eQuest - TMY Data and changing the weather

- Weather data play a key role in building energy simulation, so it is useful to know how to work with eQuest’s weather files and utilities.

First – what are TMY data?
Typical Meteorological Year (TMY)

- A set of hourly values of solar radiation and meteorological data used in solar energy conversion systems and building energy modelling.
- Representative of the long term climate of a location.
- Not useful for simulation of worst-case conditions.

Current TMY-style data

- Derived from the 1961–1990 National Solar Radiation Data Base (NSRDB), current TMY datasets also known as TMY2.
- Original TMYs were derived from 1952-1975 data.
- For eQuest (http://doe2.com/intex_With.html) has a variety of weather data resources, including CTMY2 for 40 Canadian locations, TMY2 for 238 US locations and a variety of sources for non-US data (e.g., Asia, Australia, Europe, Mexico, Mid-east, UK).
- Weather data in EnergyPlus weather format — 295 locations in the USA, 71 locations in Canada, and more than 800 locations in 100 other countries throughout the world.
- The national renewable energy laboratory is currently working towards an update of the NSRDB to include the years 1991-2005 and plans to create a TMY from 1971-2000 data.
How is a TMY derived?

• Constructed using an empirical approach that selects individual typical months from different years from the period of record,

• These typical months are then concatenated to form a complete year of data.

• The 12 selected typical months are chosen from a statistical method that utilizes the following nine meteorological indices:
  – maximum, minimum and mean daily dry bulb temperature
  – maximum, minimum and mean dew point temperature
  – maximum and mean daily wind velocity
  – total global horizontal radiation.

• Other meteorological elements included in TMY data files, such as rainfall, may not be typical as they are not included in the selection process.

TMY construction method...

• Step 1
  – Calculate monthly Cumulative Frequency Distributions (CFD) for each met index, compare to the 30 year long term CFD for that index using the Finkelston-Schafer (FS) statistic:

   \[
   FS = \left(1 - \frac{1}{n}\right) \sum_{i=1}^{n} \delta_i
   \]

   Where \( \delta_i \) = the absolute difference between the long term CDF and the individual month CDF at \( x_i \).
   \( n \) = the number of daily readings in a month.

  – For each month a weighted FS statistic is then calculated, some indices are judged more important than others so this is calculated using weighting factors for each index.
  – For each month of the year, the top five months with the best FS statistics are selected.
TMY construction method..

- **Step 2**
  - The top five months are then ranked with respect to the closeness of the month to the long term mean and median.

- **Step 3**
  - For the top five months the persistence of mean dry bulb temperature and daily global solar radiation are evaluated.
  - For temperature the number of consecutive warm days (> 67%ile) and consecutive cool days (<33 %ile) is calculated.
  - For solar radiation the number of consecutive low radiation days (<33 %ile) is calculated.
  - The highest ranking candidate month that meets the following criteria is included in the TMY:
    - The month with the longest run is excluded,
    - The month with the most runs is excluded,
    - Any month with zero runs is excluded.

- **Step 4**
  - The twelve selected months are then concatenated to make a complete year.
  - Curve fitting techniques are used to remove discontinuities created by concatenating months from different years.
TMY Data Formats

Standard TMY data has this format...

Actual data used in building energy simulation programs is often a simplified version of TMY data.

http://rredc.nrel.gov/solar/pubs/tmy2
TMY Data Format - eQuest-style weather files…

**HEADER LINES**

- **IWID**: LOCATION I.D.
- **IWYR**: YEAR
- **WLAT**: LATITUDE
- **WLONG**: LONGITUDE
- **IWZT**: TIME ZONE NUMBER
- **IWSOL**: SOLAR FLAG
- **CLN**: CLEARNESS NO.
- **GT**: GROUND TEMP.

**DATA LINES**

- **KMON**: MONTH (1-12)
- **KDAY**: DAY OF MONTH
- **KH**: HOUR OF DAY
- **WBT**: WET BULB TEMP (DEG F)
- **DBT**: DRY BULB TEMP (DEG F)
- **PATM**: PRESSURE (INCHES OF HG)
- **CLDAMT**: CLOUD AMOUNT (0 - 10)
- **ISNOW**: SNOW FLAG (1 = SNOWFALL)
- **IRAIN**: RAIN FLAG (1 = RAINFALL)
- **IWND**: WIND DIRECTION (0 - 15; 0=N, 1=NNE, ETC)
- **HUMR**: HUMIDITY RATIO (LB H2O/LB AIR)
- **DENS**: DENSITY OF AIR (LB/CU FT)
- **ENTH**: SPECIFIC ENTHALPY (BTU/LB)
- **SOLRAD**: TOTAL HOR. SOLAR (BTU/HR-SQFT)
- **DIRSOL**: DIR. NORMAL SOLAR (BTU/HR-SQFT)
- **ICLDT**: CLOUD TYPE (0 - 2)
- **WINDS**: WIND SPEED (KNOTS)

READ (11,9005) KMON, KDAY, KH, WBT, DBT, PATM, CLDAMT, ISNOW, IRAIN, IWND, HUMR, DENS, ENTH, SOLRAD, DIRSOL, ICLDT, WINDS

9005 FORMAT(3I2,2F5.0,F6.1,F5.0,2I3,I4,F7.4,F6.3,F6.1,2F7.1,I3,F5.0)
DoE2.com Weather Data & Utilities

- [http://doe2.com/index_Wth.html](http://doe2.com/index_Wth.html)
- Weather Data (CTMY, CTMY2, CZ2 (CA), TMY2, TMY3!!!)
- eQ_WthProc (convert from EnergyPlus weather epw to eQuest bin files).

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How to Edit TMY Data…

- Two programs have been made available for viewing/editing TMY data
  - bin2txt.exe converts a binary weather tape file (must be named WEATHER.bin) to a text format (named WEATHER.fmt) that can be edited within Excel
  - txt2bin.exe converts a text format version of a weather tape (must be named WEATHER.fmt) file back to a binary form (named WEATHER.bin) that can be used by eQuest

- **Note**: eQuest does not use the full format of the standard TMY2 data sets. Hence, the text output from txt2bin has a much shorter set of variables than is actually available from the raw TMY2 data.
How to Edit TMY Data… 1/2

- General procedure to edit a file:
  - Go to Program Files/eQuest3-5/weather/tmy2 directory
  - Copy the desired weather file (say PORTLAOR.bin) to WEATHER.bin and move the new file to a convenient location – where you have the 2 programs txt2bin and bin2txt. This file should be 146 kB in size.
  - Run bin2txt – it will automatically find WEATHER.bin and convert it to WEATHER.FMT. This file should be 685 kB in size. Rename it as WEATHER_OLD.FMT
  - Open WEATHER_OLD.FMT in EXCEL
  - The first three rows are HEADER information “Portland OR TMY2 1977…” etc…
  - Note: All data are in a single column format. Drybulb temperature is in the 13-15th space (use “=mid(A4,14,3)” in Excel to extract temperature to a new column (starting with the 4th row).
  - Copy this formula down (for all of 8760 hours of data) by selecting the desired cell, typing <ctrl> <shift> <end> followed by <ctrl> D

How to Edit TMY Data… 2/2

- Break the string into components using “=left(A4,13)”, “=mid(A4,14,3)”, and “=right(A4,62)”. Copy these substrings through entire data record (8760 hours).
- Modify the temperature string as desired and combine strings again using the “=concatenate( )” function – =CONCATENATE(I4,L4,".",J4) – in this example I4 is the left string, L4 is the modified temperature string, the “.” is needed to guarantee the value is seen as a temperature and the J4 cell is the right side of the string. Copy the formula down to the bottom.
- Copy and paste special (as values) the MODIFIED string to a new blank worksheet. Be sure to include the 3 header lines at the top of the new file…
- Use the SAVE AS option within the File menu. From the spreadsheet that has only the NEW-weather on it issue a save as “tab-delimited” text. Name the file “WEATHER.FMT” (be sure to use the quotes in the name and Excel will give it the proper extension (rather than weather fmt.txt). This file should be 685 KB in size.
- Then run txt2bin. The resulting WEATHER.BIN file should be 146kb in size and can be used by eQuest by copying it to the Program Files/Equest3-5/weather/tmy2 directory.
- COMMON ERRORS – extra/missing spaces, you forgot to include the header, extra significant figures in values (e.g., eQuest needs temperatures like 41. (in deg. F) NOT 41.0 !!! Sometimes if you are not careful, the temperature > 99 is now 3 digits and may need you to revisit the =mid command…
In-class Exercises

• Model a typical 2-story office building in Portland, subject to “current” TMY data (use Schematic Design Wizard)
• Make a copy of the Portland TMY data and systematically modify weather as follows:
  – Group 1: increase T by 4 deg. F, regardless of month.
  – Group 2: increase T by 3 deg. F in summer (April – Sept) and 5 deg. F in winter (all other months)
  – Be sure to give the hot climate file a name such as “hotPortland.bin”
  – Group 3: Increase wind speeds by a uniform 20% every hour
  – Group 4: Decrease “Total Horizontal Solar” by 10%
  – Group 5: Decrease “Direct Normal” by 10%
  – Group 6: Decrease BOTH Total Hor and Dir Norm by 10%

Building Energy Codes and Standards

• ASHRAE 90.1 and IECC
• OR Code
• CA Title 24
• LEED
ASHRAE Energy Efficiency Standards

- **Purpose of ASHRAE Standard 90.1**: to provide minimum requirements for the energy efficient design of buildings except low rise residential buildings.

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ASHRAE 90.1 Compliance

- **Building System**: Envelope, Lighting, Mechanical (HVAC, SWH)
- **Compliance Options**: Prescriptive Option, Trade Off Option, Energy Cost Budget
- **Mandatory Provisions**: required for all compliance options

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ME 422/522
What is the International Energy Conservation Code? (IECC)

• Establishes minimum regulations for the design of energy efficient buildings and structures.
• Regulates design and selection of:
  – Building envelope components.
  – Mechanical systems.
  – Electrical power and lighting systems.
  – Service water heating systems.

Structure of the IECC

• Chapter 1 Administrative & Enforcement
• Chapter 2 Definitions
• Chapter 3 Design Conditions
• Chapter 4 Residential - Systems Analysis
• Chapter 5 Residential - Component Performance
• Chapter 6 Simplified Prescriptive Requirements
• Chapter 7 ASHRAE Standard 90.1 Energy Code Reference
• Chapter 8 Design by Acceptable Practice for Commercial Buildings
• Chapter 9 Climate Maps
• Chapter 10 Referenced Standards
IECC Compliance

- **Compliance based upon ASHRAE 90.1** - Chapter 7 of the IECC.

- **Model Energy Code Envelope Compliance** based upon the Chapter 8 of the 2003 IECC using COMcheckEZ design software.

- Building Energy Codes website: [www.energycodes.gov](http://www.energycodes.gov)

Oregon Energy Code

(www.oregon.gov/ENERGY...)

- Residential
  - Prescriptive approach: 10 prescriptive paths (e.g., max U values for windows, etc)
  - Alternative systems analysis (whole building)

- Non-residential
  - Prescriptive approach
  - Simple tradeoff: determine if a proposed building has no larger annual heating load through the exterior envelope and no larger annual cooling load through the exterior envelope than a similar building meeting the Prescriptive Path Approach.
  - Whole building
OR: Residential

<table>
<thead>
<tr>
<th>Building Component</th>
<th>Fan 1</th>
<th>Fan 2</th>
<th>Fan 3</th>
<th>Fan 4</th>
<th>Fan 5</th>
<th>Fan 6</th>
<th>Fan 7</th>
<th>Fan 8</th>
<th>Fan 9</th>
<th>Fan 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum allowable window area</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
<td>No Limit</td>
</tr>
<tr>
<td>Interior doors</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
</tr>
<tr>
<td>Wall insulation</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
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<td>6.92%</td>
</tr>
<tr>
<td>Underfloor insulation</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
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<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
</tr>
<tr>
<td>Flat ceilings</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
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<td>6.92%</td>
<td>6.92%</td>
<td>6.92%</td>
</tr>
<tr>
<td>Skylight clerestory</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
<td>15-40%</td>
</tr>
<tr>
<td>Skylight overhang</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
<td>&lt;3%</td>
</tr>
<tr>
<td>Below-grade wood, veneer or</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
</tr>
<tr>
<td>Insulation value</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
</tr>
<tr>
<td>South facing edge insulation</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
<td>8-12</td>
</tr>
</tbody>
</table>

OR: Climate Zone Definitions

6. Climate Zones

- **Zone 1** - A building site is in Climate Zone 1 if its elevation is less than 3000 feet above sea level and it is in one of the following counties: Benton, Columbia, Clackamas, Clatsop, Coos, Curry, Douglas, Jackson, Josephine, Lane, Lincoln, Linn, Marion, Multnomah, Polk, Tillamook, Yamhill, or Washington

- **Zone 2** - Building sites not in Zone 1, or where construction site elevation is 3000 feet or higher in Zone 1, are in Zone 2.
### Code Requirements - Zone 1

<table>
<thead>
<tr>
<th>Zone 1</th>
<th>Wall Requirements</th>
<th>U-value requirement</th>
<th>R factor requirement</th>
<th>Maximum U-Factor</th>
<th>Max. R Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2500</td>
<td>0.850</td>
<td>0.590</td>
<td>0.900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500-3000</td>
<td>0.900</td>
<td>0.650</td>
<td>0.950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000-3500</td>
<td>0.950</td>
<td>0.700</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3500-4000</td>
<td>1.000</td>
<td>0.750</td>
<td>1.050</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000-4500</td>
<td>1.050</td>
<td>0.800</td>
<td>1.100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Code Requirements - Zone 2

<table>
<thead>
<tr>
<th>Zone 2</th>
<th>Wall Requirements</th>
<th>U-value requirement</th>
<th>R factor requirement</th>
<th>Maximum U-Factor</th>
<th>Max. R Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2500</td>
<td>0.850</td>
<td>0.590</td>
<td>0.900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2500-3000</td>
<td>0.900</td>
<td>0.650</td>
<td>0.950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000-3500</td>
<td>0.950</td>
<td>0.700</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3500-4000</td>
<td>1.000</td>
<td>0.750</td>
<td>1.050</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000-4500</td>
<td>1.050</td>
<td>0.800</td>
<td>1.100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### Commercial Envelope

- Zone 1 (< 3000ft)
- Zone 2
Alternative systems analysis:

NA1107.3 Analysis procedures: The analysis of the annual energy usage of the building and the proposed alternative systems shall be conducted in accordance with the following procedures:

1. Climate and building characteristics shall be established based on the building's location and the local climate data.
2. Building energy usage shall be calculated based on actual or estimated building operations.
3. Building energy usage shall be compared to the proposed alternative systems for efficiency and cost-effectiveness.
4. The analysis shall be conducted using accepted and recognized standards.
5. The analysis shall be conducted by a qualified professional.

Table NA1107.2 – Basis for Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Proposed Building</th>
<th>Code Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Envelope</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Optimize Construction Materials</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Fenestration Performance</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Shading devices</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Window Area</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Skylight Area</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Building Orientation</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Solar Gain</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Building Infiltration</td>
<td>0.35 ACH Natural</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>HVAC Systems</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>HVAC System Type(s)</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>HVAC Efficiency</td>
<td>Code efficiencies</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Heating Fuel</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Cooling Fuel</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Temperature Setpoints</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Equipment Capacity</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
<tr>
<td>Mechanical Ventilation</td>
<td>As designed</td>
<td>Same as proposed</td>
</tr>
</tbody>
</table>

Lighting

| Artificial Lighting               | As designed       | Same as proposed |
| Daylighting                       | As designed       | Same as proposed |

Design Conditions

| Building Occupancy                | As designed       | Same as proposed |
| Building Operational Schedule     | As designed       | Same as proposed |
| Climatic Data                    | As designed       | Same as proposed |
| Interval Loads                    | As designed       | Same as proposed |
| Cooling Fuel                     | As designed       | Same as proposed |
Oregon – Business Energy Tax Credits (BETC)

• The tax credit is 50 percent of the eligible project costs (taken over 5 years) for:
  – High Efficiency Combined Heat and Power
  – Renewable Energy Resource Generation
  – Renewable Energy Resource Equipment Manufacturing Facilities
  – Homebuilder Installed Renewable Energy Facilities - up to $9,000; High Performance Home - up to $12,000

• For other projects, tax credit is 35 percent of eligible project costs (cost beyond standard practice), over 5 years.

• See www.oregon.gov/ENERGY/CONS/BUS/BETC.shtml

Categories of BETC Qualifying Projects

**Energy Efficiency Projects**
- Conservation Projects
- Horizontal-Axis Washer Projects
- Lighting

**Homebuilders**
- High Performance Homes
- Homebuilder Installed Renewable Energy Facilities
Categories of BETC Qualifying Projects

**Renewable Energy Projects**
- High Efficiency Combined Heat and Power Projects
- Renewable Energy Resource Equipment Manufacturing Facilities
- Renewable Energy Resource Generation Projects
- Solar Photovoltaic (PV) Projects
- Solar Thermal Projects
- Biomass Infrastructure Projects

**Rentals**
- Appliances for Rental Dwellings
- Rental Dwelling Weatherization

**Transportation Projects**
- Alternative Fuel Infrastructure Projects
- Alternative Fuel Vehicles
- Efficient Truck Technology
- 2009 International SmartWay Truck
- Hybrid Vehicles
- Transportation & Telework

**Other Projects**
- Fuel Cell Projects
- Recycling Projects
- Sustainable Buildings
Much of the following content on CA Title-24 was extracted from a presentation by: Peter C. Jacobs, PE, Architectural Energy Corporation

Per Capita Energy Use in California
Total Electricity Use, per capita, 1960 - 2001
California vs. ASHRAE 90.1

Scatter Plot of California 2001 and ASHRAE 1999
(Note T24 is the same as California 2001)

Highlights – All Buildings

• Time Dependent Valuation (TDV)
• New Water Heater and Air-Conditioner Standards
Highlights – Nonresidential Buildings

- Cooling Towers
- Cool Roofs
- Demand Control Ventilation
- Relocatable Public School Buildings
- Duct Efficiency
- Indoor Lighting
- Skylights for Daylighting in Buildings
- Thermal Breaks for Metal Building Roofs
- Efficient Space Conditioning Systems
- Unconditioned Buildings

Cool Roofs

- In 2001, a credit for cool roofs was added that can be used with both the prescriptive overall envelope approach and the whole building performance method
- In 2005, Cool roofs will became a prescriptive requirement for low-slope applications
Skylights in Large Open Spaces

- Applies to spaces larger than 25,000 ft²
- Automatic controls required
- Minimum area depends on light transmission of the glazing and well factor

Update of Lighting Power Densities

- Efficacy of fluorescent lighting is improved with premium T-8 and T-5 lamps and ballasts
- Ceramic metal halide lamps are available that may be used in display lighting applications.
- Pulse start metal halide is the industry standard.
Outdoor Lighting

• Lighting Power Limits
  – LZ1 - State and national parks, recreational areas, wildlife preserves,
  – LZ2 – U.S. Census rural areas.
  – LZ3 - US Census urban areas
  – LZ4 - special districts
• Shielding

Title 24 Summary

• New power plant is deferred every nine months
• California 2001 is about 12% more stringent than ASHRAE 1999/2001
• California 2005 is about 11% more stringent than California 2001
• California 2005 is estimated to be about 20% more stringent than ASHRAE 1999/2001
Where to Get More Information

General Title 24 Information:
http://www.energy.ca.gov/title24/index.html

2005 Title 24 Update:

Spring 2007

LEED: Leadership in Energy & Environmental Design.

• Launched in December 1998 by the U.S. Green Building Council in response to the U.S. market's demand for a definition of a "green building."

• Green building rating system for commercial and high-rise residential projects.

• Encompasses new construction, major renovation, and built projects.
• Encourages use of existing, proven technologies.

• Evaluates and recognizes performance in accepted green design categories.

• Takes a whole-building integrated approach to sustainable building design.