NEW GENERATION OF SOFTWARE?
MODELING OF ENERGY DEMANDS FOR RESIDENTIAL VENTILATION
WITH HTML INTERFACE

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ABSTRACT

The paper presents an interactive on-line package for calculation of energy and cost demands for residential infiltration and ventilation, with input and output data entry through a web browser. This is a unique tool. It represents a new kind of approach to developing software employing user (client) and server (package provider) computers. The main program, servicing "intelligent" CGI (Common Gateway Interface) calls, resides on the server and dynamically handles the whole package performance and the procedure of calculations. The "computing engine" consists of two parts: RESVENT - the previously existing program for ventilation calculations and ECONOMICS - for heating and cooling system energy and cost calculations. The user interface is designed in such a way, that it allows simultaneous access by many users from all over the world.

INTRODUCTION

This is an interactive on-line computing tool for residential building infiltration and ventilation energy analysis with data entry through HTML (Hypertext Markup Language) forms, via Internet browser. It was primarily intended for those who are familiar with air leakage, blower doors, residential ventilation systems, etc. However, the program is not restricted to them and can also help the general public to conserve energy, protect the environment, and save money on energy. Papers [1] and [2] can help with those problems. They are available on-line, being connected to the program by Internet links. The package is user-friendly; it is easy to use, free of charge, interactive, and useful for performing calculations of energy and costs in single-family houses for a variety of climates throughout the U.S.

The whole package is rather complicated owing to its innovative character and lack of entirely appropriate tools. However, it is already much improved when compared with the first Internet calculational tool developed at the beginning of 1996 ([3] and [4]). Ow-

ing to the dynamic progress with the software which is used to serve WWW applications, one can expect that in the near future the presented tool can be further improved. Presently, the package consists of programs, routines and scripts coded in C, HTML and JavaScript as well as several data files.

The main program of the package is mounted on the server and uses the WWW browser (Netscape, Mosaic, Internet Explorer) as the user interface, making it accessible on Internet to general public from all over the world.

The paper describes the method of programming for web which was developed as well as the methods used for modeling and utilized by the "computing engine", i.e. calculation of infiltration and ventilation, heating and cooling loads necessary for conditioning of the air, estimation of energy demands based on approximated efficiency and estimated yearly cost of heating, cooling (restricted to ventilation air conditioning) and ventilation.

The suggestions for further improvements and development are included.

You may view and use the program at URL:
http://www-epb.lbl.gov/ventilation/program.html
You may view the program DEMO on this CD-ROM. From Netscape use "File/Open File" option and specify Selection as follows:
- for UNIX users:
/dir/vol1/p210/readme.htm
where "dir" represents the name of the directory under which the CD-ROM has been mounted.
- for Windows/MS-DOS users:
D:\vol1\p210\readme.htm
where "D" represents the name of the CD-ROM drive.
- for Macintosh users:
Building Simulation 97/vol1/p210/readme.htm
where "Building Simulation 97" is the name of the CD-ROM.

MODELING

The heart of the package, i.e. the "computing engine" consists of two parts: the previously existing program RESVENT and new ECONOMICS part. RESVENT is an enhancement of VENTNRG ([5], [6]). It simulates the annual air flow rates on an hourly basis using the LBL infiltration model ([7]) and effective ventilation rates applying the Sherman/Wilson method. This infiltration model is incorporated into ASHRAE Handbook of Fundamentals ([8]). The seasonal average air change rates, the overall measures of tightness (ASHRAE Standard 119, [9]) and rates for adequate ventilation (ASHRAE Standard 62, [10]) are calculated from hourly values of specific infiltration and air flow rates evaluated by the LBL infiltration model ([1]). These hourly values are also used to determine the heating and cooling loads needed to condition infiltration and ventilation air. A simplified method called Infiltration Degree-Days (IDD) ([11]) is utilized for this purpose.

RESVENT uses the weather data from the LBNL library of approximately 240 representative weather sites across the US and evaluates the heating and cooling loads necessary for conditioning the air. These weather files have been selected to be representative of typical years for each location and are derived from the WYEC (Weather Year for Energy Calculations), TMY (Typical Meteorological Year), TRY (Typical Reference Year), and CTZ (California Climate Zones) weather tapes [1]. Each weather file contains outside temperature, humidity, wind speed and direction, and barometric pressure.

Based on the survey conducted by the Energy Information Administration for the U.S. Department of Energy ([12]) 32 different types of single-family houses were defined ([1]). These types differ by age (old vs. new, using 1980 as a dividing point), number of stories (single-story vs. multistory), duct systems (present or not), floor leakage (present or not), the house condition (good or poor).

The detailed information regarding the modeling of infiltration and ventilation as well as the seasonal heating and cooling loads can be found on-line by clicking on the titles of two papers which discuss the subject ([1] and [2]) and are linked to the program on web.

In the next part of the "computing engine" the energy demand and cost are evaluated on the basis of heating and cooling loads computed by RESVENT.

Energy used for heating may be described by the formula

$$UEC_h = \frac{Load_{total} * (1 - FrH)}{EFF_h * conv} \qquad (1)$$

where

UEC_h - the end-use heating unit energy consumption (UEC),

$Load_{total}$ - total heating load calculated by RESVENT,

FrH - free heat (percent of the heating load which is met through internal and solar gains),

EFF_h - efficiency of the heating system,

$conv$ - coefficient which converts units for various energy sources (gas, oil, lpg, and electricity: for electric resistance heating or heat pump).

The unit energy consumption for air conditioning is described by an equation similar to formula (1) above for the energy used for heating, i.e. by

$$UEC_{cond} = \frac{Load_{total}}{EFF_c * conv_1} \qquad (2)$$

where

UEC_{cond} - air conditioning UEC, kWh/yr,

EFF_c - efficiency of the cooling system,

$conv_1$ - coefficient converting units.

Efficiency of the heating and/or cooling system in equations (1) and (2) respectively, is described by

$$EFF = EFF_{equip} * EFF_{dist} \qquad (3)$$

where

EFF_{equip} - heating or cooling equipment efficiency: the ratio of the estimated seasonal heating or cooling output to the seasonal power consumption for an average U.S. climate, %,

EFF_{dist} - efficiency of the distribution system.

The efficiency of both the heating and cooling equipment has in general been improving since the early 1970s, when first data are available [13]. The measure of efficiency of heating equipment is expressed as an Annual Fuel Utilization Efficiency (AFUE) (for fuel furnaces and electric resistance heating). AFUE of electric resistance heating equipment for both furnaces and room heaters is assumed to equal 100% [13]. Electric devices that use compressors, such as heat pumps in a heating mode, have their own measures of efficiency. This is the Heating Seasonal Performance Factor (HSPF). For central air conditioning and the cooling mode of the heat pumps the cooling equipment efficiency is the Seasonal Energy Efficiency Ratio (SEER), while for room air conditioners, the efficiency measure is the Energy Efficiency Ratio (EER),

which is based on the whole year operation. Shipment-weighted efficiences of the heating and cooling equipment were assumed as functions of the year of their production according to [13].

The efficiency of the heating and cooling distribution systems has been shown to be a very important factor in overall heating and cooling performance in residential buildings [14]. For air distribution through ducts systems, the efficiency is influenced by the duct construction and location. It depends mainly on both the air leakage causing losses of conditioned air from ducts and entering of unconditioned air, and the heat transfer between the duct air and surroundings. For the hydronic distribution systems through piping, inefficiency occurs mainly through heat transfer losses to the surrounding air.

The values of distribution systems efficiency, EFF_{dist}, for both the heating and the cooling distribution systems were assumed according to [15], as follows

$EFF_{dist} = $ 70% for ducts in attics and crawl spaces,

$EFF_{dist} = $ 80% for ducts in conditioned spaces and in basements,

$EFF_{dist} = $ 75% for ducts partly in attics.

For hydronic systems which are usually located in partly conditioned spaces, a baseline efficiency of

$EFF_{dist} = $ 90% was assumed for single-family houses,

$EFF_{dist} = $ 70% for multi-family houses for all locations.

For single-room air conditioners the assumed efficiency of distribution equals 100%.

Finally, the cost of energy used for the space heating and/or cooling, in *dollars/yr*, is calculated from the equation

$$Bill = UEC * conv_k * Price \qquad (4)$$

where

Price - the price of fuel used for space heating, *dollars/kWh* for electricity, *dollars/therm* for gas, or *dollars/gallon* for oil and lpg,

$conv_k$ - coefficients converting units for various fuels.

The energy used by fans is calculated from the following formulas [16]:
For furnace fan:

$$UEC_{f\ fan} = UEC_h * 0.03 * conv \qquad (5)$$

For cooling fan:

$$UEC_{c\ fan} = UEC_{cond} * 0.065 * conv \qquad (6)$$

where *conv* denotes coefficients converting units.

Annual costs of heating and/or cooling of ventilation air are calculated as a sum of annualized ventilating equipment costs and operating costs.

PROGRAMMING

The flow of data while calling the "web program" and the way in which the input and output data are handled are crucial to understanding the limitations of the web programming, and to see the methods of the possible solutions. Those limitations become especially important when dealing with multiple forms data entry, multiple logical paths in the program, and long time computing. Most of those limitations do not apply to simple web calculations and data collections.

Programming in CGI - what is this?

CGI (Common Gateway Interface) turns the Web from a collection of static documents into an interactive medium. It is the part of the Web server that can communicate with other programs running on the server. There are special techniques that are particular to CGI, including some special types of input and a few strict rules on program output.

One of the important problems to solve in Web programming is a problem of multi-user access. "Multi-user" means the possibility to access the program and perform calculations by more than one user at the same time. However the nature of the "httpd" server (which handles the HTTP requests over the network) allows the multi-user access without any limitations, but the final implementation of the particular program depends on the way in which the CGI script communicates with the computing "engine". This problem was already discussed in [3] and [4] and one of the solutions proposed there was applied presently.

Accessing the system by more than one user at the same time is possible by a static and by a dynamic approach.
I. Static approach

- using the *multi-user database* to collect the input data from each user, or

- *blocking the second user* from using the program for the duration of the first user's session, or

- using *different filenames for different users.*

The second solution, although simpler than the first one is in fact non-trivial to implement. However, a

mixture of properly set time-outs and locking flags (perhaps by using the UNIX System V semaphores) should make the implementation possible. The third solution is the simplest: instead of the "input file", a dedicated (for each user) filename should be generated, different than other (recently used) filenames. This, in fact, is a poor-man-database approach, because the collection of the "recently used" filenames would constitute a database. An additional technical problem with this approach is how to transfer the dedicated filename from the CGI call (where it will be computed) to the HTML interface seen by the user, which sends the FORMs for the CGI calculations.

Again, there are several options to adopt: either asking the user to re-type the proposed (unique) acronym or to ask the user to generate his own acronym. The above re-typing is needed to feed the subsequent forms with the necessary identifier, but is far from being intuitively accepted. The other approach is better: the user types his or her code, the code gets verified and then the user will type his or her acronym before any computations/selections are done by the CGI script.

Experiments with the CGI calls and use of the HTML scripts bring one to the conclusion that the static restrictions imposed by the HTML standard cause serious problems when using complex data processing with multiple input data. Because the data has to be processed (and eventually stored) on the httpd server's site, more action should be controlled by the CGI-call mechanism than by the pure start-up HTML script.

This suggests an alternative approach to static HTML/CGI multi-user access, namely:
II. Dynamic approach - "intelligent" CGI-call servicing utility which does the following:

- handles the FORM POST-transferred data,

- proceeds with the computations, and

- generates the subsequent HTML texts to be displayed to the user.

This solution was finally chosen. The main program VENT_AGENT, "intelligent" CGI-call servicing utility written in C, resides on the server and - by using the httpd daemon - dynamically handles the whole package performance and the procedure of calculations. It also generates most of the subsequent HTML texts to be displayed to the user, input and output forms and uses the web browser (Netscape, Mosaic, Internet Explorer) as the user interface. Combining the FORM-handling with the package data processing eliminates the input-file generation and related problems. Dynamic generation of the HTML texts solved many more problems with the single trick: it enabled more uniform state/city selection, enabled accumulation of the collected data, and made the package totally multi-user. As a matter of fact, this "intelligent-CGI"

program can do a lot of other actions, dynamic by nature: it can change the size and format of the presented HTML forms and frames, can open new windows, can produce suitable graphics (adapted to the specific input, output or other data), can return new forms with suitably arranged default values, etc.

The whole package consists of 2 programs written in C, VENT_AGENT ("intelligent" CGI-call) and VENT_LOADS ("computing engine"), several scripts written in HTML (Hypertext Markup Language) and JavaScript as well as several data files.

The heart of the package, i.e. "computing engine" consists of two parts: the previously existing program RESVENT and new ECONOMICS part. RESVENT ([5]) simulates the annual air flow rates on the hourly basis using the LBL infiltration model ([7]). The ECONOMICS calculates the energy demand and cost for 32 types of houses, 240 locations, some common kinds of ventilation systems, and various heating, cooling and distribution systems.

Since JavaScript is not supported by some old browsers, its usage is presently restricted to scrolling messages on the window status lines. The users of old browsers will not be able to view these messages but can use the program and receive the correct results.

Input Data

Input data to the program are read in three different modes: from the user input, through the default values in the program, and from data files placed on the hard disc. The user input is self-explanatory. Its Graphical User Interface (GUI) is defined by the HTML forms which include several questions concerning the program variables. Some questions have to be answered directly by printing numbers - values of some program variables - as input data into the HTML forms. The other data are entered by multiple choice options and the user needs only to select the right option. Answering some questions is optional; should the user not know the correct number, the default value of variable is assumed by the program.

The user input variables are read through four different forms. These are as follows:

I) Selection of the closest weather station (mandatory),

II) Selection of the house description data (mandatory),

III) Selection of the mechanical ventilation (optional),

IV) Selection of the data regarding cost (optional).

As it was stated above, two forms have to be filled since they contain some mandatory data. Filling of the remaining two forms is optional. If they are not filled,

it is assumed that the house has no mechanical ventilation and/or that the cost of heating and cooling of an infiltration (and ventilation if present) air will not be computed. The sequence of forms may be arbitrarily chosen by the program user.

I) Selection of the closest weather station is necessary to perform calculations. It can be chosen from the alphabetical list of all stations included or by selecting state and then station from that state.

If the data is not provided, the error message is printed and execution of the program terminates.

II) As was already mentioned, the selection of the house description data is also mandatory. However, only the house floor area has to be written into the form explicitly. All other variables have the built-in default values. The program user has to select one of the options or just accept the default (already selected) value. The variables in this form are as follows:

1) Wind environment:

 - shielding parameters (by class); multiple choice,
 - terrain parameters (by class); multiple choice.

2) House configuration; all variables are selected by multiple choice:

 - the type of the house and basement,
 - the age of the house,
 - the information about existence of the duct
   system, and
 - information about retrofitting.

3) The leakage area; effective or normalized.
4) The house dimensions:

 - floor area (mandatory),
 - volume and height (both optional; if these spaces are left blank, the height is taken at default and the volume is calculated.

The effective leakage area quantifies the absolute size of openings in the building, and for the LBL infiltration model it is determined by summing the respective component leakage areas of a specific building. The effective leakage area can be obtained from a whole building pressurization test. If a test is not available, it can be calculated on the basis of component leakage areas. If this section is left blank, the default effective leakage will be calculated in a function of normalized leakage (as defined in ASHRAE Standard 119 ([9])). If the normalized leakage value section is also left blank, a default value from the LBNL database will be used for the type of house entered. The default effective leakage area will be calculated on this basis.

III) Selection of the mechanical ventilation is optional; if this form is not selected, it is assumed that the house does not have mechanical ventilation.

This program can take into account a few common kinds of mechanical ventilation systems, including both room and whole-house systems. The whole house ventilation system is selected by multiple choice from: supply, exhaust, or balanced system options. The user can also provide some additional, i.e. optional, data. These are as follows:

 - the air flow rate,
 - the power consumption,
 - the number of hours daily when the system is
   operating and
 - the percentage of the heat recovered (if recovery system is assumed to exist; this option works
   only for balanced ventilation system).

The room fans may be chosen from the following options:

 - 3 different bathroom fans,
 - 2 kitchen fans,
 - 1 clothes dryer fan.

For each of them the user may enter the air flow rate. If these boxes are left blank, the default values are assumed (for selected fans).

IV) Selection of the data regarding cost (optional). The questions on this form allow the user to select the data regarding energy and cost. The following variables are included:

 - prices of various fuels; optional,
 - the type of the heating and cooling systems;
   both multiple choice,
 - the type of the heating and cooling distribution
   systems; both multiple choice,
 - the efficiency of the heating and cooling equipment; both optional,
 - the year of production of the heating and/or
   cooling equipment; optional.

If this form is not selected, the energy and cost will not be calculated.

The remaining input data are read from input files. These are as follows:

 - prices of the energy sources in all states, including: gas, oil, lpg, and electricity,
 - efficiency of the heating equipment since 1972,
 - efficiency of the cooling equipment since 1972,
 - free heat for 32 types of houses and for each of
   the weather stations ([1], source: [17]),
 - normalized leakage, terrain and shielding parameters, for 32 types of houses and for each of
   the 240 weather stations,
 - climate parameters for all weather stations.

Several HELP files are available for the data entry forms providing assistance with better understanding the input variables as well as helping with selecting and entering the correct input values. The following subjects are covered in HELP files:

 - normalized leakage,
 - terrain parameters for Standard Terrain Classes,
 - Local Shielding Classes,
 - effective leakage area,
 - representative weather data, and
 - weather data selection,
 - the house dimensions,
 - the further options of proceeding with calculations,
 - the house description data,
 - mechanical ventilation systems,
 - room (local) fans,
 - whole house ventilation system,
 - economics,
 - heating and cooling equipment efficiency,
 - output - further options,
 - air change rates in output.

Output

Program VENT_AGENT creates an HTML form and writes the results of computations on this form. The form is passed from the server directly to the user (client) via the Internet and displayed by the user's browser (Netscape, Mosaic, Internet Explorer). As it was mentioned previously, Output from the program is self-explanatory. It includes the following information:

1) Basic input data:

 - the weather station,
 - the house description: the type of the house and foundation, the age, retrofitting and duct systems information,
 - the house floor area, height and volume,
 - the kind of the heating and cooling systems,
 - the kind of the heating and cooling distribution systems.

2) The values which are read from the user input or computed:

 - effective leakage area, and
 - normalized leakage; read from the user data or LBL database,
 - leakage class, according to leakage classes of ASHRAE Standard 119 ([9]); computed.

3) Air change rates

 - according to ASHRAE Standard 136 ([18]),
 - Effective Air Change Rate,
 - the date with minimum daily infiltration, and
 - the date with maximum daily infiltration.

The results of computations are then compared with two ASHRAE Standards requirements: Ventilation Standard 62-1989 ([10]) and Tightness Standard 119-1988 ([9]). Information whether they are met or not, is printed.

Finally, annual heating and cooling loads, energy, the price of energy, and cost for conditioning the infiltration and ventilation air, for furnace, cooling and ventilation fans (equipment and operation) are printed as well as the total sums.

Error messages are produced when data is missing in created input data file.

User Interface

The basic interface of the package is defined by the HTML forms with ACTION (client side) pointing to VENT_AGENT program used as "intelligent" CGI call (on server). The version of HTML in common use today doesn't support calculations, and while it can be used for the collection of information and data, it cannot directly process this information. One of the other HTML limitations is its lack of logical "paths" or multiple "pop-up"s selections. This limitation caused problems with the selections of pairs of "state and weather station". The present solution required separate HTML forms for each primary selection. These forms are dynamically created by the VENT_AGENT program and displayed by user's Web browser regardless of platform (e.g. Mac, PC, UNIX). Since HTML forms are dynamically written during each user session, some information regarding values of already selected variables is available and can be displayed in the subsequent forms.

FUTURE PERSPECTIVES

The basic problems with the multi-user access, when analyzed in the situation of the current implementation (i.e. "call the CGI" - "wait for the results") increase when the time of the computations (solving the model) increases. Currently, this is not a problem, because the computations take few seconds to complete. Attempts to make existing compute-intensive software work through the web might encounter a different problem: the user would be rather unhappy pressing the "Compute" button and waiting too long for the results.

   The way in which the CGI calls are handled does not allow the user to "go back" with his browser and to read (say) other pages while waiting: he/she has to wait until the CGI call completes. In addition, there is no way to send the user any partial information, e.g. the estimated time to wait. This is because the "httpd" daemon handles the CGI calls with the basic fork()/exec()/wait3() technique, which hangs the parent process on waiting for the "completion of the child

process" (the CGI execution).

To solve this problem I would recommend yet another approach: a batch style of execution.

In otherwords, after initial selection of the data, the user may start the computations, but will be merely informed that the computation process was queued and the results will be available after, say, N seconds (minutes?, hours?).

This approach is easy to apply even long-time computing models, and will make the interface more user-friendly (no blocking/waiting time). It requires, however, an "intelligent" database to store the data, to store the batched process identifiers and to store the results. The programmer may design the customized database for this purpose or connect the package to one of the existing databases, for example Oracle.

CONCLUSIONS

This interactive, multi-user, on-line package is a unique tool which represents a new kind of approach to developing software, using two computers: user (client) and server (package provider), connected by Internet. It proves that CGI can be successfully used for creating a fully functional interface to put a calculation program on the Web, eliminating limitations discussed in [4].

The package is mounted on the server. It employs "intelligent" CGI-call servicing program which handles the procedure of calculations, dynamically creates most of the subsequent HTML texts to be displayed to the user, generates input and output forms and employs the web browser (Netscape, Mosaic, Internet Explorer) as the user interface. The user interface enables simultaneous access by many users at the same time - without any limitations.

This innovative, Internet-based computing tool has some distinct advantages when compared to the traditional software. There is an ease of software handling, installing, updating, revising, and fixing possible bugs. Regardless of the ease in disseminating the information and problem shooting, this kind of programming also substantially lowers all costs involved and makes software available to the whole world. An additional advantage is that users of any browsers can access the tool regardless of platform (UNIX, PC, Mac).

This approach also enables a very easy feedback from the users to the program developer. The results of computations may be automatically stored for the future use. The unique feature of this kind of calculational tool is also the ease of connecting to other information by Internet links. This feature will allow an easy comparison of the results with information stored on other Web sites related to this subject.

When compared with the first software of this kind,

developed at the beginning of 1996 and described in [3] and [4], several technical problems were overcome. Nonetheless, no single programming language could serve to develop the package at the time of its creation (second half of 1996) and the tool is rather complicated. Since the progress with the software used on web is very dynamic, and cannot be compared with that of the traditional programming tools, one could expect that the next version of an internet calculating tool would be more straightforward and less complicated.

It should be mentioned that the "internet software" is not necessarily restricted to public domain. A built-in password or other options will enable, if needed, collection of appropriate fee for calculations.

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