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A REVIEW OF ENERGY ANALYSIS SIMULATION TOOLS

UDC:

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Abstract: Sustainable design is the philosophy of designing physical objects, built environment, and services to comply with the principles of social, economic, and ecological sustainability. The most widespread method for achieving this goal is the use of energy analysis simulation tools. The paper presents comparison between software tools regarding their use in BIM environment and gives advice on most usable application.

Key Words: *Building Information Modeling (BIM), energy analysis, simulation tools.*

1. INTRODUCTION

The building industry is under pressure to provide value for money, sustainable design and construction, etc. and this has propelled the adoption of Building Information Modeling (BIM) technology, which transforms the paradigm of the construction industry from 2D based drawing information systems to 3D object based information systems [1]. It changes the base documentation used in building design and construction to a new representations which are machine readable for automation as opposed to human readable for manual conducts [2]. Therefore, BIM adoption is becoming an increasingly important matter for the construction industry that has been facing barriers and challenges to increase productivity, efficiency, quality and for sustainable development. A large number of commercial and free simulation applications are available on the market. The use of building performance simulation in architectural design processes is hindered by three key bottlenecks – the significant time and skill required to create building models for energy simulations, the time required to compute accurate simulations for geometrically complex models, and the difficulty of understanding and visualizing the results. Thus, the creation of models for building energy simulations relies on model simplification in order to speed simulation time and reduce the effort required to augment the geometric model with the additional meta-data necessary for simulation.

Conventional methods of producing thermal models through extrusion of prismatic building elements are reinforced by currently available thermal modeling software interfaces such as Ecotect, eQuest, IES-VE, DesignBuilder, OpenStudio, ArchiCad 16-Energy Evaluation etc. Furthermore, simulation engines such as EnergyPlus and DOE2 exploit these simplified space volumes to decrease simulation time.

2. A REVIEW OF ENERGY ANALYSIS APPLICATION

Sustainable design is more important than ever. BIM solutions make sustainable design practices easier by enabling architects and engineers to more accurately visualize, simulate, and analyze building performance earlier in the design process. Large number of energy analysis applications is available today for engineers. In the following text we will give an overview of the most used programs with their main capabilities.

ArchiCAD is architectural BIM CAD software for Macintosh and Windows developed by the Hungarian company Graphisoft. ArchiCAD offers specialized solutions for handling all common aspects of aesthetics and engineering during the whole design process of the built environment-buildings, interiors, urban areas, etc. Development of ArchiCAD started in 1982 for the original Apple Macintosh. ArchiCAD is recognized as the first CAD product on a personal computer able to create both 2D drawings and parametric 3D geometry. In its debut in 1987 ArchiCAD also became the first implement of BIM under Graphisoft's "Virtual Building" concept [3]. In the previous version of ArchiCAD application it was possible to install EcoDesigner as a plug-in that enables energy balance analysis. EcoDesigner does not require any special preparations and takes all necessary data from the existing model. Before evaluation is started few additional information about project like location, activity, MEP system, energy type, and availability of green energy systems must be provided. Using provided structural and opening lists designer can re-evaluate all parameters of the construction elements and openings, gain better understanding of the energy model and modify data if needed. The built-in U-value calculator enables user to achieve proper heat transmission coefficient values. Based on those data EcoDesigner calculates yearly energy consumption, CO_2 emission and monthly energy balance. All data are given as charts or tables and can be saved as XLS or Pdf file. From version 16 EcoDesigner is discontinued and replaced with the built-in Energy Evaluation functionality. In contrast with previous application, before any simulation is commenced all spaces in the project must be allocated to the specific zones. Upon every project modification zones must be updated. This way previous "one click" functionality is lost. Results from the simulation are similar with previous EcoDesigner application and includes yearly energy consumption by sources and targets, CO2 emission and monthly energy balance. All simulation results are represented as charts or tables that can be saved as XLS or Pdf file.

Revit Conceptual Energy Analysis Tool enables analysis of annual carbon emission, monthly heating load, monthly cooling load and annual energy use within Revit application. The tool works with massing model enabling the designer to acquire knowledge about building performances in early design phases. The evaluation mechanism is based on web service that automatically shows results as charts, and enables comparison of different alternatives.

Autodesk Ecotect Analysis is the stand alone application intended for measuring environmental design factors during conceptual design. It can read large number of file formats depicting both building geometry and building performance parameters including gbXML files. The application can be used to create analysis model from the scratch or to expand it from the imported data. Main advantage of the application is its ability to represent all analysis results in visual manner, enabling the designer to quickly understand implications of his/her decisions. The program can perform large number of specific types of thermal, solar, lighting and acoustical analysis. The application can export its results to large number of formats, enabling presentation of results in various external applications or transfer of data to other analysis tools [4].

The Green Building Studio (GBS) is web based application intended for whole building energy analysis, forecasting how a building will consume resources and providing estimates in tabular report form. Ecotect tools measure how the environment may impact the building performance over time and provides graphical displays of information that allows architects and designers to interact with the data in real time. The application reads model data only as gbXML files. Based on provided data it can perform whole building energy analysis, calculate carbon footprint, consider design alternatives to improve energy efficiency, analyze qualification for LEED day lighting credit, estimate water use, provide ENERGY STAR scoring and summarize natural ventilation potential. The application can export its results to a number of formats, enabling transfer of data to other analysis and presentation tools [5].

OpenStudio is a cross-platform (Windows, Mac, and Linux) collection of software tools to support whole building energy modeling using EnergyPlus and advanced daylight analysis using Radiance. OpenStudio includes graphical interfaces along with a Software Development Kit (SDK). The previous version of OpenStudio (now called the Legacy OpenStudio Plug-in) only included the SketchUp Plug-in. The new OpenStudio graphical applications include the updated SketchUp Plug-in, the stand alone OpenStudio application, and ResultsViewer. The SketchUp Plug-in is an extension to the popular 3D modeling tool that adds OpenStudio context to the SketchUp program. The Plug-in allows users to quickly create geometry and assign space attributes using the built-in functionality of SketchUp including existing drawing tools, integration with Google Earth, Building Maker, and Photo Match. The OpenStudio application is a graphic energy modeling tool. It includes visualization and editing of schedules, editing of loads constructions and materials, a drag and drop interface to apply resources to spaces and zones, visual HVAC and service water heating design tool, and high level results visualization. Radiance can also be integrated into the simulation workflow. This is accomplished by using an annual Radiance simulation to measure daylighting, and then creating an electric lighting usage schedule for EnergyPlus. OpenStudio also gives the modeler integrated access to data from the Building Component Library. ResultsViewer enables browsing, plotting, and comparing EnergyPlus output time series data. OpenStudio allows building researchers and software developers to quickly get started through its multiple entry points, including access through C++, Ruby, and C# [6].

Virtual Environment by Integrated Environmental Solutions (IES-VE) is dynamic building energy simulation software. IES-VE consists of a suite of integrated analysis tools, which can be used to investigate the performance of a building either retrospectively or during the design stages of a construction project. The VE software does not require the user to have any knowledge of computer programming or of the mathematics and equations that govern building physics, as all the interaction between the user and the software is done through a graphical user interface (GIU). Such a piece of software is known as a "black box" in computing parlance. The user, therefore, is only required to give the software specific inputs, whilst the outputted results are given graphically. However, knowledge of building physics is fairly essential in being able to interpret the results with any sense. A model of a building can be constructed within VE using the "ModelIT" module, which can then be analyzed in a variety of ways: with a module called "Radiance" that looks at the viability of day-lighting, a module called "MacroFlo" that investigates the effectiveness of natural ventilation, and thermal analysis module the "Apache", which provides either steady-state or dynamic analysis of energy consumption and indoor thermal conditions [7].

The eQUEST is a one of the freeware building energy analysis tool which provides high quality results by combining a building creation wizard, an energy efficiency measure wizard and a graphical results display module with an enhanced DOE-2.2 derived building energy simulation program [8]. The building creation wizard walks a user through the process of creating a building model. Within eQUEST, DOE-2.2 performs an hourly simulation of the building based on walls, windows, glass, people, plug loads, and ventilation. DOE-2.2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices. The eQUEST allows users to create multiple simulations and view the alternative results in side-by side graphics. It offers energy cost estimating, daylighting and lighting system control, and automatic implementation of energy efficiency measures [9]. The eQUEST calculates hour-by-hour building energy consumption over an entire year (8760 hours) using hourly weather data for the location under consideration.

Input to the program consists of a detailed description of the building being analyzed, including hourly scheduling of occupants, lighting, equipment, and thermostat settings. The eQUEST provides very accurate simulation of such building features as shading, fenestration, interior building mass, envelope building mass, and the dynamic response of differing heating and air conditioning system types and controls.

The eQUEST contains a dynamic daylighting model to assess the effect of natural lighting on thermal and lighting demands. The simulation process begins by developing a "model" of the building based on building plans and specifications. A base line building model that assumes a minimum level of efficiency (e.g., ASHRAE 90.1) is then developed to provide the base from which energy savings are estimated. Alternative analyses are made by making changes to the model that correspond to efficiency measures that could be implemented in the building. These alternative analyses result in annual utility consumption and cost savings for the efficiency measure that can then be used to determine simple payback, life-cycle cost, etc. for the measure and, ultimately, to determine the best combination of alternatives [9].

The DOE-2.1E is a widely used and accepted freeware building energy analysis program. It was developed by the Lawrence Berkeley National Laboratory and is one of the most widely used thermal simulation engines today. The engine was designed to study energy performance of the whole building during the design phase [10, 11]. The last official LBNL release of DOE-2.1E in 1994 included knowledge and expertise gained over a development process of 30 years. Due to its long presence on the market several user interfaces have been developed for DOE-2 [8, 10]. The DOE-2 engine is able to simulate the thermal behavior of spaces in a building, where heat loads, such as solar gain, equipment loads, people loads, lighting loads, and air conditioning systems can be modeled and simulated with the engine. The geometry for the simulation needs to be fairly simplified from the real geometry of the building. The user input is combined with the materials, layers and construction library into the BDL input processor. The Building Description Language (BDL) processor transforms the input into a computer readable format that is later used by the four subprograms (simulation modules), LOADS, SYSTEMS, PLANT and ECONOMICS, which are executed sequentially.

The LOADS subprogram uses this BDL description and weather data to perform heat loss and gain calculations based on assumed heating and cooling loads of related systems at a fixed space temperature at every time step. The second subprogram, SYSTEMS, uses gains and losses to determine additional heating or cooling needs for the space in question according to defined temperature set points. Next the PLANT subprogram calculates the fuel requirements of the HVAC components to accomplish the calculated performance of the systems. Finally, the ECONOMICS subprogram calculates the cost based on these fuel requirements and utility pricing structures [11]. DOE-2 first calculates loads in a space considering only external and internal loads. Based on the temperature difference between two adjacent spaces heat transfer is determined according to the so-called weight factor method which accounts for thermal mass. In the next step the resulting loads are used as input for the HVAC system calculations, and the simulation engine tries to satisfy space loads with the defined HVAC system, if possible [10]. There is no feedback from the HVAC system calculation to the load calculation. As mentioned in the general simulation chapter, this process does not include feedback (data flow is only forward). This approach assumes that the loads in each space can be satisfied at every time step of the simulation. If loads can not be satisfied with the systems the temperature in the space changes and has an effect on further steps of the calculation. The air and water systems (as part of the SYSTEMS subprogram) can be modeled based on different predefined system definitions, which include some optional components or variations the user is able to select [10].

The EnergyPlus is based on an integrated (loads and systems simulation) approach [10, 12], which leads to more accurate predictions of temperatures in spaces and therefore a better estimate of various resulting parameters, such as thermal comfort. The load calculations are based on AHSRAE's preferred heat-balanced-based approach [13]. EnergyPlus also contains inter-zonal airflow, moisture absorption and desorption, definitions of more realistic HVAC system controls and radiant heating and cooling systems. In addition, EnergyPlus enables automated sizing of many component-specific parameters. In summary, results are more accurate and reliable than with DOE-

2 for most of the simulated buildings and systems. Today, an EnergyPlus simulation is mainly based on input from text files, which increases the effort to define all necessary input data compared to engines with graphical user interfaces. Several user interfaces are under development and some can be tested as beta versions. Basic applications of the Energy Plus software are listed below:

- Integrated, simultaneous solution where the building response and the primary and secondary systems are tightly coupled (iteration performed when necessary).
- Sub-hourly, user-definable time steps for the interaction between the thermal zones and the environment; variable time steps for interactions between the thermal zones and the HVAC systems (automatically varied to ensure solution stability).
- ASCII text based weather, input, and output files that include hourly or sub-hourly environmental conditions, and standard and user definable reports, respectively.
- Heat balance based solution technique for building thermal loads that allows for simultaneous calculation of radiant and convective effects at both in the interior and exterior surface during each time step.
- Transient heat conduction through building elements such as walls, roofs, floors, etc. using conduction transfer functions.
- Improved ground heat transfer modeling through links to three-dimensional finite difference ground models and simplified analytical techniques.
- Combined heat and mass transfer model that accounts for moisture adsorption/desorption either as a layer-by-layer integration into the conduction transfer functions or as an effective moisture penetration depth model (EMPD).
- Thermal comfort models based on activity, inside dry bulb, humidity, etc.
- Anisotropic sky model for improved calculation of diffuse solar on tilted surfaces.
- Advanced fenestration calculations including controllable window blinds, electrochromic glazing, layer-by-layer heat balances that allow proper assignment of solar energy absorbed by window panes, and a performance library for numerous commercially available windows.
- Daylighting controls including interior illuminance calculations, glare simulation and control, luminaire controls, and the effect of reduced artificial lighting on heating and cooling.
- Atmospheric pollution calculations that predict CO2, SOx, NOx, CO, particulate matter, and hydrocarbon production for both on site and remote energy conversion.

The IDA Indoor Climate and Energy (IDA ICE) is a tool for building simulation of energy consumption, the indoor air quality and thermal comfort. It covers a large range of phenomena, such as the integrated airflow network and thermal models, CO2 and moisture calculation, and vertical temperature gradients. For example, wind and buoyancy driven airflows through leaks and openings are taken into account via a fully integrated airflow network model. The first version of IDA ICE was released in 1998 and the present version, 3.0, was released in November 2001. There are available Swedish, Finnish, German, and English versions of this tool. IDA ICE is commercially available and marketed by the Swedish company EQUA Simulation AB . The model library of IDA ICE was written in the Neutral Model Format (NMF). NMF is a program-independent language for modeling the dynamical systems by using differential algebraic equations. IDA, on which IDA ICE is based, is a general-purpose simulation environment, which consists of the translator, solver, and modeler [14]. The Division of Building Services Engineering, the Royal Institute of Technology in Stockholm (KTH), and the Swedish Institute of Applied Mathematics (ITM) have developed IDA. The mathematical models of the IDA ICE have been developed at the Royal Institute of Technology in Stockholm and at the Helsinki University of Technology [14]. The library of the mathematical models of the building components was developed and tested for measurements and to other programs in the scope of IEA Task 22 "Building Energy Analysis Tools" [15, 16, 17, 18]. IDA ICE was validated according to prEN 13791 defined test cases [19] and to Envelope BESTEST in the scope of IEA Task 12 [20]. IDA ICE may be used for the most building types for the calculation of:

- The full zone heat and moisture balance, including specific contributions from: sun, occupants, equipment, lighting, ventilation, heating and cooling devices, surface transmissions, air leakage, cold bridges and furniture.
- The solar influx through windows with a full 3D account of the local shading devices and those of surrounding buildings and other objects;
- Air and surface temperatures.
- The operating temperature at multiple occupant locations, e.g. in the proximity of hot or cold surfaces. The full non-linear Stephan-Boltzmann radiation with the view factors is used to calculate the radiation exchange between surfaces.
- The directed operating temperature for the estimation of asymmetric comfort conditions.
- Comfort indices, PPD and PMV, at multiple arbitrary occupant locations.
- The daylight level at an arbitrary room location.
- The air, CO2, and moisture levels, which both can be used for controlling the of VAV (Variable Air Volume) system air flow.
- The air temperature stratification in displacement ventilation systems.

Table 1. Comparison of features of simulation software tools

Features	Simulation tool						
	Energy plus	IDA-ICE	IES-VE	TRNSYS	Eco Designer	GBS	Ecotect
Simulation solutions							
Simulation of loads, systems and solutions	+	+	+	+	-	+	+
Iterative solution of nonlinear systems	+	+	+	+	-	+	-
Duration of time calculation							
Variable time intervals per zone for interaction of the HVAC syst.	+	-	-	-	-	-	-
Simultaneous selection of building systems and user	-	+	+	+	+	+	+
Dynamic variables based in transient solutions	+	+	-	-	-	-	+
Complete geometric description							
Walls, roofs and floors	+	+	+	+	+	+	+
Windows, skylights, doors and external coatings	+	+	+	+	+	-	+
Polygons with many faces	+	+	+	-	+	+	+
Imports of building from CAD programs	+	+	+	+	+	+	+
Export geometry of buildings for CAD software	+	+	-	-	+	+	-
Import/Export of simulation models of programs	+	+	+	-	+	+	+
Calculation of thermal balance	+	+	+	+	+	+	+
Absorption/release of moisture from the building materials	+	+	+	+	+	-	+
Internal thermal mass	+	+	+	+	+	+	+
Human thermal comfort	+	+	+	+	+	+	+
Solar Analysis	+	-	-	+	+	+	+
Analysis of Isolation	+	+	+	+	+	+	+
Advanced fenestration	+	+	+	+	-	+	+
Calculations of the building in general	+	-	+	+	+	-	+
Surface temperatures of zones	+	+	+	+	+	-	+
Airflow through the windows	+	-	+	+	+	+	+
Driving surfaces	+	+	+	+	-	+	+
Heat transfer from the soil	+	+	+	+	-	+	-
Thermophysical variable	-	+	-	-	+	+	+
Daylighting and lighting controls	+	+	+	-	+	+	+
Infiltration of a zone	+	+	+	+	-	+	+
Automatic calculation of coefficients of wind pressure	-	-	+	-	+	+	+
Natural ventilation		+	-	+	+	+	+
Natural and mechanical ventilation	-	-	+	+	+	+	+
Control open of windows for natural ventilation	+	+	-	+	+	+	+
Air leaks in multiple zones	+	+	-	+	-	-	+
Renewable Energy Systems							
Solar Energy	+	-	+	+	+	+	+
Trombe Wall	+	+	+	+	-	-	-
Photovoltaic panels	+	-	+	+	-	-	+
Hydrogen Systems	-	-	-	+	+	+	+
Wind Energy	-	-	-	+	+	+	+
Electrical Systems and Equipment							
Energy production through R.E.	+	-	-	+	-	+	+
Distribution and management of electric power loads	+	-	-	+	-	-	+
Electricity generators	+	-	-	+	+	+	+
Network connection	+	-	-	+	+	+	-
HVAC systems							
HVAC idealized	+	+	+	+	+	+	+
Possible configuration of HVAC systems	+	+	+	+	-	+	-
Repetitions cycle air	+	+	+	+	-	-	-
Distribution systems	+	+	+	+	-	+	+
Modeling CO_2	-	+	+	+	+	+	+
Each distribution of air per area	+	+	+	+	+	+	+
Forced air unit per zone	+	+	+	+	-	+	+
Equipment unit	+	-	+	+	+	+	+

- Wind and buoyancy driven airflows through leaks and openings via a fully integrated airflow network model. This enables to study temporarily open windows or doors between rooms.
- The airflow, temperature, moisture, CO2 and the pressure at arbitrary locations of the air-handling and distribution systems.
- The power levels for primary and secondary system components.
- The total energy cost based on time-dependent prices.

The TRNSYS, a transient systems simulation program that has been commercially available since 1975 [21], continues to develop by the international collaboration from the United States (Thermal Energy System Specialists and the University of Wisconsin-Solar Energy Laboratory), France (Centre Scientifique et Technique du Bâtiment), and Germany (TRANSSOLAR Energietechnik). TRNSYS remains a flexible energy simulation software package by facilitating the addition of mathematical models, the available add-on components, and the ability to interface with other simulation programs. TRNSYS has been used extensively to simulate solar energy applications, electrical energy systems, conventional buildings, and even biological processes. Almost 35 years after the initial release, the philosophy remains the same: simulate the performance of the entire system by breaking it down into individual black box components. Since the inception of TRNSYS, it has had the open modular structure with open source code. The end user is able to create custom components for their dynamic simulation needs, or the end user may choose from the TRNSYS standard library of components such as solar (thermal and photovoltaic), HVAC, hydrogen systems, and many others [22].

RIUSKA is a tool for the dynamic simulation of comfort and energy consumption in building services design and facilities management. It calculates inside temperatures and the heating and cooling of individual spaces, and can be used to compare and dimension HVAC systems as well as for calculating the energy consumption of whole buildings. RIUSKA also has a module to calculate the heat loss of a building in a steady-state condition. RIUSKA covers all the requirements of thermal performance simulation from preliminary design to facilities management and renovation. It has been developed specifically as a practical design tool for use by engineers in their everyday work. The simulation data used by RIUSKA is saved in a special database so that it can be used for life-cycle data management. RIUSKA is developed by Granlund. The core of the software is the world-wide used DOE 2.1E simulation program. Granlund collaborates with the developer of DOE 2.1E, Lawrence Berkeley National Laboratories (LBNL). RIUSKA has been officially certified by the IAI to comply with the IFC 2x, IFC 2.0 BLIS (Building Lifecycle Interoperable Software) and the IFC 1.5.1 standards. The building geometry modeling for use in RIUSKA can be performed also by SMOG, an object-oriented 3Dspace modeling software program also developed by Granlund. RIUSKA is used for the following simulations:

- Space simulations which involving simulations of indoor air temperatures by hourly basis thought year.
- System simulation for dimensioning and comparing HVAC-systems.
- Building simulations for calculating energy consumption for the whole building or for groups of individual spaces.

RIUSKA also has a Heat Loss Module used for calculating heat losses for each space in the building in the given outdoor temperature. Building geometry can be imported in IFC format and the calculated results can be saved back to the same IFC file. It can be used for analyzing the heat loss distribution among walls, windows and doors. It is easy to change for example the U-values of certain window types and see the effect of that. It is also helpful, when checking the overall U-value of the building envelope [23].

Table 2. Comparison of RIUSKA and e-QUEST

	Simulation tools	
Functionality	RIUSKA	eQUEST
Engine	DOE-2.1E	DOE-2.2E
Weather file format	BIN	BIN
HVAC systems	Only four different types (with limited parameters) No PLANT, No ECONOMICS	All DOE-2 systems
Interoperability/data exchange	IFC through BSPro-Server (building geometry)	DXF import (one footprint only) gbXML data exchange (via inp file import)
Features	Supports different design alternatives	Supports different design alternatives Input wizards Conformance analysis
Auto sizing	No DOE-2 design day sizing Basic sizing capabilities	Uses DOE-2 design day sizing capabilities
Data exchange problems	Floor based IFC import (multiple story spaces) Internal/external walls/slabs No plenums available	For gbXML: Incorrect shading surfaces Missing walls Internal/external walls

3. COMPARISON OF SOFTWARE TOOLS

Each mentioned energy simulation software tool has certain characteristics, and specific applications [24, 25]. The table 1 presents a summary of the features of each software tool, grouped in the following categories: solution of simulation, calculus duration, geometric description, renewable energy systems, electrical systems and equipment, and HVAC systems. The table provides information that is valuable to all building designers that transform their traditional practice to BIM technology and want to incorporate energy simulation software tools in the design process to achieve better quality of their products. The table 2 presents comparison of eQUEST and RIUSKA simulation tools that are both based on DOE-2 engine.

4. EXAMPLE OF ANALYSIS

The evaluation of the energy analysis simulation tools was conducted on the identical building model made in the ArchiCAD 16 BIM application. The building model is the single floor family house with the outside walls made of blocks, plastered on the outside and with styrofoam insulation 5mm thickness. The total area is 213.1 m2 and the volume is 434.9 m3. Heating of the object is done with the boiler station. The 70% of the energy required for the heating is realized by using natural gas, and 30% using oil. For the analysis only the lower level of the house was considered as heated with the area of 106.5 m2 and the volume of 287.6 m^3 (Figure 1).

Figure 1. Residental family house for analysis

The ArchiCAD 16 comes with the built-in Energy Evaluation application. Within ArchiCad 16 it was necessary to zoning of the building, to be able to determine the proper surface and volume facilities required for the whole energy building analysis.

In addition to this, it was necessary to include in the Options menu location of the object so that they can adopt automaticaly the appropriate climate parameters from Strusoft Climate Server or enter manually from EnergyPlus-Energy simulation software-weather data. Finally, before starting Energy Evaluation software are only needed to include appropriate parameters for heat generation and fuel prices. Adopted prices of the oil is 1.3 EUR/lit and a natural gase price is 0.5 EUR/m^3.The report (Figure 2) which is obtained as an output from this simulation tools is shown on the next figure, and generally can be save as a pdf and can be printed. From this report it can determined that the annual total energy consumption is 64215 kWh and the annual total energy costs is 2517 EUR..

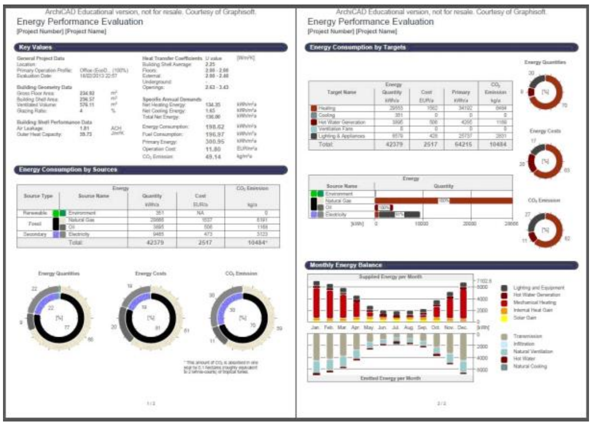

Figure 2. Report from Energy Evaluation software

To start analysis in the Ecotect it is also need to make building zoning in the ArchiCad 16 and then save the file using gbXML format. Upon importing data in the Ecotect application it is necessary to define thermal performances, material costs, solar exposure, etc. using built in tools. Based on all that data the appliaction generates evaluation report (Figure 3).

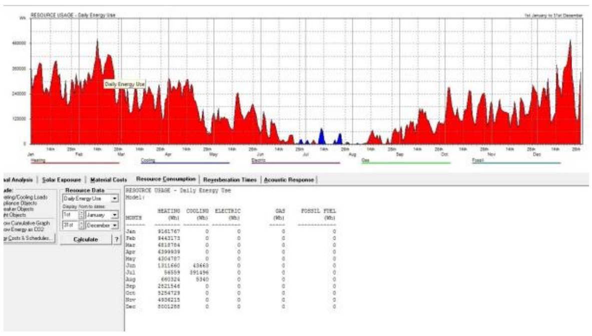

Figure 3. Report from Ecotect Analysis software

From the report, it can be determined that the annual total energy consumption is 59611 kWh and the annual total energy costs is 2337 EUR. The difference between energy consumption results between two application is 4604 kWh or 7.17%.

5. CONCLUSION

Currently there are many energy simulation software tools with different levels of complexity and response to different variables. Among the most common used simulation software tools are the Energy Plus, (Energy Simulation Software tool), the

IDA ICE (Indoor Climate Energy), IES-VE (Integrated Environmental Solutions - Virtual Environment) and TRNSYS. Being the most complete software tools, these are also the most complex and therefore require greater expertise. Among the reviewed energy simulation software tools, TRNSYS is the most complete, but depending on the user perspective and final purpose other software tools could be more appropriate. Comparison of eQUEST and RIUSKA shows slight advantage of the eQUEST application.

The above mentioned software is developed prior to BIM technologies and requires custom input formats. The EcoDesigner, Green Building Studio (GBS), and Ecotect are software tools designed to work together with BIM applications and to provide seamless data exchange [4]. The Ecotect is the application that provides the user with the largest set of building simulations, but requires professional knowledge. The EcoDesigner and Green Building Studio are tools intended to give quick and easy simulation results to the users without professional knowledge on energy efficiency simulation.

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