DEVELOPMENT OF THE POTENTIAL ENERGY SAVINGS ESTIMATION (PESE) TOOLKIT

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ABSTRACT

This study has developed a prototype computer tool called the Potential Energy Savings Estimation (PESE) Toolkit. Baltazar's methodology for potential energy savings estimation from EBCx/retrofit measures has been improved in several ways and implemented in the PESE Toolkit, which is based on VBA (Visual Basic for Application) and Microsoft® Excel spreadsheets for input and output. It is intended to help engineers in estimating the potential energy savings in a given building and identifying the corresponding energy conservation measures (ECMs) in the early phase of an EBCx project or energy retrofit project. Using the tool requires limited information about the building and the built-in HVAC system type, as well as sorted bin weather and energy consumption data. It provides comprehensive output of energy costs and savings, energy use, space loads, and system parameters. The tool is also illustrated in an example of application.

INTRODUCTION

Today, as energy prices increase, saving money on energy bills through an existing building commissioning (EBCx) or an energy retrofit project is attractive to many commercial building owners. At the beginning of such a project, some form of screening is often applied to determine whether there is sufficient potential for savings to justify an EBCx assessment or an energy audit. If screening results are positive, the assessment/audit is performed and the potential for energy savings in the building is evaluated before the owner/operator decides that further work is likely to produce significant energy savings meeting the owner's economic criteria.

Baltazar (2006) proposed a methodology for estimating the potential energy savings in commercial buildings, which is considered appropriate for this type of pre-screening. At its core is a procedure for obtaining the minimum energy use cost required to maintain indoor thermal comfort. This methodology was applied to several existing buildings that have been retrofitted and/or commissioned. The measured savings in one of the buildings was about 85% of the estimated potential savings, close enough to suggest value for this approach. This methodology is promising, but to make it a useful tool in EBCx assessments or energy audits, further testing is necessary, which requires development of a prototype computer tool.

METHODOLOGY FOR POTENTIAL ENERGY SAVINGS ESTIMATION

Baltazar's Methodology

This methodology defines the potential energy savings in each outside air temperature bin as the difference between the actual energy cost during a particular period, preferably a whole year, and the minimum energy cost needed to maintain comfortable indoor conditions using the existing air-side HVAC systems in the building under the same weather conditions (Eq.1) (Baltazar, 2006). Here the minimized energy cost is comprised of individual costs of electricity, cooling and heating. The electricity cost consists of two parts: (1) lighting and equipment consumption which is estimated from measured data and remains constant, and (2) fan power consumption which is simulated. (Eq.2)

$$\text{Potential Energy Savings} = \text{Energy Cost}_{\text{ACTUAL}} - \text{Energy Cost}_{\text{MINIMIZED}} \quad (1)$$

$$\text{Energy Cost} = (\text{ELE Cost}_{\text{LTEQ}} + \text{ELE Cost}_{\text{FANP}}) + \text{CHW Cost} + \text{HHW Cost} \quad (2)$$

The required bin outside air dry-bulb temperature, mean coincident humidity ratio and the total of measured energy consumption to determine the potential savings can be prepared from hourly measured weather and consumption data.

The essence of this methodology is the procedure for determining the minimum energy use cost, which has two major components as **Figure 1** demonstrates: the model illustrated as a compound function in the figure, which thermodynamically represents the performance of the built-in HVAC system and the numerical procedure for energy cost minimization. The model takes weather conditions into account through a load calculation procedure and it becomes part of the input for the air-side system simulation. Both the load calculation and system simulation follows the modified bin method (Knebel, 1983). The numerical procedure generates and seeks the parameter values which will produce minimum total energy use cost while meeting the indoor thermal comfort requirements.

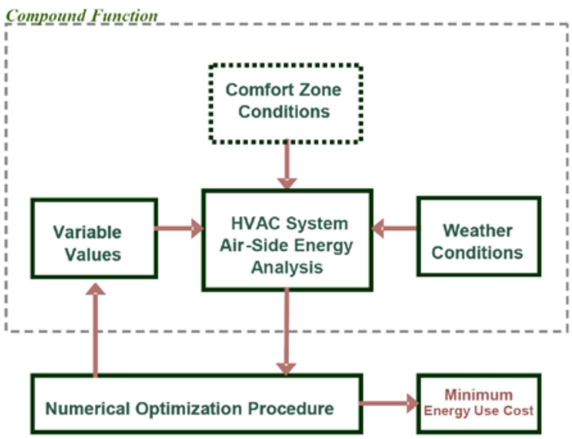


Figure 1 Block diagram of the methodology for potential energy savings determination (Baltazar, 2006)

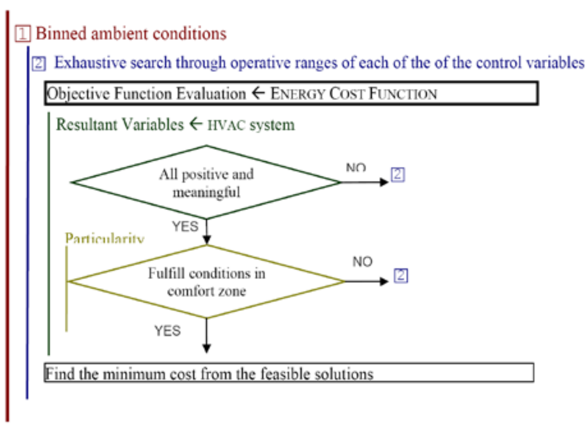


Figure 2 Flowchart of the methodology for evaluating potential energy savings in a building through binned ambient conditions. The total potential savings will be the sum of the individual products of the energy savings in each bin multiplied by its frequency. (Baltazar, 2006)

Sequential exhaustive search is employed as the optimization method and manages through representative equivalent ambient conditions obtained by "bin sorting". **Figure 2** illustrates the procedure of implementation of the methodology in determining the minimum energy cost for each bin. The total potential energy cost savings during the period evaluated are then the sum of savings found in each bin.

Improvements on Methodology

In PESE Toolkit, several major improvements have been made on Baltazar's implemented methodology as follows:

Optimization Parameters. Four parameters are selected for optimization in Baltazar's methodology: cold deck and hot deck (for dual duct systems) leaving air temperature set points; minimum supply airflow per square foot of floor area (for VAV systems); and the fraction of outside airflow in total design airflow. In this study, the volumetric outside airflow is optimized instead of optimizing outside air fraction because volumetric control is required in order to implement the optimization result; the minimum supply airflow is not optimized since the optimized value is always equal to the designated lower limit. In addition to the above changes, room temperature set points in the exterior and interior zones are included as additional optimization parameters, since space loads are dependent on these two parameters. In addition, options are provided to PESE users to optimize any combination of these five parameters. This may be helpful in evaluating savings based on the existing control capability.

Space Load Calculation. In Baltazar's implementation, space cooling and heating load are calculated based on fixed occupied period room temperature set points (e.g. 75°F). This can lead to inaccurate optimization results when the room temperatures are optimized using unoccupied resets and seasonal resets, because the conduction load makes up a significant fraction of the total space load. Therefore, in this study, a space load calculation procedure is developed based on the modified bin method and linked with the optimization procedure, so that the space load will be re-calculated dynamically as room temperature set points change in the optimization process.

Simulation of Buildings with Multiple Types of Systems. Two input parameters are introduced to account for this problem - the fractions of exterior and interior zones served by each type of system. They are applied to calculated whole-building exterior and interior zone space loads. Here, it is assumed that the space load is proportional to floor area. This assumption works fine with buildings having each type of system serving an entire floor or several floors, or buildings having two different types of systems serving the exterior zone and interior zone respectively.

AHU Shut-down Simulation. The cooling and heating energy use during unoccupied period typically comprises two parts: the energy use during the AHU shut-down period (there is usually still a lower and upper limit on the room temperature to bring the AHU back to work) and the energy use at start-up. Based on an energy balance, this energy use can be estimated to be approximately equal to the sum of the largest two components of the space load: the internal heat gain and the conduction load.

During the AHU shut-down period, the room temperature changes under the influence of internal heat gain and conduction through the building envelope. This challenges one of the major limitations of the modified bin method, which is based on time averaging techniques and does not take the thermal capacitance of the space into account. However, based on the measured data in an office building in Texas, where AHU shutdown has been implemented, it is found that the average room temperature during the unoccupied period has an approximately linear relationship with the average outside air temperature. This finding is used to estimate the average conduction load during the unoccupied period. It is noted that the relationship can vary from building to building depending on the building’s size, construction, internal heat gain, etc.

COMPUTARIZED IMPLEMENTATION OF THE POSTENTIAL ENERGY SAVINGS ESTIMATION: THE PESE TOOLKIT

The PESE Toolkit is a prototype computer tool developed to implement a test the improved methodology for potential energy savings estimation. The tool is capable of estimating the theoretically potential energy use cost savings (including electricity cost, cooling cost and heating cost) achievable by optimizing certain control parameters in the HVAC system of a given commercial building. Since the methodology is expected to help engineers in the early phase of an EBCx assessment or an energy audit to identify no-cost/low-cost ECMs and the corresponding savings, only limited information about the building and the built-in HVAC system is required to use the tool. The PESE toolkit is developed with Visual Basic for Application (VBA) programming language, and the interface for input and output is based on Microsoft® Excel 2003 spreadsheets. The following is a list of important features included in the prototype:

1) Input interface to specify building and system parameters and optimization constraints.

2) The user only needs to input information regarding building location and dimensions, internal heat gain, weather and thermal properties of the envelope in order to perform the cooling and heating load calculation procedure.

3) Up to five optimization parameters are included. The user can decide which ones to activate for optimization depending on the system configuration (e.g. pneumatic control or DDC control, availability of a flow sensor for outside air intake). With none of the optimization parameters activated, a simulation without optimization will be executed, which could be used for the purpose of calibration to measured consumption data or checking the impact on energy use of changing certain parameters.

4) Air-side simulation models of four common HVAC systems are provided: Single Duct Constant Volume (SDCV) system, Dual Duct Constant Volume (DDCV) system, Single Duct Variable Air Volume (SDVAV) system, and Dual Duct Variable Air Volume (SDVAV) system.

5) Common HVAC system configuration and control options are provided, such as preheat and reheat type (electric or using hot water), and control method of minimum outside air intake.

6) Comprehensive output for each bin is provided to the user including energy costs and savings, energy consumption, space loads, system loads and parameters. Most of them are also illustrated in plots versus bin temperature for easy analysis.

The PESE toolkit is essentially composed of worksheets for input and output.

Input
There is a worksheet named “Input” in PESE, where the user can type in all the necessary information about the building, the HVAC system and optimization options. PESE also requires input of weather data and measured energy consumption data (electricity, chilled water and hot water) for each bin during occupied and unoccupied period respectively. The worksheet named “BinData” is for this part of the input.

Output
The “BinData” worksheet holds not only the input but also the output for each bin during occupied and unoccupied periods. The output comprises several

sections: energy costs (current and optimized), potential energy cost savings (in dollars and percentage), optimized energy consumption, space loads (including components), HVAC system loads (cooling, heating and fan power) and system parameters (temperatures, air flow rates and fractions, humidity ratios, etc.). For easy interpretation and analysis of the results, PESE provides plots of most of the above results versus bin temperature.

EXAMPLE OF APPLICATION

Using the PESE Toolkit for potential energy savings estimation analysis is explained in the following example of an office building.

Introduction

The selected building is located on the main campus of Texas A&M University with a total area of 24,446 square feet. It has three stories (including a half-underground basement) consisting of offices and conference rooms. The building is generally occupied weekdays from 8:00 AM to 5:00 PM. The HVAC system consists of one multizone unit (AHU1) serving the basement, one single duct VAV unit (AHU2) serving the first floor, two single duct VAV rooftop units (RTU1 and RTU 2) serving the second floor and one outside air pre-treat unit (OAHU) serving AHU1 and AHU 2. Electric strips are used as heaters in the terminal boxes associated with the SDVAV systems. EBCx measures have been implemented in this building since 7/15/2008. Since EBCx, the HVAC system is turned off during the unoccupied period at 10:00 PM and turned on again around 6:00 AM the next morning.

Input

Figure 3 and **Figure 4** show the PESE input for the example building: **Figure 3** collects information about the building, the built-in HVAC system and optimization options; **Figure 4** presents a typical bin data sample. The items in each section are explained as follows.

The left section in **Figure 3** is for building information, which has four subsections as general, internal heat gain, weather, and envelope. In the "general" subsection, the following information about the building is needed: the name, city, latitude of location (rounded to 1°), orientation of the long wall which falls in the range of N-SSE clockwise (it is illustrated in the figure on right), dimensions, number of floors above the ground, whether there is a basement, whether the basement is conditioned if applicable, total floor area, and exterior and interior zone areas. In the "internal heat gain" subsection, it has included the number of occupants in the exterior and interior zones during full occupancy, the Average Occupied Factor for the occupied and unoccupied periods, and the average whole-building lighting and equipment electricity use during the occupied and unoccupied periods (This can be derived from hourly consumption data by subtracting the estimated fan power use.). In the "weather" subsection, it requires the Fraction of Possible Sunshine in July and January (found in Knebel 1983), the peak summer and peak winter bin temperatures, and the average outside temperature on design day. Finally, the "envelope" subsection includes the U-values of the components of the envelope (walls, windows, roof, and the ground), the window area fractions on each wall, the average Shading Coefficients of the windows on each wall as well as the skylight(s) if applicable, the shades of color of the wall and roof.

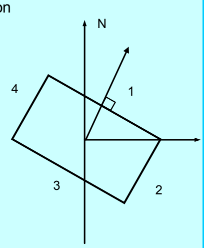
The right top section in **Figure 3** is for HVAC system information, which comprises a main subsection and a subsection for the VAV systems. The main subsection holds the following information: system type, preheat and reheat type (use hot water or electricity), whether there is an economizer (only applicable for a simulation without optimization), whether the AHUs are shut down during unoccupied periods, fractions of the exterior and interior zone areas served by the system being evaluated (100% if there is only one type of system), exterior and interior zone temperature set points during occupied and unoccupied periods, total design supply air flow, exterior and interior zone supply air flows (only for constant volume systems), cold deck and hot deck leaving air temperature set points as a function of outside air temperature which are illustrated in the plot on right, rated fan power of supply and return fans, whether the outside air is controlled by a minimum flow rate or a minimum fraction (only applicable for a simulation without optimization) and the corresponding values, and maximum outside air flow rate. For VAV systems, additional input for the VAV mechanism (outlet dampers, inlet vanes, or variable speed drive) and the exterior and interior zone minimum supply air flows during occupied and unoccupied periods (These values are explained in the following section) are also necessary.

The right bottom section in **Figure 3** is for optimization options, which contains two subsections. The first asks which parameter(s) is/are activated for optimization, as well as the range of values and grid division of each parameter during the occupied and unoccupied periods. In this example, the limiting values used for zone temperatures during occupied period are suggested by ASHRAE (2007a); those for zone temperatures during unoccupied period and cold deck set points are following typical EBCx practice in hot and humid climate; the lower limits for outside air intake are determined by the required amount in the breathing zone by ASHRAE (2007b), while the upper limit is the outside air duct size limits. The greater the numbers of grid divisions are, the longer time it will take to run the simulation. With the values used in this example, it takes about a minute to run on a recent office computer. The second subsection is for specifying the energy prices as well as the lower and upper limits of the indoor relative humidity during occupied period. It is noted that if the energy prices are not available in the form of chilled water and hot water consumption per MMBtu, conversions are required. The button which activates the PESE program is also in the second subsection. It should be noted that for those parameters activated for optimization, it is not required to input the current setting in the system information section. For example, in the application shown in **Figure 3**, the cold deck and hot deck reset schedules are activated for optimization. Therefore, it is not necessary to fill out the corresponding fields in the system information section (however, they are still filled to show the plotting feature in this section.). This is useful for estimating the potential energy savings without much information about the current system settings.

The PESE Toolkit also requires input of weather data (dry-bulb temperature and mean coincidence humidity ratio) and measured energy consumption data (electricity, chilled water and hot water), which are sorted into bins with occupied and unoccupied periods separated. This special bin data can be prepared from hourly data by a "bin sorting" procedure, which requires hourly data of any one of the three humidity parameters – wet bulb temperature, dew point temperature, and relative humidity – in order to obtain the humidity ratios.

BUILDING INFORMATION

General	
Name	Sanders Corps of Cadets Center
City	College Station
Latitude	30 °
Orientation (Wall# 1)	NE
Length	180 ft
Width	110 ft
Height	15 ft
Above ground floors	1
Has Basement	FALSE
Basement conditioned	FALSE
A_{tot}	19,800 ft^2
A_e	7,800 ft^2
A_i	12,000 ft^2



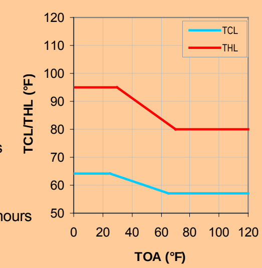
Internal Heat Gain	
Ocp_e	20 pep
Ocp_i	20 pep
AveOcpFactor (Ocp)	1.00
AveOcpFactor (Unocp)	0.10
LTEQ (Ocp)	54 kW
LTEQ (Unocp)	25 kW

Weather	
FPS_July	0.72
FPS_January	0.48
Tpc	107 °F
Tph	27 °F
$T_{o,des}$	86 °F

Envelope	
U-wall	0.09 Btu/(h·ft²·°F)
U-window	1.00 Btu/(h·ft²·°F)
U-roof	0.05 Btu/(h·ft²·°F)
U-ground	0.05 Btu/(h·ft²·°F)
A_{win}/A_{wall} 1	25.0%
A_{win}/A_{wall} 2	15.0%
A_{win}/A_{wall} 3	25.0%
A_{win}/A_{wall} 4	15.0%
$A_{skylights}$	0 ft^2
SC 1	0.45
SC 2	0.15
SC 3	0.20
SC 4	0.25
SC skylights	0.00
Wall color	Medium colored
Roof color	Dark colored

SYSTEM INFORMATION

System Type	SDVAV		
Reheat Type	Hot Water		
Preheat Type	Hot Water		
Has Economizer	FALSE		
AHU shut off	FALSE		
Fraction of A_e	100.0%		
Fraction of A_i	100.0%		
Zone T set point during occupied hours			
T_{e_ocp}	°F		
T_{i_ocp}	°F		
Zone T reset point during unoccupied hours			
T_{e_unocp}	°F		
T_{i_unocp}	°F		
V_{TD}	27,545 cfm		
V_e	cfm		
V_i	cfm		
T_{CL} (setpoint 1)	64 °F	@ $T_{OA}1$=	25 °F
T_{CL} (setpoint 2)	57 °F	@ $T_{OA}2$=	65 °F
T_{HL} (setpoint 1)	95 °F	@ $T_{OA}1$=	30 °F
T_{HL} (setpoint 2)	80 °F	@ $T_{OA}2$=	70 °F
$P_{SF\text{-}rated}$	30 hp		
$P_{RF\text{-}rated}$	0 hp		
OA controlled by	VOAmin	VOA_{max}	cfm
X_{OA,min_ocp}		X_{OA,min_unocp}	
V_{OA,min_ocp}	cfm	V_{OA,min_unocp}	cfm
VAV systems			
VAV mechanism	Variable Speed Drive		
V_{e,min_ocp}	3,820 cfm	V_{e,min_unocp}	0 cfm
V_{i,min_ocp}	3,600 cfm	V_{i,min_unocp}	0 cfm



OPTIMIZATION OPTIONS

Variables	Select	Ocp: range & grid				Unocp: range & grid			
Te	TRUE (°F)	70	–	78	9	65	–	85	11
Ti	TRUE (°F)	68	–	72	5	65	–	85	11
TCL	TRUE (°F)	55	–	70	16	55	–	70	16
THL	FALSE (°F)	80	–	115	16	80	–	115	16
VOA	TRUE (cfm)	600	–	4,500	11	0	–	4,500	12

ELE Price	0.092 $/kWh
CHW Price	9.602 $/MMBtu
HHW Price	13.099 $/MMBtu
RHz1	10 %
RHz2	60 %

ESTIMATE POTENTIAL ENERGY COST SAVINGS

Figure 3 Snapshot of the PESE input interface for the example of application

BIN DATA INPUTS — OCCUPIED PERIOD

Outside air temperature (°F) TOA	Outside air humidity ratio - wOA	Zone relative humidity (%) RHOA	Hours of occurrence (hr) HOURS	Measured ELE consumption (kWh) ELE_Meas	Measured CHW consumption (kBtu) CHW_Meas	Measured HHW consumption (kBtu) HHW_Meas
27	0.001948	65.2	2	131	340	328
32	0.002618	69.5	5	327	954	794
37	0.003551	77.1	33	2,159	6,992	5,060
42	0.004116	73.4	56	3,663	13,045	8,283
47	0.004348	64.1	110	7,196	27,939	15,675
52	0.005150	62.9	112	7,326	30,805	15,354
57	0.005589	56.8	163	10,663	48,265	21,463
62	0.006464	54.9	192	12,560	60,894	24,243
67	0.008619	61.3	290	18,970	97,537	33,043
72	0.010431	62.3	351	22,960	121,535	32,031
77	0.012683	63.9	382	25,169	139,677	16,188
82	0.014488	61.8	374	25,135	148,545	13,516
87	0.014880	54.0	290	19,890	122,998	8,671
92	0.014615	45.4	282	19,748	126,638	6,673
97	0.013313	35.5	140	10,014	65,899	2,439
102	0.012134	27.9	11	804	5,423	123
107	0.012752	25.2	1	75	521	5

BIN DATA INPUTS — UNOCCUPIED PERIOD

Outside air temperature (°F) TOA	Outside air humidity ratio - wOA	Zone relative humidity (%) RHOA	Hours of occurrence (hr) HOURS	Measured ELE consumption (kWh) ELE_Meas	Measured CHW consumption (kBtu) CHW_Meas	Measured HHW consumption (kBtu) HHW_Meas
27	0.002106	70.5	11	374	1,675	2,782
32	0.002643	70.1	76	2,586	12,942	18,657
37	0.003461	75.2	186	6,329	35,019	44,282
42	0.003995	71.3	303	10,310	62,495	69,893
47	0.004601	67.8	378	12,861	84,761	84,393
52	0.005675	69.3	428	14,563	103,669	92,387
57	0.007088	71.9	445	15,141	115,788	92,761
62	0.008834	74.8	538	18,305	149,681	108,163
67	0.010686	75.7	646	21,980	190,560	121,143
72	0.013023	77.5	813	27,662	246,615	134,016
77	0.015470	77.6	1,030	35,046	321,319	112,886
82	0.015346	65.3	532	18,101	167,240	45,876
87	0.014747	53.5	298	10,353	97,964	21,916
92	0.014614	45.3	205	7,369	72,233	13,797
97	0.012826	34.2	82	3,052	30,520	5,007
102	0.010645	24.5	10	386	3,913	548

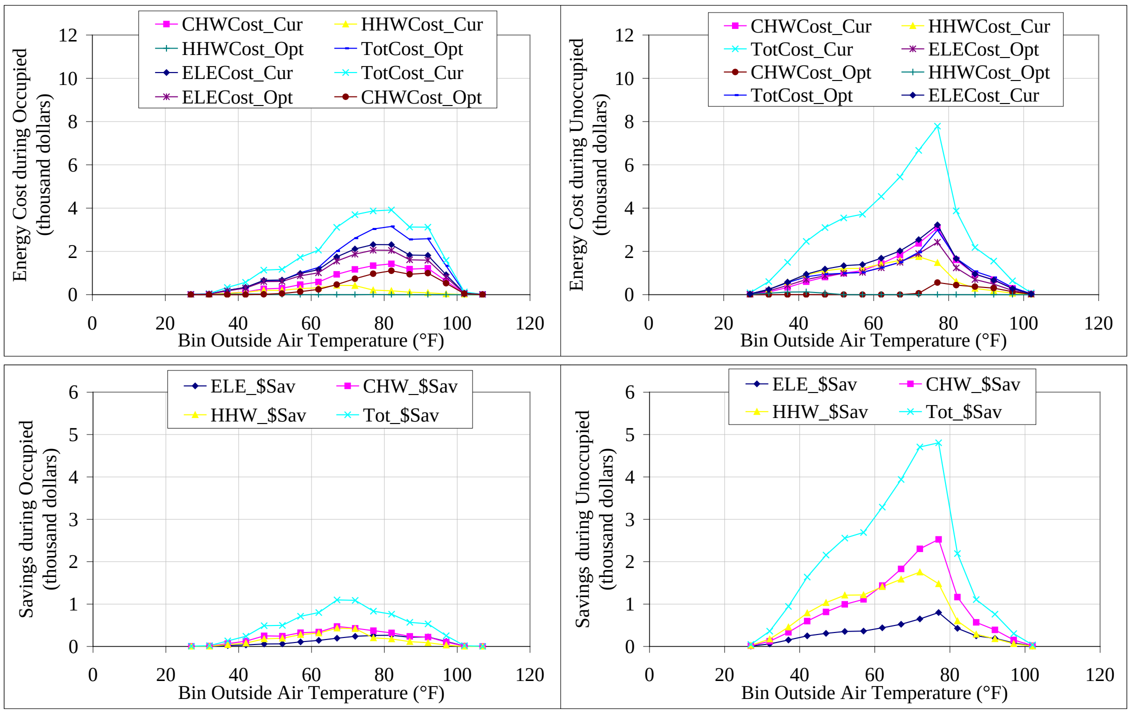
Figure 4 Snapshot of the bin data input interface

Exterior and interior zone minimum air flows are not parameters that can be optimized by the methodology employed by PESE. However, resetting the minimum air flow is an important ECM in VAV systems and usually has significant influence on the energy use. Therefore, the reset values should be determined in a proper manner. According to Taylor and Stein (2004), ANSI/ASHRAE Standard 62.1-2007 for ventilation and ANSI/ASHRAE Standard 90.1-2007 for energy (ASHRAE, 2007c), the minimum airflow during the occupied period can be reset to the largest of the following: (1) the airflow required to meet the design heating load at a supply air temperature that is not too warm (e.g. 85°F); (2) 30% of design airflow or 0.3 cfm/ft^2 if the design airflow is oversized; or (3) the minimum breathing zone outside air required by ANSI/ASHRAE Standard 62.1-2007. Following this procedure, the exterior and interior zone minimum air flows in this example are determined to be 3,820 cfm and 3,600 cfm, respectively. The minimum air flows during the unoccupied period are reset to zero in this case. A simulation with only the minimum air flows reset but without optimization is performed to reveal the savings from this single ECM.

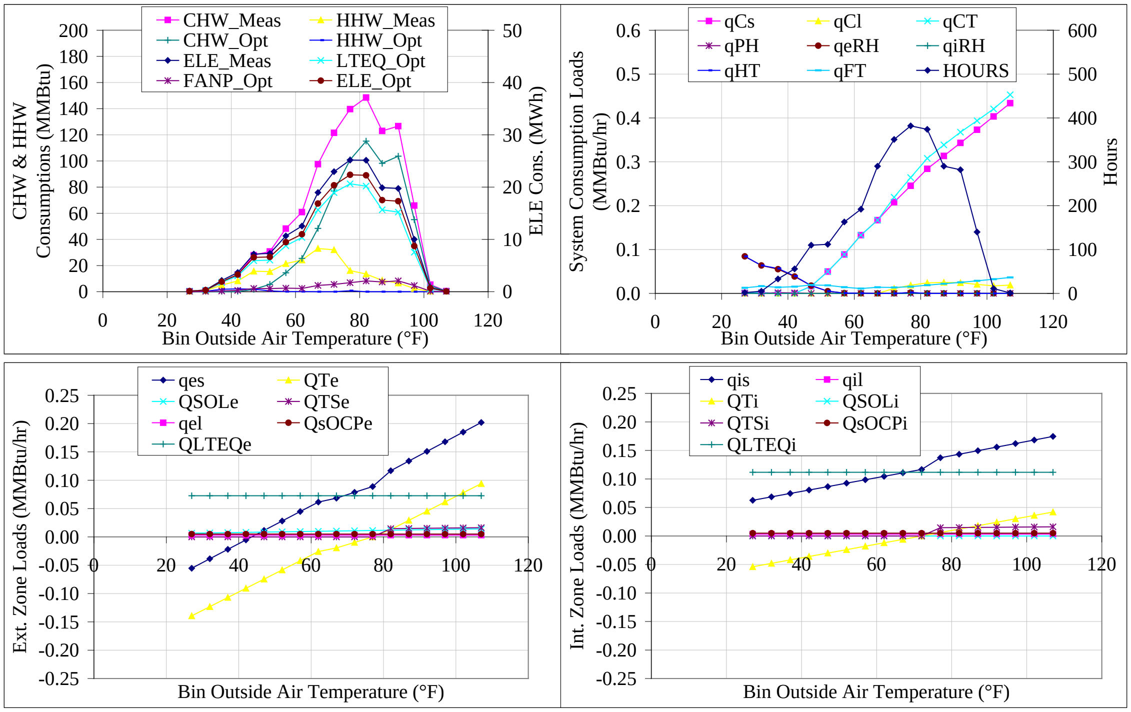
Results and Analysis

There are five chart sheets in PESE showing the following categories of output, respectively: (1) energy cost and saving during occupied and unoccupied period; (2) consumption values, system and space loads during occupied period; (3) system parameters during occupied period; (4) consumption values, system and space loads during unoccupied period and (5) system parameters during unoccupied period. Each chart sheet contains four plots, and the theme of each plot is listed in **Table 1**. The PESE optimization results for the example application are illustrated in **Figure 5**. Chart sheet No.4 and No.5 are omitted because they are similar to No.2 and No. 3, respectively.

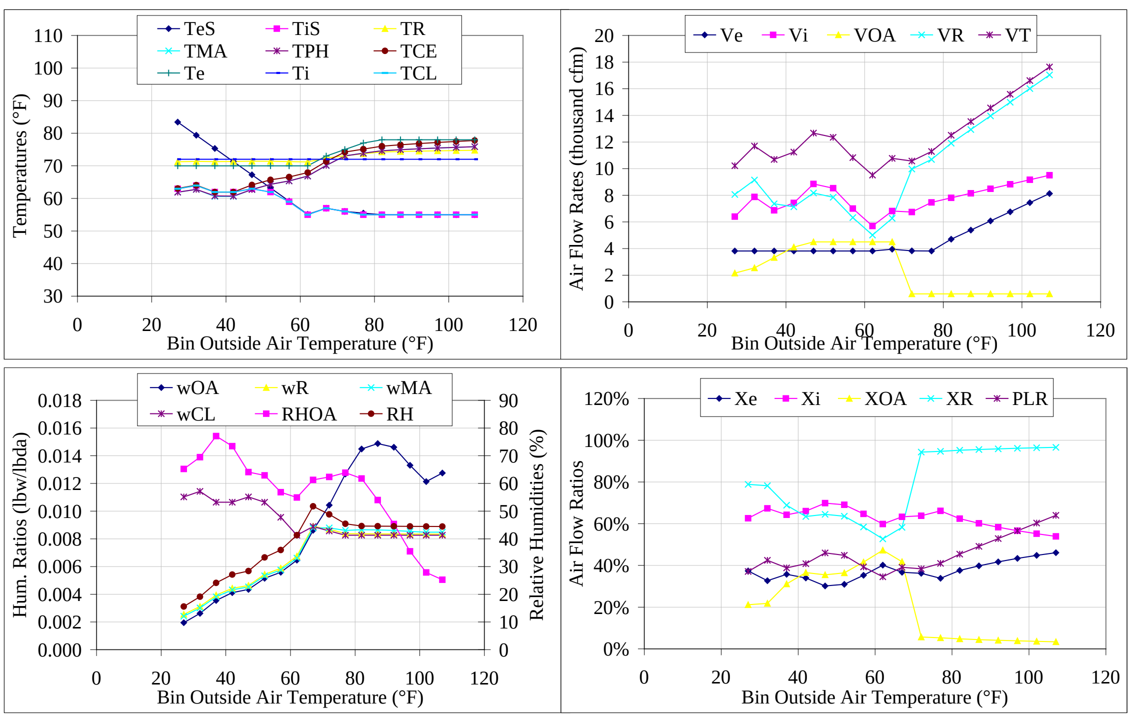
The baseline energy use costs, the savings from only resetting the minimum air flows, and the potential energy savings are compared in **Table 2**. It shows that the total savings from only resetting the minimum air flows are $5,796 (20%) and $25,603 (54%) during occupied and unoccupied periods, respectively; the potential energy savings are $8,054 (27%) and $31,562 (66%) during the two periods. The additional savings beyond resetting the minimum air flows are only 7% and 12% during occupied and unoccupied periods, respectively. The optimized profiles of control parameter settings are given in **Figure 6**. It is noted that these profiles are not intended to be implemented exactly in practice, but to be used as reference.



(a) Chart sheet No.1



(b) Chart sheet No.2



(c) Chart sheet No.3

Figure 5 Snapshots of PESE output charts in the example application

Table 1 Component charts in each chart sheet in PESE Toolkit

Chart Sheet	Plot*	Unit
(1) Energy cost and saving	(a) Energy cost during occupied	Thousand $
	(b) Energy cost during unoccupied	Thousand $

	(c) Savings during occupied	Thousand $
	(d) Savings during unoccupied	Thousand $
(2) Consumptions and loads during occupied period	(a) Measured and optimized energy use	MMBtu; MWh
	(b) System consumption loads and bin hours	MMBtu/hr; hours
	(c) Exterior zone loads	MMBtu/hr
	(d) Interior zone loads	MMBtu/hr
(3) System parameters during occupied period	(a) Temperatures	°F
	(b) Air flow rates	Thousand cfm
	(c) Humidity ratios and relative humidity	Lbw/lbda
	(d) Air flow ratios	%
(4) Consumptions and loads during unoccupied period	(a) Measured and optimized energy use	MMBtu; MWh
	(b) System consumption loads and bin hours	MMBtu/hr; hours
	(c) Exterior zone loads	MMBtu/hr
	(d) Interior zone loads	MMBtu/hr
(5) System parameters during unoccupied period	(a) Temperatures	°F
	(b) Air flow rates	Thousand cfm
	(c) Humidity ratios and relative humidity	Lbw/lbda
	(d) Air flow ratios	%

*In each chart sheet, (a), (b), (c), (d) refer to the upper left, upper right, lower left and lower right plot.

Table 2 Comparison of baseline energy use cost, savings from only resetting the minimum air flows, and potential energy cost savings in the example application

		ELE ($)	CHW ($)	HHW ($)	TOTAL ($)	ELE (%)	CHW (%)	HHW (%)	TOTAL (%)
Occupied	Baseline Energy Use Cost	17,185	9,775	2,671	29,630	-	-	-	-
	Savings from Resetting V_{min}	1,166	2,199	2,432	5,796	7	22	91	20
	Potential Energy Savings	1,964	3,525	2,565	8,054	11	36	96	27
Unoccupied	Baseline Energy Use Cost	18,806	16,289	12,686	47,782	-	-	-	-
	Savings from Resetting V_{min}	3,990	9,962	11,651	25,603	21	61	92	54
	Potential Energy Savings	4,875	14,381	12,306	31,562	26	88	97	66

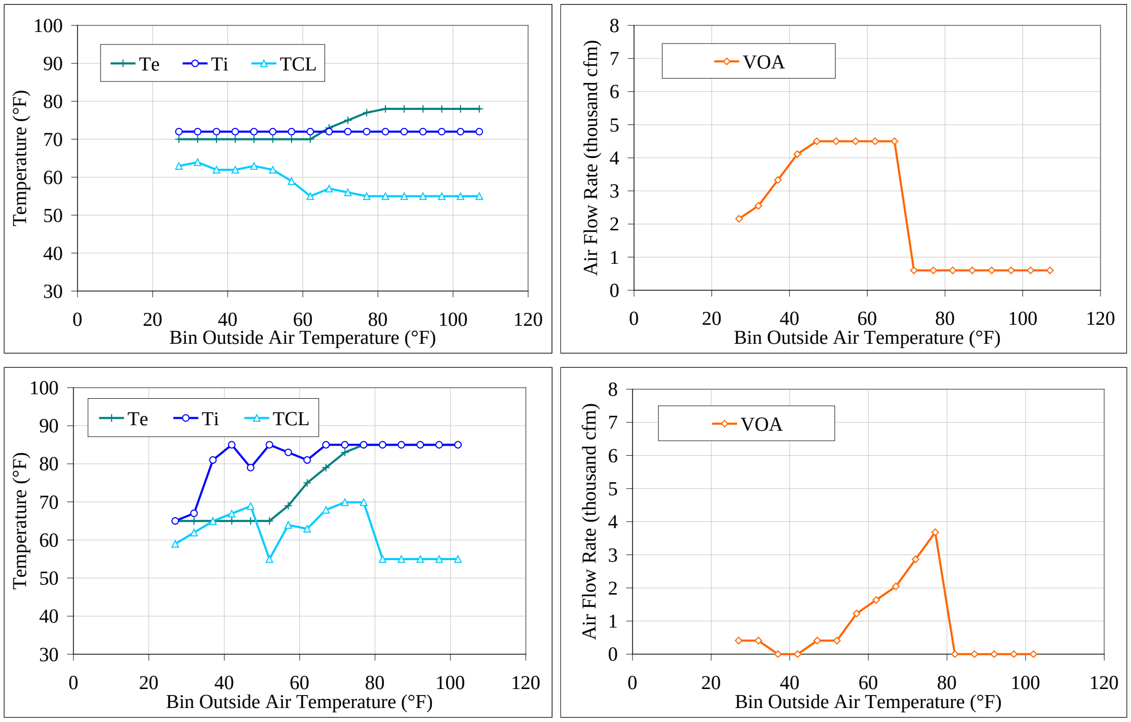


Figure 6 PESE optimized parameter settings during occupied (top) and unoccupied (bottom) periods as a function of bin temperature in the example application

CONCLUSIONS

This study has developed a prototype computer tool called PESE for pre-screening purposes in the early phase of an EBCx project or energy retrofit project. Baltazar's methodology for potential energy savings estimation from EBCx/retrofit measures has been improved in several ways and implemented in the PESE Toolkit which will also help to make future testing of the methodology much easier. Using the tool only requires limited information about the building and the built-in HVAC system, as well as sorted bin weather and energy consumption data. It provides comprehensive output of energy costs and savings, space loads, and system parameters, etc.

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