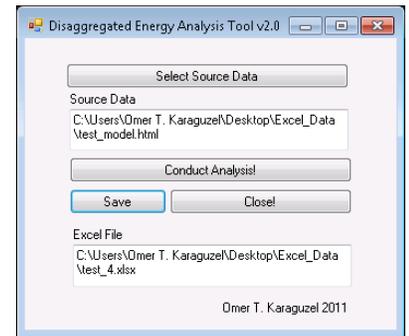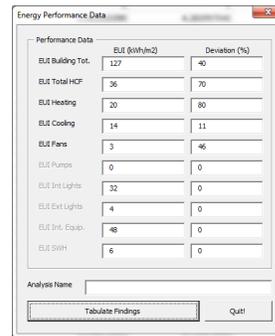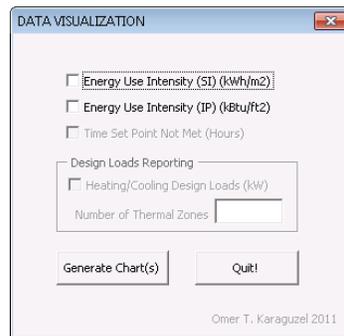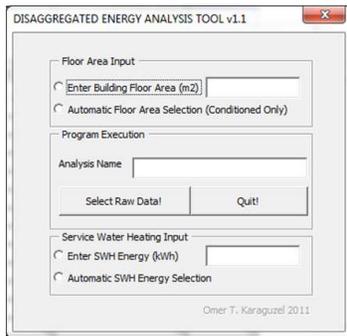Task 2.2.11 – CMU Report 06:
Programs for Design Analysis Support and Simulation Integration

Department of Energy Award # EE0004261

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February 2012

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Introduction/Executive Summary

A suite of programs is developed in order to facilitate analysis and interpretation of EnergyPlus simulation outputs for design decision support purposes. The developed programs can be categorized into three groups with respect to their functionality:

- Design Decision Support: Whole Building Parametric Analysis Tool v1.0
- Performance Analysis Automation: Disaggregated Energy Analysis Tool v1.0 (Excel Version), and v2.0 (Stand-Alone Version)
- Simulation Integration: Parametric Model Generator v1.0

Embedded applications within these programs are MS Excel and EnergyPlus v6.0 and its outputs read as HTML format. Programming language is Visual Basic and Visual Basic Express 2008 (for stand-alone version). Brief explanations of the above mentioned programs are as follows:

- *Whole Building Parametric Analysis Tool v1.0:* An MS Excel based user interface developed with VBA to automate the process of analyzing and interpreting a set of simulation outputs generated during exhaustive parametric runs performed by EnergyPlus v6.0 coupled with GenOpt v3.0. This tool searches the entire parameter space for a matching combination of user selected parameters and extracts simulation results (together with necessary data visualization) pertaining to this selection. This analysis is a not a stand-alone application. It's executed within MS Excel application as a macro with a user form linked to an existing worksheet.
- *Disaggregated Energy Analysis Tool v1.0:* A tool to automate the process of data visualization for default HTML-based EnergyPlus summary outputs. Raw data from HTML outputs are selected to produce tables of cumulative and normalized disaggregated annual energy consumption (by end-uses) with SI and IP units. Simulation data pertaining to zone by zone HVAC space heating and cooling design loads together with annual unmet load hours are also visualized for quick performance interpretation.
- *Disaggregated Energy Analysis Tool v2.0:* Previously developed MS Excel based user interface is modified to be a stand-alone executable tool (by code modification with Microsoft Visual Basic Express 2008). Similar functionality with the previous version was maintained in this version which reduces user interaction with MS Excel functions.
- *Parametric Model Generator v1.0:* This macro was developed in MS Excel environment with the objective of automatic generation of multiple EnergyPlus input files (with IDF extension) in which a matrix of user specified design variables (related to building envelope retrofit options) can be implemented to different IDF files.

1. Whole-Building Energy Parametric Analysis Tool v1.0

An MS Excel based user interface developed with VBA to automate the process of analysing and interpreting 720 different simulation outputs generated during exhaustive parametric runs performed by EnergyPlus v6.0 coupled with GenOpt v3.0. This tool searches the entire parameter space for a matching combination of user selected parameters and extracts simulation results (together with necessary data visualization) pertaining to this selection.

Current version (v1.0) maps user specified design parameters to corresponding simulation outputs

User can select only one from a list of all simulated alternatives for each different class of energy efficiency measures

"Calculate Performance" initiates the search process results of which are tabulated in the proceeding screen

User can quit the interface anytime during the selection process

Performance to design mapping functionality is not implemented yet
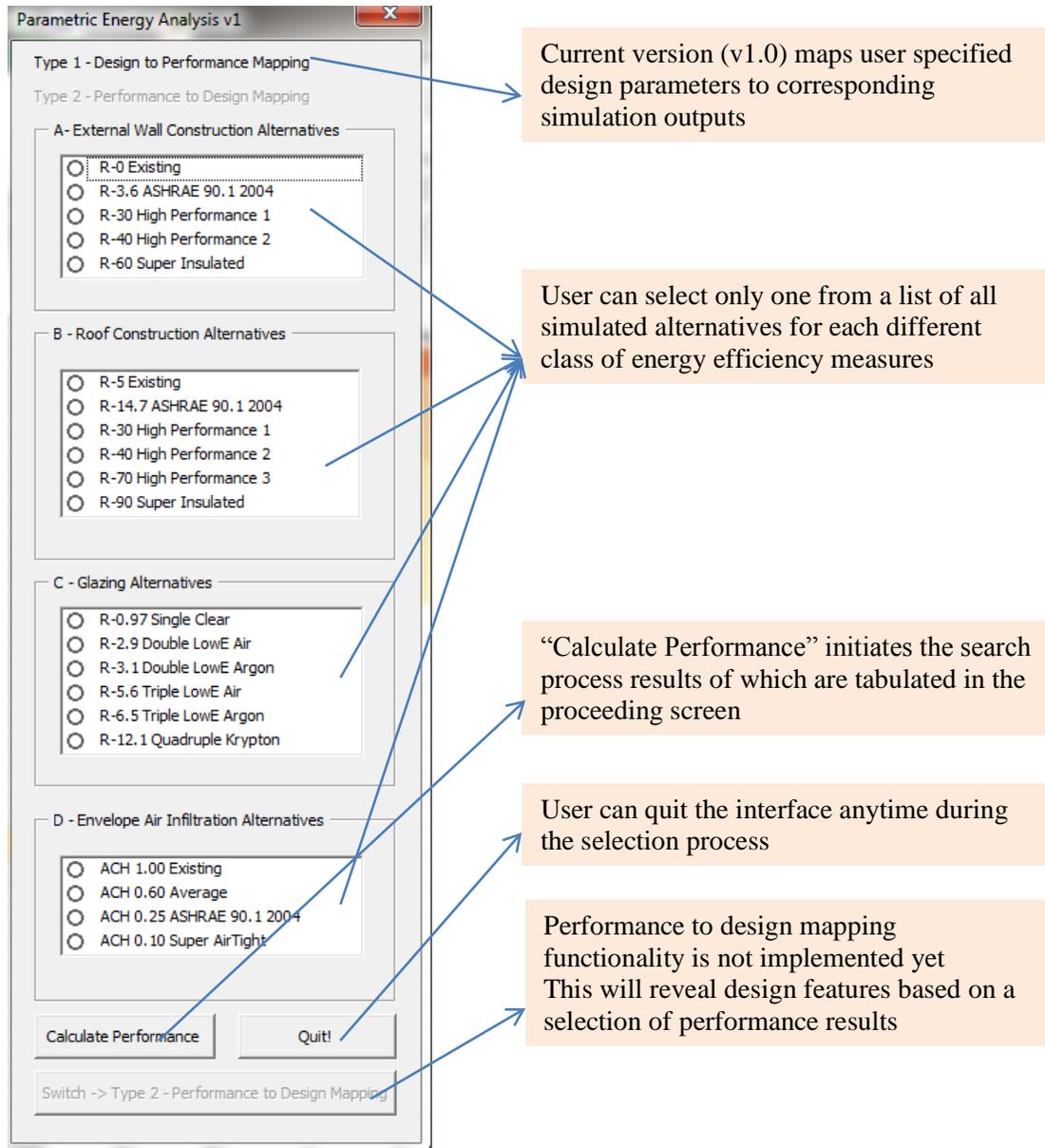This will reveal design features based on a selection of performance results

Figure 1 Main screen of parametric energy analysis tool

This analysis is a not a stand-alone application. It's executed within MS Excel application as a macro with a user form linked to an existing worksheet. For data processing simulation outputs has to be exported to MS Excel an sheet. Data rows can be extended, however columns should be in a specific order. Internal search functions of excel are utilized in the VBA code.

Performance data is presented as building totals as well as disaggregated by main end-use categories

For relative performance analysis, percent deviation from the baseline simulation model is provided for each of the energy performance category

For Building 661 analysis, total energy consumption for space heating, cooling, and fans is given separately

For Building 661 analysis, end-use categories of interior lights, exterior lights, interior equipment, and service water heating are with faded letters. Parametric variations are not effecting these categories and they remain constant between different alternatives

User can give a name to his/her analysis, this name will be given to a newly created worksheet where resultant data is visualized

Figure 2 Results screen of parametric energy analysis tool

"Tabulate" results command of the results screen, initiates the last screen of this tool which is the "Data Visualization". This screen provides alternative reporting formats from which user can make a selection. Current data can be further analysed as tables and accompanying pie charts of disaggregated end-use energy consumption levels in SI and IP units.
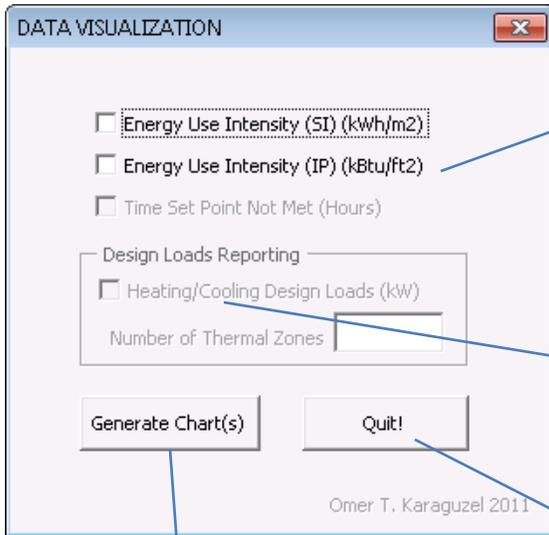
User can make a selection for visualization type. Current alternatives are Energy Use Intensity (EUI) analysis in SI and/or IP units.

Since there is no data to report for the other possible data type, they are set as inactive components. Other design support tools have this functionality.

User can quit the interface at this stage and return to original analysis screen for another round of parametric design analysis.

This button will open a new worksheet in which current data is automatically visualized/processes in the user specified visualization style/type.

Figure 3 Data visualization commands screen of parametric energy analysis tool

Simulation results are automatically tabulated and/or visualized in a new worksheet.
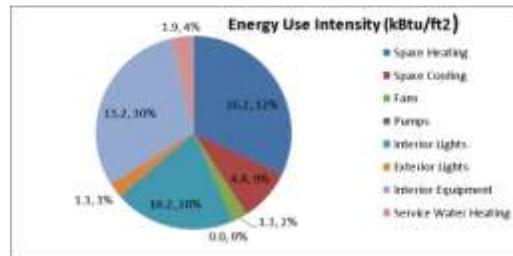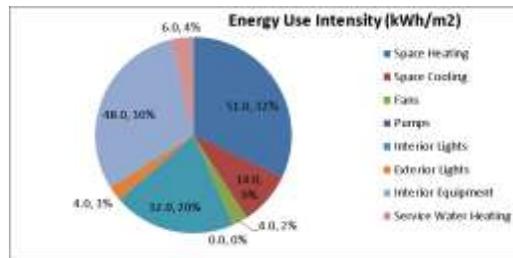

Figure 4 EUI analysis results visualized automatically by the parametric energy analysis tool

Error Handling: Robustness of the tool is increased by a number of warnings and connected actions in all possible cases of user errors.
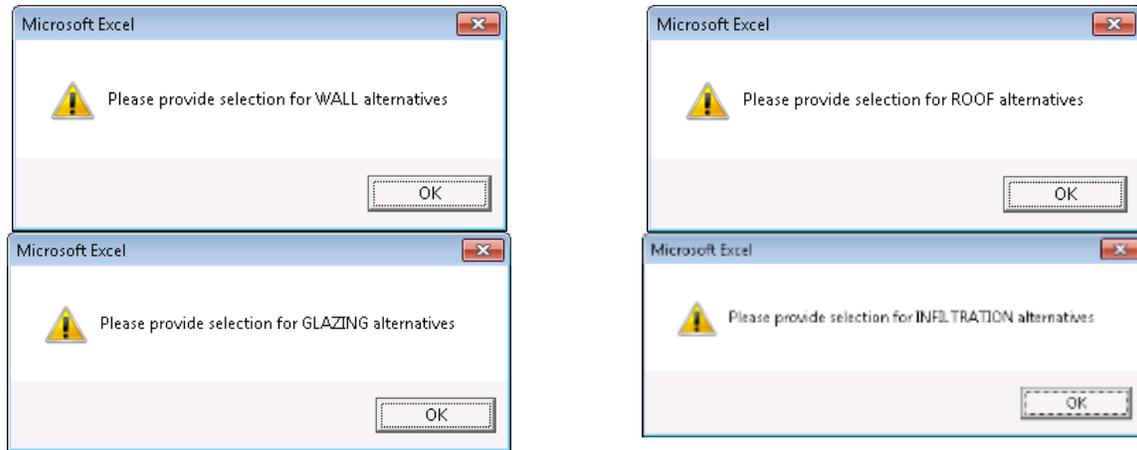
Figure 5 Sample of error logs generated by the analysis tool

2. Disaggregated Energy Analysis Tool v1.0 (Excel Version)

An MS Excel based user interface developed with VBA to automate the process of data visualization for default HTML-based EnergyPlus summary outputs.

User can enter the building floor area for the normalization of the cumulative energy use data from simulation outputs.

Alternatively, user can let the program to detect building floor area from EnergyPlus HTML output.

Program Execution section let the use to give a name to his/her current result analysis.

"Select Raw Data" button opens a windows file browser from which the user points the typical EnergyPlus simulation summary report in HTML format.

Program can be terminated at any time before the selection of the raw data.

User can enter a typical annual energy use (kWh) amount for service water heating category if this is not simulated by EnergyPlus.

Alternatively, program can locate and implement SWH energy to the simulation output analysis routines (in case SWH system is already simulated).

Figure 6 Main screen of disaggregated energy analysis tool

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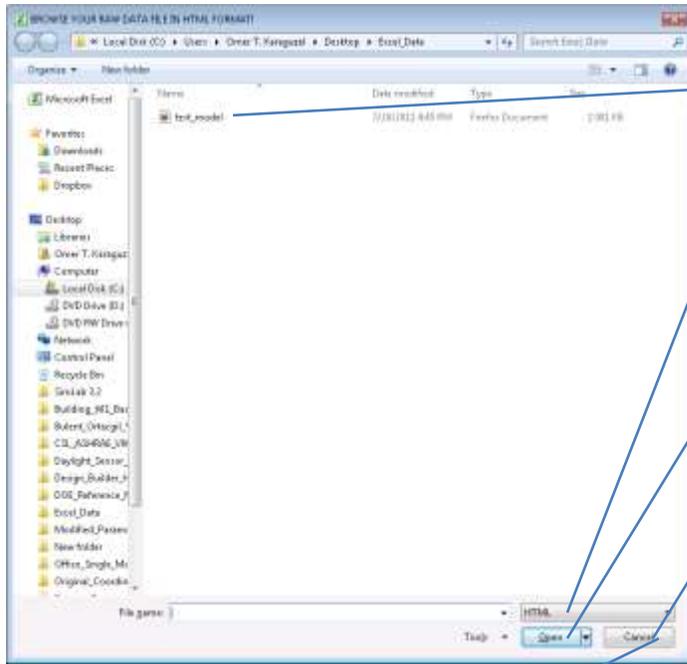
After "select raw data" execution user can browse to the directory where EnergyPlus HTML simulation output is saved.

Only HTML file format can be selected, this is restricted by the available file type.

User can enter the building floor area for the normalization of the cumulative energy use data from simulation outputs.

"Open" command initiates automated data processing functions.

"Cancel" command terminates the program and user is prompted with a warning.
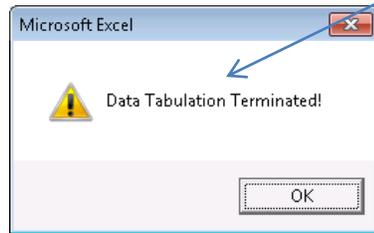
Figure 7 HTML output data file selection for analysis

"Open" command executes the following functions:

- Search the HTML format for specific EnergyPlus output tables (Building Area, End Uses, HVAC Sizing Summary, and set-point Not Met Summary).
- Copy the selected tables into a new worksheet.
- Extract and manipulate useful data from such tables and create a separate end-use energy analysis table (in cumulative and normalized format) with SI and IP units.
- Initialize the second screen of the program as a prompt for data visualization formats.

EUI results can be visualized as pie charts (SI and IP units).

Time set-point not met values can be reported as bar charts for total heating and cooling hours.

For HVAC sizing, design heating and cooling loads can be reported for each thermal zone of the building separately as a bar chart. User needs to provide the total number thermal zones in the building model.

User can quite the program at this stage. And continue with the already tabulated simulation results without visualizations.

"Generate Charts" starts charting process, at least one selection should be made for the program to progress.

Figure 8 Data visualization command screen of disaggregated analysis tool

In addition to end-use energy breakdown pie charts shown before, this tool also generated bar chart for time set-points not met values and HVAC sizing design loads.
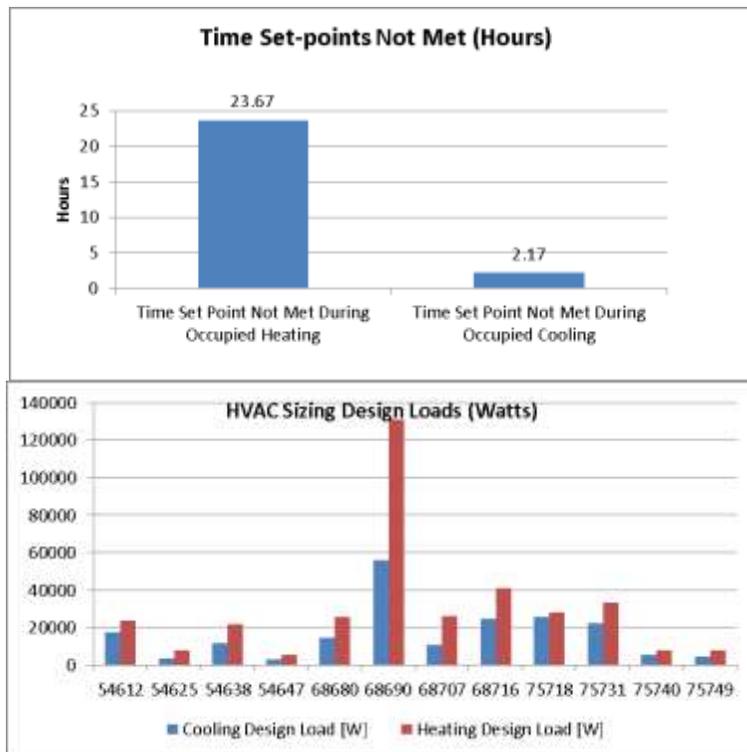

Figure 9 Additional results for energy performance analysis

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This tool is robust enough to detect possible logical errors made by the user. Incorrect commands, and/or entries are prompted by a warning. In, most cases program is terminated. Some cases lets the user return to latest successful phase of the tool progress.
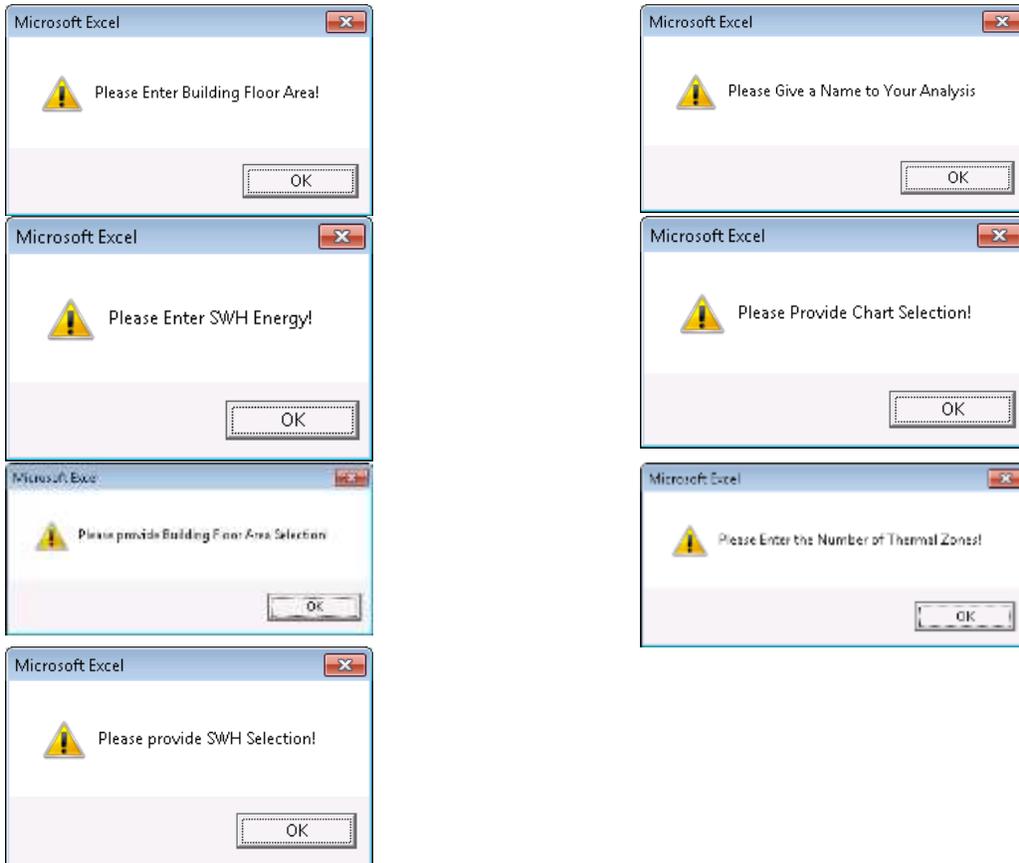

Figure 10 Sample of error logs generated by the disaggregated energy analysis tool

3. Disaggregated Energy Analysis Tool v2.0 (Stand-alone Version)

Disaggregated energy Analysis Tool v2: Previously developed MS Excel based user interface was modified to be a stand-alone executable tool (by code modification with Microsoft Visual Basic 2008). Similar functionality with the previous version was maintained in this version which reduces user interaction with MS Excel functions. This tool is a not a macro code within MS Excel, but a stand-alone MS application that can be extended to communicate with other applications installed on the Windows operation system.
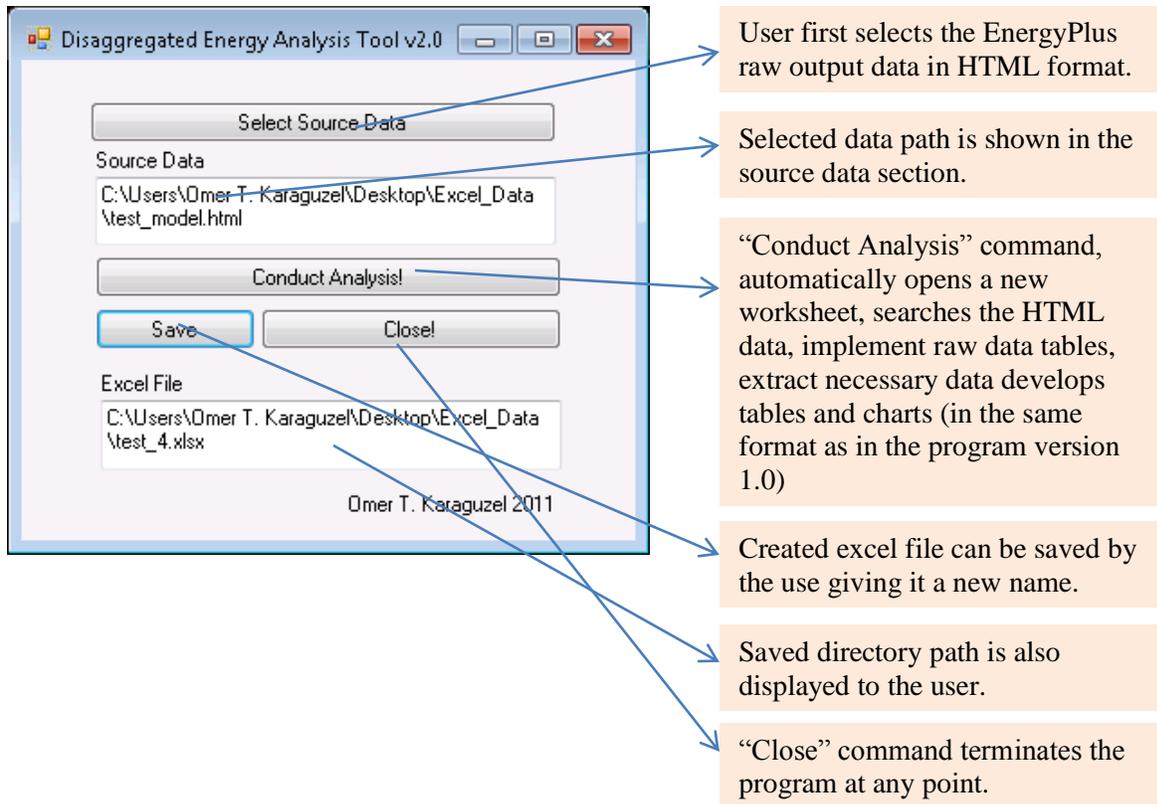

Figure 11 Main screen of disaggregated energy analysis tool version 2

4. Parametric Model Generator v1.0 (Without a User Interface)

This macro was developed in MS Excel environment with the objective of automatic generation of multiple EnergyPlus input files (with IDF extension) in which a matrix of user specified design variables (related to building envelope retrofit options) can be implemented to different IDF files.
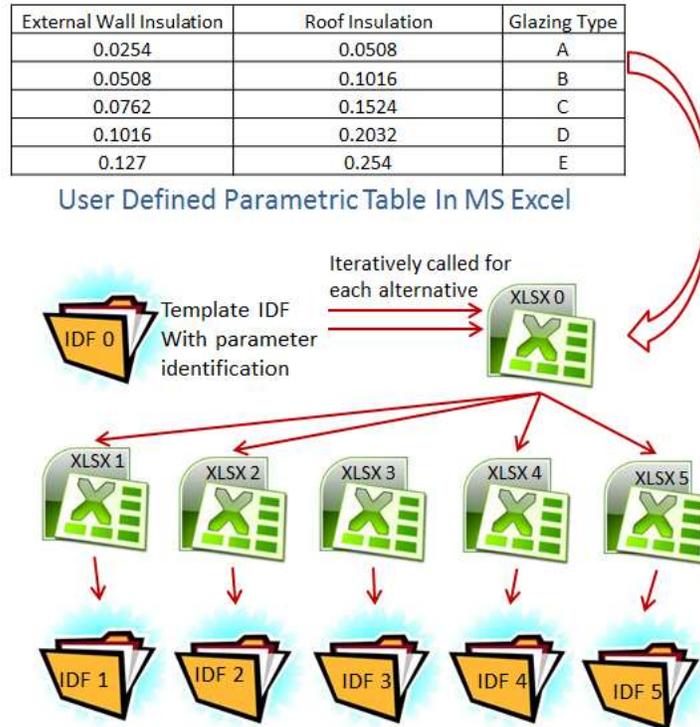
External Wall Insulation	Roof Insulation	Glazing Type
0.0254	0.0508	A
0.0508	0.1016	B
0.0762	0.1524	C
0.1016	0.2032	D
0.127	0.254	E

User Defined Parametric Table In MS Excel

Figure 12 Schema of parametric model generator structure

Variables in each row of the parametric matrix are written to (replaced with a pre-defined parameter string defined with a special syntax %parameter%) a separate EnergyPlus IDF file. Source IDF file is the template include all the related parameter strings. Source excel file contains the parameter matrix as well as the IDF generator macro. Each different model alternative is first created as an excel file and transformed to a text-based ASCII compatible file with *.idf extension. All alternative models are given different names and saved to a user defined location (currently hard coded in the macro itself).

5. Conclusions

A suite of programs are developed based on MS Excel – VBA programming language with the objective of providing effective and efficient design support with energy performance simulation. Future work can be enhancing the functionality of current tools together with increasing their robustness. Replicating the same functionality by code transformation to JAVA platform without recourse to the use MS Excel functions can be another future work item related with this study.