation	Court sports area sports arena	Living quarters hotel	
Warehouse	Courtroom court house	Lobby	
Workshop	Department store sales area retail	Lobby religious buildings	
	Detailed manufacturing facility	Lobby motion picture theatre	
	Dining area	Lobby auditorium	
	Dining area hotel	Lobby performing arts theatre	
	Dining area family dining	Lobby post office	
	Dining area lounge or leisure dining	Lobby hotel	
	Dining area motel	Lounge or recreation	
	Dining area transportation	Mall concourse sales area retail	
	Dining area penitentiary	Mass merchandising sales area retail	
	Dining area civil services	Medium or bulky material warehouse	
	Dormitory bedroom		

	Dormitory study hall Dressing or locker or fitting room gymnasium Dressing or locker or fitting room court house Dressing or locker or fitting room performing arts theatre Dressing or locker or fitting room auditorium Dressing or locker or fitting room exercise center	Merchandising sales area retail Museum and gallery storage Nurse station hospital or healthcare Office enclosed Office open plan Office common activity areas inactive storage Operating room hospital or healthcare	

Building Types in eQUEST	**Activity Area Types in eQUEST**
Community center	Auditorium
Conference/convention center	Auto repair workshop
Health/fitness center	Bank/financial institution
Heath, hospital (inpatient)	Bar, cocktail lounge
Health, long-term care (nursing home)	Barber and beauty shop
Health, medical clinic/prof. building (outpatient)	Casino/gaming
Lodging, motel	Classroom/lecture
Lodging, high-rise hotel	Courtroom
Multifamily, low-rise (exterior entries)	Comm/ind work (general, high bay)
Multifamily, mid-rise (interior entries)	Comm/ind work (general, low bay)
Multifamily, high-rise (interior entries)	Comm/ind work (precision)
Museum	Conference room
Office bldg, high-rise	Convention and meeting center
Office bldg, mid-rise	Copy room (photocopying equipment)
Office bldg, two story	Corridor
Office bldg, bank/financial	Dining area
Religious worship	Dry cleaning (coin operated)
Restaurant, full service (full menu)	Dry cleaning (full service commercial)
Restaurant, quick service (fast food)	Exercising centers and gymnasium
Restaurant, bar/lounge	Exhibit display area/museum
Retail, department store	Hotel/motel guest room (incl. toilets)
Retail, large single story	Kitchen and food preparation
Retail, stand-alone structure	Laboratory, medical
Retail, single storefront	Laundry
Retail, strip mall	Library (reading areas)
Retail, service station	Library (stacks)
Retail, service station/convenience store	Lobby (hotel)
Retail, warehouse sales	Lobby (main entry and assembly)
School, preschool/daycare	Lobby (office reception/waiting)
School, k-6 elementary	Locker and dressing room
School, middle school	Mall, arcade and atrium
School, college/university	Mechanical/electrical room
Storage, conditioned high bay	Medical and clinical care
Storage, unconditioned high bay	Office (general)
Storage, conditioned low bay	Office (executive/private)

Storage, unconditioned low bay Theater/performing arts Unknown, custom or mixed use	Office (open plan) Police station and fire station Religious worship Residential (high-rise) Residential (multifamily dwelling unit) Residential (single family) Restrooms Retail sales and wholesale showroom Smoking lounge Storage (conditioned) Storage (unconditioned) Theater (motion picture) Theater (performance) Vocational areas Unknown

Appendix 4b. Definition of items in the Evaluation Matrix

Item	Description
I. SYSTEM	
Operating platform	
Windows	Tool operates within Windows environment without additional software or emulators
Mac OS	Tool operates within Macintosh environment without additional software or emulators
Unit system	Measurement units used by the tool
Energy design guidance	Assistance in conducting energy simulations, such as guidance on simulation workflow and appropriate modeling methods
Built-in library **Weather data** **Material** **Construction** **Schedule** **Internal heat gain** **Infiltration** **HVAC system type** **HVAC equipment**	Availability of selection of specific cases with complete and realistic description of relevant input parameter
Simulation application	
Stand-alone	Simulation conducted on local workstation
Web-powered	Simulation conducted on off site server via network
Program stability	The ability of the tool to continue operations and maintain correctness under an amplitude of input changes
Weather file	Method used to select climatic data
Types of weather files	Format of climatic data used
History Tracking	
Undo/redo	The tool keeps track of states allowing the feature of redo and undo
Error logging	The tool maintains an error log upon failures

Item	Description
II. EXTENSION	
Interoperability	
IFC compliance	The tool allows import / export of data in IFC format without additional software
File exchange with other energy simulation tools	The tool allows import / export of complete energy model data with other simulation tools without additional software or intervention
File exchange with CAD tools	The tool allows import / export of complete geometric data with CAD systems without additional software or intervention
Drawing data input	
Import as underlay	The tool allows import of 2D drawings from CAD systems to facilitate geometric modeling
Building element import	The tool allows import of 3D elements from CAD systems to facilitate geometric modeling

III. FUNCTIONALITY	
Technical approach	Simulation engine used by the tool
Types of energy calculation	
Building load calculation	Calculation of building heating, cooling and electricity load
Building energy simulation	Calculation of energy consumption by the various equipment in the mechanical system, in order to meet the building heating, cooling and electricity load
Parametric operation	
Single run/single input and output	Tool allows simulation of a model and presents the results
Batch Processing	Tool allows queuing of multiple models for simulation
Code compliance	Tool includes features to consider if the results of the energy models comply with regulations
Cost estimation	Tool includes features to estimate the costs related to the building that is being modeled

Item	**Description**
IV. USER	
Documentation	
Tutorial / manuals / wizard	Types of documentation available to assist in learning how to use the tool and understanding the workflow
Engineering documentation	Technical documentation explaining the computational processes, methods and assumptions used by the tool
Help function	Integrated help feature by button, keystroke or menu to assist in using the tool interface and explaining the workflow
User support	Types of resources available to users in learning the tool
File save interval	Restrictions on when the user can invoke the save command
Navigation between windows	Restrictions on the user to toggle between different windows: Flexible – Tool allows user to toggle between windows in no particular sequence Random – Tool allows user to toggle between any two windows
Clarity of menu and tool bars	The organization and naming of the menu and tool bars are with clarity
Model view	Allows user to view the energy model geometrically
Model display	Shading methods available when viewing the energy model
Expertise required	General expertise required of user to use the tool effectively

V. MODELING	
Zone management	Method used to manage the thermal zones in the energy model
a. PROJECT INFORMATION	
Building type definition	Tool allows user specification of building type to check, modify or recommend various parameter settings
Space type definition	Tool allows user specification of space type to check, modify or recommend various parameter settings

Item	Description
b. BUILDING MODELING	
Geometry	
Space composition	
Build-up by spaces	Tool allows geometric model to be constructed additively
Subdivision of floor plate	Tool allows modeled elements to be subdivided
Direct drawing input	
Primitive shapes	Tool allows modeling by selecting basic forms Boolean operations
Extrusion based on closed curve	Tool allows modeling by drawing profiles and extruding
Surfaces	Tool allows modeling by constructing surfaces
Building element definition	Tool allows specification and modification of individual elements as various building element types
Different heights within floor	Tool allows different spaces on the same level of the model to have different floor to ceiling heights
Sloped roof	Tool allows the modeling of sloped roofs
Sloped floor	Tool allows the modeling of sloped floors
Building orientation	Tool allows the north direction to be modified via a single orientation parameter
Accessible coordinate data	Tool shows the dimensions of each element and allows them to be changed by direct numerical input
Snap function	Tool provides modeling snap-to-point features
Modification	Tool allows modeled elements to be transformed geometrically
Geometry checking	Tool provides features to check that the geometric model has been constructed properly
Building construction	
Material	Notes on how the tool allows the user to define materials
Layer	Notes on how the tool allows the user to define layers
Construction	Notes on how the tool allows the user to define constructions
Shades	Notes on how the tool allows the user to model sun shading devices
Default values	Tool specifies some realistic default construction properties for building elements based on some project information such as type of building or space being modeled
Recommendations	Tool makes recommendations for construction types and material values based on some project information such as type of building or space being modeled

Item	Description
Internal loads	
Occupant	
Load	
Density	Tool allows variation of occupancy density across different spaces
Total Number of occupants	Tool allows specification and modification of number of occupants
Schedule	Tool allows specification of a schedule for occupancy
Lighting	
Load	
Density	Tool allows variation of lighting loads across different spaces
Individual appliance	Tool allows specification of individual light appliances within each space
Schedule	Tool allows specification of a schedule for lighting loads
Equipment	
Load	
Density	Tool allows variation of equipment loads across different spaces
Individual appliance	Tool allows specification of individual electrical appliances within each space
Schedule	Tool allows specification of a schedule for electrical loads
Default values	Tool specifies some realistic default internal loads conditions based on the type of building or space being modeled
Recommendations	Tool makes recommendations for internal load conditions based on some project information such as type of building or space being modeled
Infiltration	
Rate	Tool allows specification of infiltration rates
Schedule	Tool allows specification of a schedule for infiltration
Default values	Tool specifies some realistic default infiltration conditions based on the type of building or space being modeled
Recommendations	Tool makes recommendations for infiltration conditions based on some project information such as type of building or space being modeled
Utility	
Rate	Tool allows specification of utility rates
Schedule	Tool allows specification of a schedule utility rates
Default values	Tool specifies some realistic default utility rates based on some project information such as type of building being modeled or location of building
Recommendations	Tool makes recommendations for infiltration conditions based on some project information such as type of building being modeled or location of building

Item	Description
c. HVAC MODELING	
Thermostat set point	Tool allows specification of heating and cooling set points for each zone in the HVAC system
HVAC zoning	Tool allows specification of HVAC zones from the spaces defined by the geometric building model
Relationship between HVAC zone and building space	Relationship between HVAC zones and spaces defined by the geometric building model
Zone Grouping	Tool allows several zones to be grouped in a hierarchical manner
HVAC schedule	Tool allows specification of a schedule for HVAC operations
Default values	Tool specifies some realistic default HVAC schedules based on some project information such as type of building or space being modeled
Recommendations	Tool makes recommendations for HVAC scheduling based on some project information such as type of building or space being modeled
Outside air requirement	Tool allows specification of outside air requirements as part of HVAC system
Default values	Tool specifies some realistic default outside air requirements based on some project information such as type of building or occupancy being modeled
Recommendations	Tool makes recommendations for outside air requirements based on some project information such as type of building or occupancy being modeled
HVAC system	Tool allows specification of the type of HVAC system
Default system	Tool specifies some realistic default HVAC system based on some project information such as type of building being modeled
Recommendations	Tool makes recommendations for HVAC system based on some project information such as type of building being modeled
System sizing	Tool includes feature to size the HVAC system accordingly

VI. RESULT OUTPUT	
Output export	Tool allows simulation results to be exported for processing in other spreadsheet or analysis applications
Format of Report	
Numeric	Tool produces numerical reports of simulation results
Graphic	Tool produces graphical reports of simulation results
Tabulated data	Tool produces tabular reports of simulation results
Spreadsheet	Tool produces spreadsheets from simulation results
Data visualization	Tool includes some features of presenting the data in visuals that assist in understanding the thermal performance predicted by simulation
Types of Report	
Single runs report	Tool produces reports for a single simulation
Comparative runs report	Tool presents results from multiple simulations on a single report for comparison
Content of Report	
Parameter	
Temperature profile	Report on outdoor mean air temperature and mean space temperature for all spaces
Heat gain/loss	Report on heat gain / loss for all spaces
Zone load	Report on all zone loads
Building load	Report on building load
Building energy use	Report on active building energy use
Breakdown of building energy use	Report on active building energy use breakdown
Utility bills	Report on building utility bills
Frequency	
Building lifecycle value	Reports presented over lifecycle of building with appropriate time values
Annual value	Reports presented as cumulative annual values
Monthly values	Reports presented as 12 monthly values
Daily values	Reports presented as 365 daily values
Hourly values	Reports presented as 8760 hourly values
Summary	
Total	Reports includes a total value
Average	Reports includes an averaged values
Peak	Reports indicates maximum and minimum value occurrences

Appendix 5a. Hypothetical building for experimental testing of energy modeling in early design phase

Figure 1

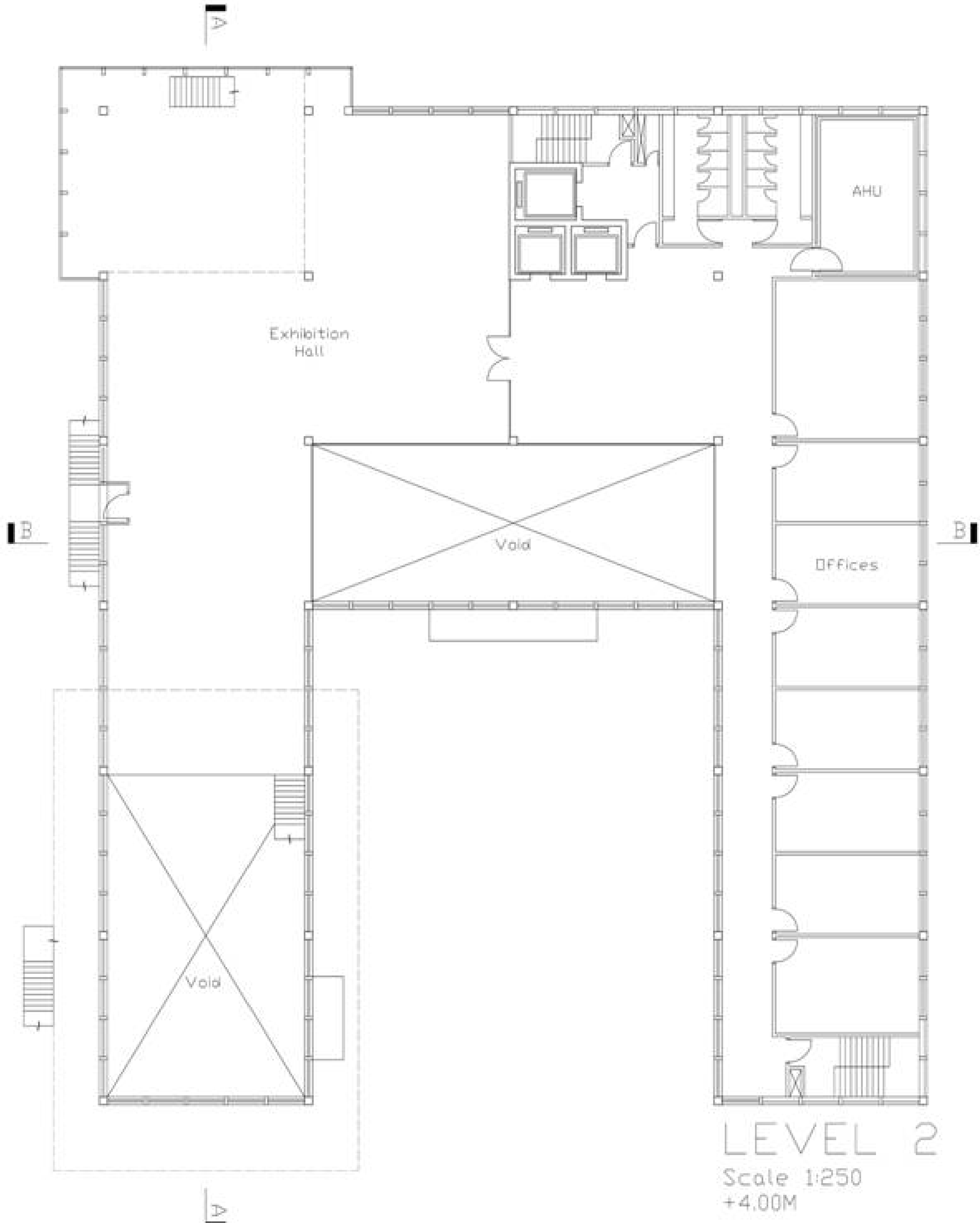


Figure 2

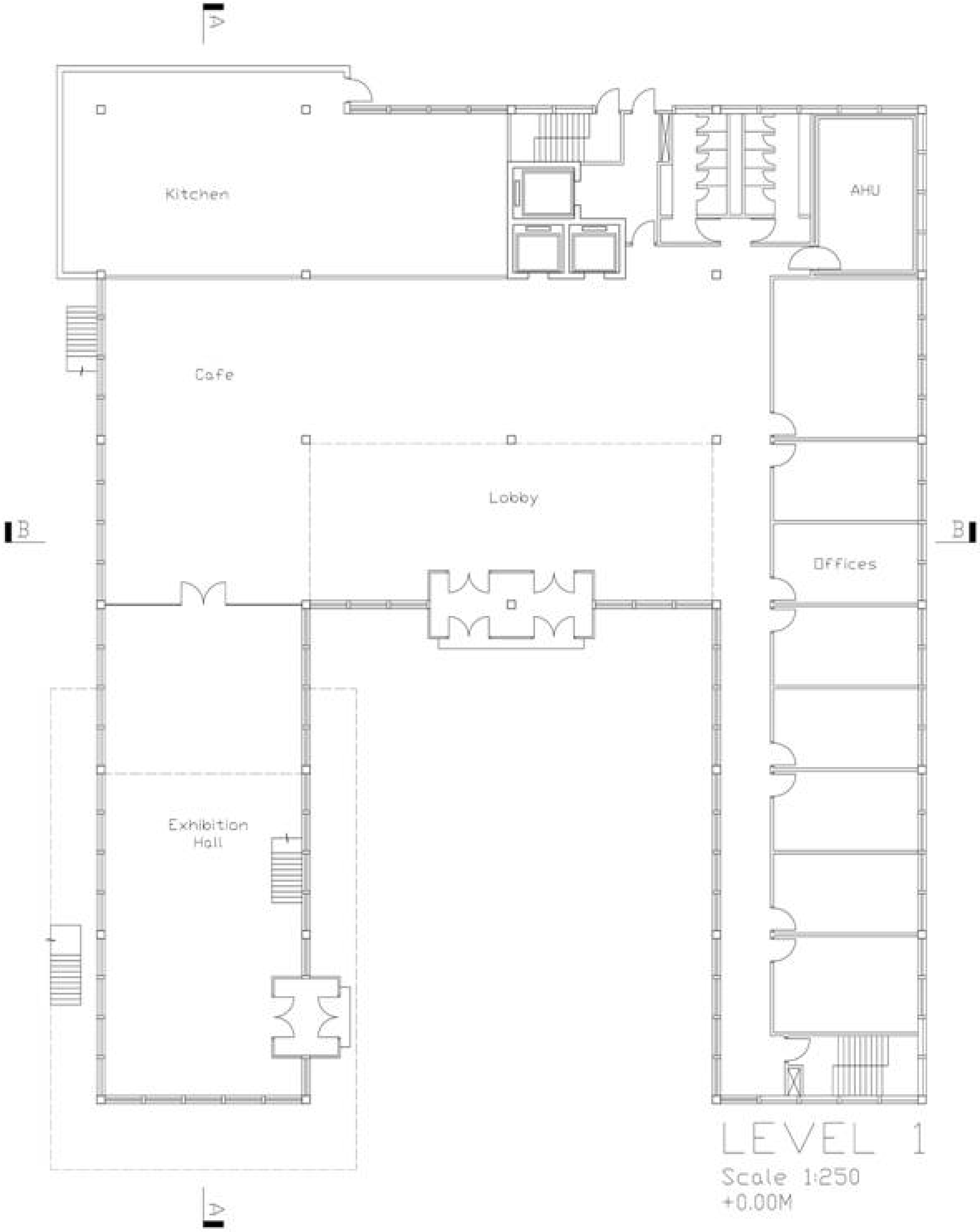

A
Kitchen
AHU
Cafe
Lobby
B
B
Offices
Exhibition
Hall
LEVEL 1
Scale 1:250
+0.00M
A

Figure 3

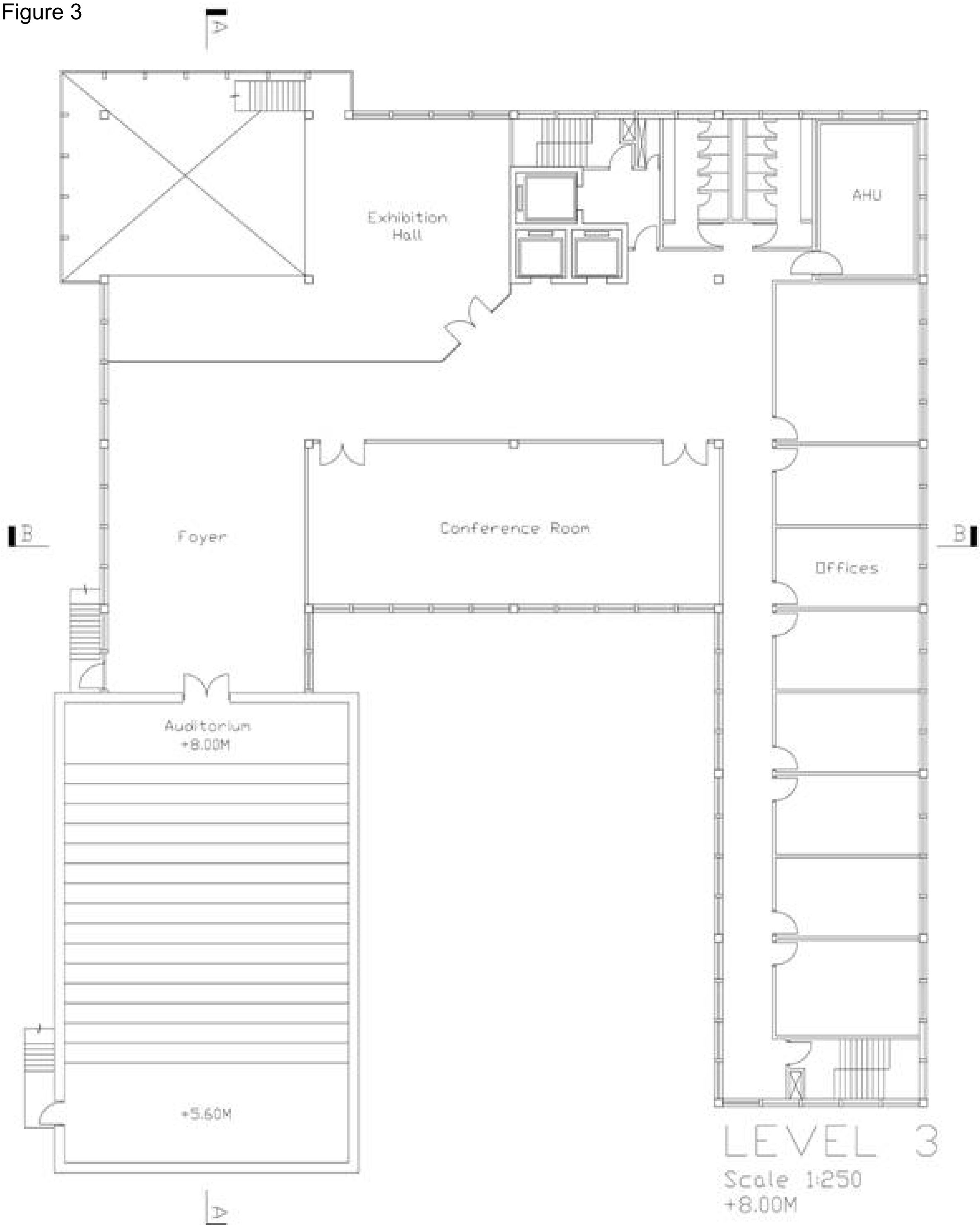

A
Exhibition Hall
AHU
B
Foyer
Conference Room
Offices
B
Auditorium +8.00M
+5.60M
LEVEL 3
Scale 1:250
+8.00M
A

Figure 4

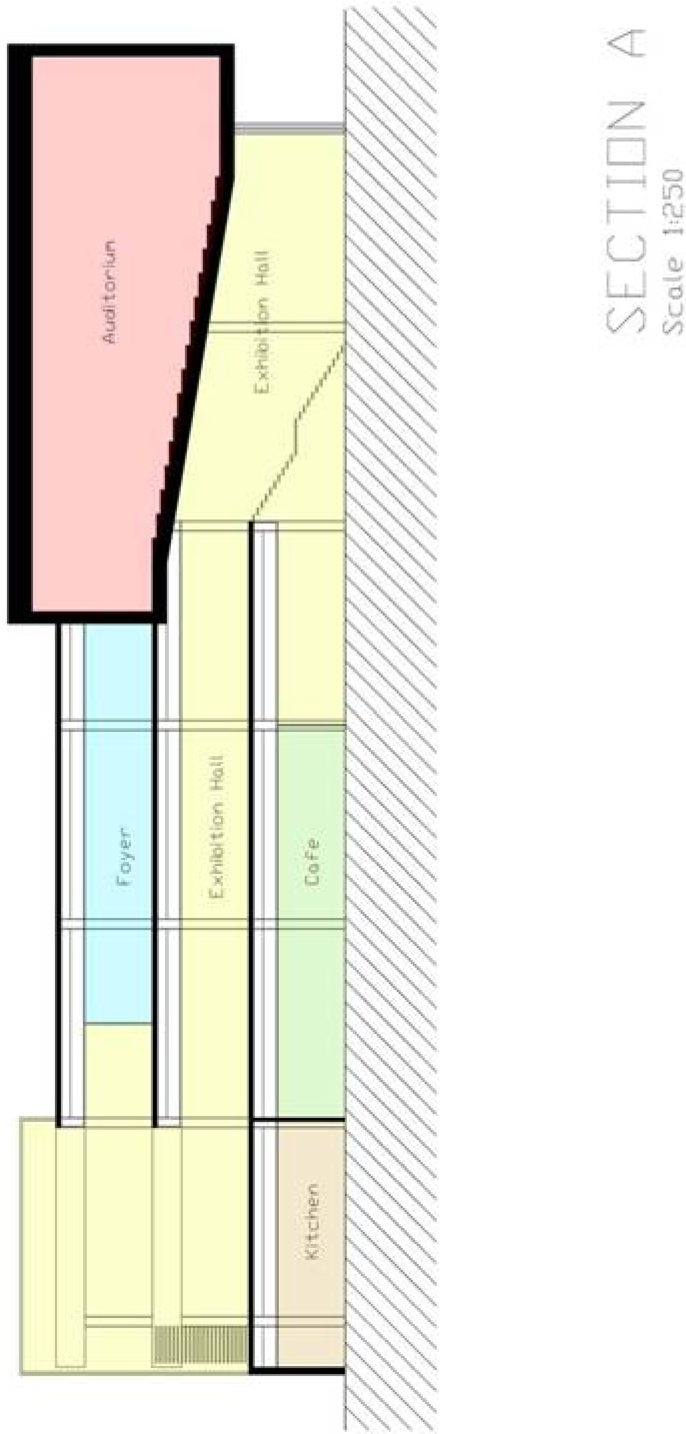
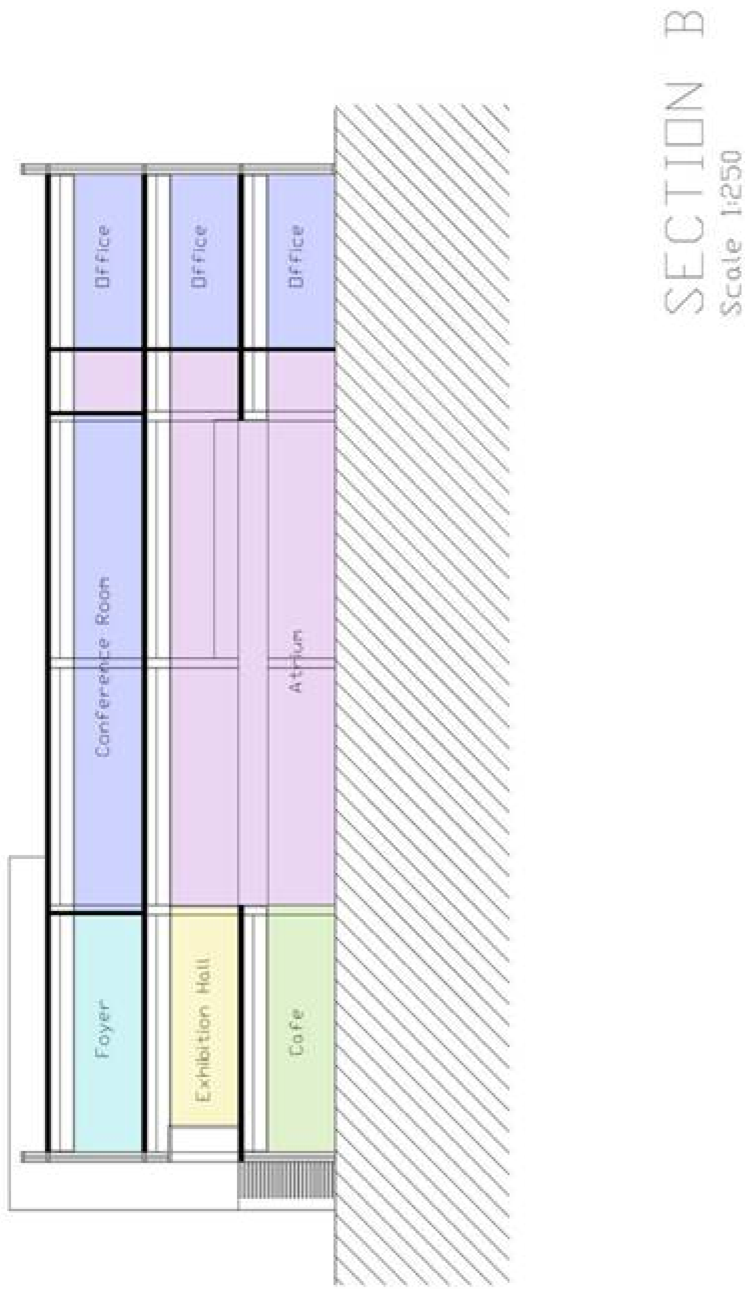

SECTION A
Scale 1:250
Auditorium
Exhibition Hall
Foyer
Exhibition Hall
Cafe
Kitchen

Figure 5


SECTION B
Scale 1:250
Office
Office
Office
Conference Room
Atrium
Foyer
Exhibition Hall
Cafe

Appendix 5b. Input parameter assumptions in the experimental testing of energy modeling

Construction	Material	Thickness(m)	Conductivity (W/m-K)	Density (kg/m3)	Specific Heat (kJ/kg-K)	Resistance (m2-K/W)
Ext_Wall	Half_Brick	0.1016	1.3	2080	920	0.08
	Extruded Polystyrene	0.0762	0.029	40	1220	2.63
	Half_Brick	0.1016	1.3	2080	920	0.08
	Gypsum Board	0.0127	0.16	800	1090	0.08
Int_Wall	Gypsum Board	0.0127	0.16	800	1090	0.08
	Air Space	0.0762				0.65
	Gypsum Board	0.0127	0.16	800	1090	0.08
Roof	Asphalt_Shingle	0.0127	0.74	1100	1510	0.02
	Bitumen_Paper	0.003175	0.06	1090	1000	0.05
	Polyuretherane	0.1016	0.025	24	1590	4.06
	Concrete	0.1016	1.73	2240	840	0.06
Floor_Slab	Cement_FiberSlab	0.0508	0.082	350	1300	0.62
	Concrete	0.1016	1.73	2240	840	0.06
	Screed	0.0127	1.4	2100	650	0.01
	Carpet	0.00635	0.055	240	732	0.12
Int_Floor	Concrete	0.1016	1.73	2240	840	0.06
	Screed	0.0127	1.4	2100	650	0.01
	Carpet	0.00635	0.055	240	732	0.12
Int_Floor_ME	Concrete	0.1016	1.73	2240	840	0.06
	Screed	0.0127	1.4	2100	650	0.01
Ceiling	Acoustical_Tile	0.0254	0.053	340	800	0.48
Windows	ClearGlass	0.006	0.9			

	Area (m2)	People		Lighting		Equipment		Infiltration (ACH)	
		Design Level	Schedule	Design Level (W/m2)	Schedule	Design Level (W/m2)	Schedule	Rate (ACH)	Schedule
L1 Stairs	26	0		7.5	ALL HOURS	0.0	ALL HOURS	0.2	ALL HOURS
L2 Stairs	26	0		7.5	ALL HOURS	0.0	ALL HOURS	0.2	ALL HOURS
L3 Stairs	26	0		7.5	ALL HOURS	0.0	ALL HOURS	0.2	ALL HOURS
L1 Office	295	20	OFFICE HOURS	14.0	OFFICE HOURS	21.5	OFFICE HOURS	0.2	NON OFFICE HOURS
L2 Office	295	20	OFFICE HOURS	14.0	OFFICE HOURS	21.5	OFFICE HOURS	0.2	NON OFFICE HOURS
L3 Office	295	20	OFFICE HOURS	14.0	OFFICE HOURS	21.5	OFFICE HOURS	0.2	NON OFFICE HOURS
L1 ME	49	0		7.5	OFFICE HOURS	1.1	OFFICE HOURS	0.2	ALL HOURS
L2 ME	49	0		7.5	OFFICE HOURS	1.1	OFFICE HOURS	0.2	ALL HOURS
L3 ME	49	0		7.5	OFFICE HOURS	1.1	OFFICE HOURS	0.2	ALL HOURS
L1 Service	132	0		7.5	OFFICE HOURS	1.1	OFFICE HOURS	0.2	ALL HOURS
L2 Service	132	0		7.5	OFFICE HOURS	1.1	OFFICE HOURS	0.2	ALL HOURS
L3 Service	132	0		7.5	OFFICE HOURS	1.1	OFFICE HOURS	0.2	ALL HOURS
L1 Kitchen	234	10	OFFICE HOURS	23.7	OFFICE HOURS	21.5	OFFICE HOURS	0.2	NON OFFICE HOURS
Exhibition	833	60	OFFICE HOURS	17.2	OFFICE HOURS	10.8	OFFICE HOURS	0.2	NON OFFICE HOURS
L1 Lobby	627	10	OFFICE HOURS	14.0	OFFICE / REDUCED	2.2	OFFICE / REDUCED	0.2	NON OFFICE HOURS
L2 Corr	204	0		14.0	OFFICE / REDUCED	2.2	OFFICE / REDUCED	0.2	NON OFFICE HOURS
L3 Atrium	419	0		14.0	OFFICE / REDUCED	2.2	OFFICE / REDUCED	0.2	NON OFFICE HOURS
Auditorium	367	150	AUDITORIUM	17.2	AUDITORIUM	10.8	AUDITORIUM	0.2	NON OFFICE HOURS
Conference	166	20	CONFERENCE	14.0	CONFERENCE	10.8	CONFERENCE	0.2	NON OFFICE HOURS

hour	OFFICE HOURS Mon-Fri	ALL HOURS Mon-Sun	OFFICE / REDUCED Mon-Fri	AUDITORIUM Mon, Thu	CONFERENCE Mon, Wed	NON OFFICE HOURS Mon-Fri
1	0	1	0.6	0	0	1
2	0	1	0.6	0	0	1
3	0	1	0.6	0	0	1
4	0	1	0.6	0	0	1
5	0	1	0.6	0	0	1
6	0	1	0.6	0	0	1
7	0	1	0.6	0	0	1
8	0	1	0.6	0	0	1
9	0	1	0.6	0	0	1
10	1	1	1	1	1	0
11	1	1	1	1	1	0
12	1	1	1	0	1	0
13	1	1	1	0	0	0
14	1	1	1	0	0	0
15	1	1	1	1	0	0
16	1	1	1	1	0	0
17	1	1	1	0	0	0
18	0	1	0.6	0	0	1
19	0	1	0.6	0	0	1
20	0	1	0.6	0	0	1
21	0	1	0.6	0	0	1
22	0	1	0.6	0	0	1
23	0	1	0.6	0	0	1
24	0	1	0.6	0	0	1

Appendix 6. Comparison of simulation results from five selected tools with EnergyPlus

U-Values of Construction

		Ecotect	TAS	eQUEST	EnergyScheming	GBS	E+	E+
Concrete Slab On Ground	2 Inch Cement Fiber Slab, 4 Inch Concrete Slab, 1/2 Inch Screed and 1/4 Inch Carpet on Inside.	1.02	0.394	1.08	Report Not Available	Report Not Available	Report Not Available	Report Not Available
Concrete Floor Suspended	4 Inch Concrete Slab, 1/2 Inch Screed and 1/4 Inch Carpet on Inside.	2.75	4.223	Non-Conditioned Spaces Not Modeled	Report Not Available	Report Not Available	Report Not Available	Report Not Available
Concrete Floor Carpeted Suspended	4 Inch Concrete Slab, 1/2 Inch Screed on Inside.	4.04	1.06	3.31	Report Not Available	Report Not Available	Report Not Available	Report Not Available
External Wall	4 Inch brick, 3 Inch Extruded Polystyrene, 4 Inch brick with 1/2 Inch Gypsum Board inside.	2.03	0.33	0.34	Report Not Available	Report Not Available	Report Not Available	Report Not Available
Internal Wall	1/2 Inch Gypsum Board, 3 Inch Air Space and 1/2 Inch Gypsum Board.	0.3	1.04	1.07	Report Not Available	Report Not Available	Report Not Available	Report Not Available
Single Glazed Aluminum Frame	Single pane of glass with aluminum frame (no thermal break).	6	5.66	Report Not Available	Report Not Available	Report Not Available	Report Not Available	Report Not Available
Concrete Roof Asphalt Shingles	1/2 Inch Asphalt Shingles, 1/8 Inch Bitumen Paper, 4 Inch Polyuretherane, 4 Inch Concrete on inside.	0.23	0.23	0.23	Report Not Available	Report Not Available	Report Not Available	Report Not Available

Internal Loads

		Ecotect	TAS	eQUEST	EnergyScheming	GBS	E+	E+
Occupancy	310 Occupants according to specific distribution in the various zones	v	v	v	v	388 Occupants (Default settings, no distribution data)	v	v
Occupancy Schedule	Different schedules for offices, auditorium and conference zones	v	v	v	Single Schedule applied to entire building	Not Available	v	v

Heat Gains	209451 W of equipment and lighting loads according to specific distribution in the various zones	v	v	v	v	175755W (Default settings, no distribution data)	v	v
Heat Gains Schedule	Different schedules for offices, service areas, common areas, auditorium and conference zones	v	v	v	Single Schedule applied to entire building	Not Available	v	v
Infiltration	0.2 ACH	v	v	v	v	Not Available	v	v
Infiltration Schedule	Different schedules for functional and service zones	v	v	v	Single Schedule applied to entire building	Not Available	v	v
HVAC	18 ºC Heating Setpoint and 25 ºC Cooling Setpoint, 5 ºC Setback during non occupancy hours	Single Thermostat without setback settings	Single Thermostat without setback settings	v	Single Thermostat without setback settings	Not Available	v	Single Thermostat without setback settings
HVAC Schedule	Office hours schedule	v	v	v	Single Schedule applied to entire building	Not Available	v	v

Heating / Cooling Loads

	Ecotect	**TAS**	**eQUEST**	**EnergyScheming**	**GBS**	**E+** (with setback)	**E+** (w/o setback)
Annual Heating Load (kWh)	78966	75864	326464	Graphical Report of Total Net Heat Flow	75901 *	**218530**	**70005**
Annual Cooling Load (kWh)	231771	234703	538343		735276 *	**324020**	**277597**

(with respect to appropriate E+ simulation)

	Ecotect	TAS	eQUEST	EnergyScheming	GBS
Heating Load Difference (%)	13%	8%	49%	NA	8% *
Cooling Load Difference (%)	-17%	-15%	66%	NA	165% *

Annual Utility Cost

Ecotect	**TAS**	**eQUEST**	**EnergyScheming**	**GBS**	**E+**	**E+**
Not Available	Not Available	Not Available	Not Available	$101,066	Not Available	Not Available

* GBS Heating and Cooling Loads obtained by exporting energy model to DOE2 format and conducting the simulation using eQUEST. Assumptions made by GBS were not modified.

Appendix 7a. Energy Modeling Tools Survey Questionnaire

Last Name: First Name

Ages : ☐ 20-30 ☐ 30-40 ☐ 40-50 ☐ over 50 Gender ☐ M ☐ F

Organization Name :

A. Background Information

1. What is your job title?

____

2. What is your primary responsibility in your organization?

____

3. If you are interested in building energy simulation, please indicate which aspect(s)

Design Exploration
- ☐ Building Geometry
- ☐ Materials Selection
- ☐ HVAC System sizing

Design Verification
- ☐ LEED Certification
- ☐ Verifying code compliance

Other(please specify)

4. Do you have any experience with building energy simulation? ☐ Yes ☐ No

If yes, please answer the following questions.

4-1 What energy simulation tools have you used?

____

4-2 What simulation tools are you currently using?

____

4-3 How long have you been involved in energy simulation modeling?

☐ No experience ☐ Less than 1 year ☐ 1-2 years ☐ 3-5 years If more than 5, please state years ______________.

4-4 Approximately, how many building energy simulation models have you created/built?

☐ No experience ☐ Less than 5 ☐ 5-20 ☐ more than 20

4-5 Approximately, what percentage of your work time do you spend in building energy simulations?

☐ Not at all ☐ 1~10% ☐ 10~20 % ☐ 20 ~ 30% ☐ more than 30%

4-6 In what stages do you normally use building energy simulation tools?

☐ Schematic Design ☐ Design Development ☐ Final Design Others:____________________.

5. What CAD software are you currently using?

____

B. General Impression of the Energy Simulation Tool

For the energy simulation tool you used for this project, please check one box in each row.

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
6. The energy simulation tool is easy to learn.	☐	☐	☐	☐	☐
7. The energy simulation tool is easy to use once familiar with it.	☐	☐	☐	☐	☐
8. The simulation tool has good graphic user interfaces.	☐	☐	☐	☐	☐
9. The simulation tool is easy to create a building model.	☐	☐	☐	☐	☐
10. The simulation tool is easy to edit/modify the building model.	☐	☐	☐	☐	☐
11. The simulation tool provides good result reports.	☐	☐	☐	☐	☐
12. The simulation tool has a good help menu.	☐	☐	☐	☐	☐

C. Specifications

System

13. Does this simulation tool have a History Tracking? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

Extension

14. Is this simulation tool IFC compliant? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

15. Is this simulation tool able to import model input files from other simulation tools? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

16. Is this simulation tool able to export model input files to other simulation tools? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

17. Is this simulation tool able to import model input file from CAD tools? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

18. Is this simulation tool able to export model input file to CAD tools? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

Functionality

19. Is this simulation tool able to conduct parametric studies? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

20. Does this simulation tool have code compliance functions? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

21. Does this simulation tool have energy cost estimation functions? ☐ *Yes* ☐ *No* ☐ *I don't Know*

Strongly *Disagree* *Neutral* *Agree* *Strongly*

	disagree				agree
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

22. Does this simulation tool have real time network collaborative functions in geographically distributed environments? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This function is important in energy simulation modeling.	☐	☐	☐	☐	☐

USER

23. Does this simulation tool provide user documentations (manuals, tutorials)? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, it is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

24. Does this simulation tool provide a file save interval? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, it is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

25. Does this simulation tool provide file management functions? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, this function is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

26. Does this simulation tool have geometric model display? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, it is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

D. Modeling

27. Does this simulation tool have zone management functions? ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, It is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

Project information

28. Does this simulation tool provide <u>pre-defined building types (e.g., office, resident building)?</u> ☐ *Yes* ☐ *No* ☐ *I don't Know*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• If yes, it is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

29. Does this simulation tool provide <u>pre-defined space types</u> (e.g., lobby, kitchen)? ☐ *Yes* ☐ *No* ☐ *I don't Know*

If yes,

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• It is easy to use	☐	☐	☐	☐	☐
• This is important in energy simulation modeling.	☐	☐	☐	☐	☐

Building Modeling

30. Does this simulation tool have a <u>geometrical input for building modeling</u>? ☐ *Yes* ☐ *No* ☐ *I don't Know*

If yes,

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• It is easy to create geometrical building model.	☐	☐	☐	☐	☐
• It is able to create geometrical building model elements comprehensively (e.g., shading devices)	☐	☐	☐	☐	☐
• It is able to represent the design precisely (e.g., orientations, different ceiling heights).	☐	☐	☐	☐	☐
• It is easy to modify/edit geometrical building model.	☐	☐	☐	☐	☐

31. What limitations does this simulation tool have in geometrical modeling?

____

____

____

32. Concerning <u>building constructing materials:</u>

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
• The built-in library is easy to use	☐	☐	☐	☐	☐
• It is easy to define your own material properties	☐	☐	☐	☐	☐

33. Concerning <u>building construction input:</u>

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

• The built-in library is easy to use	☐	☐	☐	☐	☐
• It is easy to define your own building construction	☐	☐	☐	☐	☐
• It provides clear guideline/recommendation on building construction (e.g. code compliance, default value according to building types)	☐	☐	☐	☐	☐

34. What limitations does this simulation tool have in building construction input?

____

____

____

35. Concerning <u>internal loads (occupants, lighting, equipments) input.</u>

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• It is easy to define loads by spaces	☐	☐	☐	☐	☐
• It is easy to define your own schedules	☐	☐	☐	☐	☐
• It provides a good built-in library of schedule	☐	☐	☐	☐	☐
• It provides clear guideline/recommendation on internal loads (e.g. code compliance, default value according to building types)	☐	☐	☐	☐	☐

36. What limitations does this simulation tool have in internal loads input?

____

____

____

37. Concerning <u>infiltration input:</u>

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• It is easy to define the rate.	☐	☐	☐	☐	☐
• It provides clear guideline/recommendation on infiltration (e.g. code compliance, default value according to building types)	☐	☐	☐	☐	☐

38. Concerning <u>utility.</u>(if applicable)

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• It is easy to define the rate.	☐	☐	☐	☐	☐

• It is easy to define your own schedules	☐	☐	☐	☐	☐
• It provides clear guideline/recommendation on utility (e.g. default value according to building location)	☐	☐	☐	☐	☐

HVAC MODELING (if Applicable)

39. Concerning HVAC input.

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• It is easy to define thermostat setpoint	☐	☐	☐	☐	☐
• It is easy to define HVAC zones	☐	☐	☐	☐	☐
• It is easy to edit HVAC zones	☐	☐	☐	☐	☐
• It is easy to define HVAC Systems	☐	☐	☐	☐	☐
• It is easy to define HVAC schedules	☐	☐	☐	☐	☐
• It provides a good built-in library of schedule	☐	☐	☐	☐	☐
• It requires expert knowledge for HVAC System input	☐	☐	☐	☐	☐
• It provides clear guideline/recommendation on HVAC systems input (e.g. code compliance, default value according to building types)	☐	☐	☐	☐	☐

E. Result Output

40. Please respond following statement concerning results output.

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• The results are comprehensive and relevant for your design process	☐	☐	☐	☐	☐
• This simulation produce good graphical outputs	☐	☐	☐	☐	☐
• Numeric outputs of this simulation are well-formatted to be read easily.	☐	☐	☐	☐	☐
• The output can be easily exported to office software	☐	☐	☐	☐	☐
• The output can be readily captured for use in reports	☐	☐	☐	☐	☐
• Further processing is necessary to make the output presentable	☐	☐	☐	☐	☐

F. Others

41. Please respond following statement.

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
• Good error/warning messages that enable errors to be located.	☐	☐	☐	☐	☐
• The time taken is reasonable and does not cause difficulties in getting all the results needed.	☐	☐	☐	☐	☐
• You have a high level of confidence that the result outputs are reliable.	☐	☐	☐	☐	☐
• The use of this simulation tool requires high level of background knowledge on building simulation	☐	☐	☐	☐	☐
• Overall, You are satisfied with the tool and the results obtainable	☐	☐	☐	☐	☐

General comments on this simulation tool

Thank You!

Appendix 7b. Energy Simulation Tools Survey Results

<table>
<tr><th></th><th>GBS</th><th>ECOTECT</th><th>Energy Scheming</th><th>eQUEST</th><th>TAS</th></tr>
<tr><td>

General Impression of the Energy Simulation Tool

6. The energy simulation tool is easy to learn.
7. The energy simulation tool is easy to use once familiar with it.
8. The simulation tool has good graphic user interfaces
9. The simulation tool is easy to create a building model
10. The simulation tool is easy to edit/modify the building model.
11. The simulation tool provides good result reports
12. The simulation tool has a good help menu

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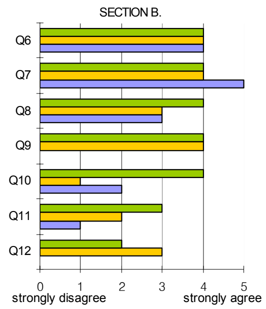

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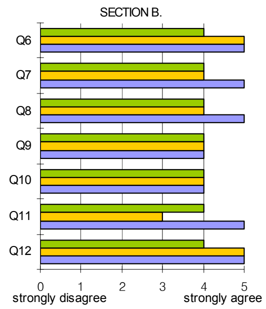

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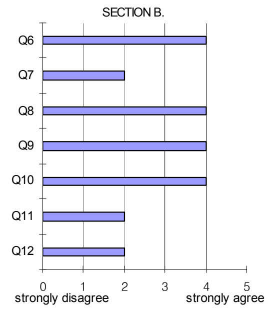

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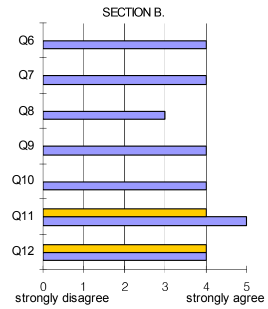

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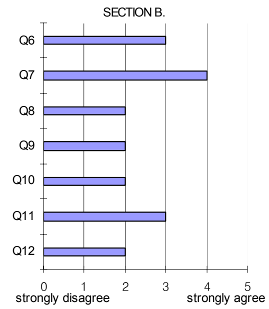

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Specifications

13. Does this simulation tool have a History Tracking?
    13-1 easy to use
    13-2 important

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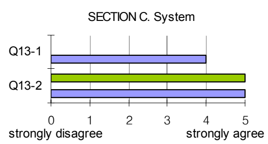

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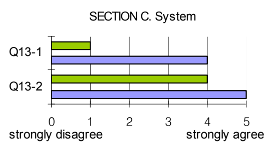

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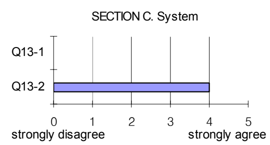

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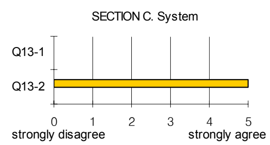

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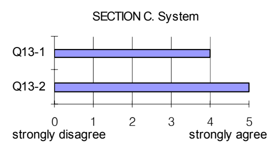

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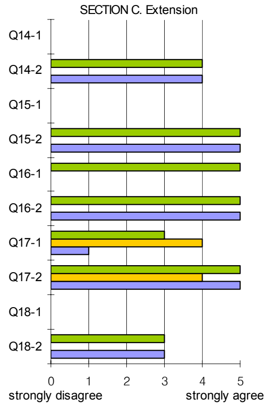
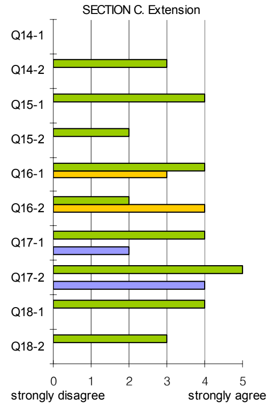
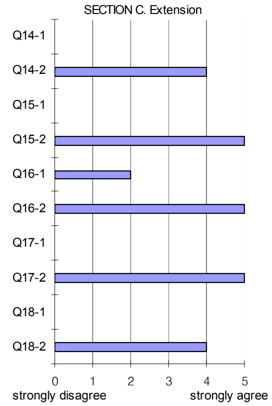
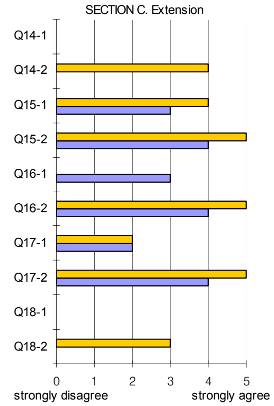
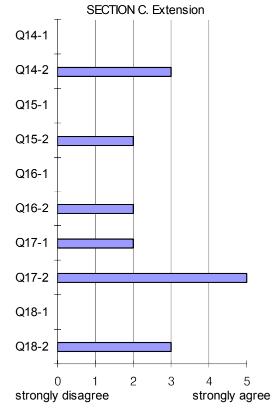
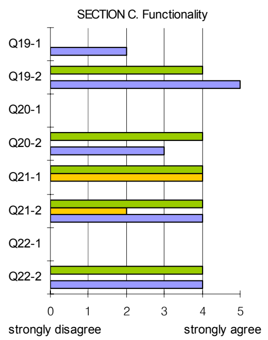
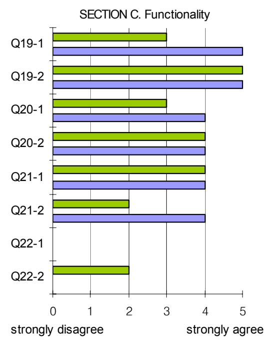
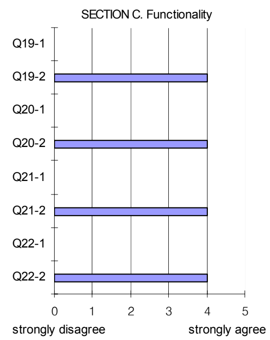
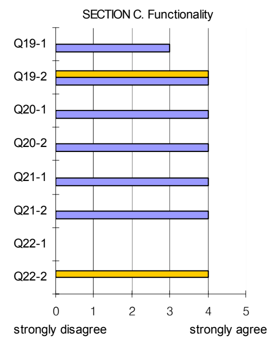
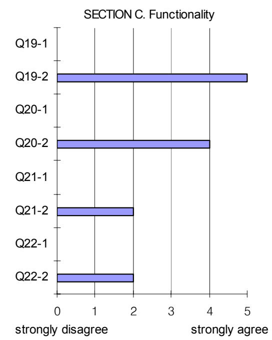
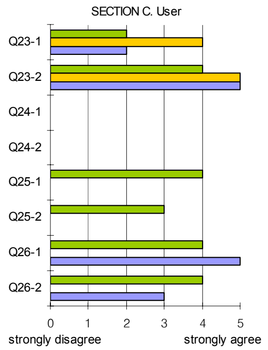
	GBS	ECOTECT	Energy Scheming	eQUEST	TAS
Specifications 14 Is this simulation tool IFC compliant? 14-1 Easy 14-2 Important 15 Is this simulation tool able to import model input files from other simulation tools? 15-1 Easy 15-2 Important 16 Is this simulation tool able to export model input files to other simulation tools? 16-1 Easy 16-2 Important 17 Is this simulation tool able to import model input file from CAD tools? 17-1 Easy 17-2 Important 18 Is this simulation tool able to export model input file to CAD tools? 18-1 Easy 18-2 Important					
Specifications 19 Is this simulation tool able to conduct parametric studies? 19-1 Easy 19-2 Important 20 Does this simulation tool have code compliance functions? 20-1 Easy 20-2 Important 21 Does this simulation tool have energy cost estimation functions? 21-1 Easy 21-2 Important 22 Does this simulation tool have real time network collaborative functions in geographically distributed environments? 22-1 Easy 22-2 Important					

User

23 Does this simulation tool provide user documentations (manuals, tutorials)?
23-1 Easy
23-2 Important
24 Does this simulation tool provide a file save interval?
24-1 Easy
24-2 Important
25 Does this simulation tool provide file management functions?
25-1 Easy
25-2 Important
26 Does this simulation tool have geometric model display?
26-1 Easy
26-2 Important

GBS



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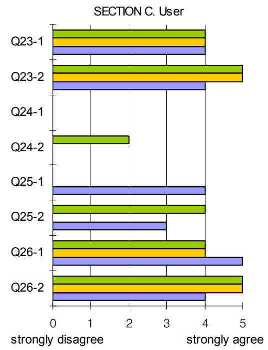
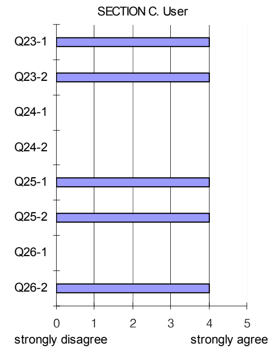


Energy Scheming



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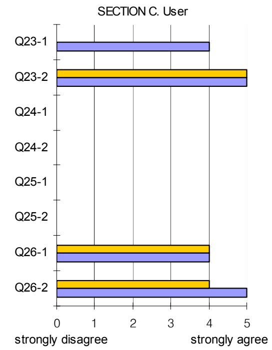
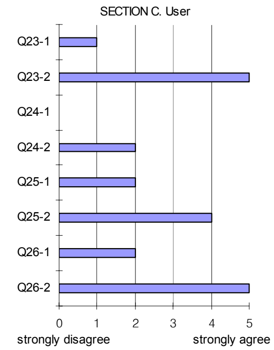


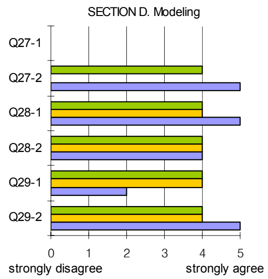
TAS



Modeling

27 Does this simulation tool have zone management functions?
27-1 Easy
27-2 Important
28 Does this simulation tool provide pre-defined building types (e.g., office, resident building)?
28-1 Easy
28-2 Important
29 Does this simulation tool provide pre-defined space types (e.g., lobby, kitchen)?
29-1 Easy
29-2 Important

GBS



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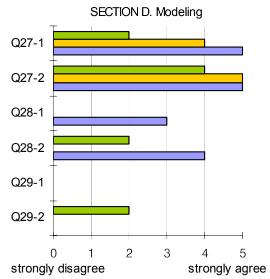

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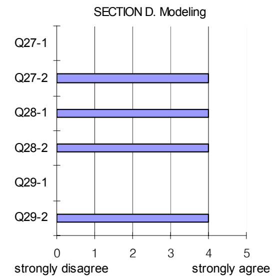

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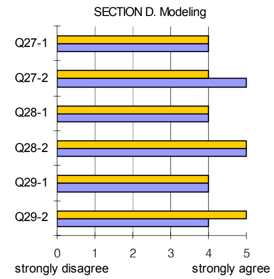

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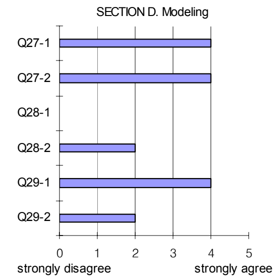
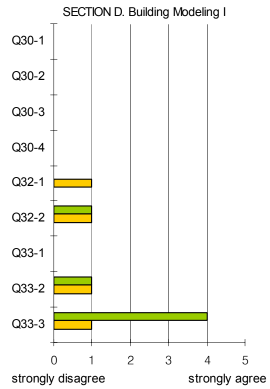


<table>
<tr><th></th><th>GBS</th><th>ECOTECT</th><th>Energy Scheming</th><th>eQUEST</th><th>TAS</th></tr>
<tr><td>Modeling
30 Does this simulation tool have a geometrical input for building modeling?
30-1 It is easy to create geometrical building model.
30-2 It is able to create geometrical building model elements comprehensively (e.g., shading devices)
30-3 It is able to represent the design precisely (e.g., orientations, different ceiling heights).
30-4 It is easy to modify/edit geometrical building model.
32 Concerning building constructing materials:
32-1 The built-in library is easy to use
32-2 It is easy to define your own material properties
33 Concerning building construction input:
33-1 The built-in library is easy to use
33-2 It is easy to define your own building construction
33-3 It provides clear guideline / recommendation on construction (e.g. code compliance, default value according to building types)</td>
<td>
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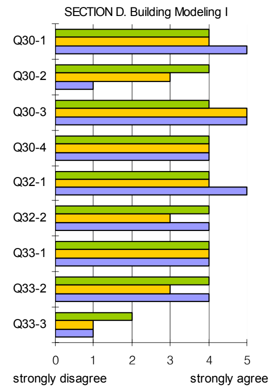
<td>
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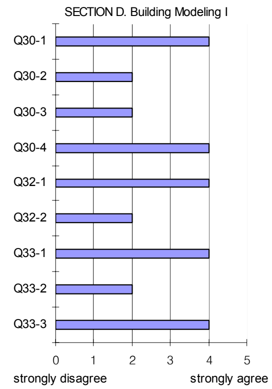
<td>
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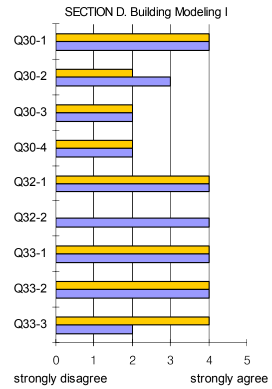
<td>
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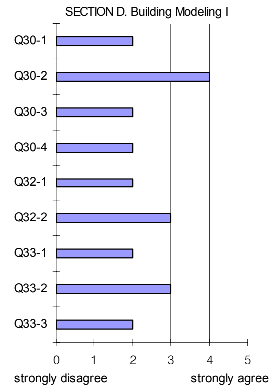
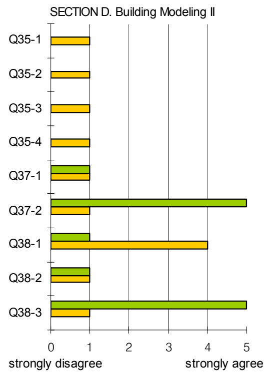
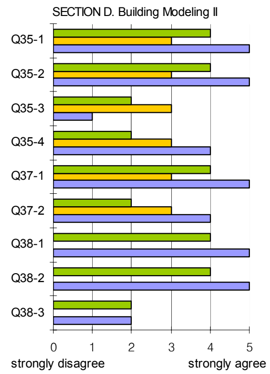
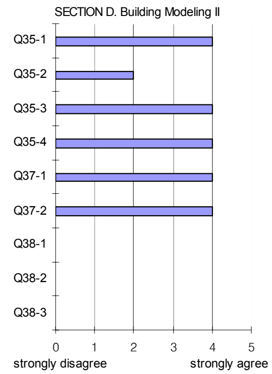
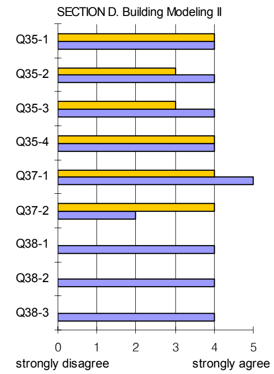
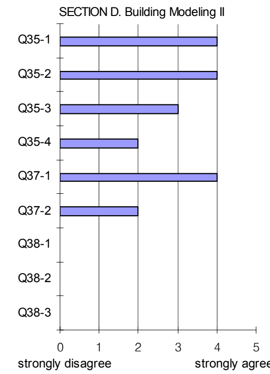
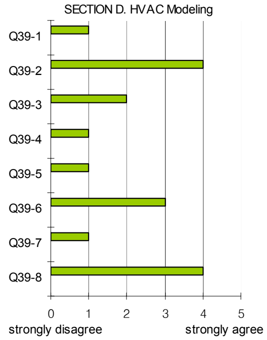
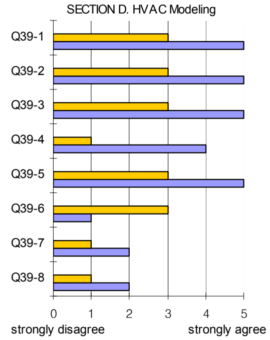
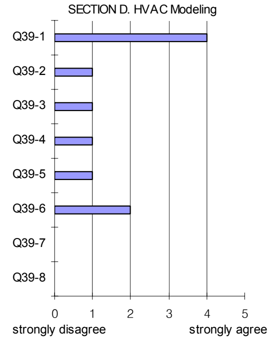
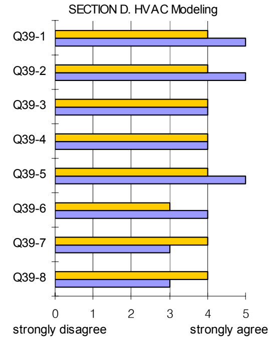
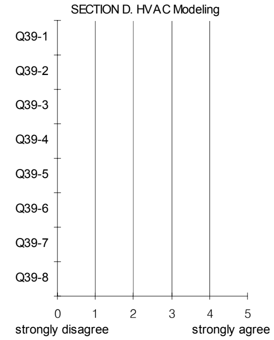
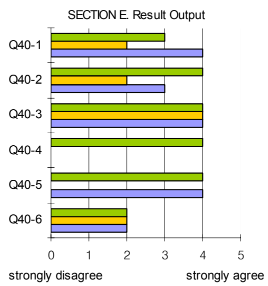
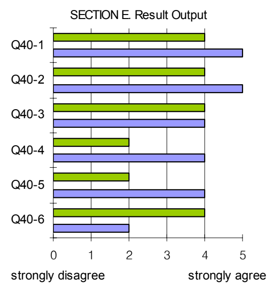
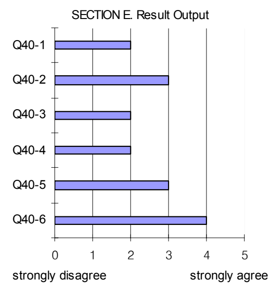
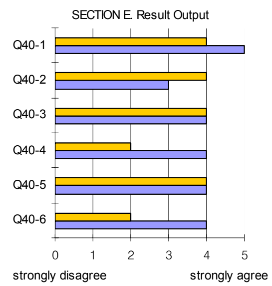
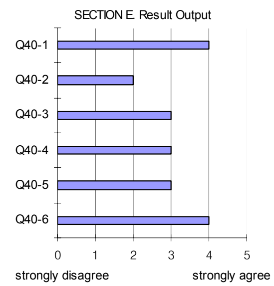
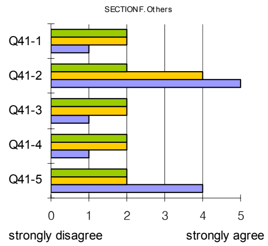
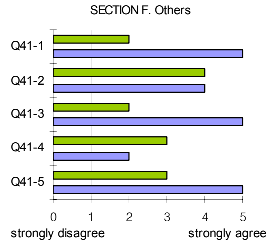
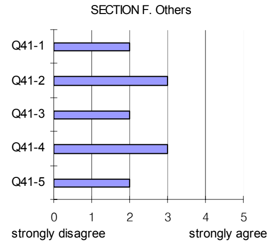
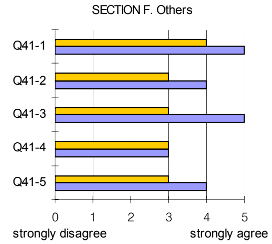
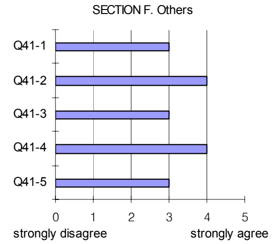
<td>
</td></tr>
<tr><td>31. What limitations does this simulation tool have in geometrical modeling?</td>
<td>- It relies exclusively on the CAD tool.</td>
<td>- Seems that there are no limitations.
- Some of the edit functions take many steps, could be streamlined.
- Validity of geometry checked separately. Requires experience and expertise to conduct check.</td>
<td>- Only exterior surfaces are needed for input.</td>
<td>- In wizard mode, double volume space and sloped floor cannot be modeled. But in detailed mode, the building can be represented accurately.
- Can't see or edit building in 3D. Input geometry using lengths and area, then modify zones using very basic graphical interface.</td>
<td>- Cannot model sloped floors. Method of geometric modeling restrictive.</td></tr>
<tr><td>34. What limitations does this simulation tool have in building construction input?</td>
<td>- I did not use that functionality. Once the file is exported I just click on "Export".
- Building constructions are selected by the program. I have neither control nor am told what was defined until the simulation is completed and results are shown.</td>
<td>- The library of default construction is very limited. The pre-defined is not very likely used in the US.
- Limited library.
- Need "time lag" value that is not common.</td>
<td>- The program asks for input values that are not familiar to the architects such as decrement factor, which makes creating new constructions difficult.</td>
<td>- Materials are only selectable from the library in the wizard mode. But in detailed mode, materials and construction are user-definable. However, the library is not editable.
-.No instructions or documentation (help menu) for these functions.</td>
<td>- Tedious to navigate and copy. Cannot modify after assignment to space.</td></tr>
</table>

	GBS	ECOTECT	Energy Scheming	eQUEST	TAS
35 Concerning internal loads (occupants, lighting, equipments) input. 35-1 It is easy to define loads by spaces 35-2 It is easy to define your own schedules 35-3 It provides a good built-in library of schedule 35-4 It provides clear guideline/recommendation on internal loads (e.g. code compliance, default value according to building types) 37 Concerning infiltration input: 37-1 It is easy to define the rate. 37-2 It provides clear guideline/recommendation on infiltration (e.g. code compliance, default value according to building types) 38 Concerning utility.(if applicable) 38-1 It is easy to define the rate 38-2 It is easy to define your own schedules 38-3 It provides clear guideline/recommendation on utility (e.g. default value according to building location)					
36. What limitations does this simulation tool have in internal loads input?	- There is none or it relies on defaults by building type. - Internal load and schedule defined by the program. I have neither control nor am told what was defined until the simulation is completed and results are shown.	- The default library is extremely limited. - Limited library. - No hierarchy in zone management. Tedious to assign.	- The number of schedules is limited, and the selected schedule applies to the whole building. The specification of internal load asks for data in non-commonly-used unit, eg. sensible heat generation of people in kJ/h instead of W.	- Cannot define schedule hour-by-hour in wizard mode. In detailed mode, schedule can be defined hourly. No sub-hour schedules can be made. In addition, the library is not editable. - No instructions for creating schedules.	- Seems quite good.

	GBS	*ECOTECT*	*Energy Scheming*	*eQUEST*	*TAS*
Modeling 39 Concerning HVAC input. 39-1 It is easy to define thermostat set-point 39-2 It is easy to define HVAC zones 39-3 It is easy to edit HVAC zones 39-4 It is easy to define HVAC Systems 39-5 It is easy to define HVAC schedules 39-6 It provides a good built-in library of schedule 39-7 It requires expert knowledge for HVAC System input 39-8 It provides clear guideline/recommendation on HVAC systems input (e.g. code compliance, default value according to building types)					
Result Output 40 Please respond following statement concerning results output. 40-1 The results are comprehensive and relevant for your design process 40-2 This simulation produce good graphical outputs 40-3 Numeric outputs of this simulation are well-formatted to be read easily 40-4 The output can be easily exported to office ware 40-5 The output can be readily captured for use in reports 40-6 Further processing is necessary to make the output presentable					

	GBS	ECOTECT	Energy Scheming	eQUEST	TAS
Others 41 Please respond following statement. 41-1 Good error/warning messages that enable errors to be located 41-2 The time taken is reasonable and does not cause difficulties in getting all the results needed 41-3 You have a high level of confidence that the result outputs are reliable 41-4 The use of this simulation tool requires high level of background knowledge on building simulation 41-5 Overall, You are satisfied with the tool and the results obtainable					
General Comments	- It is really easy to use but the results are very dubious. I don't really know if I can trust the result, too many internal assumptions. - My interest is in parametric modeling – this tool is NOT designed for this. Everything is a default, the only thing I can change is the building config back in the CAD model. - The program is like a black box. User only needs to tell it the building geometry, the building type and location. It then works on its own and gives the energy consumption and energy cost. How the results are calculated and all the other input data are assumed and hidden, which undermines the usefulness of the program. Overall, the program is very easy to use, but the usefulness of the results is arguable.	- Seems to be perfectly compatible with architects' simulation needs. Interface is architect orientated. The output is graphically orientated. Quickly and easily supports a wide range of parametric investigation. - Only limited the program to input building geometry and materials. No experience in internal loads, mechanical systems, schedules or reports. - Overall good interface and modeler, though modeling windows can be tricky. Needs better zone management. HVAC selection overly simplistic. Good tutorials and user support.	- This program can only calculate the heat gain and loss from exterior building surfaces as well as heat gain from internal occupants, lighting and office equipment. Not capable of modeling HVAC system. In addition, the program asks for the input data that are not intuitive or familiar for the architects.	- The idea of creating different modes for use in various stages of design is attractive. The wizard mode is easy to learn and use. Default values are given for most entries, which is good for users without much experience in building energy simulation. No tutorial or documentation for detailed interface. Idea of "shell" is confusing. The accuracy of the simulation results for models with several "shells" needs more investigation. - The use of the tool would be much enhanced by more tutorials and help files concerning scheduling and materials.	- Code compliance and HVAC package not tested. Basic system types not available, present emitters for internal conditions restrictive. Modeling interface unintuitive. Zone management is good, expect that assignment of internal conditions cannot be removed by zone groups.