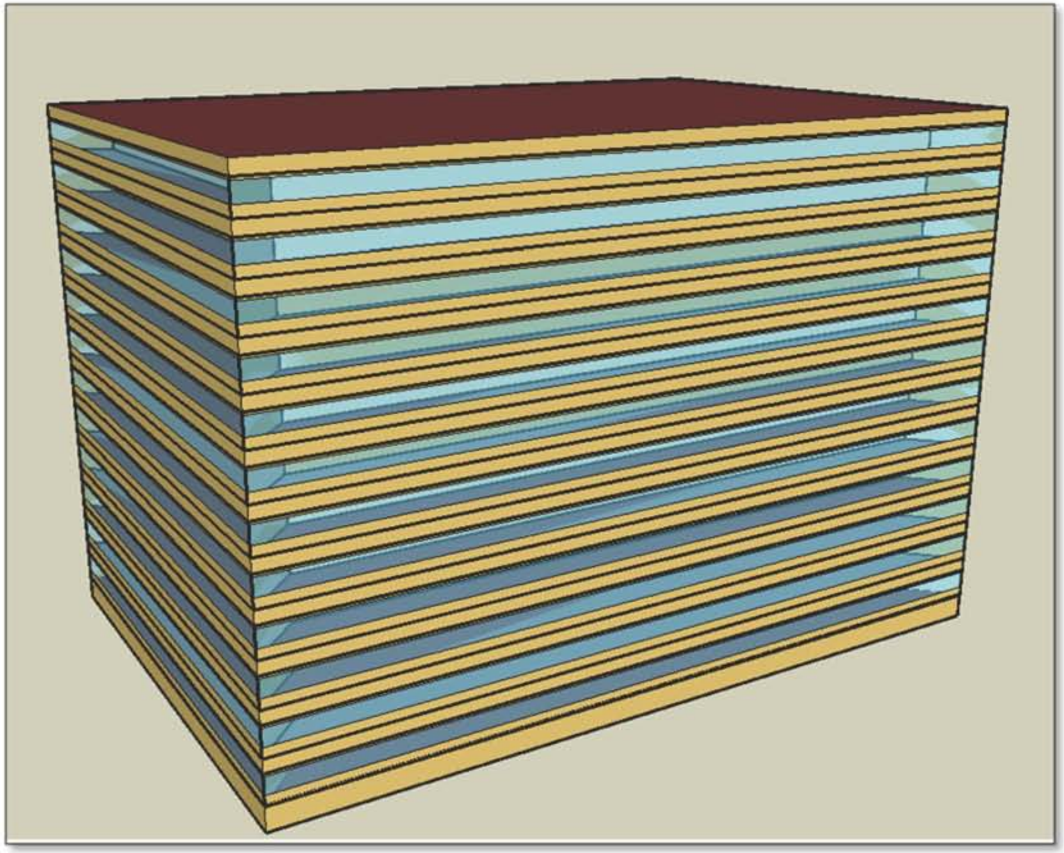
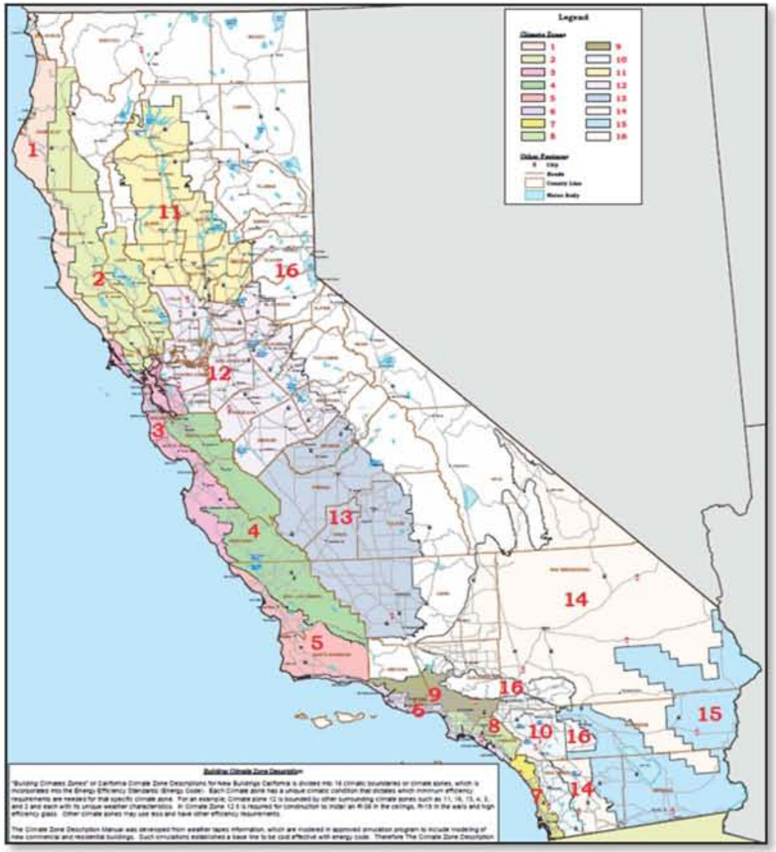
Architectural Energy Corporation

Title 24 Performance Budget – Proof of Concept, Round 2





Title 24 Performance Budget Pilot Study - Overview

Goal of Study:

- Determine the feasibility of setting an "Energy Budget" for specific building types
  - Is it possible to set a predefined EUI target? If so, what variables will impact this value?
  - Instead of modeling a baseline/reference building for each project, can research be done in advance to set an EUI target. Benefit – significant time savings for energy modelers. More time to spend on optimizing their proposed design, less on assessing a theoretical baseline design.

Scope of study:

- Start with one building type – Office
- Start with reduced number of climate zones – four
- Create list of design features that will introduce variability into the budget
- Create matrix of simulation runs that will provide enough data to assess impact of variables listed above
- Perform simulations and compile results

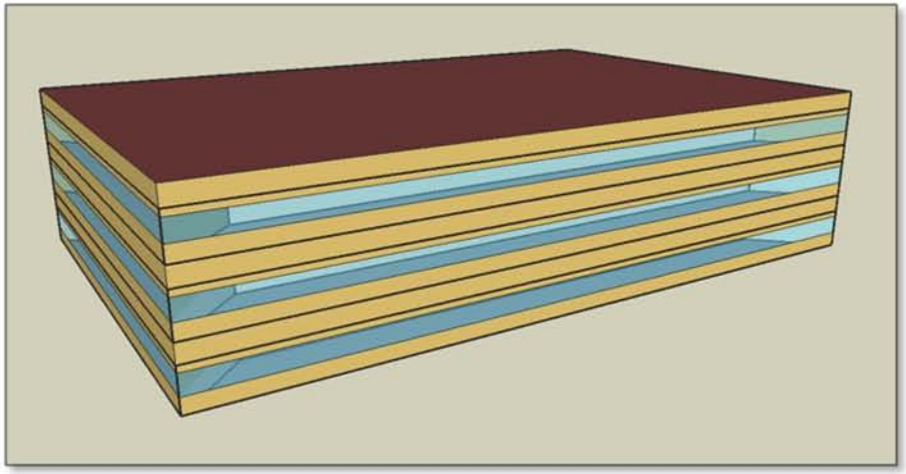
Outcomes:

- Determine the range of energy consumption results - is it predictable, or is it too wide?
- Determine what metric is best used as the budget - EUI, or other?

Building Type

Overview:

- Simulation Models will be based on DOE Commercial Reference Buildings and associated EnergyPlus files
- Chosen model:
  - Medium Office Building = 3 floors; 53,000 ft^2
- Reference buildings are based on ASHRAE 90.1-2004
- Building inputs have been modified to T24 parameters for this study



Medium Office

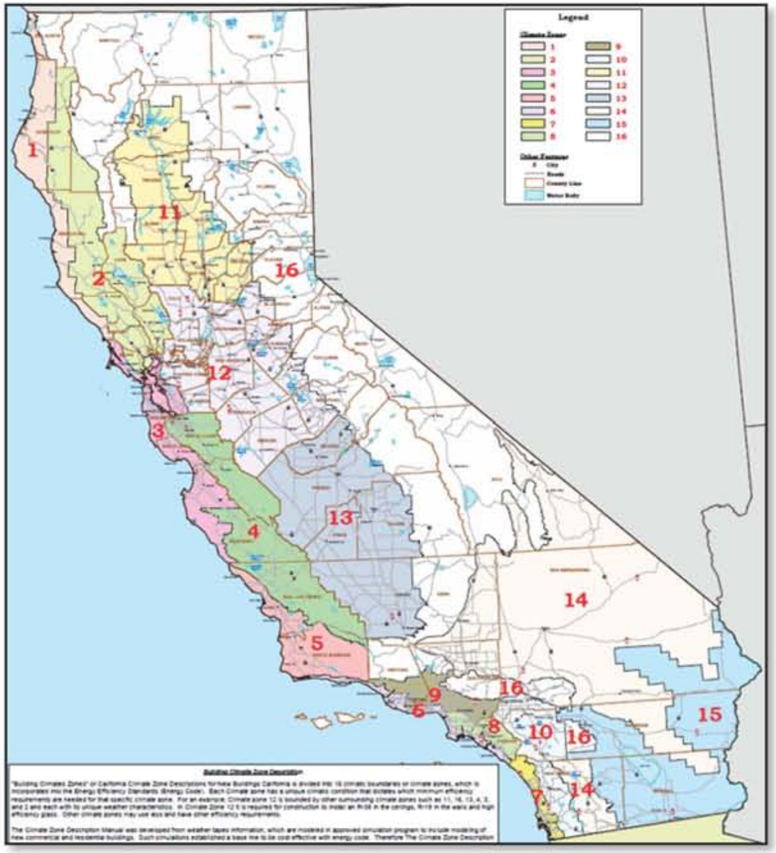
Climate Zones

Overview:

- There are 16 climate zones in California, as specified in T24, Joint Appendix 2

Scope of Study:

- 4 diverse climate zones:
  - Mild: Climate Zone 3 (Oakland/San Francisco)
  - Hot Summer/Cold Winter: Climate Zone 13 (Fresno)
  - Hot/Dry: Climate Zone 15 (Brawley)
  - Cold/Mountain: Climate Zone 16 (Bishop)



CA Climate Zone Map

Modeling Procedure

Overview:

- Energy model inputs divided into 3 categories:
  1. Proposed design features that give you "credit" for implementing efficient options
     - e.g. Lighting, HVAC, etc.
  2. Inputs prescribed by the ACM (neutral variables)
     - Occupancy, schedules, setpoints, etc.
  3. Building specific features not dictated by code
     - Geometry, etc. – see list on next page
- Category 1 will be ignored since we are not concerned with the proposed building for this study – focus is on prescriptive "baseline" inputs
- Category 2 will be used to setup the models, but these are fixed inputs and will not create variability
- Category 3 will be the main focus of this study.
  - These variables are not code mandated
  - We want to understand how much variability will be introduced by changing these features.
  - We want to understand if there is a way to normalize this variability

List of Variables

Category 3 (Building Specific) Variables:

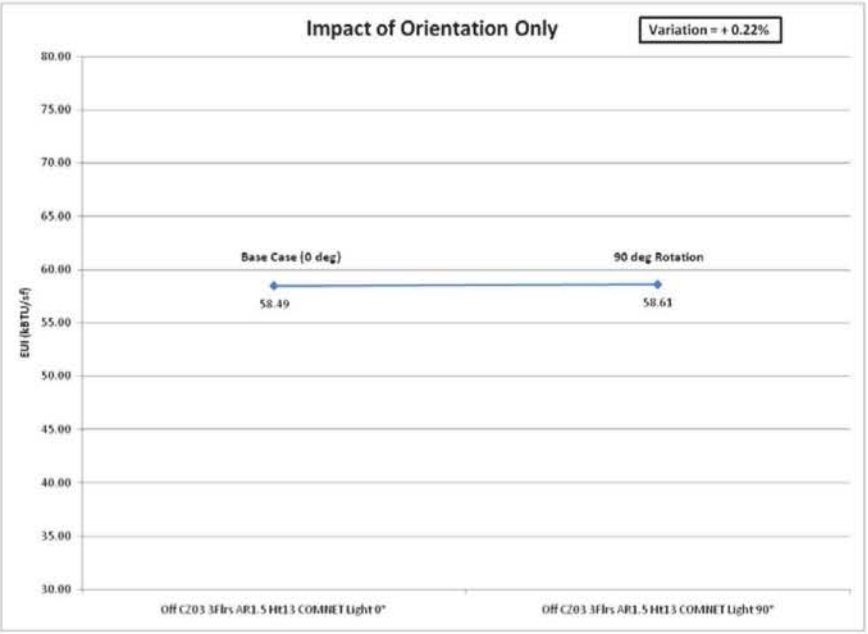
- Building geometry
  - Building area/aspect ratio
  - Building height
  - Floor-to-floor/ceiling height
  - Window-to-wall ratio
- Building orientation
- Unregulated loads
  - Receptacle
- Mass of construction materials

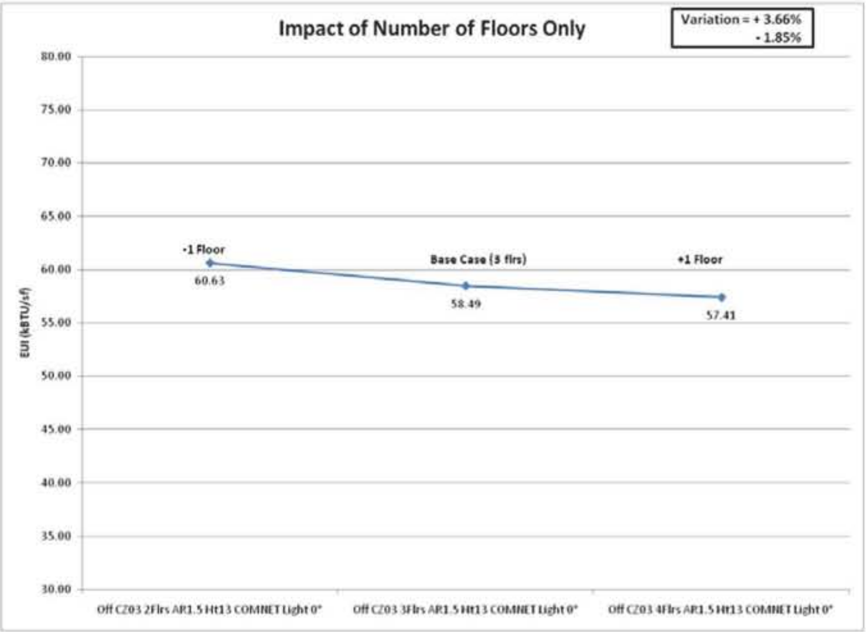
Modeling Approach

Introduce "input ranges" and assess variability of results

- Building geometry
  - Building area/aspect ratio
    - Tests – 1.5:1, 3:1, 5:1
  - Building height
    - Tests – 2 floors, 3 floors, 4 floors
  - Floor-to-floor/ceiling height
    - Tests – 12', 13', 14'
  - Window-to-wall ratio
    - Tests – 40% base (maximum allowable), 20%
    - (future consideration – does more glazing on a certain façade improve performance from daylighting)
- Building orientation
  - Tests – 0 deg, 90 deg
- Unregulated loads
  - Receptacle
    - Tests – use COMNET defaults, +/- 50%, with increment of 10%
- Mass of façade materials
  - (masonry vs. stucco)

Results – CZ3





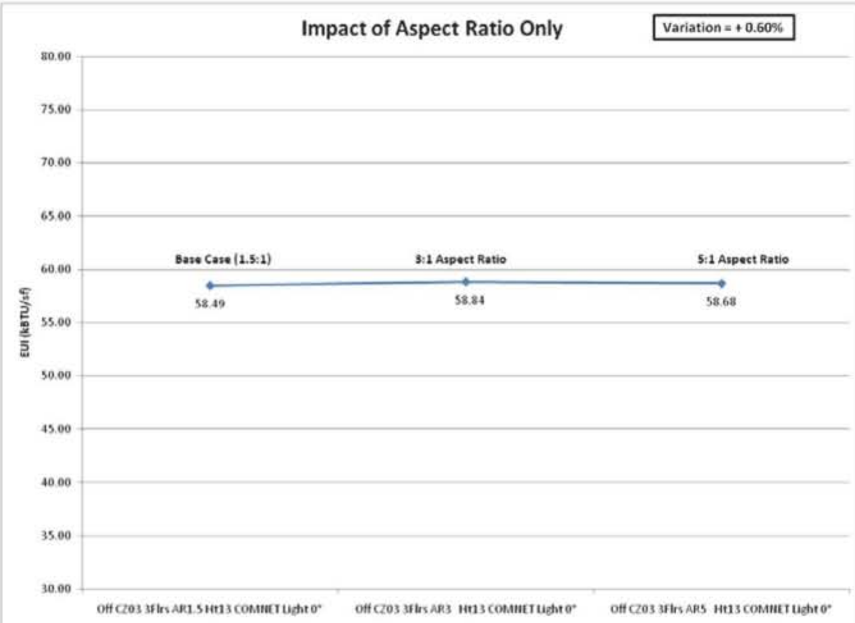
Building Orientation:
Orientation had a negligible impact on the building's energy use. The Base Case (0 degrees), and 90 degree rotation results only varied by 0.22%. Due to the symmetrical design of the test buildings, no additional rotations were analyzed. 0 and 90 were chosen as they represent the most extreme cases, yet the results indicate that orientation alone does not have a strong impact on this building's energy consumption.

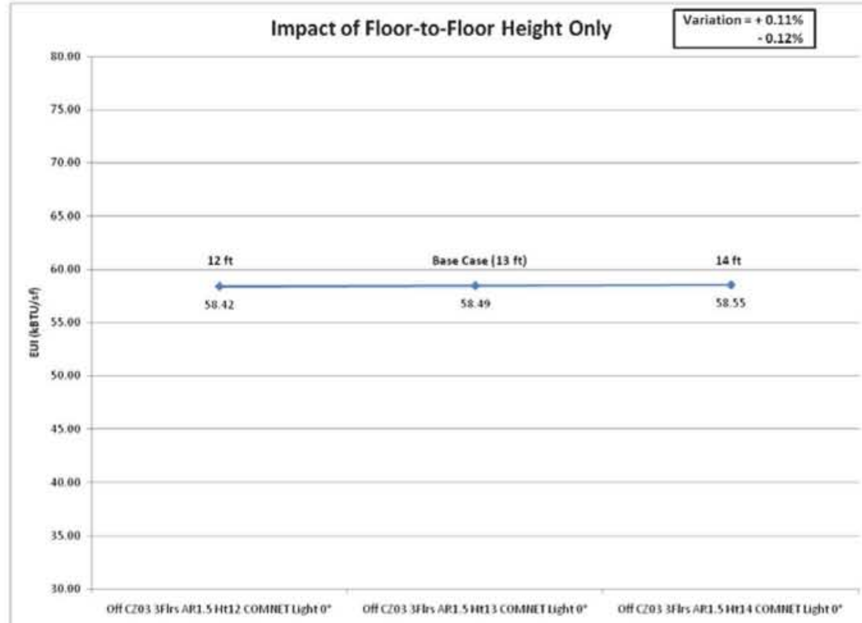
Variation = +0.22%

Number of Floors:
Number of Floors was one of the factors that did have a meaningful impact on the building's energy consumption. The Base Case (3 Floors) was compared to options of 2 and 4 floors. The results indicate that fewer floors = greater energy intensity. This can be explained due to the fact that fewer floors will have more exposed surface area per square foot of occupied space and thus experience greater heating and cooling loads.

Variation = +3.66%, -1.85%

Results – CZ3





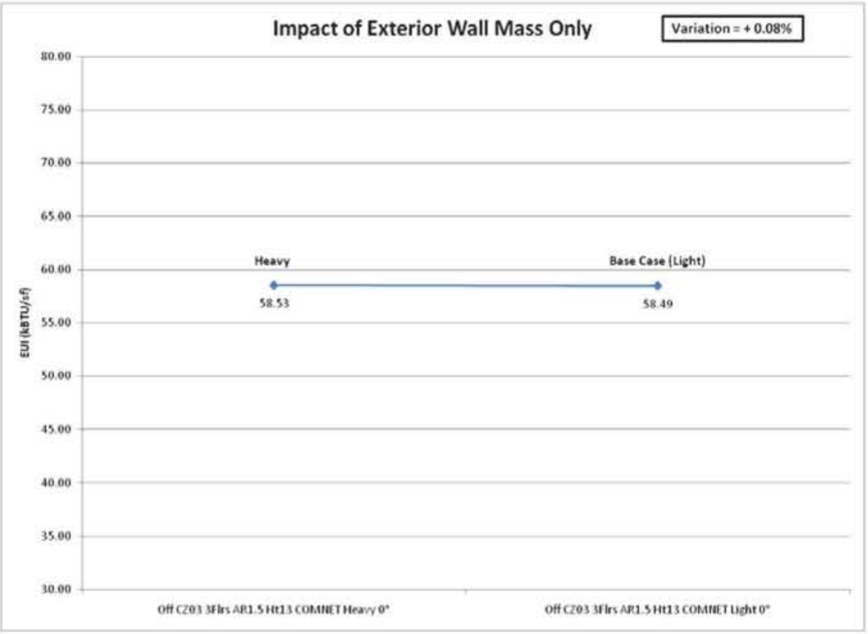
Aspect Ratio:
Aspect Ratio had a negligible impact on the building's energy use. The Base Case (1.5:1), was compared to options of 3:1 and 5:1. In this climate zone, the results indicate that aspect ratio alone does not have a strong impact on this building's energy consumption.

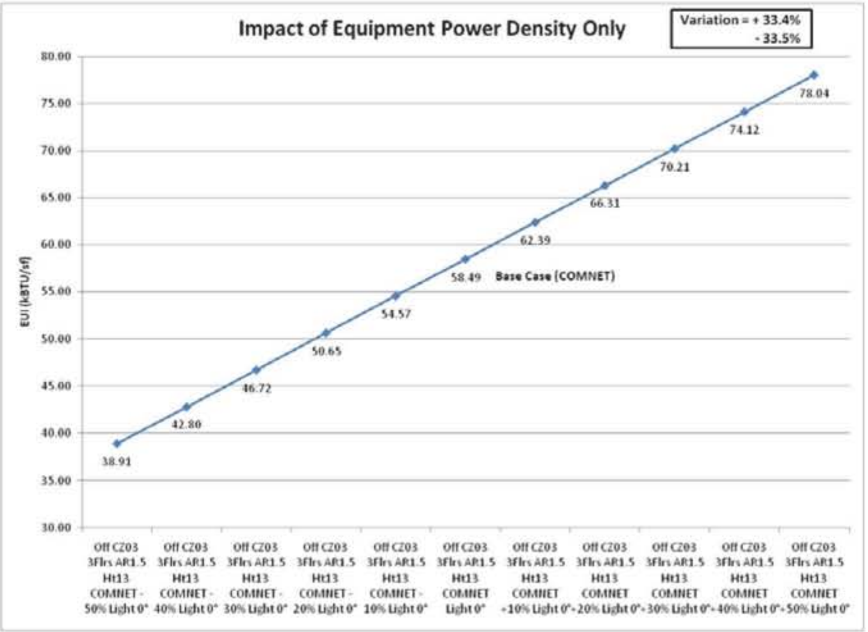
Variation = +0.60%

Floor-to-Floor Height:
Floor-to-floor height had a negligible impact on the building's energy use. The Base Case (13 ft), was compared to options of 12ft and 14ft. In all cases, a 4ft plenum was modeled. In this climate zone, the results indicate that floor-to-floor height alone does not have a strong impact on this building's energy consumption.

Variation = +0.11%, -0.12%

Results – CZ3





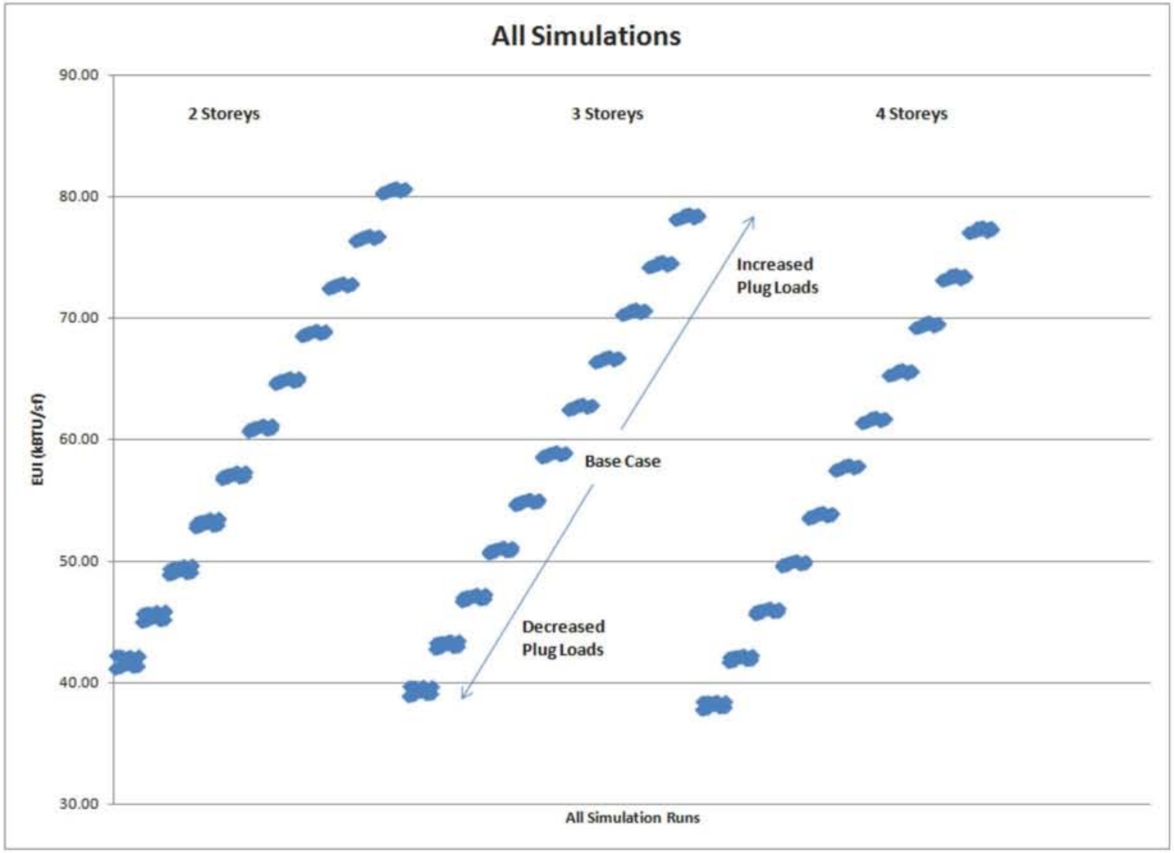
Exterior Wall Mass:
Exterior wall mass had a negligible impact on the building's energy use. The Base Case (lightweight construction), and the heavy weight construction results only varied by 0.08%.

Variation = +0.08%

Equipment Power Density:
Equipment power density had the greatest impact on the building's energy use. The Base Case (COMNET default), was compared to options of +/-50% with increments of 10%. The results vary linearly as the plug loads are varied.

Variation = +33.4%, -33.5%

Results – CZ3



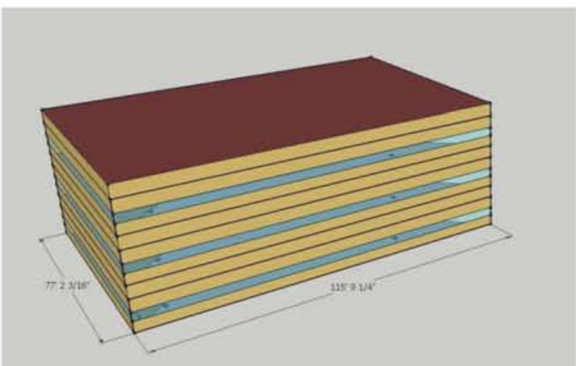
All combinations:

After investigating the individual design variables, all possible combinations were simulated. Altogether, approx. 1,200 simulation runs were performed. The results above demonstrate the impact of these combinations. It can be seen that the EUI results are grouped in very discrete clusters. For a given number of stories and equipment power density (EPD), all other variables have negligible impact on the EUI. Changing the EPD will shift the cluster up or down as will the number of stories.

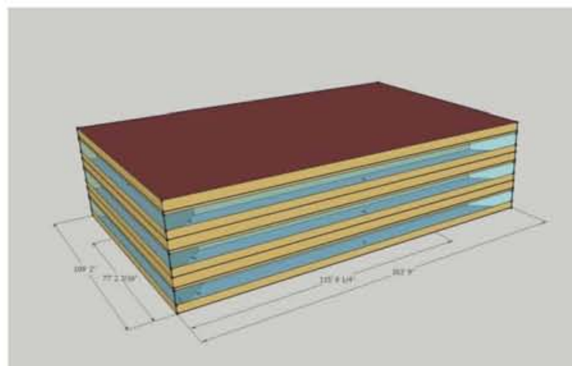
Modeling Approach – Additional Considerations

Based on the results from climate zone 3, the modeling approach was expanded to explore one other potentially impactful design variable

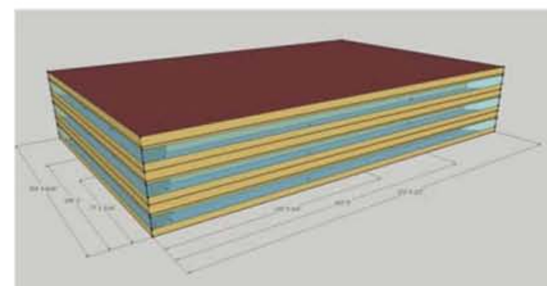
- **Area Factor** – previous simulations examined the impact of changing the aspect ratio while keeping the building's area constant. Area Factor is defined as scaling the building's area while keeping the aspect ratio constant.
  - The base case area factor = 1. Additional area factors of 0.5 and 2 were analyzed during this stage



Aspect Ratio=1.5, Area Factor=0.5



Aspect Ratio=1.5, Area Factor=1



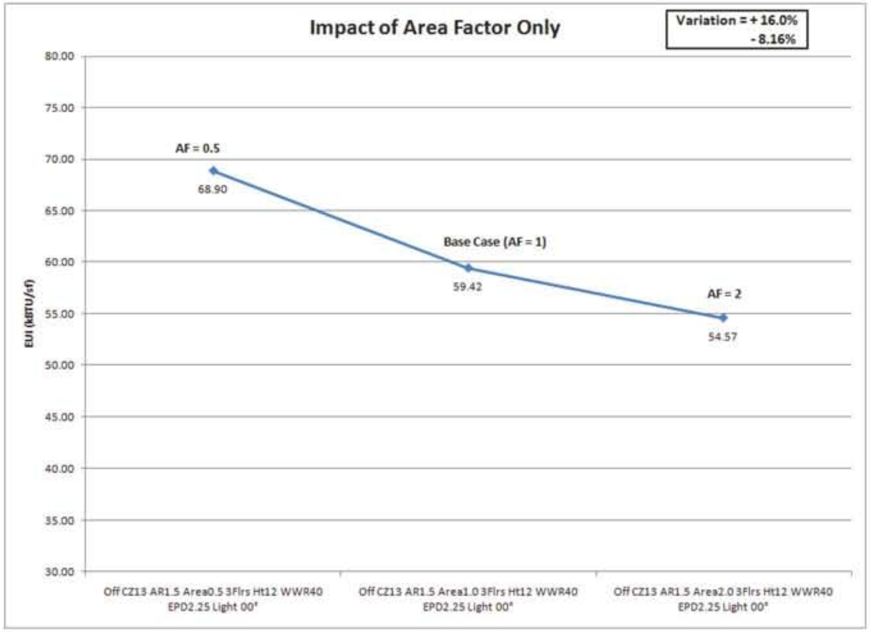
Aspect Ratio=1.5, Area Factor=2

- Additionally, the number of alternate inputs for each variable deemed to have minimal impact was reduced to limit the number of total simulations, specifically:
  - Aspect Ratio: 1.5:1, 5:1. Flr-to-flr height: 12ft, 14ft. EPD: 0.3, 0.75, 1.5, 2.25, 3.0
  - Total # of sims per climate zone = 720

Results – CZ 3

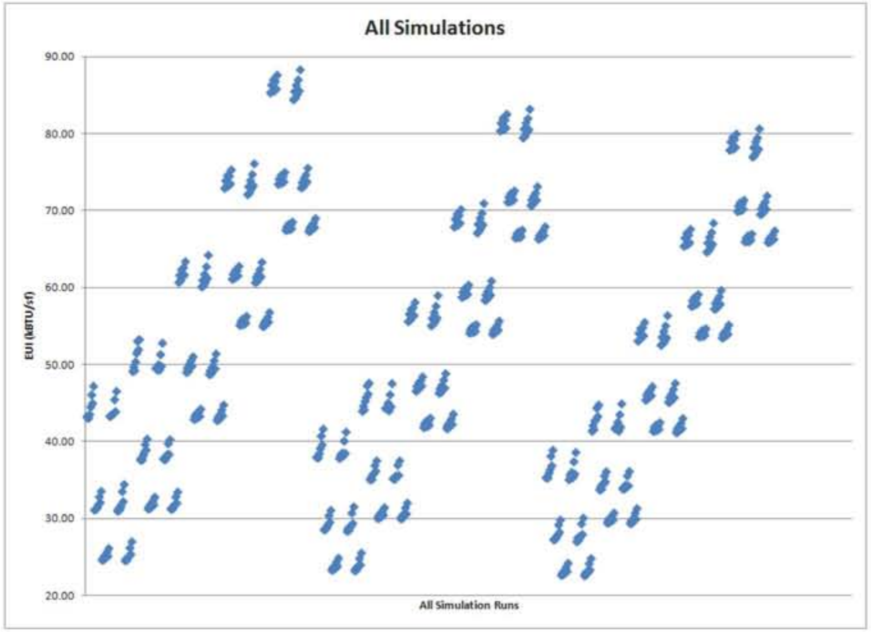
CZ 3 Analysis:
As previously noted, EPD and number of floors had the greatest impact of the variables. Introducing Area Factor into the analysis led to a third variable that would have a non-trivial impact on the building's energy intensity.

The plot below of all simulation runs show that grouping the data by number of floors and EPD no longer leads to the tight "clusters" of results. Therefore, additional analysis was performed to attempt to find predictable bands of EUI (see next slides).



Area Factor
Area factor did indeed have an impact on the building's energy consumption. The results show that a smaller area factor will lead to greater energy use intensity.

Variation = +16.0%, -8.16%

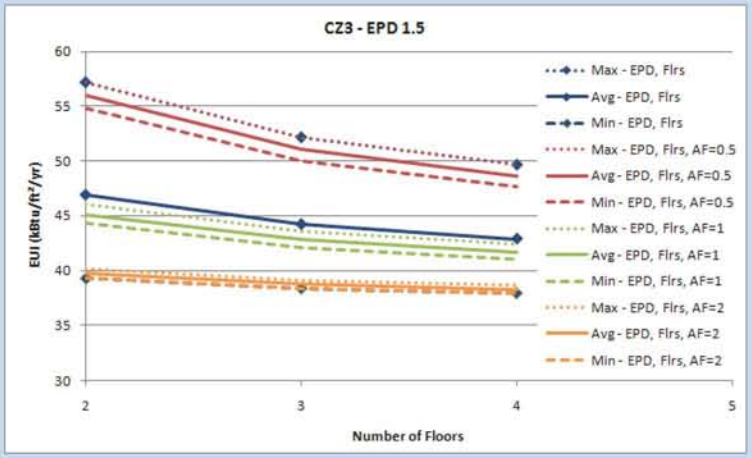


CZ 3 – Add'l Analysis

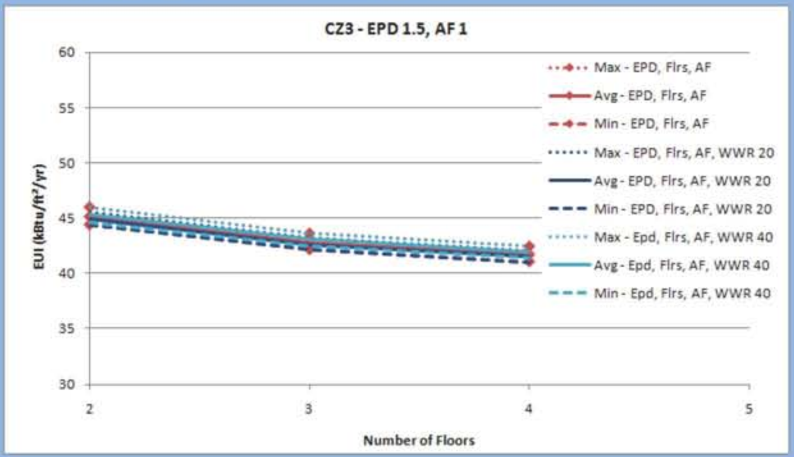
CZ 3 Analysis:
The first graph shows the impact of Area Factor and Number of Floors. One can see that the area factor plays a significant role in the magnitude of EUI. Once the Area Factor is determined, the number of floors will also impact the EUI. Number of floors has a greater impact for the building with a small area factor.

Note that all graphs assume a constant EPD.

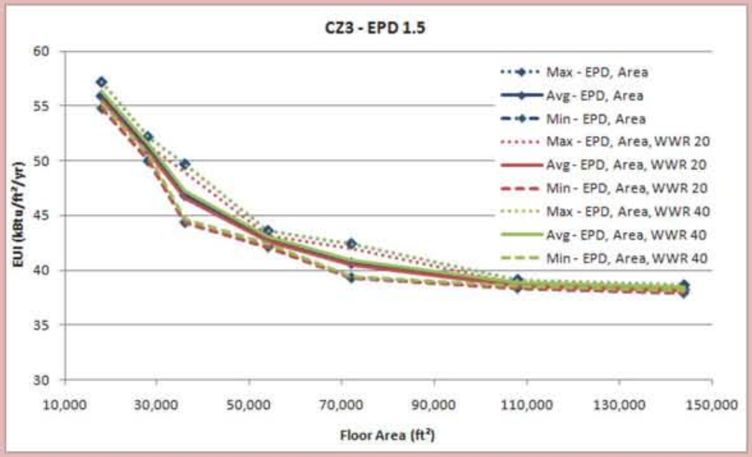
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



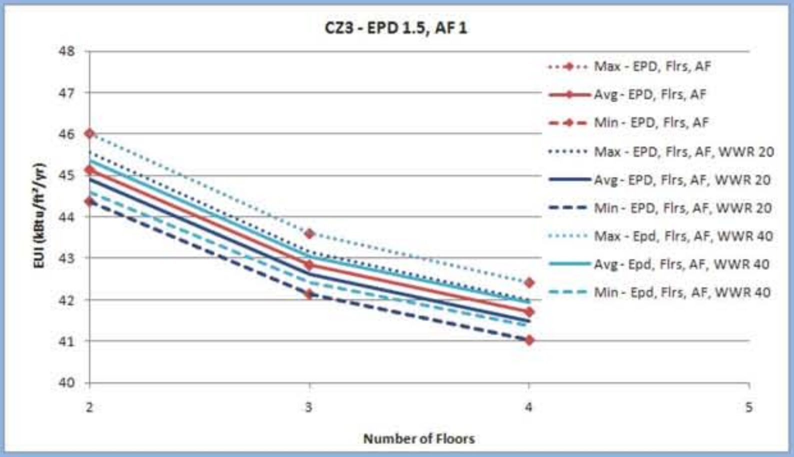
EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



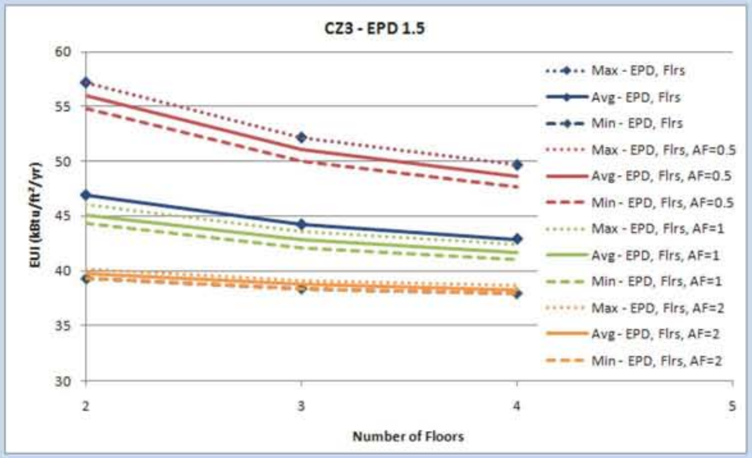
Same as above with expanded Y scale



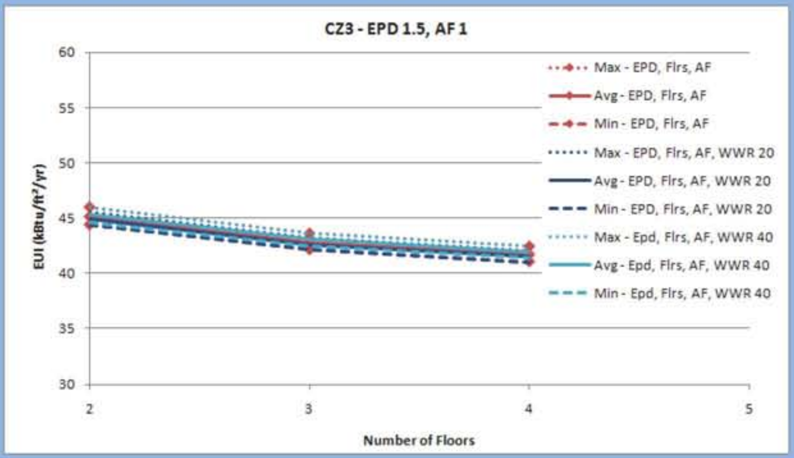
CZ 3 – Add'l Analysis

CZ 3 Analysis:
The next graph attempts to ignore area factor and number of floors, and just accounts for the total building floor area (which may be any combination of # floors and AF). Again, larger buildings tend to have a lower EUI, and the EUI tends to level out after a point on the curve. This graph also introduces window-wall ratio. One can see that more glazing will shift the EUI upwards, though not by a significant amount in this climate zone.

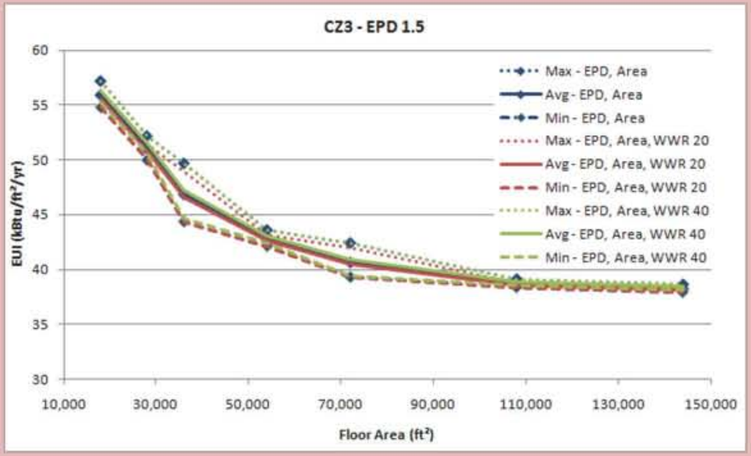
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



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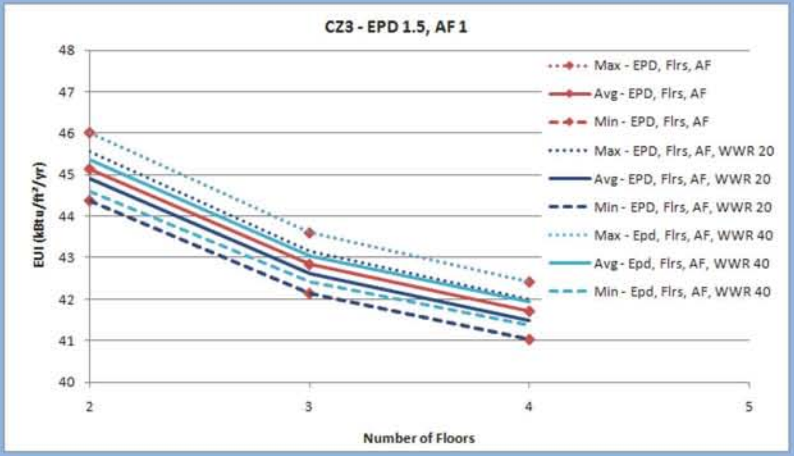
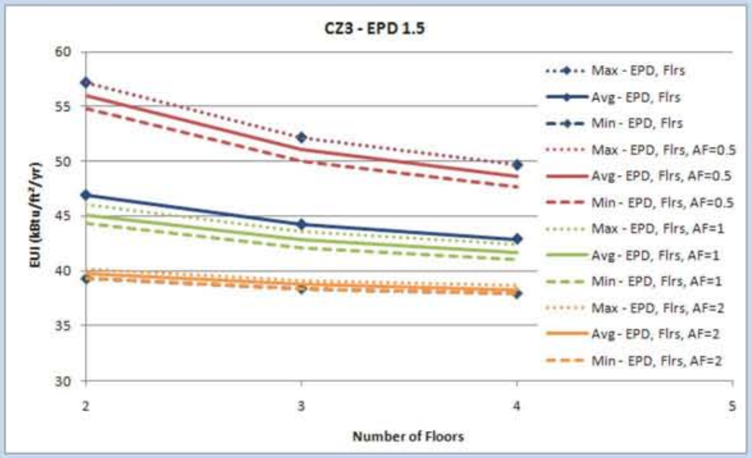


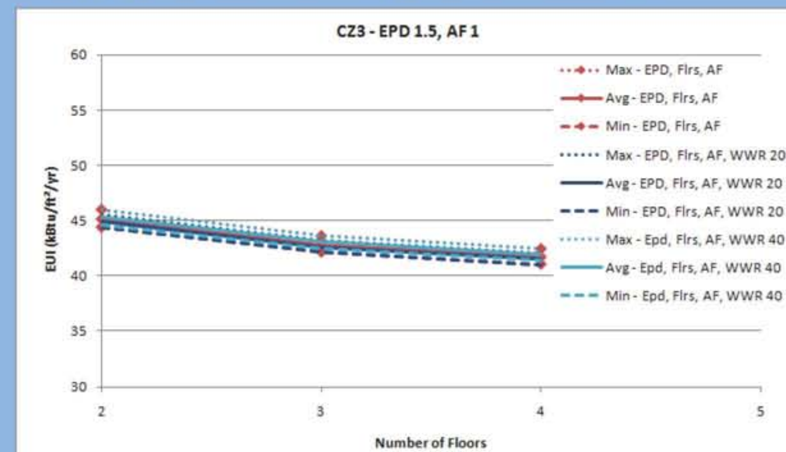
CZ 3 – Add'l Analysis

CZ 3 Analysis:
The greatest variation of results in this graph occur where there are multiple simulation files with the same area but different combinations of number of floors and area factor.

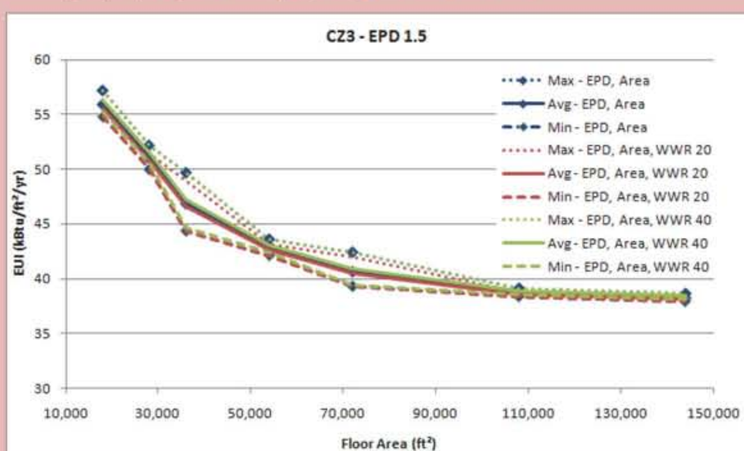
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



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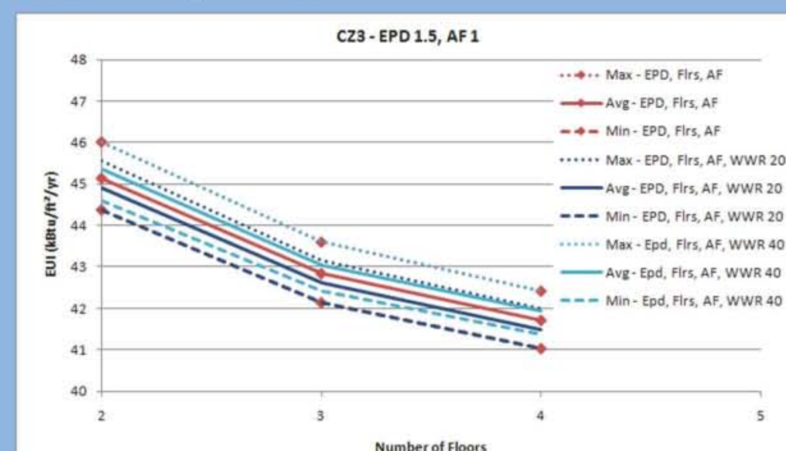
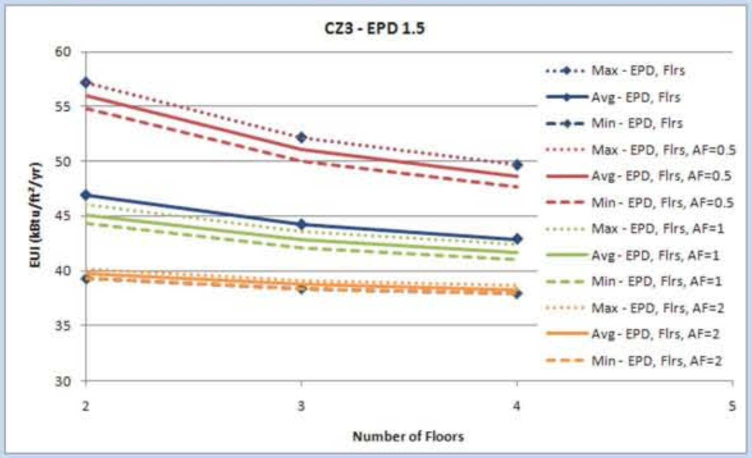


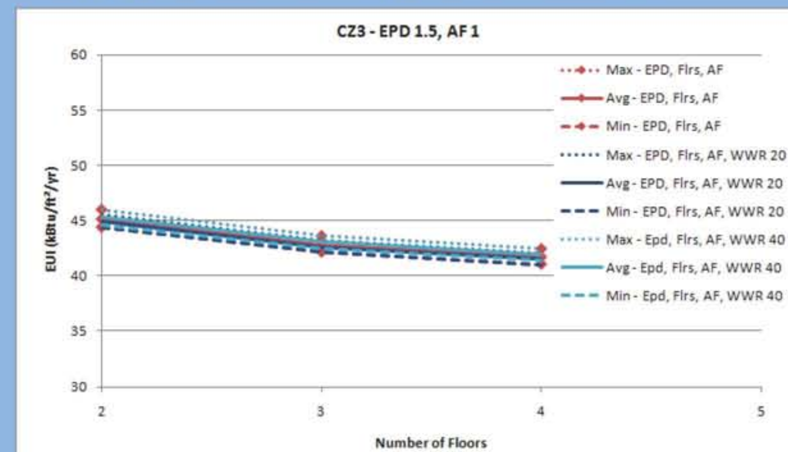
CZ 3 – Add'l Analysis

CZ 3 Analysis:
In this graph, with a given EPD and Area Factor, we can observe the impact of varying the number of floors. It can be seen that specifying EPD and AF lead to a very tight band of EUI

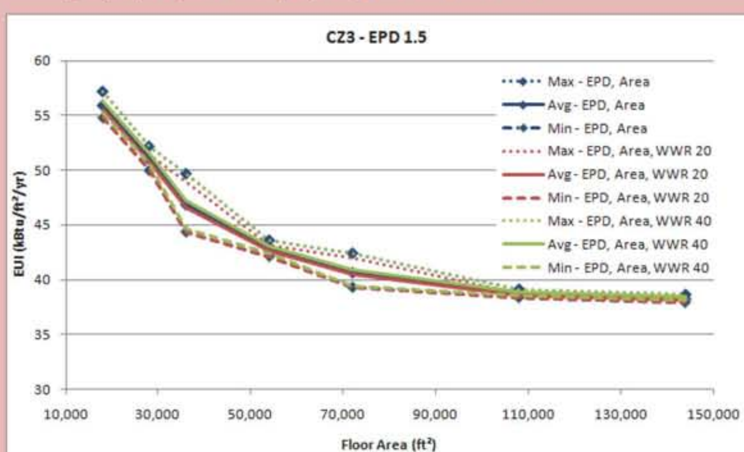
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



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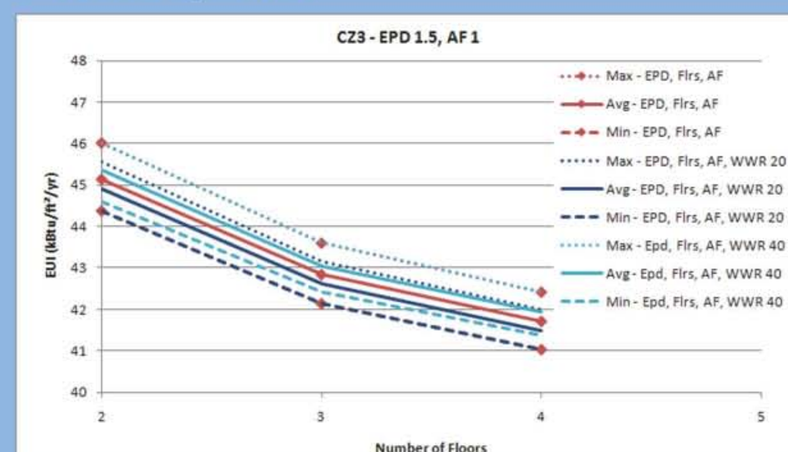
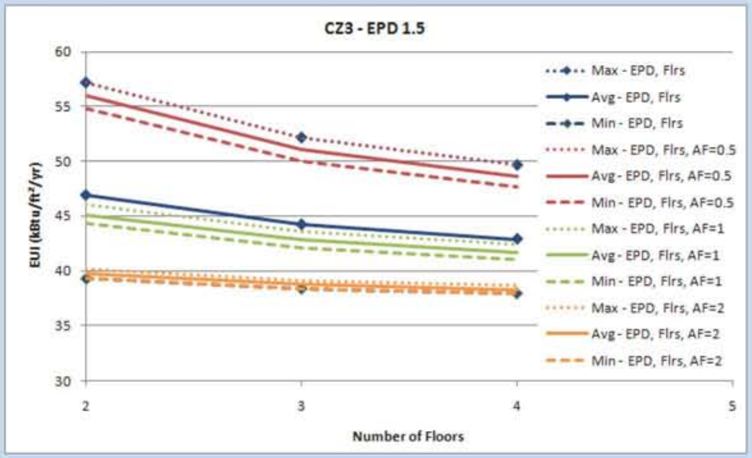


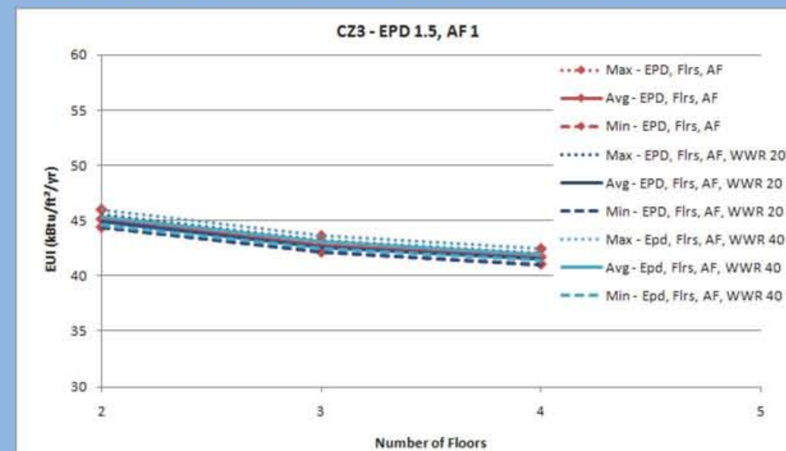
CZ 3 – Add’l Analysis

CZ 3 Analysis:
This graph is the same as above, but zoomed in to view the variation between the different test cases. It can be seen that the EUI can be predicted to a band of approximately 5 kBTU/sf-yr.

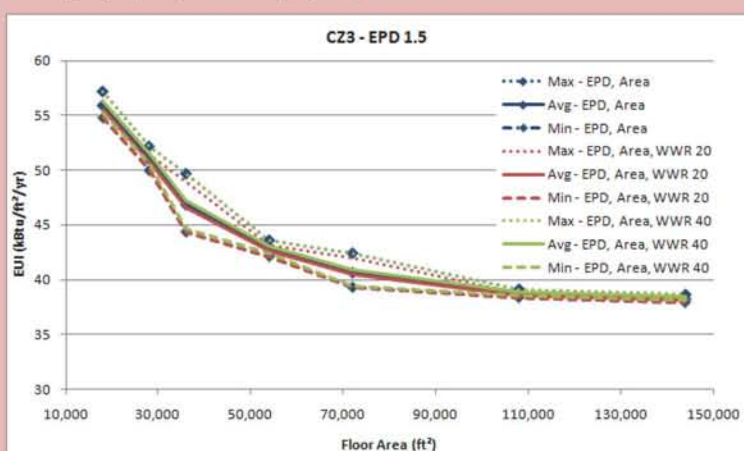
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



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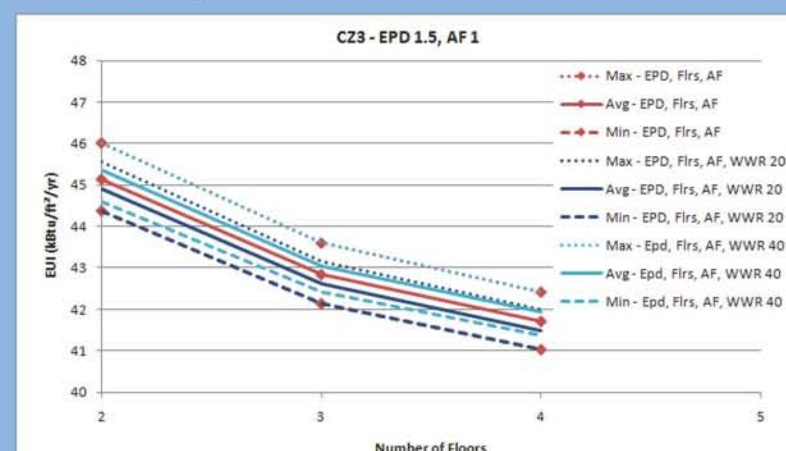
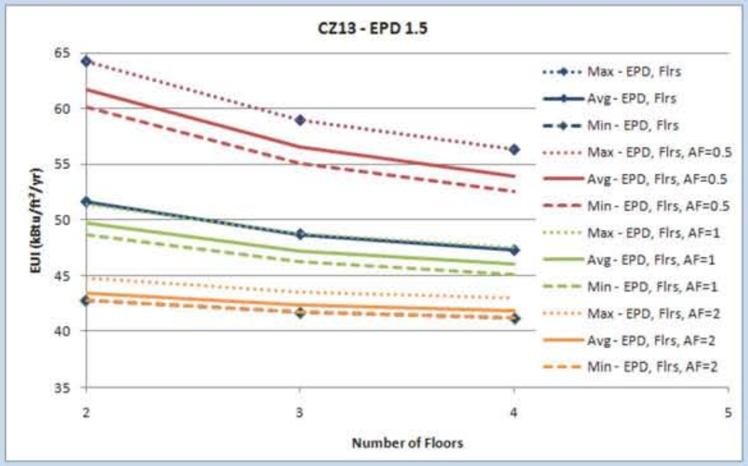


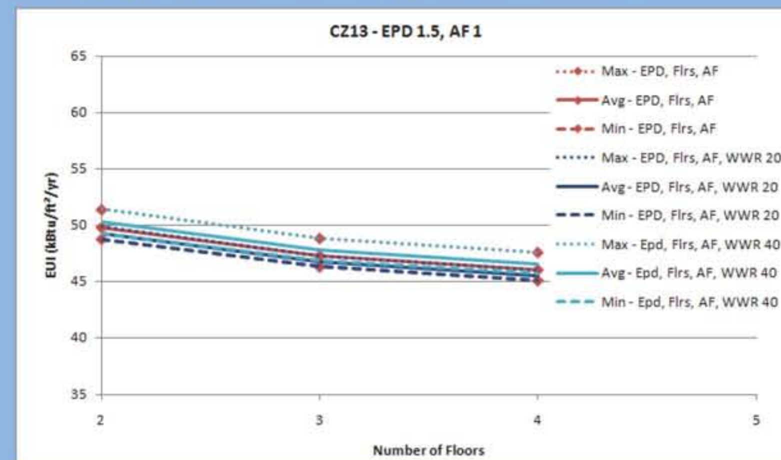
CZ13 – Add'l Analysis

CZ 13 Analysis:
The results for CZ 13 are similarly plotted. Here we see the overall EUI is higher than CZ 3. We also see that once we have determined an EPD and AF, the target EUI is predictable within a band of approx 5 kBTU/sf-yr.

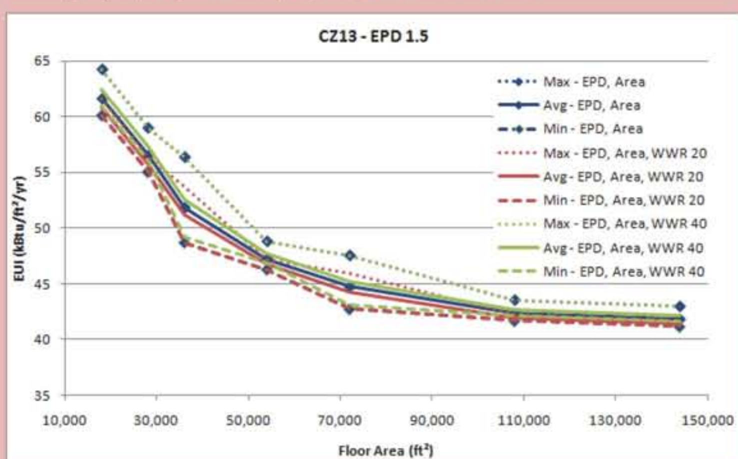
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



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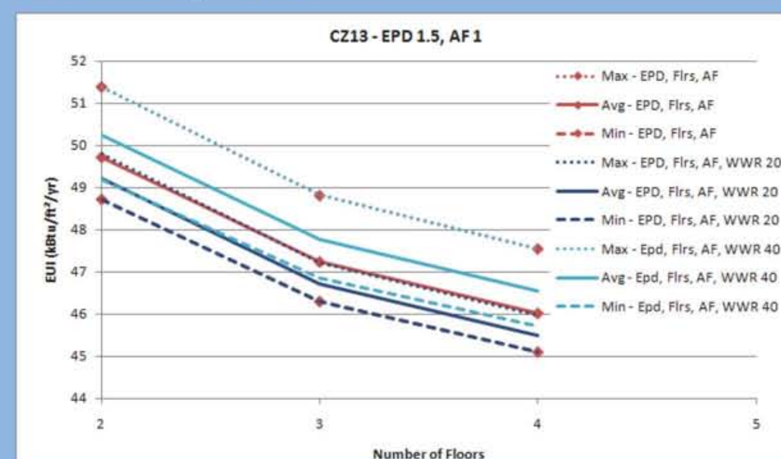
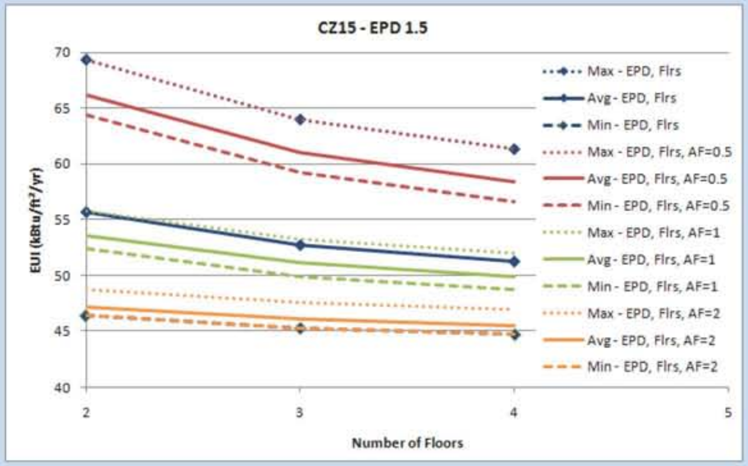


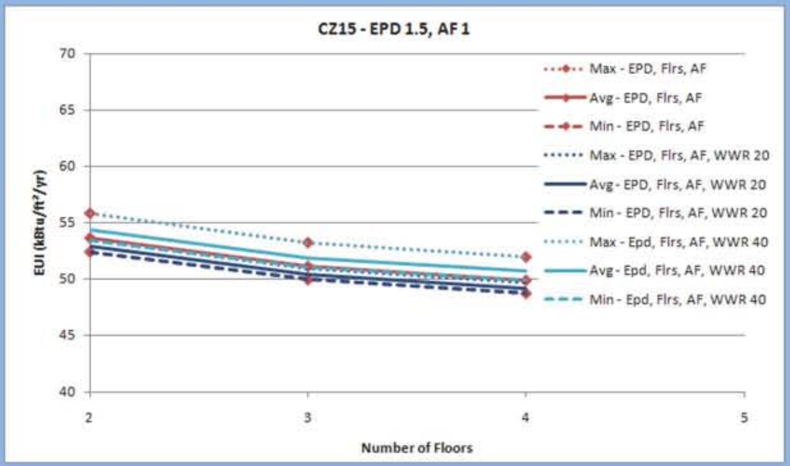
CZ15 – Add'l Analysis

CZ 15 Analysis:
The results for CZ 15 are similarly plotted. Here we see the overall EUI is higher than CZ 3 and CZ 13. We also see that once we have determined an EPD and AF, the target EUI is predictable within a band of approx 6 kBTU/sf-yr.

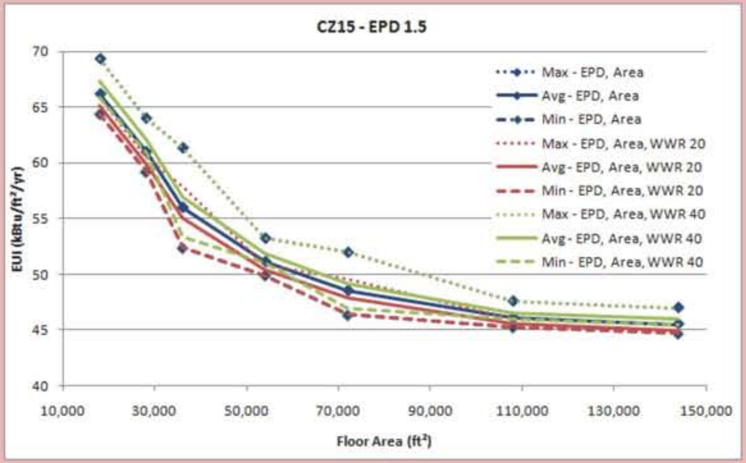
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



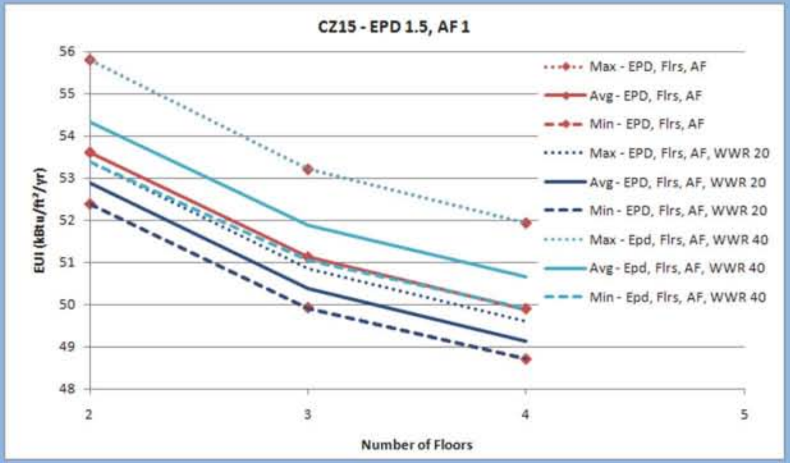
EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



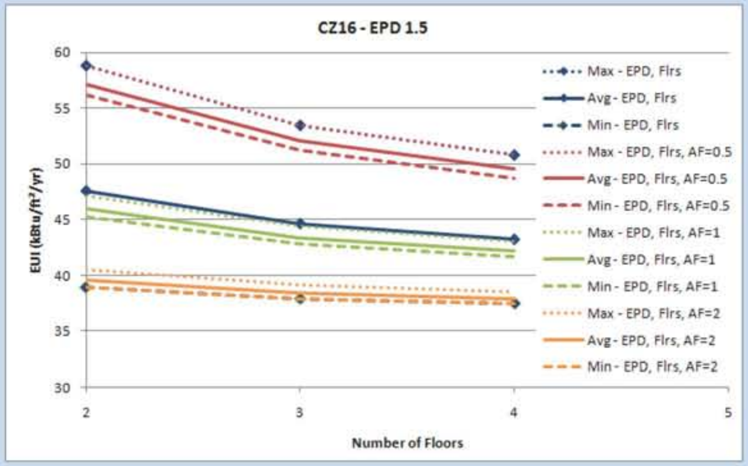
Same as above with expanded Y scale



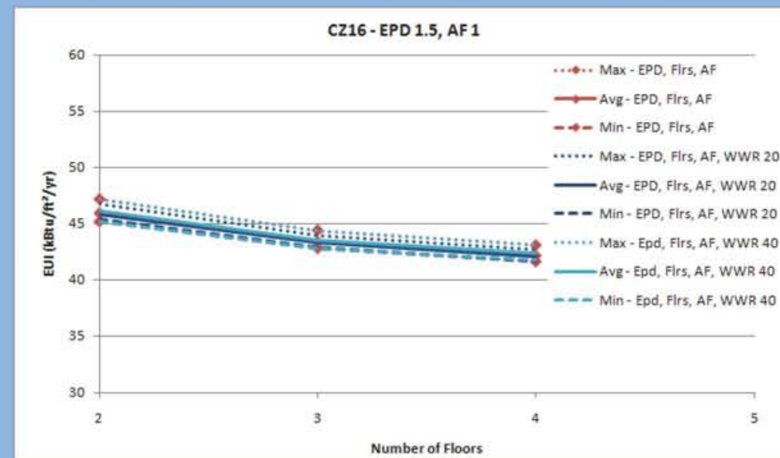
CZ16 – Add'l Analysis

CZ 16 Analysis:
The results for CZ 16 are similarly plotted. Here we see the overall EUI is comparable to CZ 3. We also see that once we have determined an EPD and AF, the target EUI is predictable within a band of approx 5 kBTU/sf-yr.

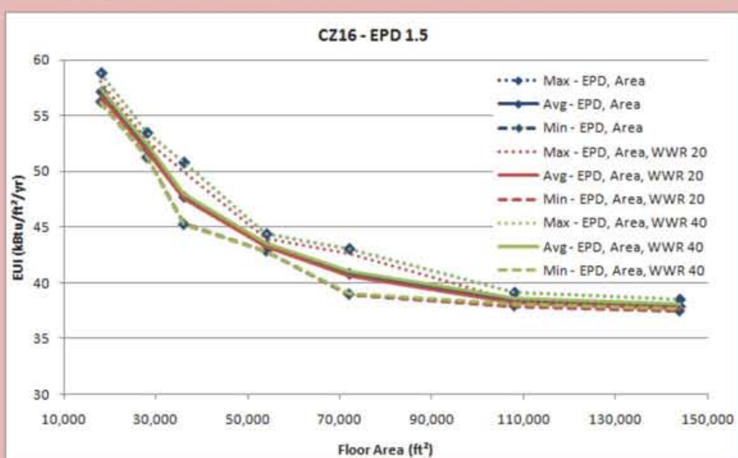
EUI Range - grouped by Number of Floors; grouped by Floors and Area Factor



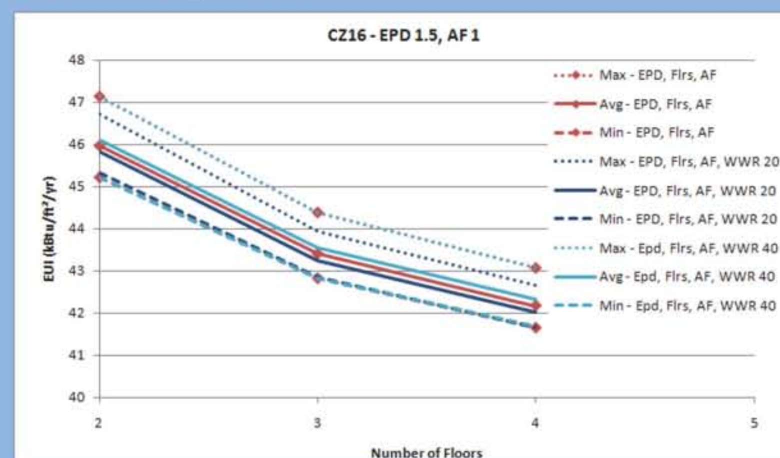
EUI Range - grouped by Floors and Area Factor; grouped by Floors, Area Factor & WWR



EUI Range - grouped by Floor Area; grouped by Floor Area and WWR



Same as above with expanded Y scale



Title 24 Performance Budget Pilot Study - Overview

Summary of work to date:

- The initial analysis of the office building seems to indicate that the concept of setting an EUI budget (rather than modeling a baseline building) is feasible
  - Key variables that impact the EUI target are EPD, number of floors, and building footprint/area

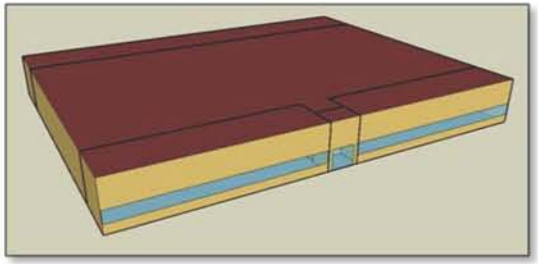
Scope for next phase of work:

- Look at 2 additional building types, and mixed use – Standalone Retail, Mixed Retail/Office, School
- Maintain climate zone scope at four CZs
- Investigate impact of alternate simulation engine (DOE2.2)

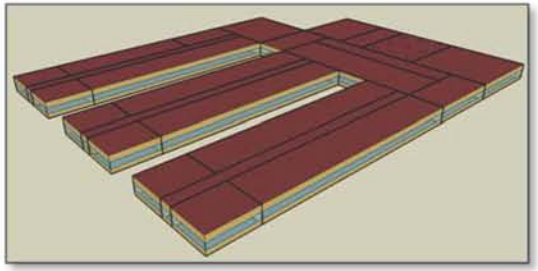
Outcomes:

- Determine whether other building types lead to predictable EUI
- Determine method to deal with buildings that have multiple space usage types, and how to deal with variability of % area of spaces within a building type (e.g. large kitchen vs. small kitchen)

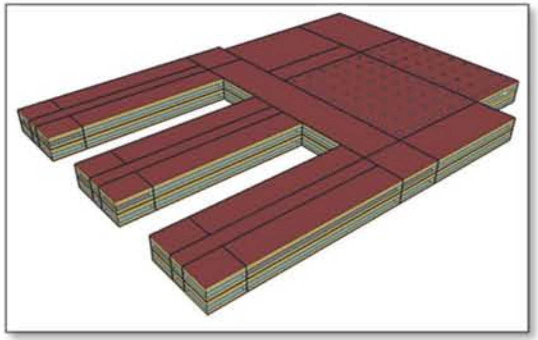
Building Types



Standalone Retail



Primary School



Secondary School

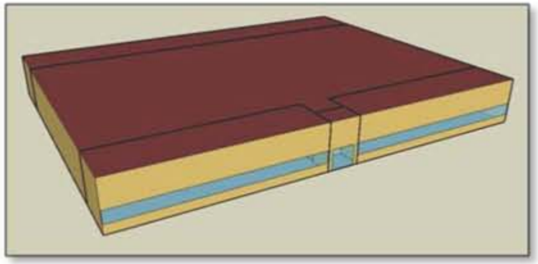
Options:

- Simulation Models will be based on DOE Commercial Reference Buildings and associated EnergyPlus files
  - Standalone Retail
  - Primary School ***OR*** Secondary School

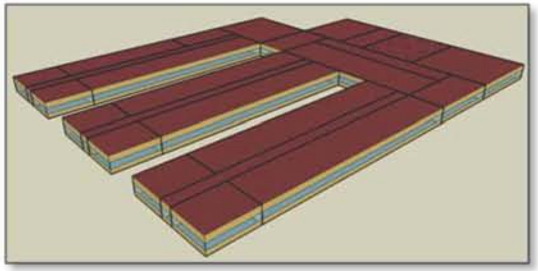
Notes:

- Reference buildings are based on ASHRAE 90.1-2004
- Building inputs will be adjusted to T24 for this study

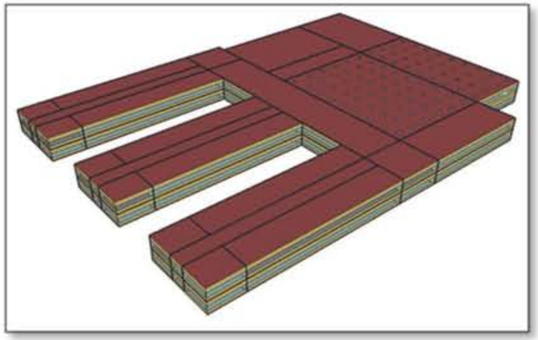
Building Types



Standalone Retail



Primary School



Secondary School

Modeling Procedure:

- Retail: Model standalone retail building using parametric runs (similar to office analysis).
- Mixed Use 1: Perform additional analysis on Office building, replacing the ground floor with Retail
- Mixed Use 2: Determine if results from standalone office and standalone retail can be "combined" to produce same results as "Mixed Use 1" analysis
- School: Model school building using parametric runs (similar to office analysis). Due to diverse space use classification, we propose that % area of each space use should be tabulated along with the results and attempt to find correlation. Investigate impact of varying these percentages.

Recommendation:

- For the School, we propose the Secondary school building should be used as the basis for this analysis because it has a bit more added complexity (including multiple floors) and should provide more meaningful results

Alternate Simulation Engine

Modeling Procedure:

- This analysis will be very much scaled back compared to the previous analysis with EnergyPlus
- Limited (for now) to comparing results from previous office building analysis (not the new building types described in this document)
- We will re-create the office building in eQUEST, and pick approx 5-10 of the building variants to perform DOE2.2 simulations. Variants may include changes to geometry or changes to climate zone.
- Compare results from DOE2.2 and EnergyPlus to determine impact of simulation engine on the EUI calculations.