MARKETMANAGER FOR WINDOWS

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ABSTRACT

Introduced in late 1993, MarketManager for Windows (MMWIN) is a productivity tool designed to meet the energy analysis needs of Utility DSM departments and of Performance Contractors. In a typical application a building is simulated as-is and compared to one or more energy-saving alternatives.

MMWIN features *Measures* to implement and keep track of the results of individual changes to the building operation, equipment, or construction. Measures are grouped into *Packages* the effect of each of which is fully simulated. An elasticity model is used to apportion overall savings among individual component measures.

Considerable attention has been given to adapt standard Windows GUI elements to perform operations necessary for building energy analysis. For example, the common edit operation drag-anddrop paste has been adapted to cut and paste building Components from one project file to another. Similarly, the hierarchical structure usually reserved for symbolic file representation and navigation has been adapted to represent the building and its Components.

Calculations are done on an hourly basis for eight typical days per month. In addition to the usual complement of heating and cooling equipment, water heating, lighting, and equipment, MMWIN can model numerous control strategies, heat recovery strategies, evaporative cooling, industrial processes, and swimming pools.

INTRODUCTION

There is a large and growing number of energy professionals dedicated to the efficient operation, maintenance, and capital improvement of existing buildings. To these users, speed and productivity of simulation tools are as essential as are accuracy and consistency of results.

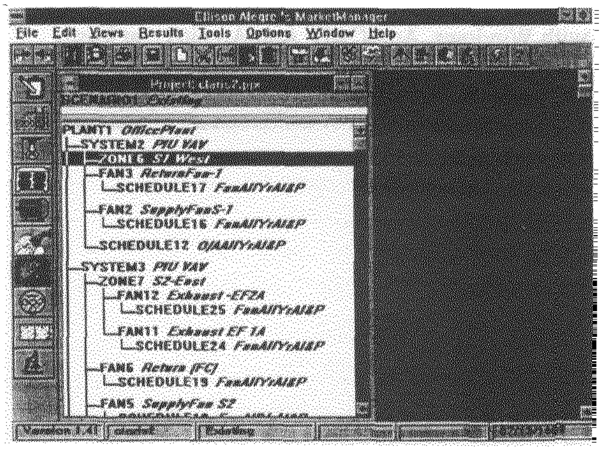
Other essential needs for a tool for energy professionals are the ability to model *all* energy end uses in a building, to be able to handle whatever system is encountered in a building, and to be able to perform the many book-keeping tasks that are a necessary by-product of simulation. Such a tool must be able to both model the characteristics of, and track the comparative results of, numerous energy saving strategies.

Building Simulation is but one of the tools needed by this community of energy professionals, but is one that Market Manager for Windows (MMWIN) and its planned spin-offs strive to provide.

USER INTERFACE

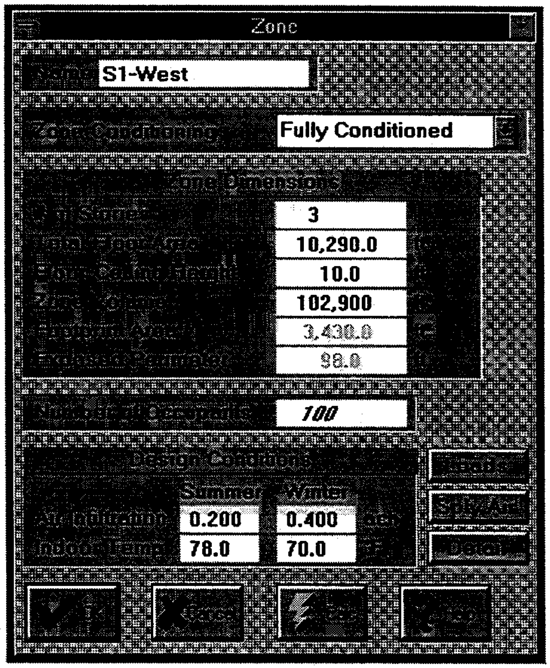
MMWIN's user interface attempts to adhere to Microsoft Windows GUI Design Guidelines through the standard use and organization of menus, iconized toolbars, and on-line documentation through Windows help.

Each *Project* (usually one building or several buildings grouped into a single facility) is represented by a single MDI window. Multiple projects can be opened at the same time, much like multiple documents can be edited simultaneously in a Wordprocessor.

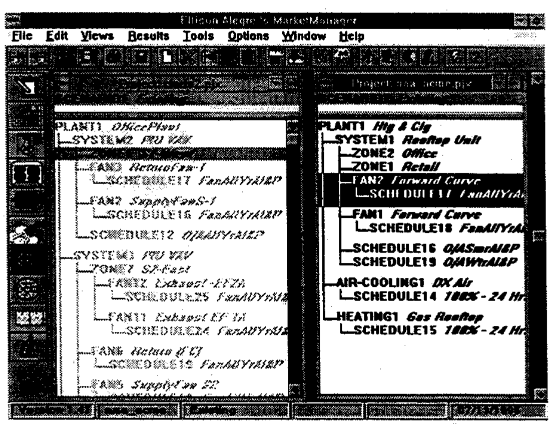


Building components are organized in hierarchical *Views*: Project view, Construction view, Lighting, Equipment, Motors, Water Heating, Heating and Cooling, Measure, Rate, and Diagnostics. Views help visualize the logical topology of a building, allow navigation among building components and provide the workspace for deleting, copying and pasting of building components from one project to another.

By double-clicking on an item in a view the user opens a *Data Form* where the actual data editing occurs. Every input change in a data form causes the default values that depend on this input and are visible to be recalculated.

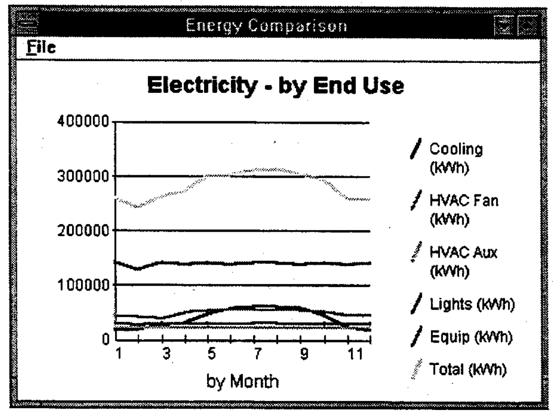


Templates and *Libraries* are special Projects available at any time for use as seed projects or sources of building components, respectively. These are simply adaptations of standard paradigms used in many commercial products.

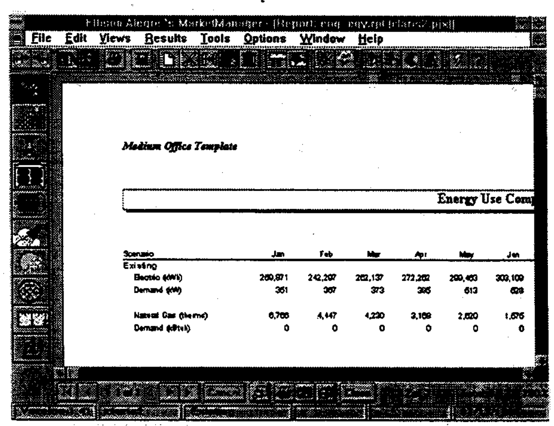


An innovative feature is the use of *Copy and Paste* and *Drag-and-Drop* edit controls to move building components and all their sub-components from one project to another.

Graphics are used extensively to visualize monthly energy consumption, demand, and cost, hourly energy loadshapes, operating and thermostat schedules, and many hourly partial results (temperatures, loads, air volumes, etc.) through the use of a *Diagnostics* feature.



Reports are produced by user selection from a number of pre-defined report formats, ranging from monthly breakdown by end use and fuel, to hourly profiles, equipment inventories, comparison reports, executive reports, and more. The pre-defined report formats may be modified and new formats created through a separate report generator.



SPECIAL FEATURES

- *Dynamic Defaults*: The values of most MMWIN inputs have defaults that depend on the values of other inputs. A simple example is the default U-value of different types of windows; a more powerful example is the cooling load of a zone, whose default value (the design value) is immediately recalculated whenever the user changes any inputs that affect loads.

- *Integration of Loads, Systems, Plant*: All inputs and calculation steps are unified into a single, interactive system. For example, if the user modifies the type and area of glazing in one zone, then returns to inspect the chiller that cools the zone's supply air, the default size of the chiller will have been recalculated, taking into account changed zone loads and supply air requirements. In a thermal storage application, in order to simultaneously size chiller capacity and ice storage volume of a TES system, MMWIN launches an hourly, iterative mini-simulation in the background to optimize both sizes simultaneously. The user is usually unaware of the mechanics of such calculations beyond the observation that some defaults take milliseconds to recalculate, while others may take fractions of a second.

- *Calculations As-Needed*: Some dynamic default calculations are more involved than others and may launch background processes far more complex than a simple table lookup. To maximize program performance MMWIN schedules the recalculations caused by a change in component (A) on an as-needed basis. Such "need" arises as soon as the user inspects the building component (B) that needs recalculation because of the change in (A). Sometimes the user may inspect yet another component (C) whose values depend on (B). Moving from a change in (A) directly to inspect (C) will cause automatic recalculation of the intermediary component (B). To continue the earlier example, if in addition to glazing, changes are also made to supply air setpoints and building operation, the new chiller size reflecting the cumulative effects of these changes are recalculated only when the user "goes to look at it."

- *Scenarios*: Each building can freely be cloned into multiple scenarios. A scenario is simply a copy of the existing building with one or more changes in its inputs. A scenario may range from something as minor as a change in a thermostat schedule to a major building reconstruction with concurrent changes in rate tariffs.

- *Measures*: Measures are an alternate, automatic way to create alternative scenarios with "cookie cutter" specifications, such as reducing night thermostat settings or removing one third of a building's light fixtures.

- *Measure Packages*: Like measures are grouped into measure packages, e.g. an Envelope package and a Lighting package. Each measure package, when *applied*, causes the creation of a scenario of the same name, with all the changes embodied in each measure of that package implemented. Additional, manual changes can be added by the user to the scenario thus created.

- *Measure Elasticity*: Each scenario, whether created manually, or by a measure package, or by a combination of both, is separately simulated by MMWIN, which also does cost-benefit calculations of the scenario's savings. In an additional step the cumulative savings of the measure package must be apportioned among the measures of the package. For example, the gas and electric savings from an Envelope Package must be apportioned among the air infiltration reduction, the reglazing, and the roof insulation measures that make up the package. This is accomplished through a Measure Elasticity model quantifying the sensitivity of various fuel consumptions on changes in a small number of parameters used to characterize the impact of each measure.

- *Database Engine*: Implementation of many of MMWIN's features was made possible through development of a database engine optimized for the particular needs of building energy analysis. In brief, while conventional database applications usually feature a relatively small number of data tables with thousands or even millions of records each, building energy analysis requires a much larger number of tables though each containing at most a few hundred records. (Typical building energy analysis tables are Zones, Walls, Systems, Heating Equipment, etc. Each zone, wall, system, or heating equipment instance is a record in the respective table).
  Furthermore, while the links among tables in a conventional database stay relatively static and the structure is simple enough to visualize, the multitude of tables in building energy analysis requires both a better visualization of the logical links as well as a convenient way to edit these links (assigning zones to different systems, copying and attaching room air conditioners to all the zones in a motel, etc.). The MMWIN database engine features an API specialized for the operations required by the *View Representations* and by the *Copy and Paste* operations discussed earlier. It also supports the management of *Calculations-on-demand* with an object-oriented approach.

- *Unique Project Files*: All data pertaining to one project and all of its scenarios, whether input, weather data, library components, or output results, are managed by the Database Engine in virtual memory. When saved to a data storage device, the same data stored to one single file. There are no scratch files, temporary files, or file catalogs to contend with. (Because the hourly loads and system data constitute two-thirds of the size of a project file and can be re-created through re-simulation at any time, the user has the option not to include them in the file saved to disk.)

The advantages of this approach are the convenient and safe transport of project data from one user to another, whether by disk, by email, or by groupware. Since the project file is self-contained, the destination user need not be in possession of the same libraries, weather data, or templates used by the sender. Current file size is limited less by available disk space than by the maximum number of logical connections (65,000) between building components.

CALCULATION METHODS

MMWIN simulates the heating and cooling requirements of a building using a traditional sequence of loads, systems, and plant modules.

Loads calculations use the Transfer Function Method to model hourly envelope loads, internal gains, and solar heat gains, as a function of outdoor weather and indoor thermal conditions. Up to eight different day types per month are modeled.

Systems calculations are performed using simple mass, heat and moisture balance methods to model the impact of setpoints, control strategies, and weather.

Plant calculations are modeled using published performance characteristics in a fashion similar, and frequently identical, to DOE 2.1.

The schematic sequence of calculations, for each day of each month, is as follows:

1. *Sensible hourly loads* for all zones are calculated component by component: (a) envelope loads are calculated using the Transfer Function Method[1]; (b) the radiant portion of instantaneous heat gains from lighting, equipment, process, and occupant loads are converted to hourly cooling loads using Room Transfer Function; (c) the convective portion of sensible instantaneous heat gains are calculated from instantaneous hourly values; (d) the sensible loads from air infiltration are calculated from daily average values; (e) duct losses are computed from duct specifications and hot and cold supply temperatures and ambient temperatures.

2. *Latent hourly loads* for all zones are obtained directly from (a) the latent portion of convective heat gains from equipment, occupants, indoor swimming pools, and process, and from (b) the latent load from air infiltration calculated on a daily average basis only; and from (c) latent duct losses computed from duct leakage and supply and ambient humidity ratios.

3. Where indoor temperature is not held constant, actual hourly *Heat Extraction Rates* are calculated from the sensible cooling loads in each zone, taking into account room air circulation and thermal mass of each zone. If indoor temperature is held constant, Heat Extraction Rates and Cooling Loads are assumed identical.

4. Hourly energy use for *Water Heating* are calculated by taking into account of actual usage schedules and storage effects during times of high demand. The energy requirements to meet water heating loads can be modeled either through stand-alone water heaters or as part of a boiler plant that also meets space heating loads.

5. System *Supply Air Requirements* and *Cooling Coil* and *Heating Coil* loads are modeled next, as a function of ventilation controls, hot and cold supply air controls, and thermostat or hygrostat controls.

6. Heating and cooling Energy to meet heating and cooling coil loads are simulated by using performance models of boilers, furnaces, chillers, DX-air equipment, air-air heat pumps and water-air heat pumps. Sensible and latent full-load capacities (total capacity only for heating equipment) are dependent on temperature and humidity ratio of ambient air and of the supply air stream at the coil. Wherever possible manufacturer's data are used to characterize the capacity dependence on the applicable temperature and humidity conditions. Part-load performance of heating and cooling equipment is modeled using polynomial fits to part-load ratio. Wherever practical, functional forms and coefficient values are taken from DOE-2.1.

7. All energy requirements by auxiliary equipment, lighting, equipment, process, swimming pools, is separately calculated on an hourly basis and tabulated by fuel type.

8. After all hourly energy requirements are calculated, monthly consumption totals and demand are calculated, and, if required by the

[1] 1993 ASHRAE Handbook of Fundamentals, Chapter 26.

energy rates specified, broken down into appropriate time-of-use periods using the hourly profiles.

9. Energy Rate calculations are performed on monthly data of consumption and demand (broken down by TOU for rates that so require). Virtually all types of commercial and industrial rates encountered in the U.S. and Canada can be modeled by MMWIN through a hierarchical rate classification scheme.

10. *Measure Calculations* are done, if measures were used to specify scenarios, to separate the individual contribution of each measure to the overall savings of the measure package that contains the measure.

WEATHER DATA

Weather data used by MMWIN is synthesized from site-specific data on:

latitude, altitude;

2. Design values for summer and winter dry bulb temperatures, summer coincident wet bulb temperature, and wind speed.

monthly average temperatures and monthly temperature ranges;

average coincident wetbulb temperatures for each 5°F (2.8°C) temperature bin;

5. average monthly percentage of possible sunshine;

6. monthly average wind speed.

Two sets of monthly hourly temperature profiles are then calculated: (a) an average day, where an hourly profile is constructed using the monthly average temperature, the monthly temperature range, and a typical hourly temperature profile represented in Table 26.2 of the ASHRAE 1993 Fundamentals; and (b) a peak day, where the same process as in (a) is used except that the temperature profile is shifted up in summer by the difference between the cooling design temperature and the peak temperature of an average design month day. (A similar process is used to shift the peak temperature profile down in winter).

Solar gains through horizontal glass and vertical glass at any azimuth are calculated using clear day hourly solar heat gain values and multiplying them by the monthly average percentage of possible sunshine.

The limitations inherent in this scheme are a legacy from older versions of this software and the necessity to maintain a database of 250 cities for existing clients. Compatibility with weather data in the formats used by popular hourly public-domain programs is envisioned for a version in the near future.

TEMPLATES

MMWIN is shipped with a number of *templates* used to start different buildings. Typical choices are: *Small Office, Large Office, School, Restaurant, Warehouse, Place of Worship, Industrial Facility*, etc.

After selecting one of these templates the user is presented with a "generic" building of this type, with some elements preset according to the selected building type:

Topology of plant, systems, and zones;

- Types of HVAC system, lighting, and other internal gains;

Building type-specific defaults (e.g., W/sqft of lighting, cfm/person of ventilation, etc.);

- Occupancy schedules.

While the user still has to enter data specific to the project, doing so on a skeleton building already pre-configured speeds up input and minimizes accidental omission of crucial inputs.

QUALITY CONTROL

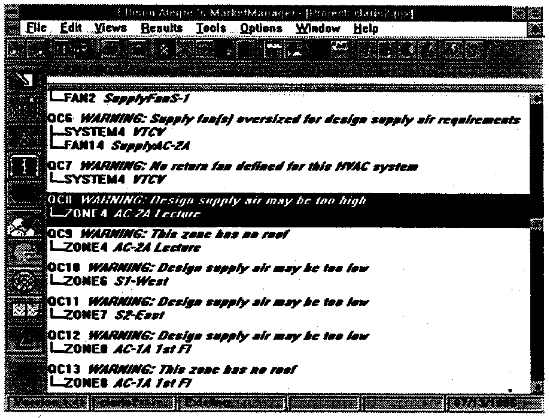
At any time during the input process the user may click on a **Q/C** icon which causes the program to check all inputs for accuracy and consistency. A *Q/C View* is produced showing *Errors* and *Warnings*.

Among the errors and warnings that this procedure issues are:

conflicting or missing schedules;

- Heating or cooling equipment whose type is inconsistent with the HVAC system selected;

Lack of floor, walls, roofs by zone;



- Surface areas of glass in excess of or disproportion to the envelope containing them;
- Thermostat schedules that exceeding design values;
- Over- or under-sized heating or cooling equipment;
- Un-physical part-load coefficients;
- Internal gains from lights or equipment exceeding energy input;
- Fans and auxiliary equipment sizes inconsistent with expected rules of thumb based on equipment size.

SOFTWARE ARCHITECTURE

MMWIN's software architecture uses a number of native and third-party Dynamic Link Libraries (DLL) to serve different functions of the software. A schematic summary is presented below.

Module or DLL	Native/ 3d party	Description
Main program	Native	User interface managers: Menus, Views, Data Forms
Calculations	Native	Real-time design calculations and simulations
Data Export	Native/ 3d party	Data export to DBASE format
Database Engine	Native	Record and Field Manager for Relational Database
Data Dictionary	Native	Catalog of 4,000 fields distributed over 90 tables.
Report Engine	3d party	Merges input and output data with user-editable formats
Graphics Engine	3d party	Produces graphs of input and output data in many formats
Help	Native	General and context-sensitive help

APPLICATIONS

MMWIN is currently used for the following technical applications:

- *Simulating* chillers, cooling towers, boilers, DX-air equipment, Air-Air heat pumps, water-air heat pumps;
- *Heat recovery*, including desuperheaters, stack heat recovery, double bundle chillers, hot water recovery;
- *Controls*, such as room thermostat setbacks, system standby modes, supply air resets; cooling tower free cooling; chilled water resets; boiler water resets;
- *Preheating fresh air* with recovered heat via air-air heat exchangers, heat pipes, heat wheels, thermosiphon, twin towers;
- *Evaporative cooling*: direct, indirect, and mixed direct-indirect systems, air washers;
- Modeling *unusual combinations* of HVAC systems and zones, innovative controls, and experimental heat recovery strategies;
- *Industrial Processes*: metal, glass, and ceramic melting, generic processes; both energy use and impact on cooling load are modeled;
- *Swimming Pools*: Outdoor and Indoor Swimming Pools.
- *Energy Rates*, including Block-rates, Time-of-Use Rates, Loadfactor Rates, and more.

BENCHMARKS AND REQUIREMENTS

Because of extensive use of libraries and dynamic defaults, satisfactory specification for a typical building off construction plans can be accomplished in less than a day.

A complete yearly simulation of typical, 5-zone building with a VAV system takes 15 seconds on an older Intel 486 system (33 Mhz, 4MB of RAM). The same building on a state-of-the-art Pentium system takes under five seconds. Quick run-times are essential for applications where many alternative scenarios are considered and optimized.

Hardware requirements are adequately met by an Intel 386 system with math co-processor, or any 486 system or Pentium. Minimum memory requirement is 4 MB of RAM. At least 10 MB of free disk space is required for a full workstation installation. MMWIN may also be run concurrently on a network.

Time-limited evaluation copies are provided to qualified potential users free of charge. Educational licenses free of charge are available also.

FUTURE DEVELOPMENT

Since its introduction late in 1993 MarketManager has gone through 4 major version upgrades, with a fifth planned for this fall.

Version 1.5 will feature automatic switching between IP and SI units, including necessary automatic conversions, currency conversion, and such mundane issues as different date and number notation by country.

Other plans for future versions include:

- Fulfillment of a user-generated, wish-list of desirable additional HVAC modeling capabilities and user interface enhancements;
- 8,760-hour calculations;
- support for standard weather data formats;
- more convenient comparison of input differences between scenarios;
- enhanced run-time customization of reports.

CONCLUSION

MarketManager for Windows (MMWIN) is a productivity tool for performance contractors and utility demand-side managers.

MMWIN combines a modern, Windows-based GUI, fast calculations, numerous graphics, flexible reports, into an engineering tool with a strong accounting side.

Innovative use of user interface elements familiar in commercial software facilitates the learning process.

Since its introduction in 1993 the program has been undergoing an aggressive program of continuing enhancements to meet the wishes of a rapidly expanding user base.