An Introduction to Energy Screening for Commercial Buildings

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Businesses increasingly view energy cost reduction measures as investment opportunities. To help make these investment decisions, building owner's and facility manager's need simple planning tools that can assess the relative potential of alternative energy efficiency upgrades. Energy audits are intended to help building owners identify appropriate energy upgrade opportunities. However, energy audits require a significant investment of time and money, particularly for facilities with multiple buildings.

Various approaches to energy screening have been developed by various organizations to meet the need to quickly assess building and end-use equipment efficiency prior to energy audits. This paper is intended to introduce the concept of screening and to highlight recent advances in energy screening tools. This paper summarizes experiences at ICF Consulting Group over the last year with five new screening tools. These tools (BEST, Scheduler, QuikFan, QuikChill, and Energy Manager) are used as examples to highlight key concepts of energy screening. Each of these programs was developed for use in the Windows environment, requires minimal user inputs (e.g. less than 10 values), and provides immediate graphical results.

These example tools show how energy screening can provide quick assessments of the energy intensity of a building, the relative energy intensity of buildings, the relative energy intensity of end-use equipment, and the potential for energy efficiency improvements. With this information a building owner can make more informed decisions about whether energy upgrade assessments are economically justifiable. If so, more detailed and costly evaluations may be initiated using more sophisticated tools.

INTRODUCTION

As companies look for ways to be more profitable, increasing attention has been given to improving building energy efficiency. These types of improvements reduce building operating costs, and can provide attractive rates of return that make such investments highly profitable. However, these investment decisions (e.g., which energy efficiency technologies to invest in) are difficult to make. The information and analysis procedures required to assess the relative energy intensity and operating costs of buildings, as well as the economic benefits of energy efficiency upgrades are generally costly and not available to building managers. The need for these types of information is especially great for owners and managers who are responsible for large numbers of buildings.

Typically, assessments of potential energy efficiency upgrades are based on the results of an energy audit. While energy audits are helpful in identifying areas for potential upgrades, they are generally detailed and costly. Energy screening can also assist in identifying areas for potential energy efficiency upgrades, but in a more simple and economical manner than an energy audit. For this reason, screening should be performed prior to an energy audit. The roles of energy audits and energy screening are discussed below.

The Role of Energy Audits in Improving Building Energy Efficiency

Energy audits help building owners to evaluate the energy use of an existing building and end-use equipment in order to identify cost-effective energy upgrade measures. Energy audits are often performed in phases, where an additional phase is only pursued if the prior phase indicates that a significant potential for energy reduction exists. Preliminary energy audits (i.e., utility billing analysis and building walk-throughs) provide an initial assessment (or baseline) of the total amount of energy being used in a building and a rough assessment of any obvious problems or inefficiencies. Detailed energy audits involve extensive monitoring to provide information about the energy requirements of each type of major end-use equipment in a building. There are two significant problems with the energy audit process:

- An energy audit of an individual building requires a significant investment of time and money; and

- An even greater investment is required to identify which of multiple buildings should be targeted for energy efficient improvements.

Energy audits are expensive due to the amount of detailed end-use information which must be collected to identify cost-effective energy efficiency upgrade measures. In addition, the auditing process does not enable the owner to *efficiently* screen multiple buildings to separate energy hogs from low-fat facilities. The expense of auditing and its inability to quickly and accurately target those buildings with greatest energy savings potential may keep many building owners from taking any additional steps towards investing in energy efficiency.

The Role of Energy Screening in Improving Building Energy Efficiency

Like energy auditing, energy screening is intended to help building owners evaluate the energy use of a building and its end-use equipment in order to identify cost-effective energy upgrade measures. However, energy screening differs in that the approach is simpler and thus cheaper. Energy screening quickly identifies priorities (i.e., cost-effective end-use strategies and technologies) for more detailed energy auditing. It does not replace auditing. When implemented in this manner, the screening process minimizes the need for large scale energy auditing and thus the overall costs of the upgrade evaluation process. Further, screening significantly reduces the effort required to evaluate the relative priorities across multiple buildings.

Screening is not a new process. In fact, utilities have used screening for many years to evaluate the potential of various energy efficiency technologies to help reduce demand at electricity generation plants. Prior to investing in large-scale marketing programs to promote energy efficiency technologies, utilities have evaluated relative potential of individual energy efficiency upgrade measures.

Purpose of Paper

This paper is intended to show how screening can provide a quick, cheap and effective approach to initial assessment of energy efficiency upgrades. This approach provides valuable information to decision makers very early in the project without having to make significant investments. Further, the results of the screening process provide direction for making future energy evaluations and investments.

This paper summarizes experiences of the authors over the last year with five new screening tools. These tools (i.e., BEST, Scheduler, QuikFan, QuikChill, and Energy Manager) are used as examples to highlight how screening can be used to make early go / no go decisions. Each of these five programs was developed for use in the Windows environment, requires minimal user inputs (e.g. less than 10 values), and provides immediate graphical results. In addition to the tools discussed here, many other building energy-related screening tools have been developed by private companies and with funding from the U.S. Department of Energy. Some of the other more popular building energy screening tools available are FLEX, and FEDS. These tools all have comparable capabilities and provide an effective screening process.

FUNDAMENTALS OF ENERGY SCREENING

Two general types of screening are introduced in the paper: (1) simple screening, and (2) detailed screening. Simple screening is typically used to identify candidate buildings for energy upgrades. This approach is based on databases of building energy intensity data. Using this data, the relative energy use of similar buildings can be compared. The most energy intensive buildings can be identified for more detailed energy analyses.

Detailed screening is typically used to identify candidate energy efficiency measures. This screening approach utilizes simplified energy analysis engines which are specifically designed to model selected energy efficiency measures.

With the preliminary information provided by the energy screening process, a building owner can make a more informed decision about whether more detailed energy upgrade assessments are economically justifiable. If so, an engineering design team will most likely rely on more detailed building energy analysis tools to develop detailed specifications for the energy efficiency measures identified using screening tools.

Simple Energy Screening

The simple energy screening process is primarily used to identify *candidate buildings* for energy upgrades. These simple tools typically have one or more of the following general capabilities: assessment of baseline level of energy use, a preliminary assessment of the relative level of energy efficiency of the building, and preliminary project planning. These types of simple assessments are briefly described below. Note that these simple screening activities do not require complex building energy calculation algorithms.

Step 1: Quantify Baseline Energy Use. A building's annual energy consumption can be easily assessed by aggregating the historical utility data for all fuels used. This baseline is a benchmark that can be used to assess the relative level of energy use for a given building. A building's baseline annual energy requirement is usually measured in terms of KBTUs per square foot (kilowatthours per square meter) or dollars per square foot (dollars per square meter).

Step 2: Quantify Potential for Energy Savings. By comparing historical energy use to reference energy data, a building can be classified as relatively energy efficient or inefficient. A preliminary indicator of the potential for improvement in energy efficiency is the difference between actual historical energy use and a reference average usage for similar buildings. Several sources of reference energy usage data exist, such as the U.S. DOE's Commercial Building Energy Consumption Survey (or CBECS) (EIA 1994). Although specific energy efficiency upgrades may not be identified in a simple screening tool, the level of overall energy efficiency improvement (i.e., reduction in annual energy use) can be quantified in the manner described above.

Step 3: Preliminary Project Planning. This overall potential for energy savings is very useful for several types of preliminary project planning purposes (e.g., budgeting, cash flow, pollution prevention, etc.). A reference library of average building upgrade costs for various building types provides the basis for a preliminary assessment of likely project costs. Such average project costs are not readily available, and must be developed from previous experience. A comparison of expected project costs and energy savings serves as a basis for a preliminary assessment of the economic viability of a project.

Detailed Energy Screening

Detailed energy screening is primarily used to identify *candidate energy efficiency measures*. The detailed screening process includes all the features of simple screening, along with the additional assessment of individual energy efficiency measures. The additional steps required in detailed screening include:

- Evaluate end-use break-down of baseline energy use;
- Identify energy upgrade strategies;
- Quantify energy savings potential of energy upgrades; and
- Assess cost-effectiveness of energy efficiency upgrades.

These steps are briefly described below. Note that some screening tools are specifically designed to assess a single type of energy efficiency measure (e.g., lighting, chillers, etc.). Other screening tools are designed to evaluate numerous types of energy efficiency measures.

Step 4: Evaluate End-Use Break-Down of Baseline Energy Use. The primary causes of annual energy use are the either the most common types of end-use equipment or the largest end-use equipment. The energy required by end-use equipment is often difficult to assess, especially for equipment that is affected by the weather (i.e., HVAC equipment). The percent of energy used by each type of end-use equipment is often similar in similar building types. In simple screening tools, rules of thumb may be used to allocate energy use by end-use equipment type. In detailed screening tools, part-load curves and duty cycle data are often used to quantify annual end-use energy requirements. The aggregate of these estimates of energy use by end-use equipment type should be checked against historical utility billing data.

Step 5: Identify Energy Upgrade Strategies. The primary purpose of an energy upgrade is to significantly reduce annual energy use and or costs. Thus, energy upgrade strategies should be targeted at the significant energy end-uses identified in Step 4. After the primary end-uses are identified, specific upgrade strategies should be identified for each. These strategies are typically selected using experience-based rules of thumb.

Step 6: Quantify Energy Saving Potential of Energy Upgrades. For each end-use upgrade strategy identified in Step 5, specific energy upgrade efficiency measures must be identified and evaluated. For any upgrade measure, there are often several levels of upgrade that are possible. Ideally, the energy savings potential for each of these upgrades should be evaluated. More typically, experience-based rules of thumb are used to select specific energy efficiency upgrade measures. Each measure is tested for cost-effectiveness as described below.

Step 7: Assess Cost-Effectiveness of Energy Efficiency Upgrades. The relative cost-effectiveness of an energy efficiency measure can be quantified using one of several commonly used methods (e.g., payback period, internal rate of return, net present value of energy cost savings, savings to investment ratio, etc.). These methods of assessing relative cost-effectiveness are typically used as the decision criteria for proceeding with the implementation of, or rejection of an energy efficiency upgrade measure. The evaluation of these ratios requires the energy savings estimates from Step 6 above and cost data for the upgrade measure.

HOW SIMPLE SCREENING TOOLS WORK

The automation of the energy screening process has been evolving gradually over the last decade. Recent advancements in Windows based development environments have made it possible to develop powerful and easy to use screening tools. Basic features of simple screening tools include: the graphic user interface, the data libraries, and the decision logic. The importance of these features is discussed below.

Graphic User Interface. The user interface should be developed using a Windows-based programming language. Primary goals for the interface include: minimal number of required user inputs (e.g., less than ten), easy to understand menu system, and highly graphical presentation of information.

Data Libraries. As indicated above, screening tools rely heavily on reference libraries of data, accumulated from experience in previous projects. These libraries are the backbone of these tools. Generally, these libraries are used to provide defaults, costs, and look-up data for the user.

Decision Logic. Simple screening tools typically only assess building level energy usage based on historical utility data. The decision logic is simply a database management application that sorts and reports specific information needed to support energy efficiency upgrade decisions. Thus, detailed energy calculations are not required for simple screening.

The primary features of two simple screening tools (i.e., BEST, and Scheduler) are summarized below. These new tools have not been rigorously validated. However, because these tools simply compare user provided utility energy consumption data to data from the CBECS database, there is minimal potential for bugs in the internal algorithms.

Example Screening Tool #1: Building Energy Screening Tool (BEST)

The Building Energy Screening Tool (BEST) was developed by ICF Consulting Group for the Montgomery County government with funding from the Urban League of Cities (ICF 1995). The Montgomery County government is responsible for approximately 200 buildings. They needed a simple management tool to evaluate the relative energy use of these buildings, to identify the most inefficient buildings, and to assess the overall dollar value of energy cost savings possible. Thus, BEST was developed to evaluate the total building energy requirements of several hundred commercial buildings.

The user inputs are kept to an absolute minimum in order to facilitate the streamlined input of information for hundreds of buildings. The inputs provide information required to identify the building size, type, location, heating fuel, as well as annual fuel use and cost. After entering the required input data for all of the buildings of interest, the user selects one of several sorting criteria. The list of buildings is then sorted in descending order of energy intensity or energy savings potential. The evaluation is based on a comparison of historical utility data for the Montgomery County buildings to a library of reference data (described below).

A reference library was developed based on energy use data for six thousand buildings from the U.S. DOE's Commercial Energy Consumption Survey. High, low, and average annual energy use statistics for one hundred and sixty building categories are included in the database. Building categories are based on combinations of building type, size, climate region, and primary heating fuel type.

Two types of decision logic are used in BEST. The first is to aggregate energy use across the various fuel types used in each building. The second is to rank each building based on one of several optional approaches, including: annual energy savings potential, annual energy cost savings, annual percent energy savings potential, or gross annual energy use. The energy savings potential is calculated as the difference between the actual energy intensity and the minimum energy intensity for that type of building in the CBECS data library.

An output screen from BEST which shows the relative energy savings potential for multiple buildings is presented in Figure 1. The sorting criteria are presented in the top left corner of the screen. The twelve buildings are listed in descending order of energy savings potential. Also, summary statistics for the twelve buildings are listed in the upper right corner of Figure 1. A building owner can use this valuable information to identify candidate buildings that are using relatively large amounts of energy.

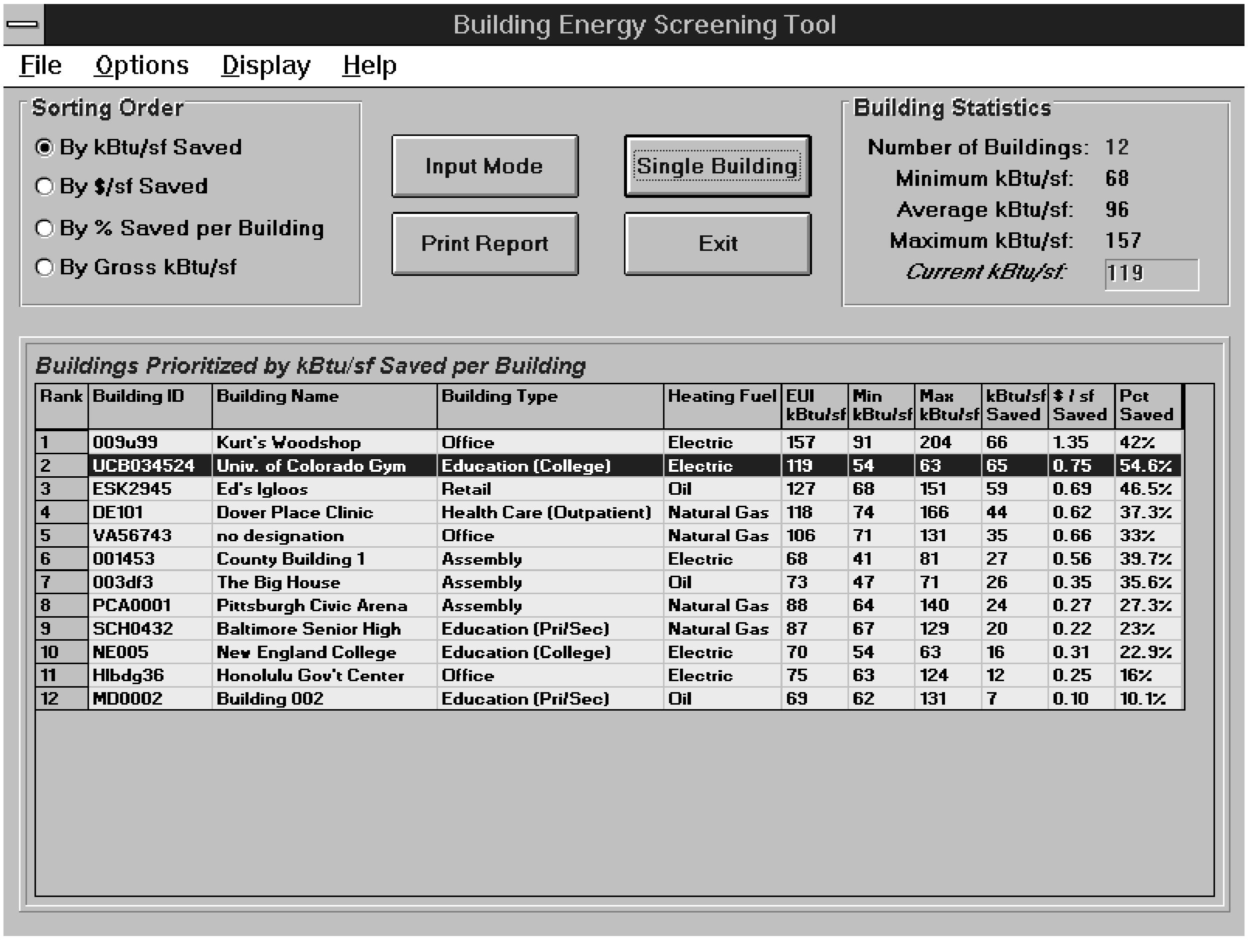
Currently, BEST is fully functional, and is available through the Urban League of Cities. It is not copyrighted.

Example Screening Tool #2: Scheduler

Scheduler was developed by the U.S. Environmental Protection Agency's Atmospheric Pollution Prevention Division to help promote energy efficiency in commercial buildings (EPA 1996a). The Scheduler program is designed to help new partners in EPA's ENERGY STAR Buildings program plan energy efficiency upgrade projects. Scheduler provides the following types of guidance: summary of upgrades completed previously, phasing of suggested additional upgrades, cash flow projections for the next 7 years, and an assessment of the pollution prevented from the project. Scheduler provides these planning capabilities for multiple buildings.

The required user inputs for Scheduler include historical utility data, completed upgrades and the floor area for each building. All other inputs are defaulted. These default values are stored in a reference library, which includes: utility rate data, energy savings data by upgrade, upgrade cost data,

Figure 1. *Output Screen from BEST Showing Relative Energy Savings Potential for Multiple Buildings*



and pollution emission factors. Most of these default values can be modified by the user.

Scheduler does not perform a building energy analysis. All planning is based on typical energy savings data in the data library. These data have been developed based on hundreds of DOE-2 simulations and 25 case studies. The only calculations performed by Scheduler are financial (e.g., cash flow), and pollution prevention estimates.

An output screen from Scheduler, which shows project-related cash flows over a 7 year period for an example participant in the ENERGY STAR Buildings program, is presented in Figure 2. In this example it is assumed that the participant implements all of the cost effective energy upgrade measures recommended in the ENERGY STAR Buildings program. In this example, the total investment required for these energy upgrades is about the same magnitude as two years of energy costs.

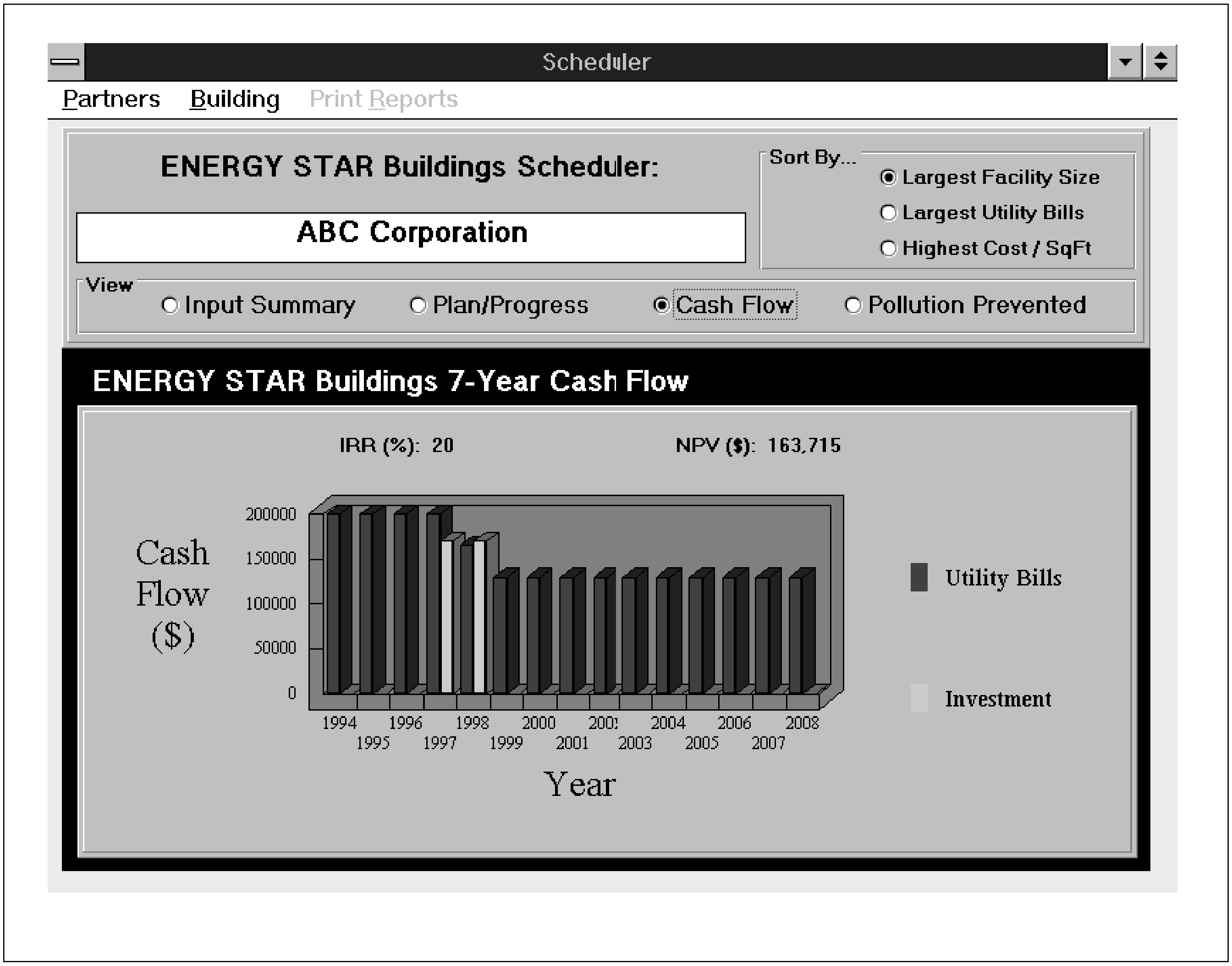
Currently, Scheduler is in a Beta version release and is available at no charge to all participants of the ENERGY STAR Buildings program. It is not copyrighted.

HOW DETAILED SCREENING TOOLS WORK

Detailed screening tools have the same basic features as simple screening tools, but each of these features are significantly enhanced. These enhanced features are briefly described below.

Graphic User Interface. The user interface provides additional layers of detail, if the user wishes, to override or to customize the library and built-in default data. The level of detail presented to the user is layered, so that the user can initially perform a quick analysis (i.e., simple screening) based on default values, and at a later time, go back to

Figure 2. Output Screen from Scheduler Showing Project-Related Cash Flows Over a 7 Year Period



perform a more detailed analysis (i.e., detailed screening). The results of the initial default-driven analysis should direct the user to gather both site-specific measured data and building/equipment specific performance data to be used in the detailed screening.

Data Libraries. The types of information and level of detail included in the reference libraries of detailed screening tools is much greater that the information stored in simple screening tools. For example, simple screening tools are generally focussed at the building level of detail, while detailed screening tools are generally focussed at the end-use level of detail. Since detailed screening tools must provide the capability to address end-use interactions, multiple end-uses are usually assessed in a these tools.

Decision Logic. Detailed screening tools use a variety of simplified energy analysis techniques to assess the performance of specific technologies at the end-use level of detail. Typically, detailed hourly energy analysis is not used in detailed screening tools.

The primary features of three detailed screening tools (i.e., QuikFan, QuikChill, and Energy Manager) are summarized below. These new tools are currently undergoing evaluation, and have not been rigorously validated for accuracy.

Example Screening Tool #3: QuikFan

QuikFan was developed by ICF Consulting Group for the U.S. Environmental Protection Agency's Atmospheric Pollution Prevention Division to help promote energy efficiency improvements in fan systems used in commercial buildings with VAV systems (EPA 1996b). After a new Energy Star Buildings participant has completed using the Scheduler program, QuikFan provides the user with detailed assessments of specific types of fan system upgrades. QuikFan is designed to evaluate the fan energy used in multiple air-handlers in a single building.

The required user inputs are limited to four key parameters for each fan in each air handler: peak supply air flow rate, system static pressure, fan efficiency, fan oversizing, motor size, and motor efficiency. Other values are defaulted. The user can modify most of these default values.

The reference library includes the following detailed technical data:

- Generic fan duty cycle data (e.g., for fans serving perimeter spaces, core spaces, mix spaces);
- Generic part load kW curves (e.g., for fans with inlet vane, VSDs and VSDs with reset);
- Available motor efficiencies by motor size; and
- Cost data for VSDs and high efficiency motors.

All data in the reference library can be user-modified.

The QuikFan program analyzes fan motor loads based on a bin calculation method. Motor loads are translated into energy use based on the part load KW curves and motor efficiency data in the library. An output screen from QuikFan, which shows energy savings due to selected fan upgrades, is presented in Figure 3. The selected upgrades, indicated in the upper left corner of this Figure, are a new downsized motor and a variable speed drive (VSD). These upgrades result in a 72 percent reduction in fan energy use, and yield a 2.1 year payback period.

Currently, QuikFan is in a Beta version release and is available at no charge to all participants of the ENERGY STAR Buildings program. It is not copyrighted.

Example Screening Tool #4: QuikChill

QuikChill was developed by ICF Consulting Group for the U.S. Environmental Protection Agency's Atmospheric Pollution Prevention Division to help promote the implementation of energy efficient chillers in commercial buildings (EPA 1996c). After a new ENERGY STAR Buildings participant has completed using the Scheduler and the QuikFan programs, QuikChill provides the user with detailed assessments of specific types of chiller system upgrades. Currently, QuikChill is designed to assess the energy use of multiple centrifugal chillers which serve a single chilled water loop in a single building.

The required user inputs include the following three parameters for each chiller in a building: rated capacity, rated efficiency, and peak cooling load. The sequencing controls for multiple chillers must be provided. A brief description of the building and previously completed upgrades must also be provided. Other inputs are defaulted. The user can modify most of the default values if desired. Much of the default data is stored in a library, which includes:

- Generic cooling load curves (e.g., for perimeter- or core-driven buildings, and for special process loads);
- Generic part load kW curves (e.g., for various families of chiller design); and
- Cost Data for high efficiency chillers.

All data in the library can be user-modified.

The decision logic in QuikChill is based on the results of a simple hourly model. This approach enables the modeling of economizers, cooling tower, and chiller operational schedule. Some of the default cooling load curves from QuikChill are presented in Figure 4. Based on the building description provided by the user, an appropriate load curve is selected from a library of twenty default load curves. These curves were generated using the DOE-2.1E building energy simulation program.

Future plans for QuikChill include the following enhancements: addition of analysis capabilities for reciprocating gas chillers, DX, and package systems; and optimization of cooling energy.

Currently, QuikChill is in a Beta version release and is available at no charge to all participants of the ENERGY STAR Buildings program. It is not copyrighted.

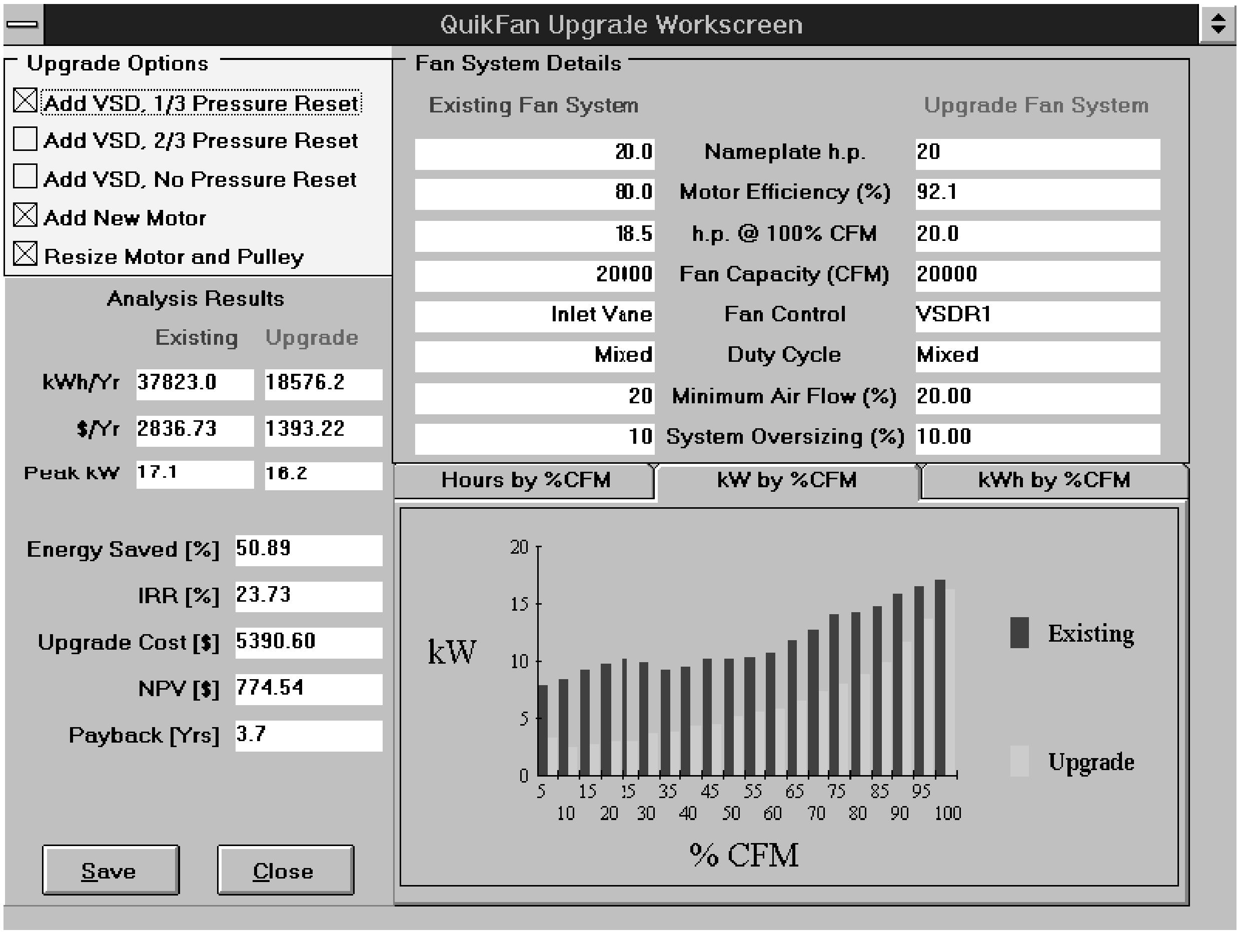
Example Screening Tool #5: Energy Manager

Energy Manager was developed by ICF Consulting Group (ICF 1996). The Energy Manager tool is an alpha version of a more fully featured BEST. It is designed to enable a facility manager to quickly evaluate a variety of energy efficiency upgrades for multiple buildings. The current version is designed to analyze only VAV systems in a few climates locations. These capabilities are currently being expanded to include other HVAC system types and climate locations.

Energy Manager has the following features:

- Baseline energy use assessment at the end-use level of detail;
- Assessment of potential energy efficiency upgrade measures; and

Figure 3. *Output Screen from QuikFan Showing Energy Savings Due to Selected Fan Upgrades*



- Tracking of utility data over multiple years to assess the effectiveness of installed upgrades.

For the baseline energy use assessment, the required user inputs are limited to seven parameters:

- 5 key building characteristics (i.e., floor area, window-to-wall ratio, perimeter-to-core floor area ratio, occupant density, and number of floors); and

- Annual energy use and costs by fuel.

The reference library includes the same types of information identified for the detailed screening tools described above. These data can be customized by the user.

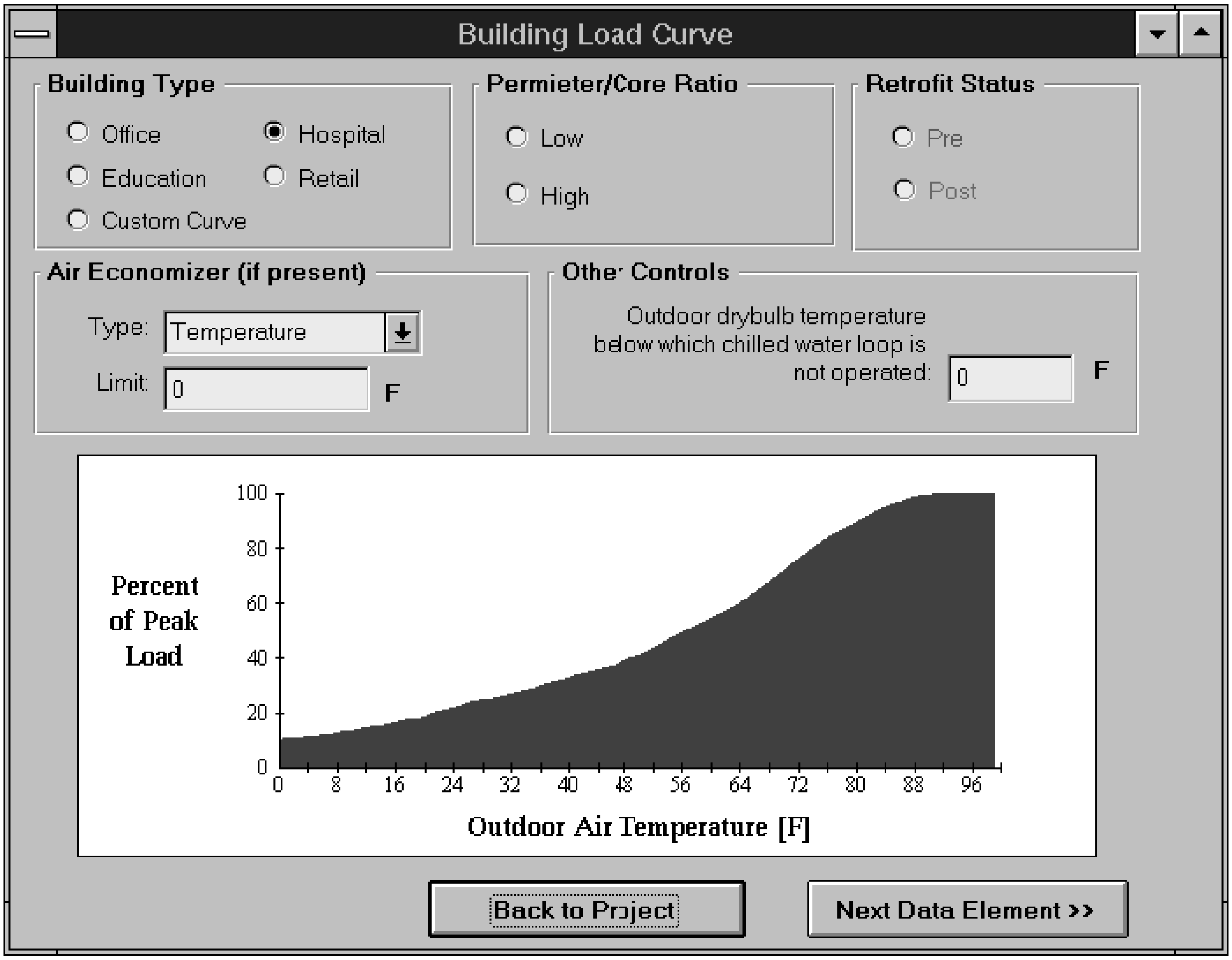
The analysis of baseline energy use and energy efficiency upgrades is performed using a BIN calculation, that is modified to account for day and night hours separately. An output screen from Energy Manager, which shows the benefit of multiple energy efficiency upgrades, is presented in Figure 5. For the example office building shown, the lighting, fan, and outdoor air modifications selected result in an annual energy savings of $0.45 per square foot. The internal rate of return for these energy efficiency upgrade investments is 20 percent. Note that the measures selected caused the heating energy use to increase relative to the base case building.

Currently, Energy Manager is in an Alpha version release and is available through ICF. It is not copyrighted.

CONCLUSIONS

The screening process will not provide definitive energy solutions. It will enable building owners to: (1) identify relatively inefficient buildings, and (2) prioritize across potential

Figure 4. *Default Cooling Load Curve from QuikChill*



energy efficiency upgrades. Compared to energy audits, simple screening tools offer the following advantages:

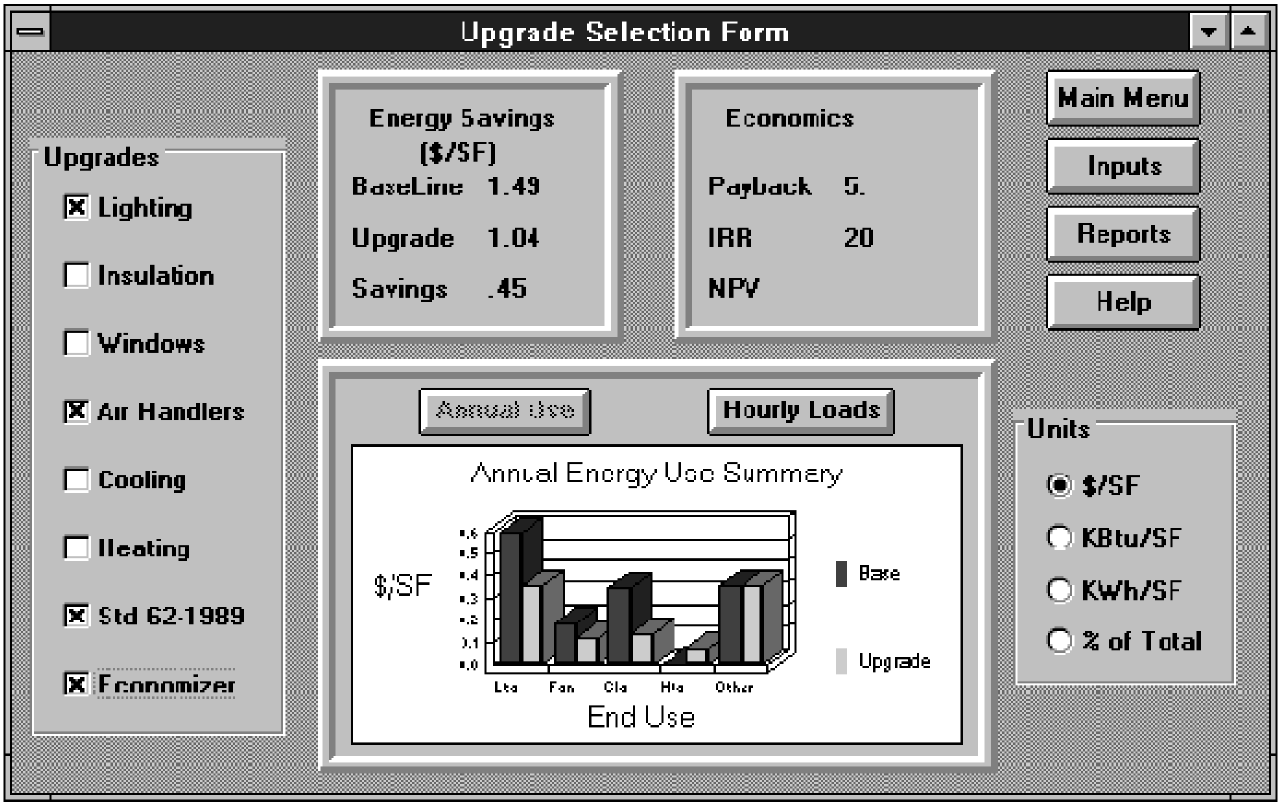
- Minimal user inputs;
- User friendly graphical input and output presentations; and
- Immediate answers, with minimal effort and cost.

These tools are extremely cost-effective to use. However, the disadvantage of these simple tools is the reduced level of accuracy in the results obtained, relative to more detailed energy analysis methods. However, for a preliminary assessment of the potential for energy efficiency upgrades, this level of accuracy is satisfactory. More importantly, screening tools are very inexpensive to use—accommodating the user who does not feel comfortable investing in detailed energy audits and analyses—with no certainty of the possible economic benefits.

Detailed screening tools are generally designed to assist in-house building management professionals to make ''go or no-go'' decisions on energy efficiency projects. Detailed screening tools offer the following advantages, relative to both simple screening tools and more detailed building energy analysis tools:

- A streamlined method of confirming the preliminary building energy savings estimates provided in simple screening tools;
- A streamlined evaluation process for individual energy efficiency measures;

Figure 5. Output Screen from Energy Manager Showing Benefit of Multiple Energy Efficiency Upgrades



- A methodology which enables the user to focus on one energy efficiency measure at a time; and
- A methodology which accounts for energy interactions when assessing individual energy efficiency measures.

Screening tools allow non-technical management staff to make preliminary decisions about the feasibility of energy efficiency upgrades. Based on the their decisions made at the end of the screening phase of a project, engineering design teams may be brought in to perform more sophisticated energy analyses.

RECOMMENDATIONS

Energy screening tools are evolving rapidly. However, there is a need for more refinement of these tools. Future areas for screening tool development include:

- Enhancements to the user interface (i.e., decision support);
- Additional development of reference library data on ‘‘typical’’ building energy usage, equipment performance data, and upgrade cost data;
- Development of validation procedures for the decision logic used in screening tools; and
- Integration of energy screening, detailed energy simulations, and commissioning tools.

Additional building-related evaluation capabilities could be added to screening tools, including many of the environmental issues facing building owners and managers (e.g., CFC phase out, indoor air quality, water conservation, etc.). For example, screening tools could be used to perform ‘‘green building’’ or ‘‘sustainability’’ evaluations.

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