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DEVELOPMENT OF AN INTERACTIVE GRAPHICAL USER INTERFACE (GUI) FOR ENERGYPLUS

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ABSTRACT

In order to make EnergyPlus easier to use in China, VisualEPlus, a Chinese graphical user interface for the program, has been developed. VisualEPlus is designed to be generic, so that it can be used in any country, as well as be linked to other modeling tools and interfaces for EnergyPlus. VisualEPlus has three main modules: (1) a Building Loads Module for defining the building geometry, envelope, and space conditions that has been adapted from an existing DOE-2 interface (DOE2IN); (2) a HVAC System Module with a drag-and-drop feature for defining the HVAC system; and (3) a View Report Module with a reporting and visualization tool for EnergyPlus reports and outputs. This paper presents the background and development of VisualEPlus, describes its main functions and features as compared to other existing interfaces for EnergyPlus, and discusses plans for the further development of VisualEPlus.

INTRODUCTION

EnergyPlus is a whole-building energy simulation program developed by the U.S. Department of Energy (DOE). It was intended as a next-generation building simulation program to replace BLAST and DOE-2, with more detailed simulation capabilities than many other simulation tools in the market (Crawley et al. 2001). However, EnergyPlus is a simulation engine only and does not have its own GUI. Developing a building model with EnergyPlus is complicated and requires high modeling skills and strong technical knowledge about building physics and HVAC system performance and controls. Therefore, EnergyPlus is still used mainly for research, with limited usage for energy analysis of new building design and existing building retrofitting. In comparison, other programs such as DOE-2, eQUEST, ESP-r, and TRNSYS are being used more and more in engineering practice around the world, and have GUIs that make it much easier to develop the building model.

Likewise, in China, the use of EnergyPlus is limited to only a few research institutes, and the following obstacles have to be overcome before EnergyPlus can become a widely-used mainstream engineering simulation tool:

- Lack of Chinese version interface. Many engineers in China prefer to using Chinese version software, even though they can understand English because of the easy communication with clients and colleagues.
- Lack of a graphical interface. Compared with other commercial building simulation tools, EnergyPlus is still difficult to use. Although DesignBuilder (http://www.designbuilder.co.uk) can help the user to define a building geometry fairly quickly, the HVAC system is still too difficult to configure with EnergyPlus IDF editor. DesignBuilder is also too expensive for the user in China.
- Lack of visualization capability. The utility function xEsoView, which comes with the current EnergyPlus release, can only view one variable at a time and do not

support the comparison of multiple simulation results from parametric runs.

- Lack of typical building material and operation schedule library. EnergyPlus users have to define their own building material library. This can be a particular problem in China because the typical construction materials are different than in US.

Up to now, there are several third-party GUIs developed for EnergyPlus calculation engine, e.g., DesignBuilder and Sketchup (Ellis et al. 2008). However, most of these third-party GUIs cover only the rapid development of the building model, while the input of the HVAC system is still relatively simple, and the visualization also just for the building geometry and templates for the HVAC system..

To promote the use of EnergyPlus in China, one of the authors (Huang), while still working at Lawrence Berkeley National Laboratory (LBNL), obtained funding from the U.S. Department of Energy (DOE) to organize a team from three Chinese research institutes (Tongji University, Shandong University, and the China Academy of Building Research) to develop a comprehensive Chinese GUI for EnergyPlus, which was later given the name of VisualEPlus. The development of VisualEPlus was started in March 2008 and the first version (VisualEPlus 1.0) released in Sep 2010.

VISUALEPLUS

Main functions

Although the initial goal was to make EnergyPlus easier to use in China, VisualEPlus has been designed to be a generic GUI that can be used in any country, as well as be linked to other modeling tools and interfaces for EnergyPlus. VisualEPlus has three main functions: (1) a Building Loads Module for defining the building geometry, envelope, and space conditions adapted from DOE2IN, an existing DOE-2 interface developed by CABR, (2) a HVAC System Module with a drag-and-drop feature for defining the HVAC system, and (3) a View Report Module with a reporting and visualization tool for EnergyPlus reports and outputs.

VisualEPlus is planned to be bilingual in Chinese and English, although in Version 1.0 the Building Loads Module is only in Chinese. The user can choose either language when starting the program. VisualEPlus consists of six modules – Building Model, HVAC System, IDF File, Report Setup, Simulation and View Report (see Figure 1).

VisualEPlus is programmed in C++ and integrates the DOE2IN Building Loads Module for developing the building geometry and envelope descriptions (see Figure 2) with a drag-and-drop HVAC System Module for describing the HVAC system configuration (see Figure 3), as well as with a View Report Module, a reporting and visualization tool for the report outputs (see Figure 11). The DOE2IN-based Building Loads Module allows the user to input the building geometry,

materials, construction, internal loads, operating schedules, etc., and is currently available only in Chinese, After the building loads input data, i.e., building geometry, envelope, internal load, and schedule, has been finished, the Building Loads Module generates an IDF file.

The user can also import building geometry information from an existing EnergyPlus file, Sketch Up 6.0 and DesignBuilder geometry files using the "Import IDF File" function .

After the user has finished all the HVAC system inputs, the HVAC System Module will generate a XML file with the user's system configuration data.

The software will merge the IDF file generated by Building Loads Module with the XML file mentioned above to generate an IDF file containing the inputs both of building loads and HVAC system.

After the IDF file is generated, the user can use the Report Setup function to define the variables and meters among all available output data as well as the frequency of outputting.

When the Report Setup icon is clicked, VisualEPlus will make an initial test run. If there are no severe errors, the report setup window will be activated. If there is a severe error, a warning message window will show up, and the user must modify the model to eliminate the error before redoing the simulation.

After the report setup is done, VisualEPlus will add the report definition part to the existing IDF file to generate a complete IDF file for output, review and simulation running (IDF File module). The user can also review the IDF file and make revisions by hand using the View IDF File function.

The user can also select the weather file using the Select Weather File function.

VisualEPlus is developed based on EnergyPlus 2.2, but version transition programs can be used to translate the IDF file to later versions of EnergyPlus.

Features

Compared with other interface tools with EnergyPlus calculation engine such as DesignBuilder, Sketch Up and etc., VisualEPlus has the following features:

(1) Graphical HVAC system input is realized. The complexity of HVAC system input of EnergyPlus has been always a hard nut to crack for the novice of energy simulation. As discussed above, the other interface tools contribute very little on this function. VisualEPlus not only visualizes the HVAC system inputted so as to facilitate the user to understand the system, but also makes the HVAC system input process easier and more efficient. VisualEPlus realizes visualized HVAC system input completely to some degree. In addition, the "zone group" function simplifies the HVAC air loop input in a very large extent.

(2) Links to other interfaces are provided. VisualEPlus is designed as an integrative platform of EnergyPlus, therefore the integration with other interfaces are considered fully. For example, the user can import IDF

geometry file produced by other interfaces via the function of "IDF file importing".

(3) The using habit of Chinese people is considered. Since the main aim of VisualEPlus is to promote the application of EnergyPlus in China, the using habit of Chinese people is a big concern, which is indicated not only by Chinese version interface but also by model configuration process.

Case study with VisualEPlus

The target building is a 3-floor rectangular building (40m*25m), with 9 zones – 4 exterior, 4 interior and 1 unconditioned core zone on each floor. The height of the first floor is 6m and that of the second and third floor is 4m.

The heat transfer features of the building envelope and the internal loads, such as occupancy density, lighting power density (LPD), equipment power density (EPD), as well as the operating schedules of each zone are listed in Table 1 and 2.

Table 1 Heat transfer parameters of building envelope components

Envelope	U-Value(W/m^2.K)	SHGC
Exterior wall	1.0	
Interior wall	2.025	
Roof	0.7	
Window	2.8	0.388

Table 2 Internal loads and operating schedules

Occupancy (m^2/p)	4
LPD (W/m^2)	11
EPD (W/m^2)	20
Outdoor air(m^3/h.p)	34
Operating schedule	8:00-19:00

The building is served by a VAV (variable air volume) system commonly used in office buildings, which consists of one AHU (air handling unit) and 24 VAV boxes (8 boxes each floor). The VAV terminals in perimeter zones contain reheat coils to meet the demand of heating in winter. Electric chiller and gas boiler are selected as the heating and cooling source plants.

Using Building Loads module DOE2IN to build the geometry model or import an IDF file with geometry information, the HVAC system is developed by the drag-and-drop HVAC System Module (see Figure 3). Figures 4 to 7 present the configurations of condenser water loop, chilled water loop, hot water loop and air loop.

The properties of each HVAC component, such as name, size/autosize, performance curve, node names, branch names and parameters can be input on the interface (Figure 8) while other parameters can be set in the System Parameter list window (Figure 9). To make it simple, the capacities and flow rates of most HVAC components are set as "autosize".

The user defined output variables and meters as well as run period are set in the Report Setup window (Figure 10). Shanghai TMY (typical meteorological year) weather file is selected to run the simulation. Figure 11 shows one of the simulation results – the electric consumption breakdown in the View Report interface.

PRINCIPLES AND PROCESS OF DEVELOPMENT

Guiding Principles

The development of VisualEPlus has been guided by the following principles, which are agreed by the developers after many discussions:

1. Focuse on HVAC GUI development

The development of VisualEPlus focuses on HVAC system interactive graphical interface. A drag-and-place interface is developed for the user to freely configure a HVAC system using basic components such as zone, coil, fan, pumps, and pipe and connecting them into branches and then loops. The user can change the property of the basic component, such as name, size/autosize, performance curve, node names, and branch name from the interactive interface. This drag-and-place interface offers very high flexibility of HVAC system configuration. Several typical HVAC systems (e.g., purchase air system, VAV system, four-pipe FCU system, CAV system and radiant heating and cooling system) are provided as examples for the user to select and revise so as to configure a HVAC system rapidly and correctly. VisualEPlus generates an intermediate XML file for the system configuration.

2. Integrate DOE2IN for building geometry input

Although our development work focuses on HVAC interface, we would like to make the software an integrative tool for building and system model establishment. Therefore an existing tool, DOE2IN is integrated into the software. DOE2IN is a Chinese version of DOE2 with DOE2.1e as the calculation engine, developed by China Academy of Building Research (CABR). It has a very detailed building material library, standard operation schedules, typical HVAC systems in China, and an interactive interface for simple building geometry. The user can input the simple geometry information of a building using DOE2IN, including materials, constructions, internal loads and operating schedules. Then an IDF input file for building geometry is migrated by VisualEPlus.

3. Provide link with other interfaces

In order to take advantage of existing software, VisualEPlus also provides link with other interfaces. The user can import geometry from existing EnergyPlus files, DOE2 file, Sketch Up 6.0 and DesignBuilder geometry files using the function of IDF File Input in the overall Interface. An IDF geometry file is then produced IDF file importing.

Development Process

The process of VisualEPlus development consists of the fulfillment of the following tasks:

1. General framework development

Technical discussions among the partners were conducted to determine the general framework of the software on the kick-off meeting on March 3rd, 2008 in Shanghai. The topics included the current status of such related tools as DRQAT and DOE2IN, the software development platforms, data exchange between modules and the scope and work plan of each partner. It was determined that the development would be focused on HVAC graphical interface, which was just that the existing interfaces lack of. The HVAC interface would be developed into a drag-and-place graphical interface so as to make it easy-to-use and flexible. An overall interface would integrate DOE2IN for building geometry description and the drag-and-place graphical interface for HVAC system configuration as well as a reporting and visualization tool for report output and it would be programmed in C++. The integration of DOE2IN and HVAC GUI is via "thermal zones". The software would be transferred into English to make it bilingual so as to benefit the user both in China and US.

2. HVAC GUI interface development

To develop a drag-and-place HVAC GUI interface, the data requirement and the format of the intermediate XML file were firstly defined. Secondly the data input requirement for both HVAC components and typical HVAC systems in idd files was specified. Thirdly, a list of common HVAC systems in both China and US that VisualEPlus would map was developed. Then the drag-and-place interface was developed, which could generate an intermediate XML file with the component linkage, component property, and graphical position of each components. Lastly, a software program was developed to process the information in the XML file to generate an IDF HVAC system file.

The function of "Zone Group" was designed to simplify the HVAC system input, i.e., all the thermal zones served by the same type of zone air distribution terminals (VAV box, FCU, Direct Air, Purchased Air) could be categorized into one zone group and the uses only needed to input zone air distribution terminal for each zone group once, then it would be duplicated automatically.

The names of all components and their inlet and outlet nodes are given by the software automatically, which can also save a great amount of work of the user.

The properties and parameters of HVAC components can be input and edited directly by clicking the icons on the drag-and-place page, however, the input and edition of other parameters such as schedule, branch and branch list, controller and controller list, loop, operating scheme, zone control, etc. have to be conducted in the window of "set system data"

3. DOE2In module integration

VisualEPlus uses the current materials and schedule library in DOE2IN. The code and data in the DOE2IN are integrated into the new software. The outputs of DOE2IN (BDL) are converted directly into EnergyPlus input format (IDF). No intermediate file is produced. At the same time, a zone name list is provided for the uses to select and build up air supply terminals for the thermal zones.

4. Report and visualization interface development

The report interface is a data analyzing software targeted to the EnergyPlus energy consumption output results; it carries out analysis of the data in the two outputted files generated during the running of EnergyPlus, including the standard ESO file and Meter file. The data outputted by EnergyPlus is all in simple text format, inconvenient for analysis, and the report part is designed based on this problem, integrating the data, showing the data in the form of tables and graphs classified, and makes it convenient to analyze the relationship between different energy consumption.

The report output and view interface is capable of displaying both standard report and user-defined report. Standard report includes all-year and monthly energy consumption and all-year and monthly energy cost as well as energy consumption breakdown. User-defined Report can display other simulation results defined by the user, such as indoor air temperatures, flow rates of nodes, hourly energy consumption, etc.

5. Software integration, debugging, and testing

After the development of all the modules in the tasks above were completed, an overall interface of EnergyPlus was generated to integrate them together. The overall interface transfers the XML file produced by the HVAC configuration interface into an IDF HVAC system file and then combines the IDF geometry file and IDF HVAC file and report parameter definition into one complete IDF file for output, review and simulation running. Next, debugging and testing were conducted on the software before making it public.

FURTHER DEVELOPMENT

This current release of VisualEPlus has the following shortcomings:

(1) The building model input interface (DOE2IN) only has Chinese version and can only develop relatively simple building geometry models.

(2) The HVAC system configuration interface only includes commonly used HVAC components, with which the user can develop normal HVAC systems. Not all components in EnergyPlus are included in VisualEPlus.

(3) There are few data in the databases of building

envelope, operating schedule and HVAC components. Thus, the further development of VisualEPlus includes:

(1) The Chinese version of DOE2IN will be translated into English, or other building geometry interfaces with stronger function will be integrated into the overall interface.

(2) The HVAC system will be fatherly developed and more available components will be added and the function of VisualEPlus will be optimized.

(3) Properties of building envelope components and HVAC components as well as operating schedules will be collected so as to develop databases of building components, HVAC components and schedules.

CONCLUSION

Although EnergyPlus have many advantages that other building energy simulation programs do not have, its complexity of model development and high requirement of technical knowledge to the user limit its application only within the research field. A Chinese interface for EnergyPlus is developed that engineers and researchers in China can use to improve building energy efficiency in both design and operation. VisualEPlus realizes the graphical input of HVAC system and offers links with other interface tools. VisualEPlus has both Chinese and English versions, so it can be used by the user not only in China but also in the other countries around the world.

ACKNOWLEDGEMENT

REFERENCES

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[3] Peter G. Ellis, Paul A. Torcellini, and Drury B. Crawley, Energy Design Plugin: an Energyplus Plugin for Sketchup, Simbuild2008, July 30 to Aug 1, Berkeley, USA, 2008
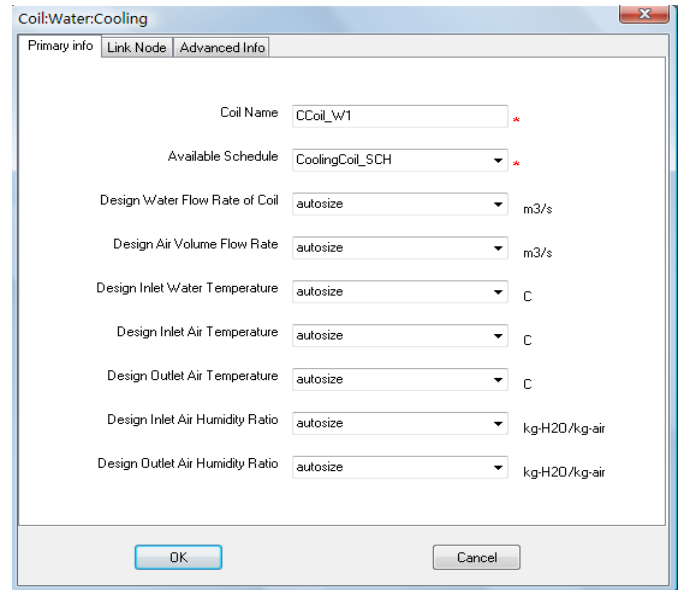
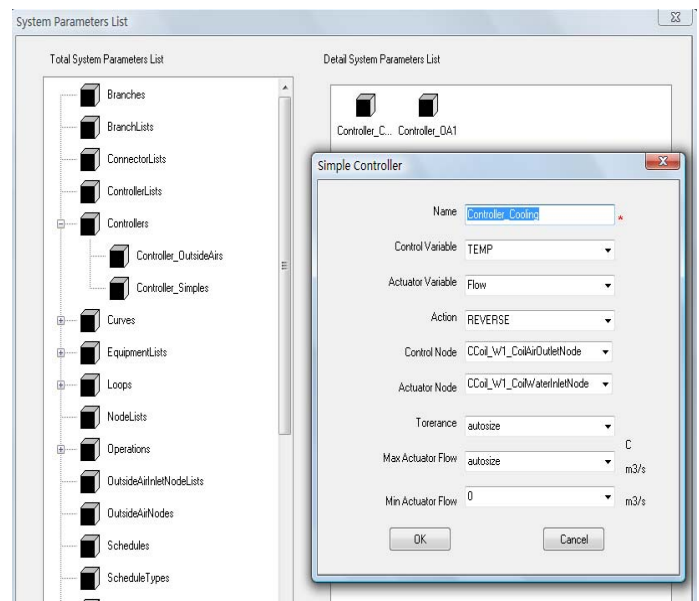**Fig. 8** Properties of the basic component setup interface

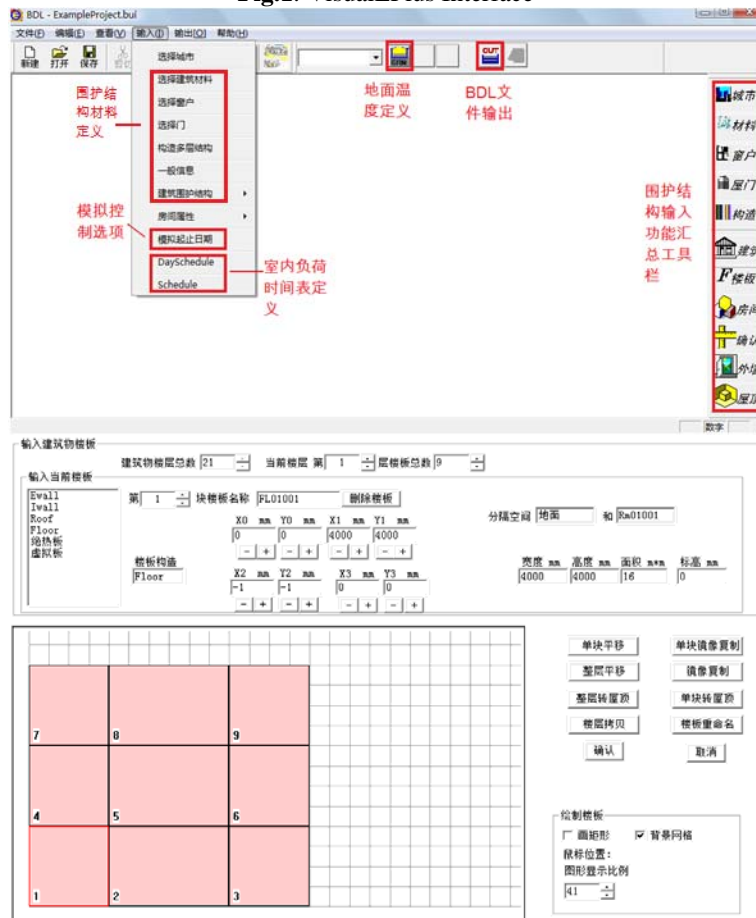**Fig. 9** System Parameter list Window

Fig.1: VisualEPlus Interface
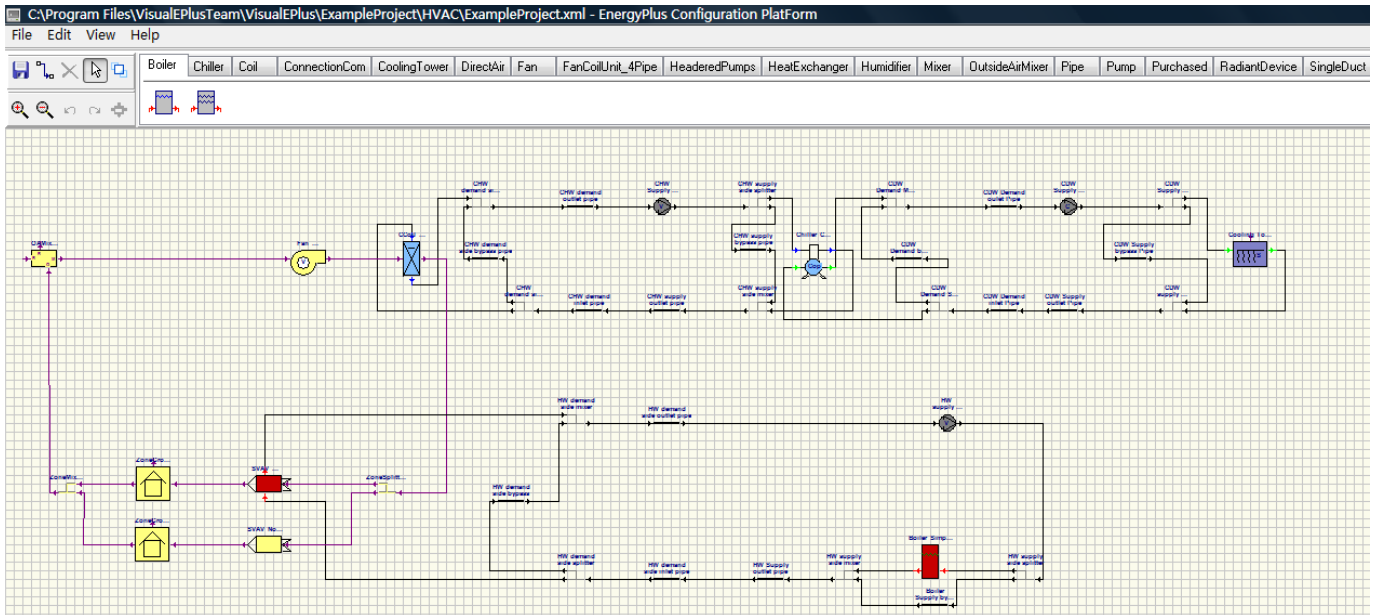

Fig.2: DOE2IN Interface

C:\Program Files\VisualEPlusTeam\VisualEPlus\ExampleProject\HVAC\ExampleProject.xml - EnergyPlus Configuration PlatForm

File   Edit   View   Help

Boiler | Chiller | Coil | ConnectionCom | CoolingTower | DirectAir | Fan | FanCoilUnit_4Pipe | HeaderedPumps | HeatExchanger | Humidifier | Mixer | OutsideAirMixer | Pipe | Pump | Purchased | RadiantDevice | SingleDuct

Fig. 3: HVAC system interface with a VAV system configuration
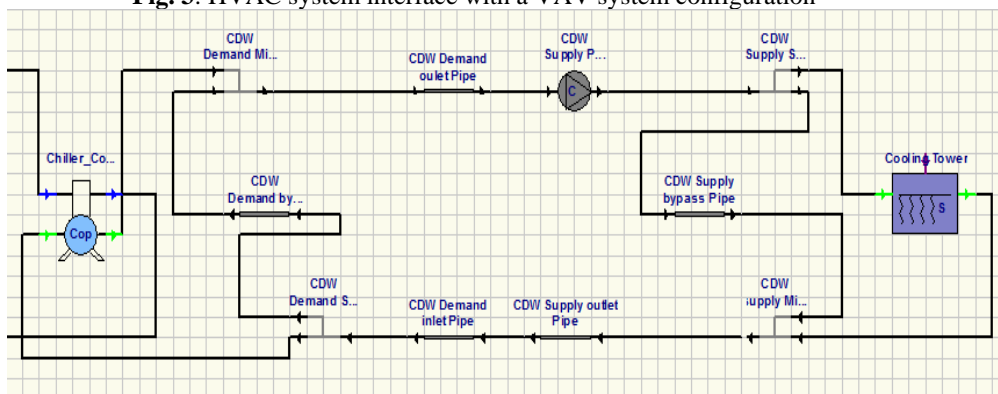
Fig. 4 Condenser water loop configuration

Cooling coil
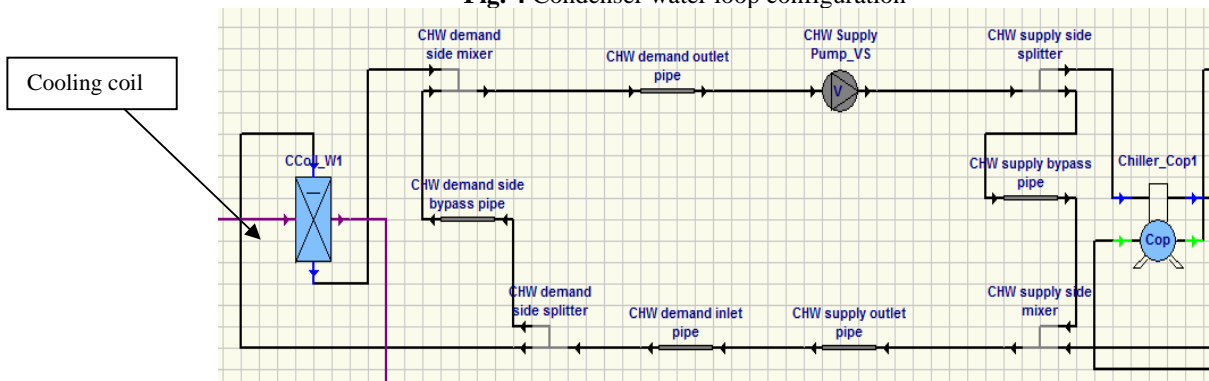
Fig. 5 Chiller water loop configuration
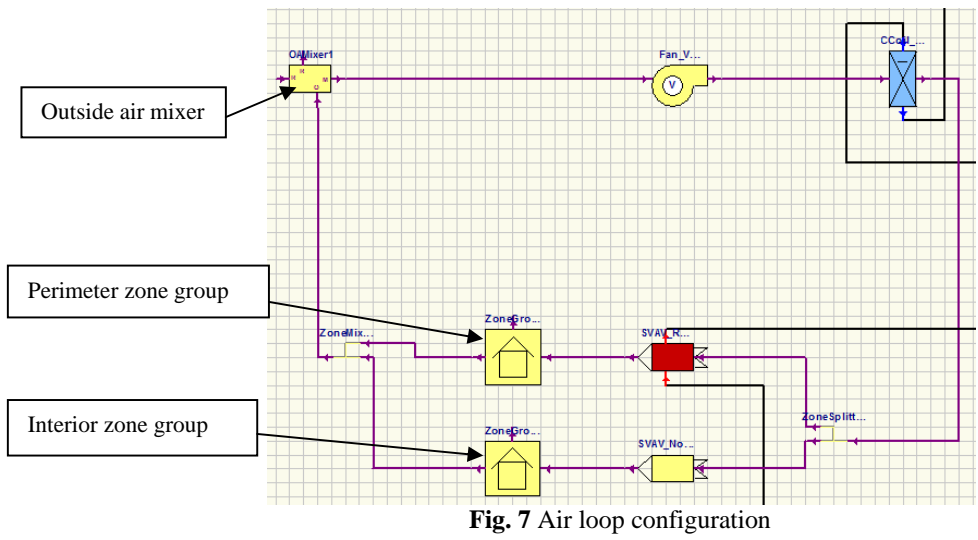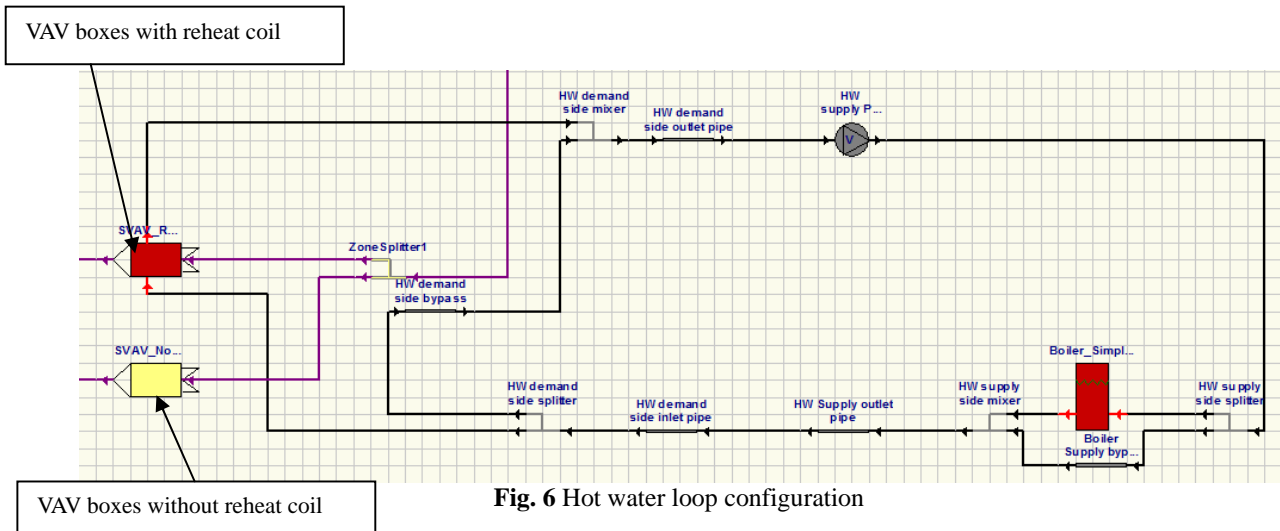
7   Copyright © 20xx by ASME

VAV boxes with reheat coil

VAV boxes without reheat coil

Fig. 6 Hot water loop configuration

Outside air mixer

Perimeter zone group

Interior zone group

Fig. 7 Air loop configuration

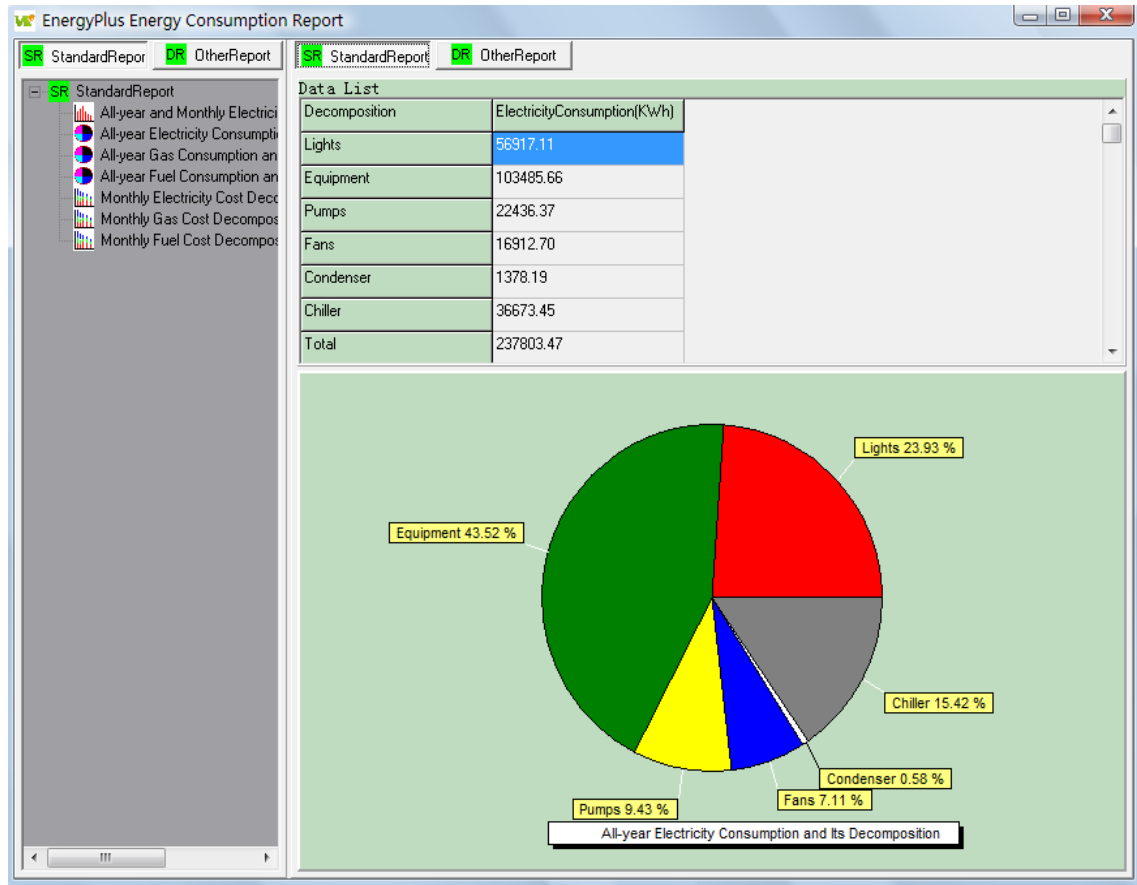**Fig. 10** Report Setup window

Fig.11: Standard report output interface: electricity use breakdown of case study