# ANALYSIS OF RESULTS OF ENERGY CONSUMPTION SIMULATION WITH EQUEST AND ENERGYPLUS

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**ABSTRACT**

*This paper is an attempt to analyse some of the features of the whole building energy simulation most commonly used programmes, eQUEST and EnergyPlus, using data from previous researchers. The whole building energy simulation programmes are increasingly being employed in the first step in the design process to help architects and engineers to take the best decision and to choose which alternative designs are more energy efficient and cost effective. To achieve this the whole building energy simulation programmes are more and more employed in the first step of the design process to help architectures and engineers to make the best decision, and to choose which alternatives design are more energy efficient and cost effective. The united state department of energy develops both programmes studied. Earlier they launched a DOE programme, the most popular program used for whole energy building simulation. The programme DOE 2.1e uses as interface EnergyPro or visual DOE, The second version of DOE 2.2 engine uses Autodesk GBS5 (ecoTect), and eQUEST. Meanwhile EnergyPlus uses the interfaces, Bentely Hevacomp, Design Builder and open studio. Comparisons of the simulation results given by eQUEST and EnergyPlus, for annual energy consumption, using previous researcher's work have been done. Using some utility data from literature, to check the closeness of the simulation programme with real heat and energy flows in building. This theoretical study confirms the previous researchers' conclusions that eQuest is the easiest programme to use and the quickest in producing results that help architects and engineers make the most energy efficient design during the preparation phase.*

**Key words:** Modeling, eQUEST, EnrgyPlus, Consumption, Energy.

## INTRODUCTION

With the increasing cost of energy in general, and in buildings in particular, this leads to an increasing interest in energy efficient building design. To achieve this, the whole building energy simulation programmes are increasingly being employed in the first step of the design process to help architects and engineers to make the best decisions, and to choose which alternative designs are more energy efficient and cost effective.

Designing sustainable buildings that also fulfill all operational requirements of the users is an unprecedented challenge of our times. Researchers, practitioners and other stakeholders are faced with enormous challenges due to the need to recognize and take account of various dynamic processes around us, such as global climate change, depletion of fossil fuel stocks, increasing flexibility of organizations, growing occupant needs and comfort expectation; increasing awareness of the relation between indoor environment and the health and wellbeing of the occupants, and consequently their productivity (J.L.M.Hensen, and Roberto Lamberts, 2011). Whole building energy simulation tools are increasingly used for analysis of energy performance of buildings and the thermal comfort of their occupants. Nowadays, there are many building simulation programmes with different user interfaces and different simulation engines that are capable of these analyses. Because of the very wide and significant variety of these simulation tools, it is more important to understand the limitations of the tools and the complexity of simulations. The reliability of data exchange and straightforward, user-friendly interfaces are major aspects of the practical usage of these tools. Due to the huge amount of data that is to be input and the availability of rich 3D geometry rendering engines, effective data exchange and software interfaces are crucial to enable faster and reliable performance of the simulation tools (Drury, B. & al 2005)

The eQUEST software is one of the most popular programmes used by the building simulation community. Simulation can be performed within a few minutes using a computer. The DOE-2 energy model takes less than a minute or a couple of minutes in case of a tertiary building to complete an annual simulation run. eQUEST efficiency results from its hour-by-hour calculations, and the sequential structure of LOADS-SYSTEMS-PLANT-ECONOMICS which does not solve the thermal dynamics of a building envelope with the HVAC system operating performance

simultaneously ( eQUEST 2013).
EnergyPlus is a new generation of simulation programmes built upon the best features of DOE- 2 and BLAST, and adds new modeling features beyond the two programmes. With DOE-2's limitations in modeling emerging technologies, more modelers, especially in the academia and research community, have begun using EnergyPlus for their simulation needs. EnergyPlus does sub-hourly calculations and integrates the load and system dynamic performance into the whole building energy balance calculations, which can provide more accurate simulation results, but runs much slower compared with DOE-2. (DOE 2013).
Both programmes offer their own set of advantages and disadvantages. Other programmes can be more or less close to one or another of these two major software, eQUEST and EnergyPlus. The purpose of this study is to perform a theoretical analysis of some of these programmes by using previous researchers' works in the building energy simulation comparison field (Drury, B. & al 2005), (Hema Sree Rallapalli,2010), and (Joana Sousa 2011).

## MATERIALS AND METHODS

Statistical results from previous researchers' works have been used in this building energy consumption analysis. Both electrical and gas real consumption were compared to the results of simulation by both eQUEST and EnergyPlus. The core tools in the building energy field are the whole-building energy simulation programmes that provide users with key building performance indicators such as energy use and demand, temperature, humidity, and costs. Drury, B. and al, listed a number of comparative surveys of energy programmes, which have been published.
In his work, the author hopes to elaborate a platform which will become a living document that will evolve over time to reflect the evolution of tools and evolution of the language the community uses to discuss the facilities within tools. This task is beyond the resources of three or four authors.
This report first provides a brief overview of each of the programmes. This is followed by 14 tables which compare the capabilities for each of the twenty simulation programmes in the following areas: General Modeling Features, Zone Loads, Building Envelope and Daylighting, Infiltration, Ventilation and Multizone Airflow, Renewable Energy Systems, Electrical Systems and Equipment, HV AC Systems, HV AC Equipment, Environmental Emissions, Economic Evaluation, Climate Data Availability, Results Reporting, Validation, and User Interface, Links to Other Programmes, and Availability.
In their report, Drury, B. Crawley, Jon W. Hand, Michaël Kummert, and Brent T. Griffith, (Drury, B. & al 2005) they provide an up-to-date comparison of the features and capabilities of twenty major building energy simulation programmes: BLAST, BSim, DeST, DOE- 2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, EnergyPlus, eQUEST, ESP-r, IDA ICE, IES <VE>, HAP, HEED, PowerDomus, SUNREL, Tas, TRACE and TRNSYS. They used the information provided by the programme developers in the following categories: general modeling features; zone loads; building envelope, daylighting and solar; infiltration, ventilation and multizone airflow; renewable energy systems; electrical systems and equipment; HVAC systems; HVAC equipment; environmental emissions; economic evaluation; climate data availability; results reporting; validation; and user interfaces, links to other programmes, and availability. After giving a brief overview on each of the twenty simulation programmes investigated, on the basis of the information published by the software developer's site, they then started a comparison among the tools. The remainder of this report contains 14 tables, which compare the capabilities and features of the 20 programmes, that are listed alphabetically.
Table 1, general modeling features, Table 2, zone loads, Table 3, Building Envelope and Daylighting, Table 4, Infiltration, Ventilation and multi-zone Airflow, Table 5, Renewable Energy Systems, Table 6, Electrical Systems and Equipment, Table 7, HVAC Systems, table 8, HVAC Equipment, Table 9, Environmental Emissions, Table 10, Economic Evaluation, Table 11, Climate Data Availability, Table 12, Results Reporting, Table 13, Validation, Table 14, User Interface, Links to Other Programmes, and Availability.
Then, the authors arrived at the following conclusions: First: There was not a common language to describe what the tools could do. There was a lot of ambiguity which will continue to require additional work to resolve in the future. Second: There are many nuances of 'capability' that the developers found difficult to communicate. The authors attempt to clarify this by providing more depth than a simple X (has capability) by including P (partially implemented), O (optional), R (research use), E (expert use), or I (difficult to obtain input data) or through extensive explanatory footnotes. Third: They found that there was a relatively new level of attention and interest in publishing validation results. Fourth: There is also the issue of trust: Do the tools really perform the capabilities indicated? What level of effort and knowledge is required by the user? How detailed is the model behind a tick in the table? For open source tools, everyone can check the model and adapt it. For the other tools, only very detailed BESTEST-like procedures can give the answer. We may need a way for users to provide feedback and ratings for these in the future. And Fifth: they suggested that this report should be used and

developed as a community resource, which will be regularly updated.
The major second work is the master thesis of Hema Sree Rallapalli,(Hema Sree Rallapalli, 2010), which deals with the comparison of the two popular EnergyPlus and eQUEST whole building energy simulation programmes. In this work the author investigated the potential of both programmes to carry out the whole building energy analysis and compare the results with the actual building energy performance. For this purpose the energy simulation of a fully functional building was done in eQUEST and EnergyPlus and the results were compared with the utility data of the building to identify the degree of closeness with which the simulation results match with the actual heat and energy flows in the building.
In this study the author observed that eQUEST is easy to use and it is quick in producing results that would especially help in making critical decisions during the design phase. On the other hand, EnergyPlus aids in modeling complex systems, producing more accurate results, but consumes more time. The choice of the simulation programme might change depending on the usability and applicability of the programme to our needs in different phases of a building's life cycle. Therefore, it makes sense if a common front end is designed for both of these simulation programmes thereby allowing the user to select either the DOE-2.2 engine or the EnergyPlus engine based upon the need in each particular case.
The author concluded, that the user interfaces for DOE-2 are currently more developed in comparison to the interfaces for EnergyPlus. The lack of user-friendly, mature and comprehensive user interfaces limits the usage of building energy performance simulation in practice. Current progress on interfaces to EnergyPlus is promising and is likely to provide adequate user friendliness and functionality in the future. They also suggested that the energy simulation tools themselves need more development and research to improve the value and accuracy of the energy simulation. An additional research and development of these tools could also, provide more accurate absolute values and provide many additional benefits to their users. They observed in their study that eQUEST is more easier to use and it is quick in producing results that would help in the decision making process during the design phase. On the other hand EnergyPlus can perform more complex modeling systems, but consumes more time.
A third work was the work Joana Sousa (Joana Sousa, 2011), entitled "Energy Simulation Software for Buildings: Review and Comparison". In this work the author sets the objective to identify some of the most important energy simulation software due to their capacity of calculating a significant number of variables and to compare them in order to establish their differences. After giving a brief description of five energy simulation programmes, EnergPlus, ESP-r (energy simulation software tool), IDA-ICE, IES VE (Integrated environmental solution, virtual environment), and finally TRNSYS, the author concluded that, among the most complete simulation software tools were the Energy Plus, the ESP-r (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 ones and therefore require greater expertise.
From the analysed energy simulation software tools, TRNSYS is the most complete, but depending on the user perspective and final purpose the other software tools could be more appropriate. The major limitation of TRNSYS is incapability to connect it with the AutoCad Software tool for importing and exporting of files. In this aspect Energy Plus, ESP-r and IDA ICE are more appropriate.

## RESULTS AND DISCUSSION

In all the previous works it has been agreed that even among the 'mature' tools, there was not quite a common language to describe what the tools could do. There was a lot of ambiguity, which will continue to require additional work to resolve in the future. These tools do not follow the same pattern to deal with one side of the simulation of the building.

**Table1**

**Comparison of measured and simulated electric consumption in kWh using eQUEST**

| Month | Meas. | Sim. | Diff. | Percent. |
|---|---|---|---|---|
| January | 2 0136 | 22436.00 | 2 300.00 | 0.95 |
| February | 19397 | 20641.00 | 1244.00 | 6.41 |
| March | 21291 | 23926.00 | 2635.00 | 12.38 |
| April | 23734 | 24270.00 | 536.00 | 2.26 |
| May | 28780 | 27686.00 | -1094.00 | -3.80 |
| June | 33516 | 32641.00 | -875.00 | -2.61 |
| July | 39480 | 39889.00 | 409.00 | 1.04 |
| August | 36877 | 35857.00 | -1020.00 | -2.77 |
| September | 30989 | 29336.00 | -1653.00 | -5.33 |
| October | 24464 | 24232.00 | -232.00 | -0.95 |
| November | 21118 | 22417.00 | 1299.00 | 6.15 |
| December | 20489 | 20873.00 | 384.00 | 1.87 |

For the general modeling features, the simulation of the BLAST, DOE2.1E, TRACE, have sequential loads, system, plant calculation without feedback, for simultaneous loads, system and plant solution almost all the programmes perform the simulation except DOE2.1E, ECOTECT, and TRACE. For iterative non-linear systems solution, only the programmes BLAST, DeST, DOE2.1E, Ener-Win, Energy express, eQUEST, and SUNREL do not perform the iterative non-linear systems solutions. Softwares, BLAST, DeST, DOE2.1E, ECOTECT, Ener-Win, HAP, Tas, and TRACE, do not offer coupled loads, systems and plant calculations. The DOE2.1E, the eQUEST, they do not simulate space temperature based on loads-systems feedback. All the programmes simulate floating room temperatures.

For the time step approach, the user selected for zone/environment interaction, nearly 50% of the software did not give this opportunity. For variable time intervals (and) for zone air/HVAC system interaction, only, BLAST, BSim, Energy Express, Energy plus, eQUEST , and ESP-r, offer air/HVAC system interaction. The user selected for both building and systems, only ESP-r, IDA ICE, IES VE, PowerDomus, and TRNSYS, which offer this opportunity. EnergyPlus, ESP-r, IDE ICE, offer dynamic variations based on solution transients, all the others do not offer this possibility. But all the software do offer full geometric descriptions, walls, roofs, floors, windows, skylights, doors and external shadings.

**Table2**

**Comparison of measured and simulated electric consumption in kWh using EnergyPlus**

| Month | Meas. | Simulated | Diff. | Percent. |
|---|---|---|---|---|
| January | 20136 | 23 777.34 | 3641.34 | 18.08 |
| February | 19397 | 21 091.93 | 1 694.93 | 8.74 |
| March | 21291 | 23 644.45 | 2 353.45 | 11.05 |
| April | 23 734 | 25 665.67 | 1 931.67 | 8.14 |
| May | 28 780 | 29 476.21 | 696.21 | 2.42 |
| June | 33 516 | 30 057.25 | -3 458.75 | -10.32 |
| July | 39 480 | 33 704.96 | -5 775.04 | -14.63 |
| August | 36 877 | 30 683.08 | -6 193.92 | -16.80 |
| Sept. | 30 989 | 28 522.46 | -2 466.54 | -7.96 |
| October | 24 464 | 26 763.62 | 2 299.62 | 9.40 |
| Nov. | 21 118 | 22 818.53 | 1 700.53 | 8.05 |
| Dec. | 20489 | 21781.59 | 1292.59 | 6.31 |

A detailed comparison between office building measured energy consumption (both for gas and electricity) and the result given by simulation using EnergyPlus, and eQUEST, are discussed. Table1 gives a comparison between the measured electricity consumption and the simulated one, using the eQUEST programme.

**Table 3**

**Comparison of measured and simulated gas consumption in Therms using eQUEST**

| Month | Measured | Simulated | Diff. | Percent. |
|---|---|---|---|---|
| January | 535 | 579.8 | -44.8 | -8.37 |
| February | 604 | 528.45 | 75.55 | 12.51 |
| March | 451 | 511.88 | -60.88 | -13.50 |
| April | 329 | 341.51 | -12.51 | -3.80 |
| May | 309 | 304.98 | 4.02 | 1.30 |
| June | 305 | 282.78 | 22.22 | 7.29 |
| July | 250 | 293.39 | -43.39 | -17.36 |
| August | 263 | 306.19 | -43.19 | -16.42 |
| Sept. | 290 | 309.1 | -19.1 | -6.59 |
| October | 401 | 355.07 | 45.93 | 11.45 |
| Nov. | 507 | 540.78 | -33.78 | -6.66 |
| Dec. | 694 | 606.42 | 87.58 | 12.62 |

Table 2 represents the real electrical energy consumption of a building office compared to the simulated consumption using EnergyPlus. The comparison of the simulated gas energy consumption using eQUEST programme, and the measured data in the same office building is shown in Table 3. The comparison of the simulated gas energy consumption using the EnrgyPlus programme, and the measured data in the same office building is shown in Table 4.

**Table 4**

**Comparison of measured and simulated gas consumption in Therms using EnergyPlus**

| Month | Measured | Simu-lated | Diff. | Percent. |
|---|---|---|---|---|
| January | 535 | 269.97 | 265.03 | 4.13 |
| February | 604 | 227.79 | 376.21 | 62.29 |
| March | 451 | 220.45 | 230.55 | 51.12 |
| April | 329 | 121.28 | 207.72 | 63.14 |
| May | 309 | 60.86 | 248.14 | 80.30 |
| June | 305 | 21.18 | 283.82 | 93.06 |
| July | 250 | 8.75 | 24125 | 96.50 |
| August | 263 | 21.26 | 241.74 | 91.92 |
| Sept. | 290 | 41.03 | 248.97 | 85.85 |
| October | 401 | 108.62 | 292.38 | 72.91 |
| Nov. | 507 | 217.9 | 289.1 | 57.02 |
| Dec. | 694 | 367.67 | 326.33 | 47.02 |

**Table 5**
**Detailed difference percentage between eQUEST and EnergyPlus**

| | Electricity consumption | | Gas consumption | |
|---|---|---|---|---|
| Month | eQUEST % | EP% | eQUEST % | EP% |
| January | 0.95 | 18.08 | -8.37 | 4.13 |
| February | 6.41 | 8.74 | 12.51 | 62.29 |
| March | 12.38 | 11.05 | -13.50 | 51.12 |
| April | 2.26 | 8.14 | -3.80 | 63.14 |
| May | -3.80 | 2.42 | 1.30 | 80.30 |
| June | -2.61 | -10.32 | 7.29 | 93.06 |
| July | 1.04 | -14.63 | -17.36 | 96.50 |
| August | -2.77 | -16.8 | -16.42 | 91.92 |
| Sep. | -5.33 | -7.96 | -6.59 | 85.85 |
| October | -0.95 | 9.4 | 11.45 | 72.91 |
| Nov. | 6.15 | 8.05 | -6.66 | 57.02 |
| Dec. | 1.87 | 6.31 | 12.62 | 47.02 |

## CONCLUSIONS

The results of comparison of the two major whole building simulation programmes show that, when we are dealing with annual energy consumption, the eQUEST results are much closer than those of the EnergyPlus results. The difference between the measured annual electrical energy consumption, and the simulated one using eQUEST programme, are +/- 0.95% for January and October, the highest difference percentage registered is 12.38% for the month of March, The others fluctuate between +/- 6%, and +/- 1%. The EnergyPlus programme shows a difference of 18% and 8%. Table 5 shows the detailed difference percentage between eQUEST and EnergyPlus, and it shows clearly that the results obtained when using eQUEST are closer than when using EnergyPlus.
The difference between the simulated results, using EnergyPlus and the real values for annual gas consumption, shows a very large percentage of difference than when using eQUEST programme.

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