

# Building Energy Modeling

## STRETCH CODE

OCTOBER 20, 2009

**RAVI S. SRINIVASAN**

Director of Technology & Innovation

The Green Roundtable

and

N E X U S

Green Building Resource Center



# Link to Stretch Code

## BUILDING ENERGY MODELING

**Summary of “Stretch” Appendix to Mass. Energy Code, Adopted by BBRB May 2009**

| Building category                                   | Definition   | Requirements based on energy performance (can do prescriptive instead where shown)                                      | Alternative “pre-scriptive” requirement – specific efficiency measures                             | Source, comments   | Benefit-cost modeling results   |
|---|--|---|--|--|---|
| New residential                                     | Single-family, multi-family of 3 stories or less                                       | HERS index 65 above 3,000 ft2, 70 below 3,000 ft2, certified by HERS rater; follow Energy Star thermal bypass checklist | None   | HERS rating = energy use as % of use under IECC code. Current Mass. code ~ HERS 99; soon-to-be-adopted IECC 2009 ~ HERS 92 | Sample 3 bedroom home, estimate \$837/year savings (\$8,103 extra construction cost = \$527/year higher mortgage, but save \$1,364/year energy costs) |
| Residential additions                               | Expansions of existing living space  | HERS 80 over 2,000 ft2, HERS 85 under 2,000 ft2; certified by HERS rater (or prescriptive option)                       | Alternative path to a HERS - rating same as residential rehab below                                |  | 3-bed home, estimate \$40/year savings (\$10,168 extra construction cost = \$661/year, but energy costs \$701/year lower)                             |
| Major residential rehab/ alterations                | Major alterations as in existing code – excludes storm windows, reroofing, doors, etc. | HERS 80 over 2,000 ft2, HERS 85 under 2,000 ft2; certified by HERS rater (or prescriptive option)                       | Prescriptive option of Energy Star Homes program; insulation equal to IECC 2009 for climate zone 5 | Quality air-sealing and insulation, EnergyStar windows   |   |
| Large commercial and large residential multi-family | Commercial above 100,000 ft2; residential 4 stories or more and 100,000 ft2            | Energy use 20% below ASHRAE 90.1 2007, determined by modeling   | None   | DOE, NGRID modeling show energy savings greater than 20%   |   |
| Medium commercial and residential multi-family      | Commercial 5,000 to 100,000 ft2, residential 4 stories or more and below 100,000 ft2   | Energy use 20% below ASHRAE 90.1 2007, determined by modeling   | IECC 2009 with NBI Core performance: improved air sealing, insulation, lighting, etc.              | Prescriptive based on New Buildings Institute program; used by utilities now for incentive programs                        | NGRID, NSTAR case studies. Example – 60,000 ft2 office bldg., \$91,000 extra cost, \$29,500 annual energy savings; and \$63,100 NGRID rebate          |
| Small commercial                                    | Below 5,000 ft2  | Exempt  | Exempt   |  |   |
| Specialty commercial                                | Supermarkets, labs, warehouses below 40,000 ft2  | Exempt  | Exempt   | Other specialty buildings can apply for waiver   |   |
| Commercial alterations                              |  | Exempt  | Exempt   |  |   |

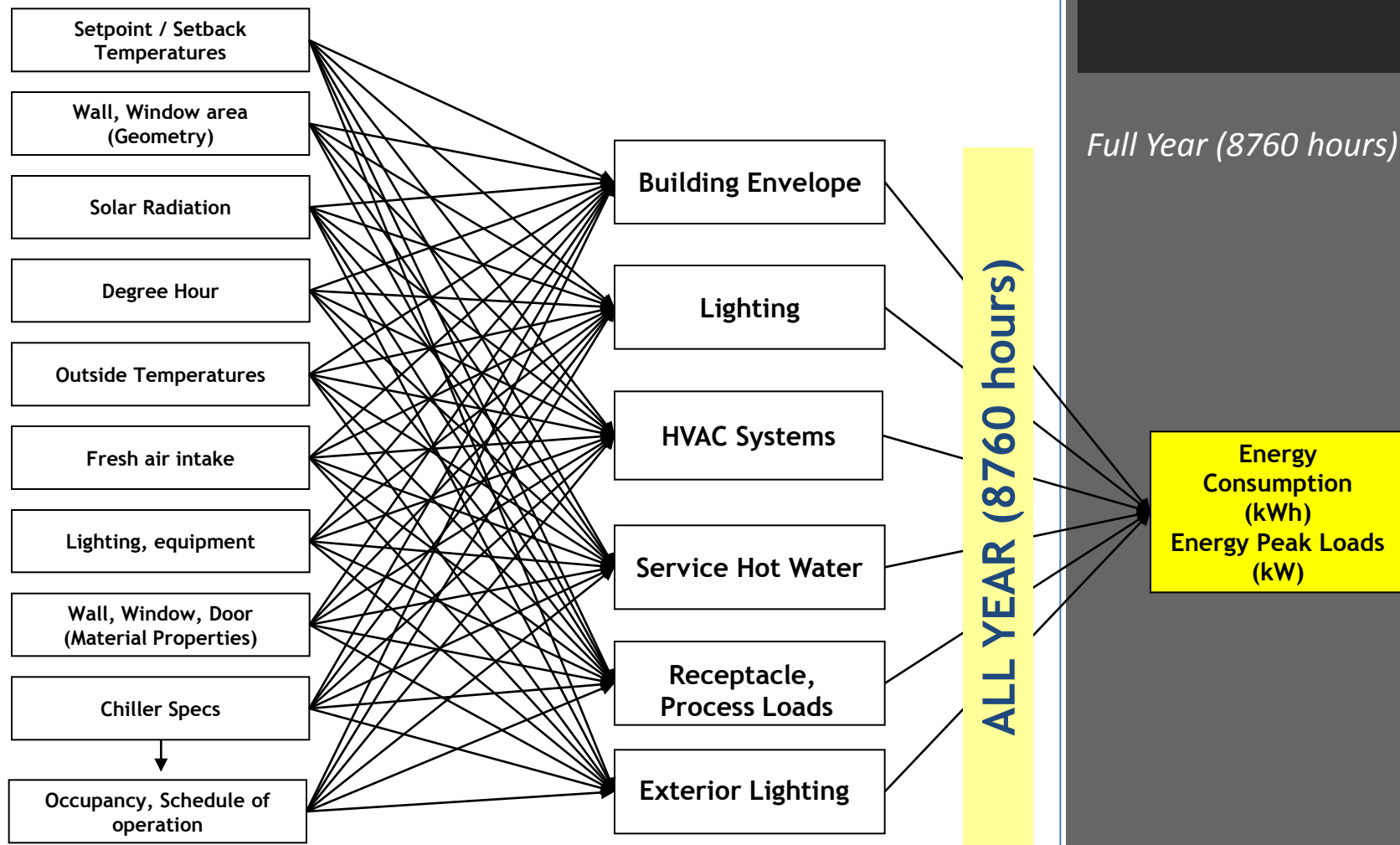
# Building Physics & Components

## BUILDING ENERGY MODELING

Approved Energy Modeling Software

US Dept of Energy

Full Year (8760 hours)



Energy Consumption (kWh)  
Energy Peak Loads (kW)

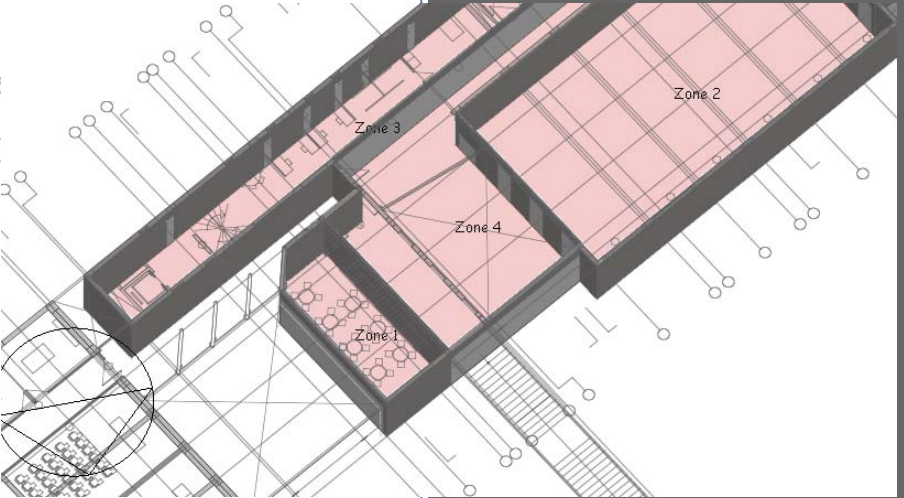
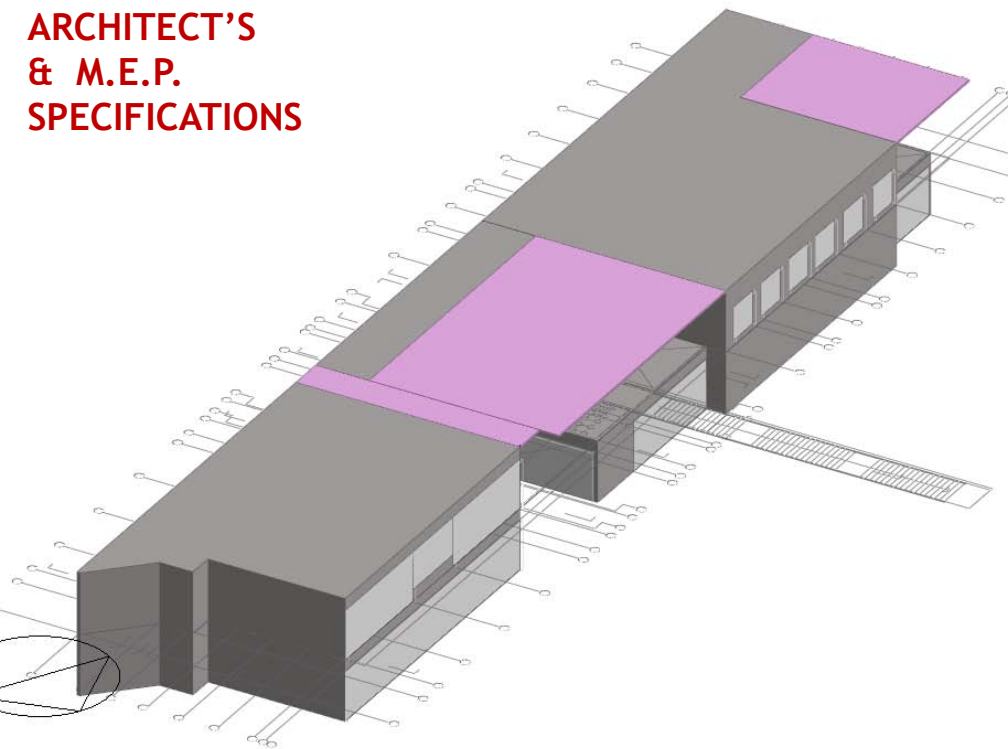
# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

ARCHITECT'S  
& M.E.P.  
SPECIFICATIONS



### INDUSTRY LEADING FEATURES / BENEFITS

- Energy Efficiency**
- 14.5-21 SEER/11.1-15 EER
- New Aesthetic Design**
- WeatherArmor Ultra™ Cabinet
    - Baked on powder paint
    - Steel louver coil guard
    - Color matched ceramic coated cabinet screws

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

ARCHITECT'S  
& M.E.P.  
SPECIFICATIONS

### Building Envelope

Wall / Internal Partitions (UFactor)  
Windows (UFactor, SHGC, VT, Shading Coefficient)  
Roof (UFactor, Reflectance)  
Floor (UFactor)

### Heating, Ventilating & Air-Conditioning

Ventilation type (mechanical)  
Heating & Cooling (type, schedule, energy source)

### Service Water Heating

Type, operation schedule

### Other Equipment

Equipment power density

### Activity Schedule

Schedule - hours, days (holidays)

### Lighting

Control (auto), Lighting energy (LPD)  
Operation schedule, luminaire type, radiant fraction  
Task / display light (gain, operation schedule)

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION



BASELINE

INPUTS FROM ASHRAE 90.1-2007

(Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F)

### ASHRAE STANDARD

## Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IESNA Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submission form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site, <http://www.ashrae.org>, or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2905. E-mail: [orders@ashrae.org](mailto:orders@ashrae.org). Fax: 404-521-5478. Telephone: 404-836-8400 (worldwide), or toll free 1-800-527-4723 (for orders in U.S. and Canada).

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[www.ashrae.org](http://www.ashrae.org)



Appendix G  
PERFORMANCE  
RATING METHOD (PRM)

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION



BASELINE

INPUTS FROM ASHRAE 90.1-2007

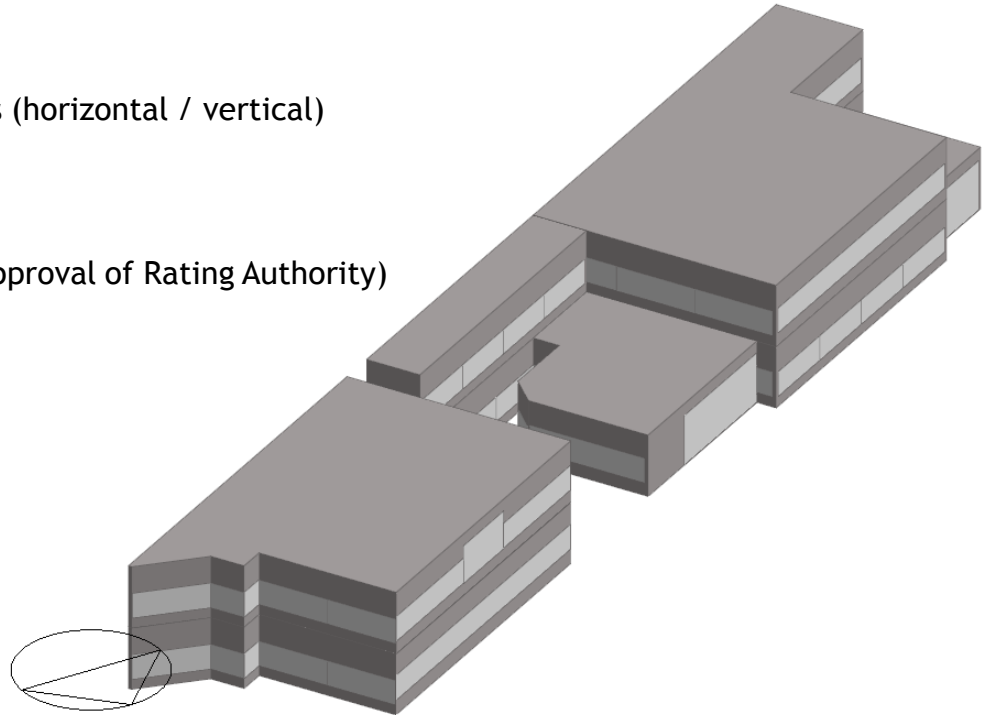
### MODEL REQUIREMENTS

#### Building Geometry

Same as As-Is Design  
Do not include shades (horizontal / vertical)

#### Schedules

Same as As-Is Design  
Variations allowed (approval of Rating Authority)



#### Modeling Limitations to the Simulation Program

Substitute a thermodynamically similar component model that can approximate the expected performance of the component that cannot be modeled explicitly.

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION



BASELINE

INPUTS FROM ASHRAE 90.1-2007

### BUILDING ENVELOPE REQUIREMENTS

| Opaque Elements                | Nonresidential       |                         | Residential      |                         | Semiheated       |                         |
|--------------------------------|----------------------|-------------------------|------------------|-------------------------|------------------|-------------------------|
|                                | Assembly Maximum     | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value |
| <i>Roofs</i>                   |                      |                         |                  |                         |                  |                         |
| Insulation Entirely above Deck | U-0.063              | R-15.0 ci               | U-0.063          | R-15.0 ci               | U-0.218          | R-3.8 ci                |
| Metal Building                 | U-0.065              | R-19.0                  | U-0.065          | R-19.0                  | U-0.097          | R-10.0                  |
| Attic and Other                | U-0.034              | R-30.0                  | U-0.027          | R-38.0                  | U-0.081          | R-13.0                  |
| <i>Walls, Above-Grade</i>      |                      |                         |                  |                         |                  |                         |
| Mass                           | U-0.151 <sup>a</sup> | R-5.7 ci <sup>a</sup>   | U-0.104          | R-9.5 ci                | U-0.580          | NR                      |
| Metal Building                 | U-0.113              | R-13.0                  | U-0.113          | R-13.0                  | U-0.134          | R-10.0                  |
| Steel-Framed                   | U-0.124              | R-13.0                  | U-0.064          | R-13.0 + R-7.5 ci       | U-0.124          | R-13.0                  |
| Wood-Framed and Other          | U-0.089              | R-13.0                  | U-0.089          | R-13.0                  | U-0.089          | R-13.0                  |
| <i>Wall, Below-Grade</i>       |                      |                         |                  |                         |                  |                         |
| Below-Grade Wall               | C-1.140              | NR                      | C-1.140          | NR                      | C-1.140          | NR                      |
| <i>Floors</i>                  |                      |                         |                  |                         |                  |                         |
| Mass                           | U-0.107              | R-6.3 ci                | U-0.087          | R-8.3 ci                | U-0.322          | NR                      |
| Steel-Joist                    | U-0.052              | R-19.0                  | U-0.038          | R-30.0                  | U-0.069          | R-13.0                  |
| Wood-Framed and Other          | U-0.051              | R-19.0                  | U-0.033          | R-30.0                  | U-0.066          | R-13.0                  |
| <i>Slab-On-Grade Floors</i>    |                      |                         |                  |                         |                  |                         |
| Unheated                       | F-0.730              | NR                      | F-0.730          | NR                      | F-0.730          | NR                      |
| Heated                         | F-0.950              | R-7.5 for 24 in.        | F-0.840          | R-10 for 36 in.         | F-1.020          | R-7.5 for 12 in.        |
| <i>Opaque Doors</i>            |                      |                         |                  |                         |                  |                         |
| Swinging                       | U-0.700              |                         | U-0.700          |                         | U-0.700          |                         |
| Non-Swinging                   | U-1.450              |                         | U-0.500          |                         | U-1.450          |                         |

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

BASELINE

INPUTS FROM ASHRAE 90.1-2007



### HVAC & DHW REQUIREMENTS

| Building Type  | Fossil Fuel, Fossil/Electric Hybrid, & Purchased Heat | Electric and Other                  |
|--|---|-------------------------------------|
| Residential  | System 1 - PTAC                                       | System 2 - PTHP                     |
| Nonresidential & 3 Floors or Less & <75,000 ft <sup>2</sup>  | System 3 - PSZ-AC                                     | System 4 - PSZ-HP                   |
| Nonresidential & 4 or 5 Floors & <75,000 ft <sup>2</sup> or 5 Floors or Less & 75,000 ft <sup>2</sup> to 150,000 ft <sup>2</sup> | System 5 - Packaged VAV w/ Reheat                     | System 6 - Packaged VAV w/PPF Boxes |
| Nonresidential & More than 5 Floors or >150,000 ft <sup>2</sup>  | System 7 - VAV w/Reheat                               | System 8 - VAV w/PPF Boxes          |

Notes:  
 Residential building types include dormitory, hotel, motel, and multifamily. Residential space types include guest rooms, living quarters, private living space, and sleeping quarters.  
 Other building and space types are considered nonresidential.  
 Where no heating system is to be provided or no heating energy source is specified, use the "Electric and Other" heating source classification.  
 Where attributes make a building eligible for more than one baseline system type, use the predominant condition to determine the system type for the entire building.

TABLE G3.1.1B Baseline System Descriptions

| System No.                  | System Type                                      | Fan Control     | Cooling Type     | Heating Type                 |
|-----------------------------|--|-----------------|------------------|------------------------------|
| 1. PTAC                     | Packaged terminal air conditioner                | Constant Volume | Direct Expansion | Hot Water Fossil Fuel Boiler |
| 2. PTHP                     | Packaged terminal heat pump                      | Constant Volume | Direct Expansion | Electric Heat Pump           |
| 3. PSZ-AC                   | Packaged rooftop air conditioner                 | Constant Volume | Direct Expansion | Fossil Fuel Furnace          |
| 4. PSZ-HP                   | Packaged rooftop heat pump                       | Constant Volume | Direct Expansion | Electric Heat Pump           |
| 5. Packaged VAV w/ Reheat   | Packaged rooftop variable air volume with reheat | VAV             | Direct Expansion | Hot Water Fossil Fuel Boiler |
| 6. Packaged VAV w/PPF Boxes | Packaged rooftop variable air volume with reheat | VAV             | Direct Expansion | Electric Resistance          |
| 7. VAV w/Reheat             | Packaged rooftop variable air volume with reheat | VAV             | Chilled Water    | Hot Water Fossil Fuel Boiler |
| 8. VAV w/PPF Boxes          | Variable air volume with reheat                  | VAV             | Chilled Water    | Electric Resistance          |

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION



BASELINE

INPUTS FROM ASHRAE 90.1-2007

### LIGHTING (EXTERIOR & INTERIOR) REQUIREMENTS

|  |  |  |
|--|--|--|
| <b>Tradable Surfaces</b><br>(Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.)  | <b>Uncovered Parking Areas</b>   |  |
|  | Parking Lots and drives  | 0.15 W/ft <sup>2</sup>   |
|  | <b>Building Grounds</b>  |  |
|  | Walkways less than 10 feet wide  | 1.0 W/linear foot  |
|  | Walkways 10 feet wide or greater   |  |
|  | Plaza areas  | 0.2 W/ft <sup>2</sup>  |
|  | Special Feature Areas  |  |
|  | Stairways  | 1.0 W/ft <sup>2</sup>  |
|  | <b>Building Entrances and Exits</b>                                      |  |
|  | Main entries   | 30 W/linear foot of door width   |
| Other doors  | 20 W/linear foot of door width   |  |
| <b>Canopies and Overhangs</b>  |  |  |
| Canopies (free standing and attached and overhangs)  | 1.25 W/ft <sup>2</sup>   |  |
| <b>Outdoor Sales</b>   |  |  |
| Open areas (including vehicle sales lots)  | 0.5 W/ft <sup>2</sup>  |  |
| Street frontage for vehicle sales lots in addition to "open area" allowance  | 20 W/linear foot   |  |
| <b>Non-Tradable Surfaces</b><br>(Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in | <b>Building Facades</b>  | 0.2 W/ft <sup>2</sup> for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length          |
|  | <b>Automated teller machines and night depositories</b>                  | 270 W per location plus 90 W per additional ATM per location   |
|  | <b>Entrances and gatehouse inspection stations at guarded facilities</b> | 1.25 W/ft <sup>2</sup> of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces") |

# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

BASELINE

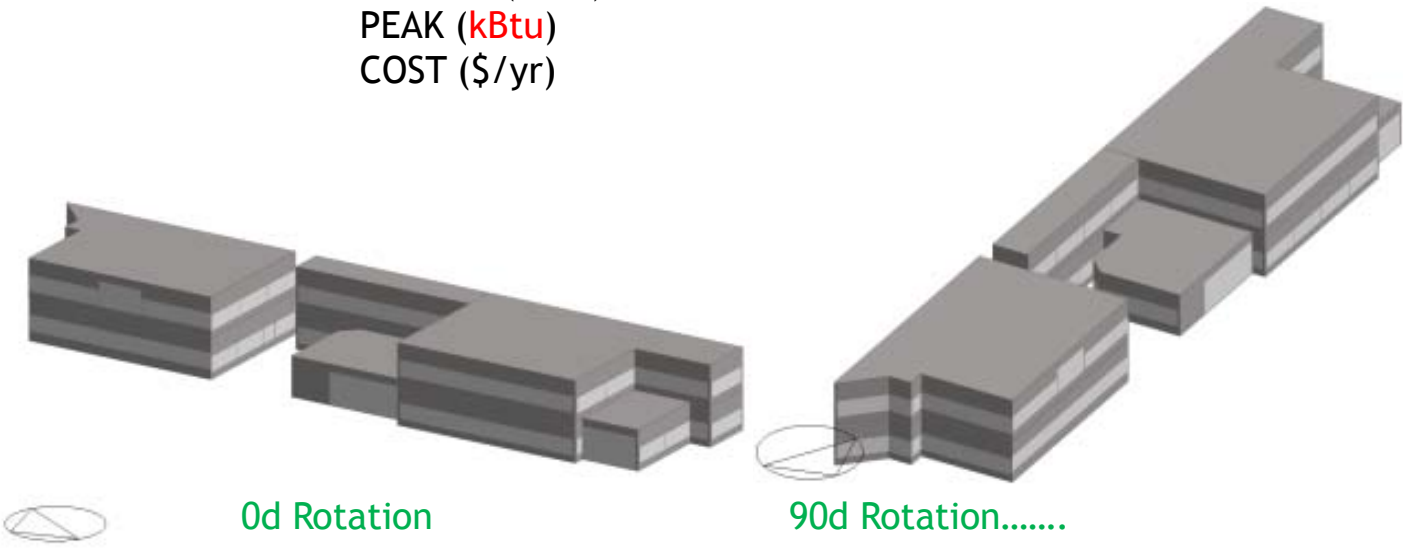
INPUTS FROM ASHRAE 90.1-2007



### MODEL REQUIREMENTS

Baseline should be independent of its orientation  
→ Baseline is rotated FOUR times (0d, 90d, 180d, 270d)  
and average value is computed:

- ENERGY (kBtu)
- PEAK (kBtu)
- COST (\$/yr)



# Modeling Process

## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

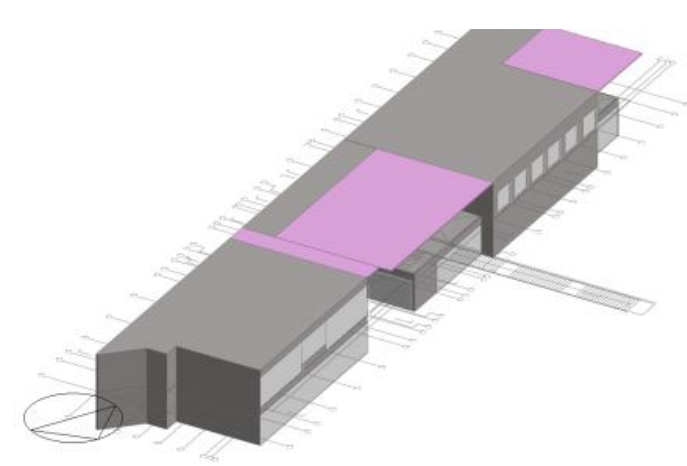


BASELINE

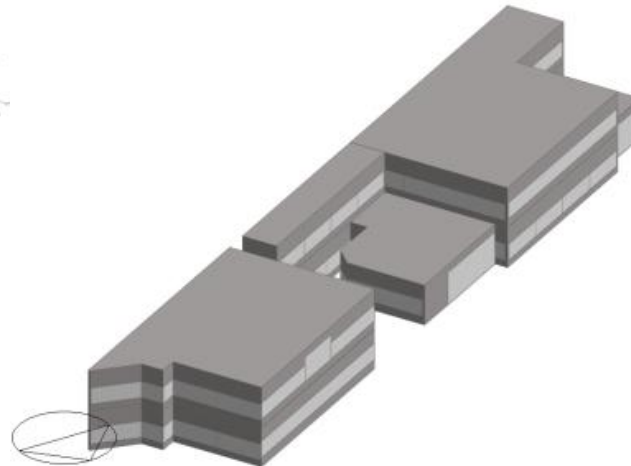
INPUTS FROM ASHRAE 90.1-2007

### MODEL REQUIREMENTS

Baseline should be independent of shades  
(techniques by which the building can be shaded)



As-Is (designed)



Baseline

# Modeling Process

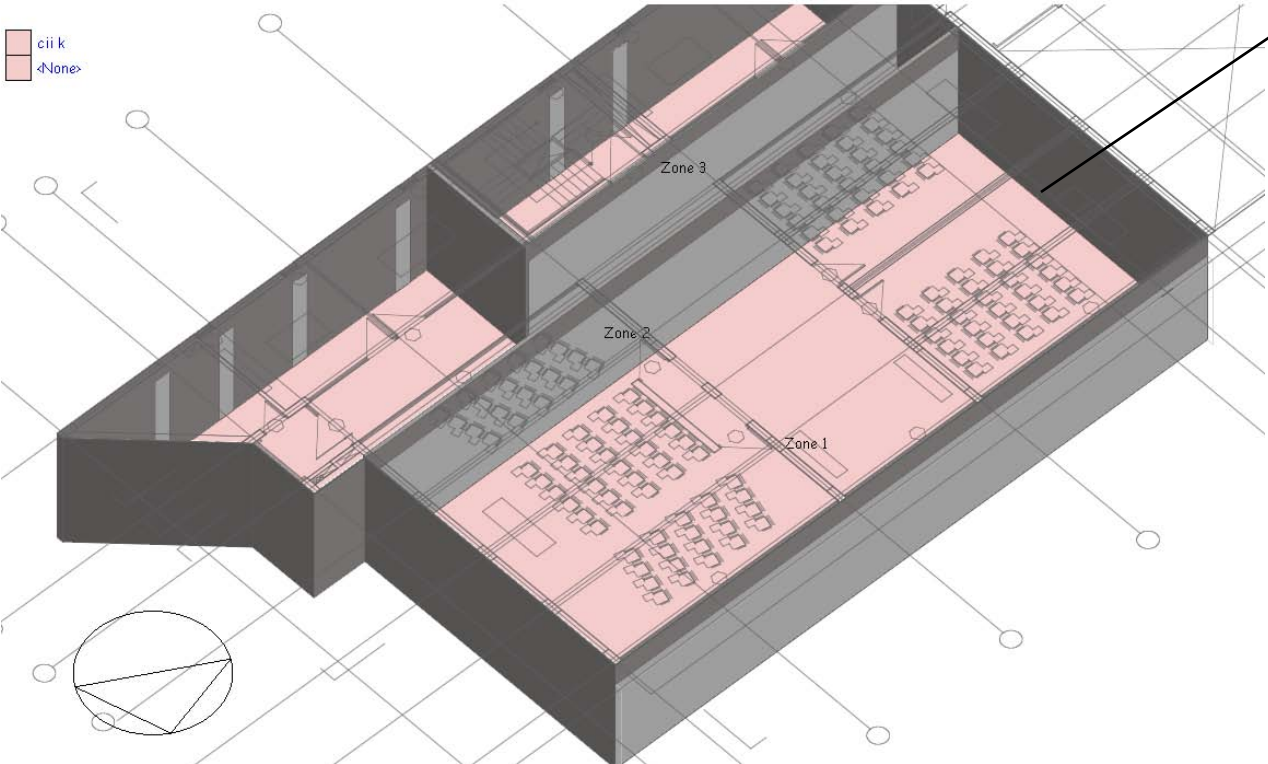
## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

BASELINE

INPUTS FROM ASHRAE 90.1-2007



Zoning (for Energy Modelling is a critical component)

# Modeling Process

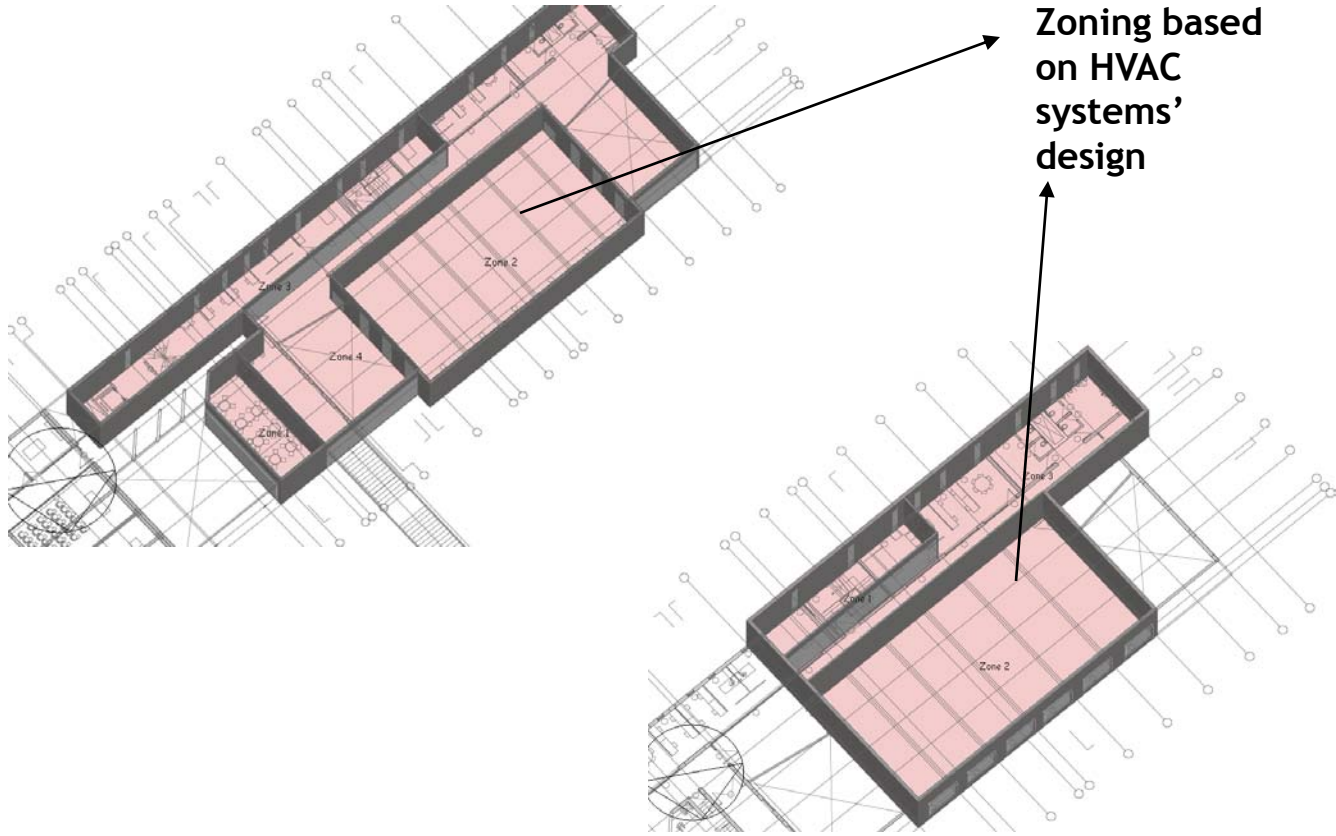
## BUILDING ENERGY MODELING

AS - IS

CURRENT DESIGN SPECIFICATION

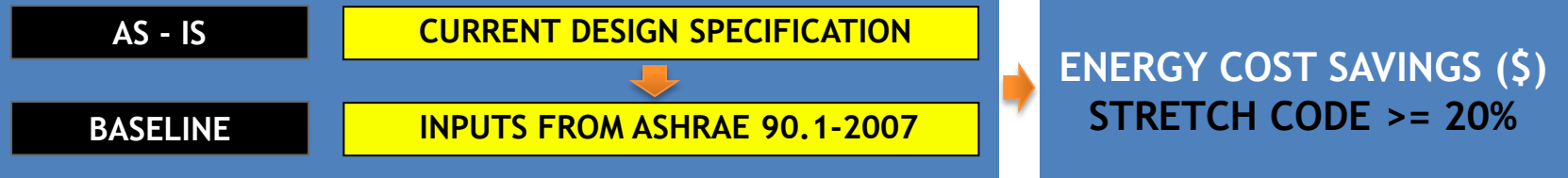
BASELINE

INPUTS FROM ASHRAE 90.1-2007



# Modeling Process

## BUILDING ENERGY MODELING



### PERFORMANCE RATING METHOD RESULTS

Note: The percentage displayed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption.

\* Denotes the base alternative for the ECB study.

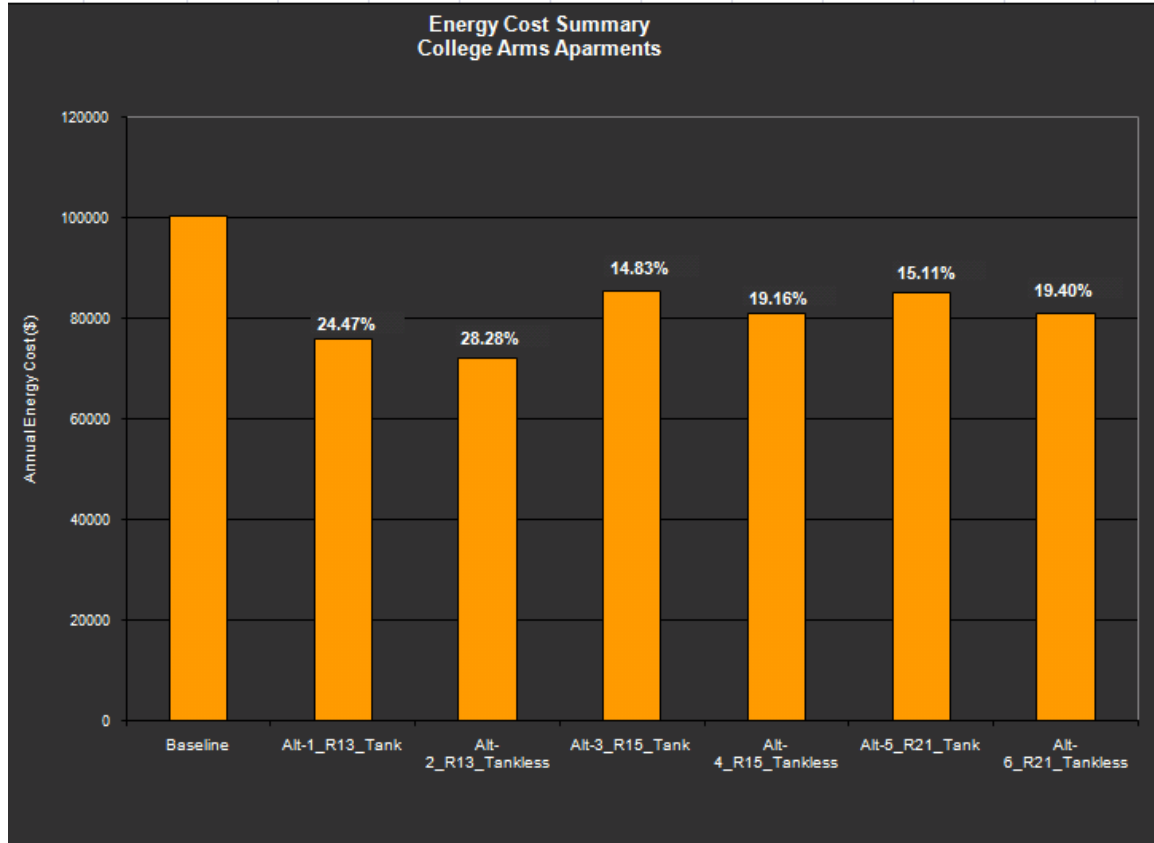
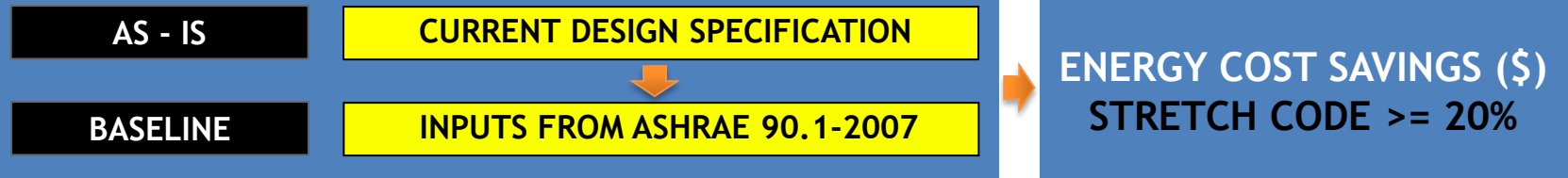
|                                   |             | * Alt-1 As Is Design with Baseli |                         |               | Alt-2 ASHRAE 90-1-2001 Baselin   |                         |               | Alt-3 As Is Design with Lighting |                         |               | Alt-4 As Is Design with Lighting |                         |               |
|-----------------------------------|-------------|----------------------------------|-------------------------|---------------|----------------------------------|-------------------------|---------------|----------------------------------|-------------------------|---------------|----------------------------------|-------------------------|---------------|
|                                   |             | Energy<br>10 <sup>6</sup> Btu/yr | Proposed<br>/ Base<br>% | Peak<br>kBtuh | Energy<br>10 <sup>6</sup> Btu/yr | Proposed<br>/ Base<br>% | Peak<br>kBtuh | Energy<br>10 <sup>6</sup> Btu/yr | Proposed<br>/ Base<br>% | Peak<br>kBtuh | Energy<br>10 <sup>6</sup> Btu/yr | Proposed<br>/ Base<br>% | Peak<br>kBtuh |
| Lighting - Conditioned            | Electricity | 1,372.4                          | 33                      | 395           | 1,372.4                          | 100                     | 395           | 1,002.5                          | 73                      | 290           | 1,002.5                          | 73                      | 290           |
| Space Heating                     | Electricity | 502.4                            | 12                      | 486           | 836.2                            | 166                     | 643           | 604.4                            | 120                     | 497           | 112.3                            | 22                      | 99            |
| Space Cooling                     | Electricity | 427.5                            | 10                      | 476           | 452.0                            | 106                     | 523           | 376.2                            | 88                      | 447           | 97.0                             | 23                      | 63            |
| Pumps                             | Electricity | 0.0                              | 0                       | 0             | 0.0                              | 0                       | 0             | 0.0                              | 0                       | 0             | 3.0                              | 0                       | 4             |
| Heat Rejection                    | Electricity | 83.0                             | 2                       | 67            | 89.3                             | 108                     | 73            | 73.6                             | 89                      | 63            | 0.0                              | 0                       | 0             |
| Fans - Conditioned                | Electricity | 532.0                            | 13                      | 65            | 533.4                            | 100                     | 66            | 532.5                            | 100                     | 65            | 262.6                            | 49                      | 30            |
| Receptacles - Conditioned         | Electricity | 647.4                            | 16                      | 235           | 998.1                            | 154                     | 248           | 998.1                            | 154                     | 248           | 998.1                            | 154                     | 248           |
| Stand-alone Base Utilities        | Gas         | 534.4                            | 13                      | 61            | 534.4                            | 100                     | 61            | 534.4                            | 100                     | 61            | 534.4                            | 100                     | 61            |
| <b>Total Building Consumption</b> |             | <b>4,099.0</b>                   |                         |               | <b>4,815.7</b>                   |                         |               | <b>4,121.6</b>                   |                         |               | <b>3,009.8</b>                   |                         |               |

|       |                                      | * Alt-1 As Is Design with Baseli |  |  | Alt-2 ASHRAE 90-1-2001 Baselin |  |  | Alt-3 As Is Design with Lighting |  |  | Alt-4 As Is Design with Lighting |  |  |
|-------|--------------------------------------|----------------------------------|--|--|--------------------------------|--|--|----------------------------------|--|--|----------------------------------|--|--|
| Total | Number of hours heating load not met | 0                                |  |  | 0                              |  |  | 0                                |  |  | 0                                |  |  |
|       | Number of hours cooling load not met | 0                                |  |  | 0                              |  |  | 0                                |  |  | 0                                |  |  |

|              |  | * Alt-1 As Is Design with Baseli |                  | Alt-2 ASHRAE 90-1-2001 Baselin   |                  | Alt-3 As Is Design with Lighting |                  | Alt-4 As Is Design with Lighting |                  |
|--------------|--|----------------------------------|------------------|----------------------------------|------------------|----------------------------------|------------------|----------------------------------|------------------|
|              |  | Energy<br>10 <sup>6</sup> Btu/yr | Cost/yr<br>\$/yr | Energy<br>10 <sup>6</sup> Btu/yr | Cost/yr<br>\$/yr | Energy<br>10 <sup>6</sup> Btu/yr | Cost/yr<br>\$/yr | Energy<br>10 <sup>6</sup> Btu/yr | Cost/yr<br>\$/yr |
| Electricity  |  | 3,564.6                          | 85,539           | 4,281.3                          | 102,736          | 3,587.2                          | 86,080           | 2,475.5                          | 59,403           |
| Gas          |  | 534.4                            | 4,799            | 534.4                            | 4,799            | 534.4                            | 4,799            | 534.4                            | 4,799            |
| <b>Total</b> |  | <b>4,099</b>                     | <b>90,337</b>    | <b>4,816</b>                     | <b>107,535</b>   | <b>4,122</b>                     | <b>90,879</b>    | <b>3,010</b>                     | <b>64,201</b>    |

# Modeling Process

## BUILDING ENERGY MODELING



# USGBC LEED™ Comparison

BUILDING ENERGY MODELING

| Rating System                 | Reference Guide   |
|-------------------------------|---|
| LEED for New Construction     | GREEN BUILDING DESIGN & CONSTRUCTION<br>2009 Edition    |
| LEED for Core & Shell         |   |
| LEED for Schools              |   |
| LEED for Healthcare*          |   |
| LEED for Retail*              |   |
| LEED for Commercial Interiors | GREEN INTERIOR DESIGN & CONSTRUCTION<br>2009 Edition    |
| LEED for Retail Interiors*    |   |
| LEED for Existing Buildings   | GREEN BUILDING OPERATIONS & MAINTENANCE<br>2009 Edition |
| LEED for Existing Schools*    |   |



# USGBC LEED™ Comparison

## BUILDING ENERGY MODELING

**STRETCH CODE (COMMERCIAL - ENERGY MODELING) IS COMPATIBLE WITH USGBC LEED™ ENERGY MODELING REQUIREMENTS**

LEED for New Construction

LEED for Core & Shell

LEED for Schools

Both use ASHRAE 90.1-2007 for Baseline Energy Consumption computation

20% better than ASHRAE 90.1-2007 is equivalent to:

5 points (New Construction & Schools)

7 points (Core & Shell)



If the project is already proceeding with LEED™ Certification, there is no double work.

# Questions

## BUILDING ENERGY MODELING

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