

THERMAL EVALUATION OF BUILDINGS.

A convenient tool.

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SUMMARY

The convenience of the use of environmental building evaluation tools, to know design conditions and thermal behavior, by using bioclimatic strategies for determining a good early design processes of the building, , as well as an evaluation of energy consumption of buildings and for the behavior of building the use of BPS - building performance simulation tool to control the power state of the building, the emission of carbon dioxide CO₂, natural lighting and thermal comfort and a CFD - Computational Fluids Dynamics analysis.

We take a deeper look about the behavior of the buildings by the use of the Design Builder software, as main practice objective, to show this we explain the process to work with a BPS - building performance simulation: Pre-process, Simulation process, Post-process.

This material was presented in a European Union Cost Action TU1104, Training School in Belgrade (Serbia) in 20 - 23 April of 2015.

Key words: Training Schools, Bioclimatic Strategies, Thermal Evaluation Tools, BPS Buildings Performance simulations.

ABSTRACT

The convenience of the use of environmental building evaluation tools, to know design conditions and thermal behavior, by using bioclimatic strategies for determining a good early design processes of the building, , as well as an evaluation of energy consumption of buildings and for the behavior of building the use of BPS - building performance simulation tool to control the power state of the building, the emission of carbon dioxide CO₂, natural lighting and thermal comfort and a CFD - Computational Fluids Dynamics analysis.

We take a deeper look about the behavior of the buildings by the use of the Design Builder software, as main practice objective, to show this we explain the process to work with a BPS - building performance simulation: Pre-process, Simulation process, Post-process.

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1 INTRODUCTION

All this material was imparted in a Training School of the COST ACTION TU 1104 "Smart Energy Regions" to different students from different countries Austrian, Spanish, British / Irish, Bulgarian, Dutch, Lithuanian, Serbian, Latvian, Bosnia and Herzegovina, Portuguese, Macedonian, Slovenian and Polish with different backgrounds Architecture, Architectural Engineering, Science and Technology and Civil Engineering all of them early stage researchers came from PhD studies, research area or professionals area.

The main topic was a "Integrated approach to retrofitting existing dwellings". The scientific focus of the Training School was the improvement of the environmental and energy performance of existing neighbourhoods at a regional scale. The main goal of the Training School was to offer an opportunity to reflect upon about how retrofitting of neighbourhoods can contribute to energy and environmental improvement of regions in a different context whilst enabling attendees to interact with other researchers from across Europe. ([http://www.smart-eu.eu/content/training-school-"integrated-approach-retrofitting-existing-dwellings"](http://www.smart-eu.eu/content/training-school-))

2 BIOCLIMATIC STRATEGIES

Bioclimatic approach to buildings are very important to study to know how to achieve high comfort levels with adaptation of geometry, orientation, construction technology to the climate and surrounding conditions.

This kind of strategies need to be study to reduce building energy consumption and emissions, adapting it to environment conditions.

The building has to guarantee the comfort of the occupants during the whole year, adapting his strategy to the seasonal conditions of the region:

- Cooling strategies during the hot season
- Heating strategies during the cold season
- All components of the building, and specially the envelope, should be design to interact like a filter between interior and exterior conditions.
- They should design to interact with natural parameters and conditions

For a bioclimatic approach to retrofitting existing buildings it is necessary to study overall parameters that determine interior building comfort:

(Thermal comfort standards defined by, ASHRAE 55- 2010)

- Air temperature
- Mean radiant temperature (walls and objects)
- Humidity
- Air velocity (m/s)
- Human metabolic rate activity (met)
- Clothing level (clo)

Whole exterior parameters that influence the building:

- Temperature and thermal oscillation
- Wind direction and intensity
- Humidity
- Solar radiation (average of daily and monthly conditions)

The most important tools used are the Building Bio Climatic Charts (BBCC) of Victor Olgyay and Baruch Givoni.

The Olgyay chart considers the temperature and the humidity as exterior parameters which condition the human body, showing the comfort zone with the appropriate temperature and humidity necessary to achieve it.

The Givoni chart predicts indoor conditions of the building according to the outdoor prevailing conditions. The chart combines different range of temperature and pressure of vapor over typical psychometric chart, combined with specific passive cooling strategy (evaporative cooling, thermal mass, natural ventilation and passive heating).

There are bioclimatic strategies to apply in building design:

The study of solar radiation diagrams to determine the quantity of radiation and the average of hours of solar direct beam radiation during the year and in the main seasons

The study of direction and intensity of the wind during the year. Determine the prevailing and the dominant winds:

- Prevailing are winds that blow predominantly along a single general direction.
- Dominant are winds that blow in a direction with the highest speed.

The study of general building data, the geometry:

- Façade disposition and orientation
- Double exposition and courtyard
- Separation between dwellings and median wall
- Height of the building, basement, ground, typical and roof level
- Windows dimension, disposition and shadows systems

The study of construction technology and materials:

- a) Type of façade and courtyard
- b) Type of separation between dwellings and median wall
- c) Type of horizontal structure
- d) Type of roof
- e) Type of windows and shadows system.

Analyzing all bioclimatic strategies and the energy performance of all components of the buildings, can be done simulating the better solutions to improve their energy behaviors.

3 BPS - BUILDING PERFORMANCE SIMULATION

Is the attempt to model the various energy and mass flows within a building in order to predict one or several performance aspects of a building using computer simulations. Example performance aspects are energy, light, acoustics, HVAC, structure, costs, comfort.

One major characteristic is the trend to progressively move towards early design phases. Due to the increasing importance of the decisions made early in the design process and their impact on energy performance and cost, several BPS

tools have been developed to help architects perform early energy analysis, and create more energy efficient more sustainable buildings. (Hensen, 2004)

To do this its necessary to do a dynamic-thermal simulation that it is a process of creating a computer model of a building whether home, office or other, to determine the energy demand and domestic comfort of the building.

A dynamic-thermal simulation it is important for the study of energy efficiency design of buildings, and it is used to compare different design variants, to demonstrate code compliance, to reduce uncertainty risk in design planning.

For architects, the most important criteria (31% and 34%) was the ability of the tool to integrate intelligent design knowledge-base to assist designer in decision making. (Shady Attia, 2010).

A dynamic-thermal simulation it is necessary when simple calculations are not sufficient to estimate the energy demand; In the design of Buildings of high consumption (hotels, offices, big residential areas).

A detailed energy performance and indoor comfort analysis calculation is required to obtain the value of some inherent characteristic of the building, cladding, building construction, system, etc.

To do a BPS we use the Design Builder software, the DB is an advanced graphical user interface that has been specially developed to run EnergyPlus simulations.

For UK and Republic of Ireland users the Design Builder interface can also be used to produce Energy Performance Certificates (EPCs) and to show compliance with the Building Regulations.

Design Builder is an application software for any location, it is a tool to control the energy state of the building, the emission of carbon dioxide, natural and artificial lighting and comfort.

It is developed to simplify the process of dynamic-thermal simulation of a building, Design Builder allows quickly compare the function and performance of designs and building systems; energy efficient and sustainable. (<http://www.designbuilder.co.uk/>)

EnergyPlus is the program of building energy simulation of the US DOE (Department of Energy, USA) for modeling and calculation of heating, cooling, lighting, ventilation and other energy flows.

It's build on the most interesting features of BLAST and DOE-2 (interface modeling) while incorporating many features of novel simulation as intervals of less simulation to an hour, integration into a simultaneous calculation of zonal balance and installation, flow multizone, thermal comfort and photovoltaic systems.

The Main Characteristics are:

- Advanced engine calculates energy flow + resource consumption including:
- Heating, cooling, lighting, ventilation, water
- Best of BLAST and DOE-2...Plus:
- Time steps < 1hr,
- Modular HVAC integrated with Zone,
- Multizone air flow for Natural ventilation, Thermal Comfort, Photovoltaic's and Water. (<http://apps1.eere.energy.gov/buildings/energyplus/>)

EnergyPlus is a standalone application, NOT a "friendly" GUI - Graphical User Interface, here it is where comes in Design Builder.

Design Builder EnergyPlus tightly integrates within your environment enabling the realization of simulation hassle, simply setting the building model, applying the results and leaving the rest to the Energy Plus simulation engine.

Design Builder has been developed specifically around EnergyPlus, incorporating comprehensive database of materials, cladding, glazing and shading devices.

The benefits provide by a BPS of this type are:

- Cost savings in energy consumption and cost of installation.
- Improved internal comfort.
- Reduction of greenhouse gases.
- Increased energy sustainability.
- Improved energy performance of the building.

Academically:

- Provides scope and approach of reality to a particular study or research.
- Being an application with a wide choose of countries and locations, can be modified values, ranges and different characteristics of study.
- Also can create a unique or particular weather conditions data via EnergyPlus.

The Design Builder program is implemented as a GUI - Graphical User Interface with a friendly modeling environment, intuitive and visual, it integrated different buildings modules for energy and environmental calculation, the data bound that use are:

- Constructive geometric description, constructive and operational system of buildings.
- Heating Cooling and ventilation (HVAC), domestic hot water (DHW), and lighting, depending on the climate of the site.
- The use of the building in summer and winter regime, also its isolation and inertia, air permeability and sun exposure.
- This format with a free use and application in any climate zone with which want to work.

All BPS has a typical simulation process and mostly all have to follow this next steps:

1. Create a new building model or load a DXF floor plan (or PDF, bitmap etc) if available.
2. Create building geometry model by adding blocks.
3. Partition blocks into zones using zoning rules.
4. Set model options as required based on design stage, early stage, etc.
5. Set as much building default data as possible.
6. Set data for individual blocks, zones, surfaces, etc.
7. Run test simulations for winter and summer weeks looking at hourly results in all zones to check for correct operation.
8. Run annual simulations without hourly results (typically select monthly and temperature distribution results).

All these steps can be divided into three different processes:

Pre-process

The first step to start the analysis Design Builder develops as a "friendly", intuitive and visual environment where you introduce different data of the building in a particular way of introduction:

Modeling, schedule, activities and building envelope data

A building can be created with or without reference to a 2-D drawing file created from a CAD system or by scanning a plan of the building. In either case, the building geometry is defined by entering one or more blocks.

Block types:

Building Blocks are used to create the model.

Outline Blocks are used to help in the creation of the building and do not affect the model.

Component Blocks are used to create visual and shading structures, ground structures and neighboring buildings.

Most of the Activity data is associated with either Internal gains or Environmental control.

There are 7 categories of internal gains in Design Builder:

- Occupancy
- Computer gains
- Office equipment gains
- Miscellaneous gains
- Catering gains
- Process gains
- Lighting (data set on the Lighting tab)

Construction systems, geometric description and building construction

To define the construction systems need to set the number of layers first, and then select the material and thickness for each layer. Constructions can have up to 6 layers. The outermost layer will be positioned adjacent to outside.

The material in any layer can be selected from the library in the same software.

HVAC - Heating and cooling, domestic hot water (DHW) and lighting, depending on the climate

HVAC can be defined in Design Builder using:

- Simple HVAC where the heating/cooling system is modeled using basic load calculation algorithms. For convective heating systems and all cooling systems the EnergyPlus 'Purchased air' system is used to calculate heating and cooling loads. 'Purchased air' supplies hot/cold air at predefined temperature and humidity for heating and cooling.

- Compact HVAC where the heating/cooling systems are defined in Design Builder using fairly simple parametric HVAC descriptions but modeled in detail in EnergyPlus.
- A DHW generator work depending on the activity and building type selected for the zone, a standard DHW demand is assumed by default.

Simulation process

Where the engine of calculation start to work, in this case the engine is EnergyPlus, the one who made the real analysis of the building, with simulation intervals annual, monthly, daily and even less than one hour, integration into a simultaneous calculation of energy balance by spaces and areas of the building, multi-zone flow, thermal comfort and photovoltaic systems.

Simulations using EnergyPlus have the following characteristics:

- Weather data comes from Hourly weather data file.
- Includes consideration of heat conduction and convection between zones of different temperatures.
- Includes solar gain through windows and shading from other buildings and self shading by the building itself.
- Simulation of HVAC equipment
- Includes one or more warm up days to ensure correct distribution of heat in building thermal mass and the start of the simulation.
- Warm up continues until temperatures/heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

In this process also counts with the CFD (Computational Fluids Dynamics) analysis, where you can introduce the data you want or work with the EnergyPlus simulation results, to do wind, temperature and pressure analysis inside or outside the building.

Computational Fluid Dynamics is the term used to describe a family of numerical methods used to calculate the temperature, velocity and various other fluid properties throughout a region of space.

CFD when applied to buildings can provide the designer with information on probable air velocities, pressures and temperatures that will occur at any point throughout a predefined air volume in and around building spaces with specified boundary conditions which may include the effects of climate, internal heat gains and HVAC systems.

Design Builder CFD can be used for both external and internal analyses. External analyses provide the distribution of air velocity and pressure around building structures due to wind effect and this information can be used to assess pedestrian comfort, determine local pressures for positioning HVAC intakes/exhausts and to calculate more accurate pressure coefficients for EnergyPlus calculated natural ventilation simulations. Internal analyses provide the distribution of air velocity, pressure and temperature throughout the inside of building spaces and this information can be used to assess the effectiveness of various HVAC system designs and to evaluate interior comfort conditions.

Post-process

The last step of the analysis, where we obtain final results of the analysis:

- Loads and energy balance

Design Builder specifically implement the calculation of maximum load of heating and cooling under ASHRAE Standard.

This functionality is interesting for the dimensioning of facilities.

Design Builder shows solar gains, gains by occupation, lighting, etc. and ventilation losses, transmission fences, etc. providing valuable information about critical elements in the heat balance of the building.

- Demand for heating and cooling.

Through a simple program option is possible to calculate the demand for the early stages of design or aimed at improving the bioclimatic design of the building without going to model in detail the HVAC.

- Consumption for heating, cooling and DHW

Introducing the facility, which can be modeled at different levels of detail and complexity, energy consumption and fuel costs (electricity, gas, biomass, etc.).

- CO₂ emissions

CO₂ emissions associated with the consumption obtained

- Indoor climate comfort

It is air-conditioned or not, we obtain results of internal building conditions, temperature and humidity, at any time of year. (in different time ranges from 5 min up daily)

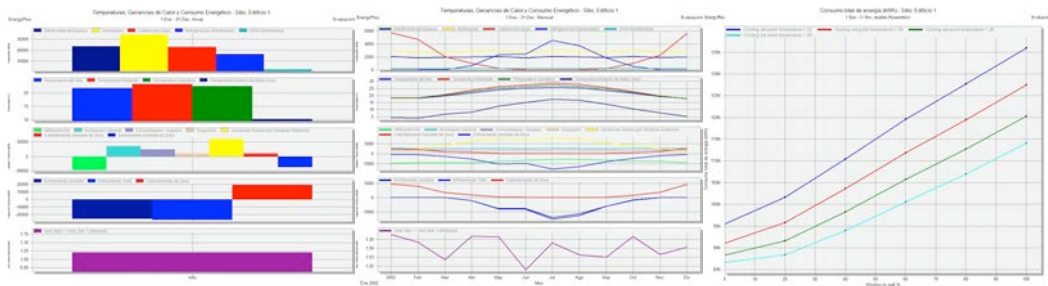
- Indices of comfort, PMV, PPD

Through various comfort indices such as PMV - Predicted Mean Vote of Fanger-ISO 7730, PPD - Percentage of People Dissatisfied, the operating temperature or the percentage of uncomforted hours at certain temperatures, are incorporated into the results Design Builder.

- Ventilation, air infiltration and flow

Obtainable renewals per hour we have in the building and in stream from each opening, if calculation has been made of natural ventilation.

The result outputs of the software shows charts, cell data, chart/table or table, also give the possibilities to export data.

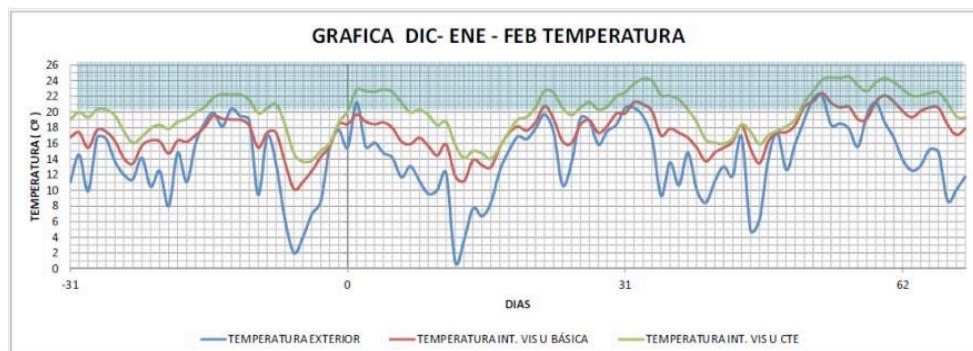


Example of annual, monthly and parametrical output charts.

The most important thing is the interpretation of the results and to know which data it's the one you want as the analysis main result, in the way to do parametrical analysis of different designs of the building.

In order to do this the Design Builder has the option of export any results in .CSV (coma separation value) file format, that the user can work with in an external spreadsheet where the user can compare different data as result:

- Comfort between building Indoor Temperature
- Consumption of heating and cooling and CO₂ emissions between systems
- Behavior between enclosures or materials
- Behavior between designs or orientations

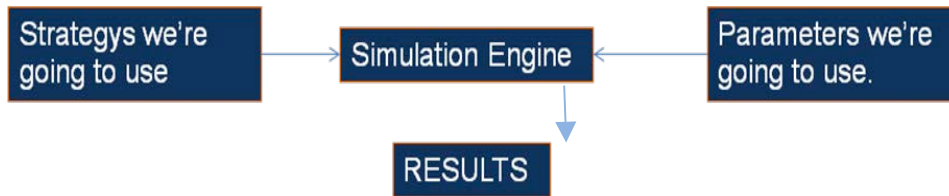


Example of indoor temperature comfort between two different construction system.

4 DISCUSSION

Points collected in training school in Belgrade, Serbia.

1. Choose either the survey data: climatic data, most favorable and less favorable day and construction data.
2. Knowing that program used to find solutions and specific results
3. We don't do analysis of the building, in the design early stage
4. HVAC – Key for energy buildings performs; Also it is Important the need to know the performance of the building before proposing a system.
5. If there's no resources for monitoring - Simulate
6. The main objective to us as architects of using any BPS, are the results. The fancy graphical look are useful, but more important the interpretation of them, following the next scheme.



7. Know the constructive system and composition of the building
8. Know the level we want to work in the analysis (and know if the software chosen work that level)

5 NOTES

Some works already done in different subjects and topics develop with a thermal analysis:

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<http://www.plea2012.pe/pdfs/T11-20120203-0091.pdf>
- PhD Thesis - Josep Maria Rieradevall i Pons
Energy rehabilitation of buildings: the building skin. The housing estates of the 70's in Barcelona: the rehabilitation of the estate of Montbau,
<http://hdl.handle.net/10803/285002>
- Dubravka Matic, Jaume Roset Calzada, Milos Eric, Mihajlo Babin, *Economically feasible energy refurbishment of prefabricated building in Belgrade, Serbia*, Energy and Buildings, Available online 5 November 2014, ISSN 0378-7788,
<http://dx.doi.org/10.1016/j.enbuild.2014.10.041>.
<http://www.sciencedirect.com/science/article/pii/S037877881400886X>)
- PhD Thesis - Fernandes, Eloisa Pizarro
 ¿Illumination o ventilation? Adaptability of design guidelines Sarah Red (Brazil) to the Mediterranean climate of Catalonia
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- Camila Burgos Leiva (Chile), Thesis: Traditional external timber cladding in mediterranean climates. For PhD title. September 2012 (In progress)
- Juan Carlos León (México), Thesis: Design parameters of solar chimney. for Master degree title. June 2013
<http://hdl.handle.net/2099.1/20593>
- Teófilo Bernardo Aguilar León (Peru), Thesis: NATURAL Ventilation for Building in height, in the city of Lima, Peru. for Master degree title. December 2013 (Finished)
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<http://hdl.handle.net/2099.1/23017>
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- Rivera De La Rosa, Chanely (Dominican Republic), Thesis: Green roofs in the Caribbean region. Case Study: Dominican Republic.
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<http://apps1.eere.energy.gov/buildings/energyplus/>

<http://www.smart-er.eu/>