NZB.RGChan.
2.1 Exploratory Report

Comparative Research on Ecotect, Radiance, DaySim, Climate Consultant, and EnergyPlus

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Research Team

Rafael G. Chan, fuap, maehp, cbp
Joanna Rose Arconcil
Denise Christine Dacanay
Moira Angelie Quero

R.G.CHAN & ASSOCIATES
ARCHITECTS ENGINEERS ENVIRONMENTAL PLANNERS
888 City Camp Road Baguio City, 2600 Philippines

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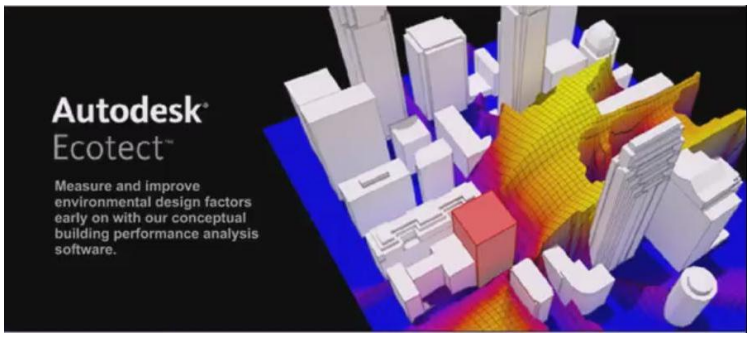
ABOUT THE SERIES

This pdf file-binding is part of the NZB.RGChan.Series on foundational researches undertaken by R.G.CHAN & Associates for in-house office use, towards systematic steps for Net Zero Building Design of projects.

Ecotect



Ecotect is a 3-D building design and environmental analysis tool by Autodesk that covers a wide range of simulation and analysis functions required to truly understand how a building design will operate and perform. It offers a diverse suite of tools for assessing aspects of design such as solar exposure, thermal performance, acoustics, and lighting and shading. It was developed by Andrew Marsh, PhD and Square One Research Ltd. in 1996 and has grown to become the leading application for analyzing building performance because of its simple interface and seamless updates and transfer of data from one application to another. In 2008, it was bought by the Autodesk Company in which three stand alone versions have been developed (2009, 2010, and 2011). By 2015, Ecotect was discontinued and functionalities of this software have been merged with Revit as a plugin tool developed with the Green Building Studio.

Features:

- Conducts detailed environmental simulations and visual results.
- Interactive 3D displays simulate building performance in response to environmental factors.
- Solar radiation, shadows and reflections, shading design, and visual impact studies
- Detailed weather, energy, water, and carbon-emission analysis (via web-service tools) that helps enable faster evaluation of multiple design alternatives.
- ENERGY STAR scoring and analysis of potential for LEED daylighting credits.
- Sun-Path Diagram
- Customizable Shadow Displays
- Thermal Analysis Tools
- Acoustic Analysis Tools
- Hourly, daily, monthly or annual total thermal load and carbon emissions can be measured
- Carbon dioxide emissions data
- Estimating cost and water use: according to the number of residents in a building/ structure
- Energy performance: Heating and cooling load quantity, occupancy influences, infiltration impacts, and effects of equipment pieces on energy performance are analyzed.
- Daylighting: intensity of light in any spot of model and daylight factors
- Shades and reflections: Location and track of sun corresponding to the model

Advantages:

- Model viewing capabilities
- Analysis results are stored in a single file
- Resultant graphics are easily understood
- Quick and precise result viewing
- Variety of displayed mediums
- Zone management system
- Ability to export to Radiance and Energy Plus for additional analysis
- Calculations have the possibility to define more than one thermal zone (varying in internal gains, orientation, usage patterns, defined comfort levels, etc.) which enables a more realistic building thermal behavior modeling.
- Uses realistic climatic data (weather files) which enables shading analysis, tracing of solar gains and daylight levels, and by using a simple model for taking into account the dynamic effects of heat transfer it is possible to determine both energy need for cooling besides the energy need for heating

Disadvantages:

- Analysis run times are very long. Running several projects simultaneously results in unexpected errors.
- Some analyses cause program instability. After closing one project, program needs to be restarted before opening new project
- Success of analyses is inconsistent
- Administering building with complicated geometry is pretty tough
- Thermal properties of materials are separated from building layers
- Each area is one zone that explains the lack of hierarchy of areas and zones
- Lack of clear explanation for HVAC system
- Lack of detail on thermal calculations
- Incomplete schedule for post processing
- Export files have restricted information for post processing
- Lack of multiple state in undo/redo
- Cylindrical geometry is converted into triangular components

Radiance

Radiance is a suite of programs for the analysis and visualization of lighting in design. This software was developed by Greg Ward Larson, then at Lawrence Berkeley National Laboratory in Berkeley, California. In January 2002, Radiance 3.4 was relicensed under a less restrictive license. It is a free program designed to help designers and architects in lighting by predicting the light levels and appearance of a space before construction.

Radiance is the only lighting software that implements a distributed raytracing method, which is optimized to simulate the diffuse distribution and propagation of light in the built environment.

Features

- Modeling and translating scene geometry, luminaire data, and material properties, which are necessary inputs to produce an output or a simulation.
- Uses raytracing to compute the effects of architectural lighting and daylighting, or the radiance values
- Generates a photorealistic gray scale renderings in all sky conditions based on analysis which may be converted as color images, numerical values, contour plots, or other file formats to be exported to other programs.

Advantages:

- There are no limitations of the geometry or the materials that may be simulated.
- Best-known for presentation-quality, accurate renderings
- Photometrically accurate computer-generated graphic simulation of lighting in indoor environments.
- Effective and friendly cooperation between users and developers. Radiance users contribute in its library that includes materials, objects, models, and images.
- Modular structure
- Variety of outputs

Disadvantages:

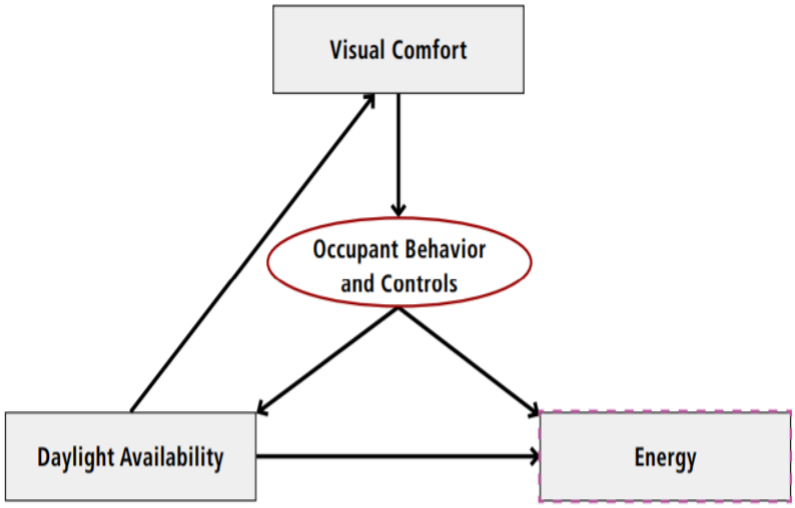
- Rendering can be time-consuming and take up considerable amount of computer memory
- Generally, the package is well-suited to programmers and people with a high degree of computer proficiency. The interface is command-based in a fashion that is familiar to UNIX users, but uncomfortable for many who are used to the menus and point-and-click interfaces of modern software.
- Only utilized through exporting from ECOTECT which limits the possibility of taking advantage of the capabilities of Radiance.
- Lack of windows-compatible material files.

DaySim

DAYSIM

ADVANCED DAYLIGHT SIMULATION SOFTWARE

Developed by the NRC-CNRC Institute for Research in Construction in Canada, DaySim (Dynamic daylight simulations) is a daylighting analysis software that calculates the annual daylighting availability in and around buildings based on the Radiance backward ray tracing feature. This modeling tool utilizes light switch occupant behavior model to imitate occupant use of personal controls, for instance light switches and venetian blinds, and to predict energy savings from automated lighting controls, such as occupancy sensors and photocell controlled dimming systems.



Features:

- Models the effects of occupant behavior and experience on daylight availability and lighting energy use, which predicts visual comfort.
- Calculates hourly or sub-hourly illuminance or irradiance values
- Provides lighting and shading schedules
- Models occupant behavior and automatic control systems
- Models annual performance of shading and lighting systems
- Simulates daylight autonomy, useful daylight illuminance, daylight glare probability, daylight factor, and annual daylight availability

Advantages:

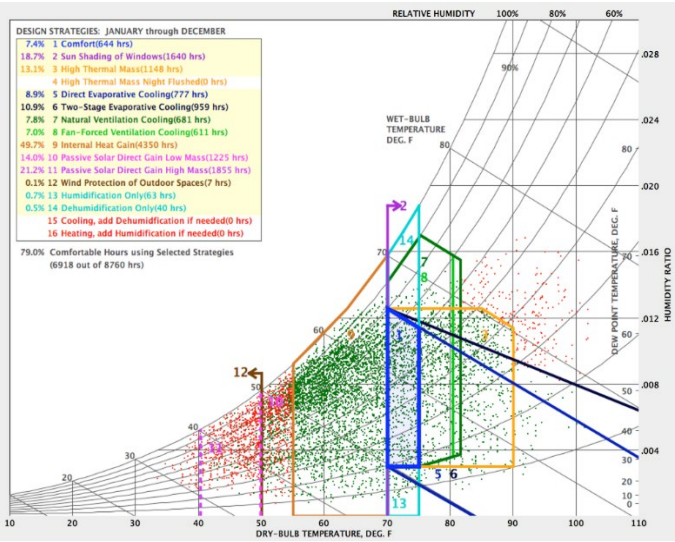
- Radiance interface – combines backward raytracing with daylight coefficients approach
- Excellent for solar shading analysis, solar animations, renderings, glare/luminance ratio and interior illuminance
- Users can model dynamic façade systems ranging from standard venetian blinds to state-of-the-art light redirecting elements, switchable glazing and combinations thereof.

Disadvantages:

- Simulation speed is on the slow side
- Complex User Interface

Climate Consultant

Climate Consultant was developed by the United States Department of Energy. The program graphically displays climate data in either metric of imperial units in many ways useful to architects including monthly bar charts, timetable charts, and psychrometric charts, sun shading charts, and sun dial charts. It translates, organizes, then represents raw climate data in easy-to-understand ways that show the subtle attributes of climate, and its impact on built form.



The Psychrometric Chart shown to the left is one of the more advanced features available in Climate Consultant. Each dot on the chart represents the temperature and humidity of each of the 8760 hours per year. Different Design Strategies are represented by specific zones on this chart. The percentage of hours that fall into each of the 16 different Design Strategy Zones gives a relative idea of the most effective passive heating or passive cooling strategies. Climate Consultant analyzes the distribution of this psychrometric data in each Design Strategy zone in order to create a unique list of Design Guidelines for a particular location.

Features

- Graphical representations for:
  - Temperature
  - Radiation Range
  - Sky Cover Range
  - Wind Velocity Range
  - Dry Bulb and Dew Point
  - Ground Temperature
  - Dry Bulb and Relative Humidity
  - Psychrometric Chart

Advantages:

- Accurate and easy to use
- Reliable thanks to the fact that it uses the annual 8760 hour EPW format climate data provided for free by the Department of Energy
- Transforms raw climate data into easy-to-understand, meaningful charts, graphs, and other graphic displays, thus, making it effective for anyone using the software.
- Comprehensively plots a lot of data.

Disadvantages:

- Does not directly show the relationship between built structure and environment.

EnergyPlus

EnergyPlus is a new-generation whole building energy simulation program, based on DOE-2 and BLAST, that engineers, architects, and researchers use to model both energy consumption – for heating, cooling, ventilation, lighting and plug and process loads– and water use in buildings. In April 2001, the program was developed jointly by Lawrence Berkeley National Laboratory, the University of Illinois, the U.S. Army Construction Engineering Research Laboratory, GARD Analytics, Inc., Oklahoma State University and others, with the support from the U.S. Department of Energy, Office of Building Technology, State and Community Programs.

Integration of Loads, Systems, and Plants: One of the strong points of EnergyPlus is the integration of all aspects of the simulation—loads, systems, and plants. System and plant output are allowed to directly impact the building thermal response rather than calculating all loads first, then simulating systems and plants. The simulation is coupled allowing the designer to more accurately investigate the effect of undersizing fans and equipment and what impact that might have on the thermal comfort of occupants within the building. The table below are the inputs and outputs of this software.

Table 1. Inputs and Outputs of EnergyPlus

Parameter			Energy Plus
Input	Weather	Outdoor air temperature	x
		Sky Temperature	x
		Wind Velocity	x
		Direct Normal Radiation	x
		Diffuse Radiation	x
		Global Radiation on a tilted surface	
	Envelope	Thermo-physical properties of construction materials	x
		Spectral average/spectral optical data type of glass panes and shading materials/blinds	x
	Other	Convective heat transfer coefficients	x
		Internal gains	x
		Occupancy schedules	x
Output		Heating/cooling loads	x
		Heating/cooling energy needs	x
		Indoor air temperature	x
		Mean radiant temperature	x
		Thermal comfort indexes	x

Features:

- Integrated, simultaneous solution of thermal zone conditions and HVAC system response that does not assume that the HVAC system can meet zone loads and can simulate un-conditions and under-conditioned spaces.
- Heat balance-based solution of radiant and convective effects that produce surface temperatures, thermal comfort, and condensation calculations
- Sub-hourly, user-definable time steps for interaction between thermal zones and the environment; with automatically varied time steps for interactions between thermal zones and HVAC systems. These allow EnergyPlus to model systems with fast dynamics while also trading off simulation speed for precision.
- Combined heat and mass transfer model that accounts for air movement between zones.
- Advanced fenestration models including controllable window blinds, electrochromic glazing, and layer-by-layer heat balances that calculate solar energy absorbed by window panes.
- Illuminance and glare calculations for reporting visual comfort and driving lighting controls.
- Component-based HVAC that supports both standard and novel system configurations
- A large number of built-in HVAC and lighting control strategies and an extensible runtime scripting system for user-defined control
- Functional Mockup Interface import and export for co-simulation with other engines
- Standard summary and detailed output reports as well as user definable reports with selectable time-resolution from annual to sub-hourly, all with energy source multipliers
- ASCII text-based weather, input, and output files that include hourly or sub-hourly environmental conditions, and standard and user definable reports, respectively.
- Transient heat conduction through building elements such as walls, roofs, floors, etc. using conduction transfer functions.
- Thermal comfort models based on activity, inside dry-bulb temperature, humidty, etc.
- Anisotropic sky model for improved calculation of diffuse solar on titled surfaces
- Atmospheric pollution calculations that predict CO_2, SO_2, NOx, CO, particulate matter, and hydrocarbon production for both on-site and remote energy conversion.
- Can be used for building load calculations and sizing equipment and uses the heat balance method recommended in the ASHRAE Handbook Fundamentals. Proper sizing of equipment without oversizing, generally saves energy as the equipment is operated neared to optimal loads.

Advantages:

- Strong in building technologies (building geometry, envelope systems, HVAC, lighting and daylighting systems, HVAC controls)
- One of the most robust and used energy simulation tools available both at academic and commercial levels.
- Open source and freely downloadable and compatible with Windows systems and Linux & Mac
- Uses text as an input therefore, a "Graphical User Interface" (GUI) such as Sketchup or Design Builder can be used together with EnergyPlus in order to have a visual interface for the building models.
- Has a library for numerous commercially available window glass, window gas, shading materials, and construction materials.

Disadvantages:

- Based on ASCII text input and output files

Comparison

To summarize the report, a table showing the differences and similarities of **Ecotect, Radiance, DAYSIM, Climate Consultant,** and **EnergyPlus** can be seen below.

Table 2. Comparision between Ecotect, Radiance, DAYSIM, Climate Consultant, and EnergyPlus

	Ecotect	Radiance	DAYSIM	Climate Consultant	EnergyPlus
Latest/ Current Version	Autodesk® Ecotect® Analysis 2011	Radiance 5.2 (2018)	DAYSIM 4.0 (2020)	Climate Consultant 5.5 (2020)	EnergyPlus 9.3.0 (2020)
System Requirements (Recommended)	Microsoft Windows 95 or later, Microsoft Windows NT 3.5, Microsoft Windows XP OpenGL compatible graphics card. XGA monitor 129 MB min RAM Size 95 MB Min Hard Drive Space 300 Hz Processor Speed	8 MB min RAM Size 16 MB min Hard Drive Space 8-bit color display Programming Language: Standard C language needed.	8 MB min RAM Size 16 MB min Hard Drive Space 8-bit color display	Microsoft Windows 95 or later, Microsoft Windows NT 3.5, Microsoft Windows XP OpenGL compatible graphics card. XGA monitor 8 MB min RAM Size 16 MB Min Hard Drive Space 300 Hz Processor Speed	Windows 10 I%, i7 or Xeon processor with 4 or more cores 8-16 GB (or more) RAM At least 200 GB free disk space 100% NVIDIA graphics adapter with hardware acceleration running in 32-bit color mode
Analysis Time	Retards or takes a long time to analyze depending on model size and complexity. (Minimum of 4 hours per analysis based on experience)	Rendering takes a few seconds to many hours depending on the processing parameters selected. Batch mode is significantly faster than the interactive mode	Depends on the execution times and complexity of the model. Minimum of 20 minutes for one simulation to 260 minutes for 8 simulations.	Instant graphical representations so long as the weather file has been loaded	Depends on complexity of model. Usually 5 minutes to calculate one zone with no windows but around an hour
User-Interface	User-friendly modeling interface. GUI (Graphical User Interface)	Command-base, familiar to UNIX Users. C language programming needed GUI (Graphical User Interface) front-end to using trad integration	Complex user interface GUI (Graphical User Interface)	User-friendly and effective interface GUI (Graphical User Interface)	Based on ASCII text input and output files GUI (Graphical User Interface)

Main Use	Basic climate analysis and sun location visualization	Solar Control, lighting, and daylighting design to improve the energy efficiency of buildings Computer-generated graphic simulation rendering	Daylighting analysis; lighting energy analysis	Understand and interpret weather data through graphical representations	To model both energy consumption – for heating,cooling ventilation, lighting and plug and process loads- and water use in buildings.
Main Features					
Solar Analysis	✓	✓	✓	No model analysis but provides data for temperature. Radiation range, sky cover range, wind velocity range, dry bulb and dew point, ground temperature, dry bulb and relative humidity, etc.	✓
Sun and Shadow Studies	✓	✓	✓		
Daylighting and Lighting	✓	✓	✓		✓
Thermal Analysis Performance	✓				✓
Acoustic Analysis	✓				
Weather Data Visualization	✓				
Mechanical Anaylsis	✓				✓

Conclusion

Green building councils all over the world have dedicated to start supporting market transformations towards 100% net zero carbon buildings in the near future. It has been a mission to transition the built environment from the major contributor of greenhouse gas emissions to a central solution to the climate crisis. With this, new resources and solutions are sought to respond to the need for buildings to not only conserve energy but also to produce it.

Architects hold a key role at the early stages of building design and can influence the overall building energy performance by including active and passive solar strategies. References such as “Sun, Wind & Light” by Mark DeKay and G.Z. Brown offer strategies and techniques needed in order to achieve Net-Zero.

Solar Design Tools such as Ecotect, Radiance, DAYSIM, and EnergyPlus, supported by climatic and weather data from softwares such as Climate Consultant can aid in the design of buildings at its early stages. Being able to see how daylight, lighting, shadows, temperature, winds, acoustics, and other factors can affect a building’s performance and energy consumption and production can help the architect and other concerned professionals design and revise accordingly to eventually arrive at a Net-Zero energy design.

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