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Energy Model Report

Clark Pacific Envelope Study

Presented by Glumac

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Disclaimer

The results of the energy analysis presented in this report shall not be construed to have absolute, predictive accuracy, representing the actual energy use of the building or its individual systems. All reasonable efforts have been taken to ensure the accuracy of the energy model inputs, including verifying that actual details correspond to the building as it is currently designed. The primary benefit of energy modeling is for comparison of alternative design options to determine their relative energy savings potential.

There are a number of factors that will cause the actual energy use of the building to diverge from the projected energy use of the model. Among these are: differences in building design relative to the building modeled; abnormal weather conditions; variations in schedules for equipment, systems, and occupancy; inconsistencies in the application of controls and operations strategies compared to those used in the model; the level of direct loads; and changes in connected loads and electricity and gas rates. In addition, the model results do not necessarily take into account all the energy uses of a facility or building site that would show up as loads on the utility meters.

Nevertheless, refinements of the energy model to reconcile all these differences, when these adjustments are made by a capable energy engineer, can yield model results that are consistent with actual energy use.

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1 Executive Summary

This report documents an envelope system study conducted comparing Clark Composite Architectural Precast Panels (CCAPP) envelope system with thermally broken windows in four (4) different climate zones. The CCAPP envelope system was compared with two (2) other typical envelope systems as well as the California Title 24 baseline envelope system. In the context of the study, the following two (2) different building types were taken into consideration:

- Commercial Office
- Residential

The following four (4) climate zones were utilized in this study:

- Los Angeles
- San Francisco
- Sacramento
- Seattle

The following three (3) window-to-wall ratios were studied:

- 40%
- 55%
- 70%

The architectural design of these buildings is based on actual projects and representative a typical design for of each of these building type.

1.1 Energy Analysis Process

The DOE-2 based software package eQuest 3.65 has been used to simulate the energy performance of the buildings. Included in the following sections is a description of how this tool was used to estimate the building performance and the documentation of associated assumptions.

The energy analysis was conducted by first creating the building energy model in Revit. The building geometry was then exported via gbXML into eQuest 3.65 where site properties, building constructions, and building systems were defined.

1.2 Energy Analysis Results

The CCAPP envelope system was beneficial in most climates and parametric runs. The CCAPP system has the most benefit in heating dominated climates.

Due to the large number of parametric runs, this report should be viewed in conjunction with the excel tool provided with tables & graphics to illustrate the differences.

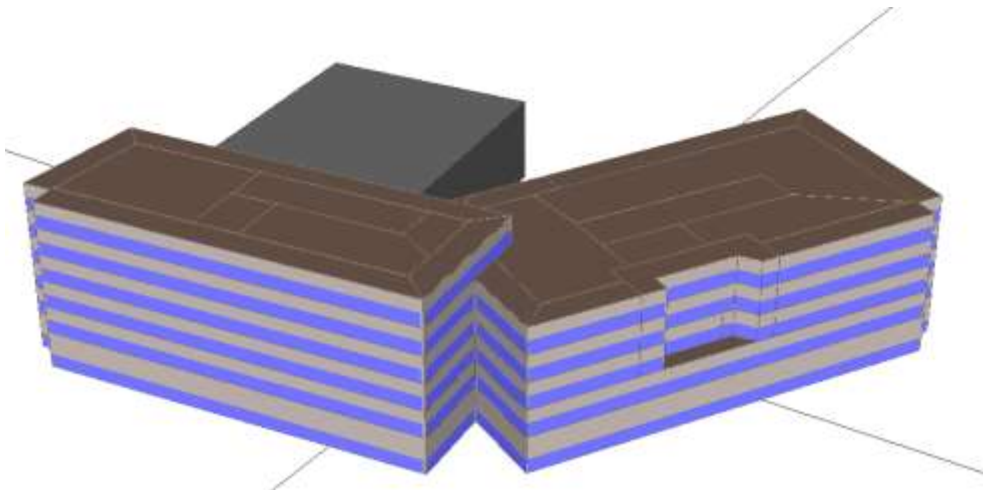
2 General Modeling Parameters

Five (5) envelope assemblies were modeled in the parametric simulations and their performances were the following:

- **Baseline (Title 24, 2016 – Los Angeles, San Francisco, Sacramento)**
    - Opaque
        - 6" metal-stud frame w/R-19 batt & 2.5" of continuous insulation (polystyrene)
        - Effective U-Value – 0.064 Btu/h-sf-F
    - Vision
        - Fixed-frame Window
        - Solar Heat Gain Coefficient (SHGC) – 0.25
        - Effective U-Value (including frame) – 0.36 Btu/h-sf-F
- **Baseline (Seattle Energy Code – Seattle)**
    - Opaque
        - 6" metal-stud frame w/R-19 batt & 3" of continuous insulation (polystyrene)
        - Effective U-Value – 0.052 Btu/h-sf-F
    - Vision
        - Fixed-frame Window
        - Solar Heat Gain Coefficient (SHGC) – 0.35 on SEW / 0.53 on N
        - Effective U-Value (including frame) – 0.31 Btu/h-sf-F
- **W1**
    - Opaque
        - Curtainwall/Window Wall with R-13 batt infill
        - Effective U-Value – 0.120 Btu/h-sf-F
    - Vision
        - Solar Heat Gain Coefficient (SHGC) – 0.26
        - Effective U-Value (including frame) – 0.41 Btu/h-sf-F
- **W2**
    - Opaque
        - 6" metal-stud frame w/R-19 batt & 0.5" of continuous insulation (polystyrene)
        - Effective U-Value – 0.151 Btu/h-sf-F
    - Vision
        - Solar Heat Gain Coefficient (SHGC) – 0.26
        - Effective U-Value (including frame) – 0.36 Btu/h-sf-F
- **W3**
    - Opaque
        - CCAPP System w/2" of continuous insulation and no Illmod
        - Effective U-Value – 0.065 Btu/h-sf-F
    - Vision
        - Solar Heat Gain Coefficient (SHGC) – 0.24
        - Effective U-Value (including frame) – 0.318 Btu/h-sf-F
- **W4**
    - Opaque
        - CCAPP System w/3" of continuous insulation and no Illmod
        - Effective U-Value – 0.046 Btu/h-sf-F
    - Vision
        - Solar Heat Gain Coefficient (SHGC) – 0.24
        - Effective U-Value (including frame) – 0.318 Btu/h-sf-F

3 Commercial Office Results

The comparative office building utilized in this study is a 6-story, 235,000 square foot, boomerang shaped office building with a typical office building floorplan & layout. The HVAC system conditioning the building was modeled after the ASHRAE 90.1 Appendix G system type and is representative of a typical HVAC system for an office building of this size. All modeled parameters are identified below the Results section.



3.1 Simulation Results

Results will be organized by Climate Zone and then the modeled Window-Wall-Ratio (WWR).

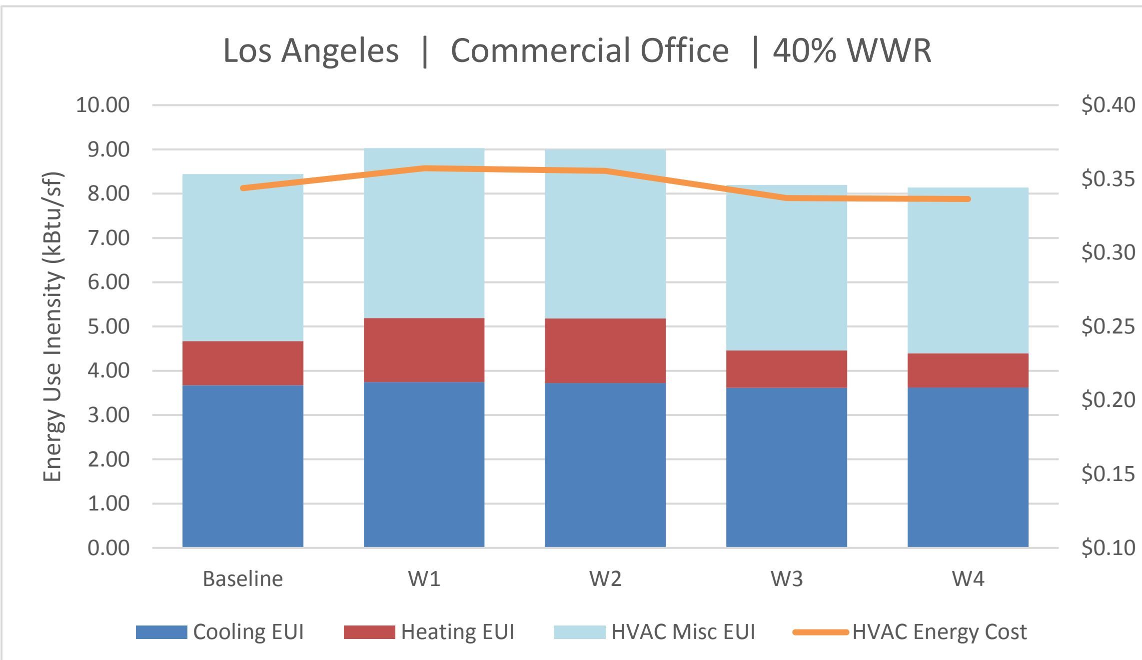
3.1.1 Los Angeles

The climate in Los Angeles is cooling-driven with most external heat gain coming from solar radiation through glazing. There were benefits for adding the CCAPP system for all WWR scenarios that were assessed. Although the benefits are great for buildings with a higher WWR.

The energy usage for W1 and W2 are worse than the baseline Title 24 envelope design for the 40% WWR building. The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~30% compared to typical construction assemblies (W1 & W2). The CCAPP system had a minimal impact on reducing cooling and miscellaneous HVAC energy use. In general, the addition 1" of continuous insulation included in W4 does not have a significant impact compared to W3 in Los Angeles.

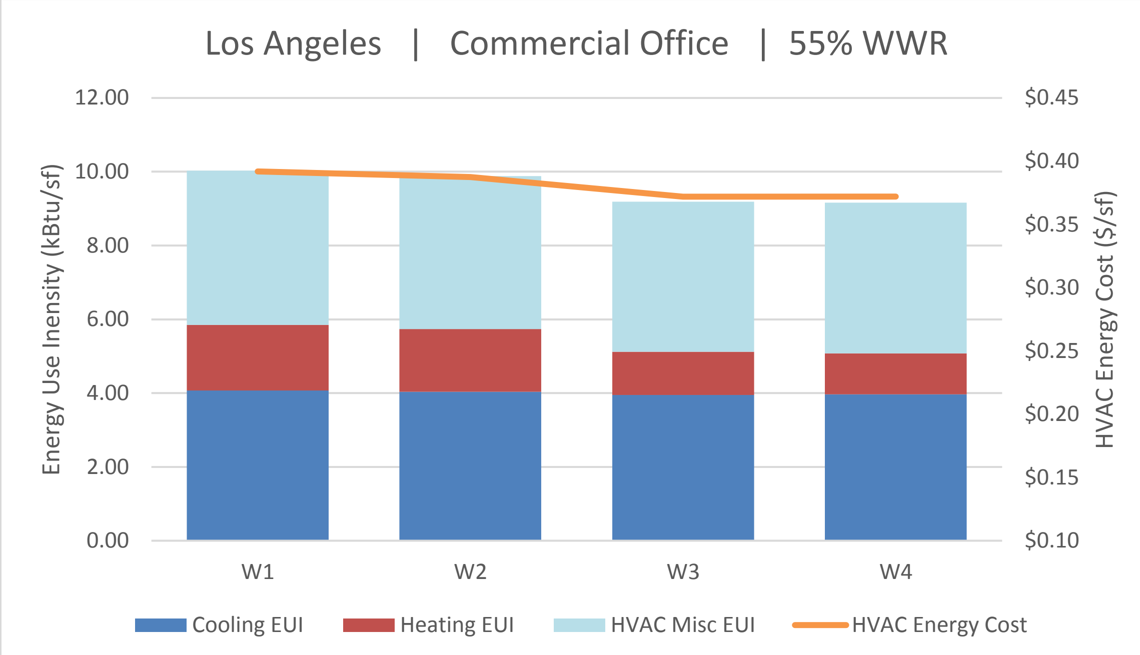
The HVAC EUI and energy cost remain within 5% of the baseline for both CAPP systems. This is due to the temperate Southern California climate, where over insulating a building can have negative impacts on energy usage.

40% WWR & Code Baseline



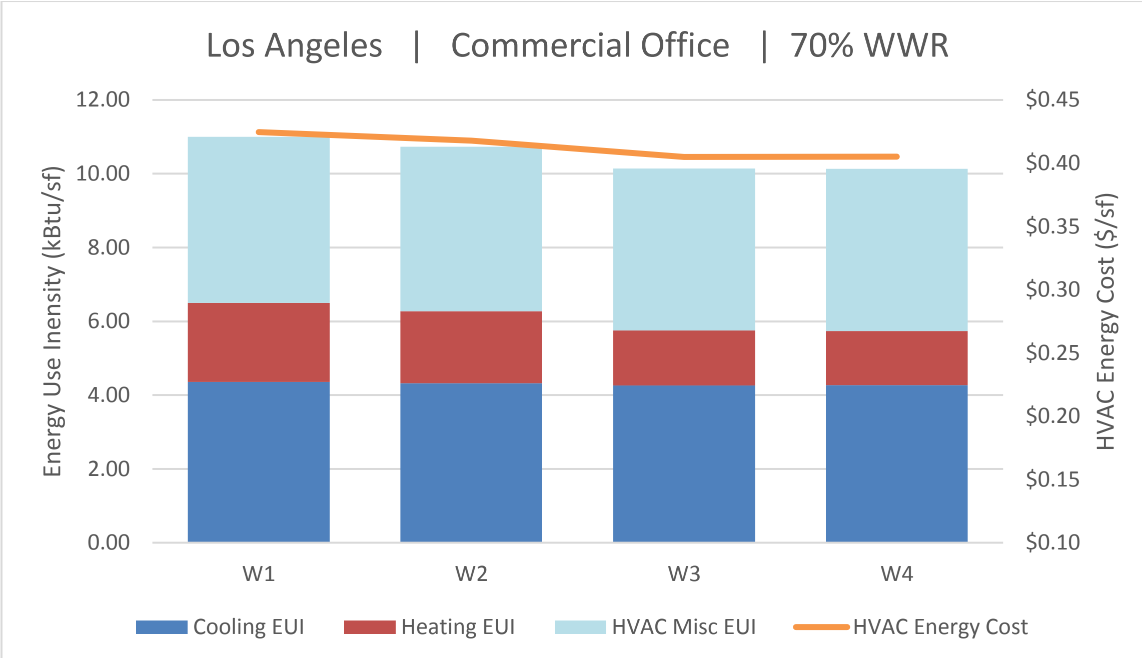
Los Angeles | Commercial Office | 40% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	3.67	-	1.00	-	3.78	-	8.44	-	$0.34	-
W1	3.75	*-2%*	1.44	*-44%*	3.84	*-2%*	9.03	*-7%*	$0.36	*-4%*
W2	3.73	*-2%*	1.46	*-47%*	3.82	*-1%*	9.00	*-7%*	$0.36	*-3%*
W3	3.61	*2%*	0.84	*15%*	3.74	*1%*	8.20	*3%*	$0.34	*2%*
W4	3.62	*1%*	0.77	*22%*	3.74	*1%*	8.14	*4%*	$0.34	*2%*

55% WWR



Los Angeles | Commercial Office | 55% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	4.07	-	1.78	-	4.18	-	10.03	-	$0.39	-
W2	4.04	*1%*	1.70	*5%*	4.14	*1%*	9.88	*2%*	$0.39	*1%*
W3	3.95	*3%*	1.16	*35%*	4.07	*3%*	9.19	*8%*	$0.37	*5%*
W4	3.96	*3%*	1.12	*37%*	4.08	*2%*	9.16	*9%*	$0.37	*5%*

70% WWR



Los Angeles | Commercial Office | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	4.36	-	2.14	-	4.50	-	11.00	-	$0.42	-
W2	4.32	*1%*	1.96	*9%*	4.45	*1%*	10.73	*2%*	$0.42	*2%*
W3	4.27	*2%*	1.49	*31%*	4.39	*2%*	10.14	*8%*	$0.40	*5%*
W4	4.27	*2%*	1.46	*32%*	4.40	*2%*	10.13	*8%*	$0.41	*5%*

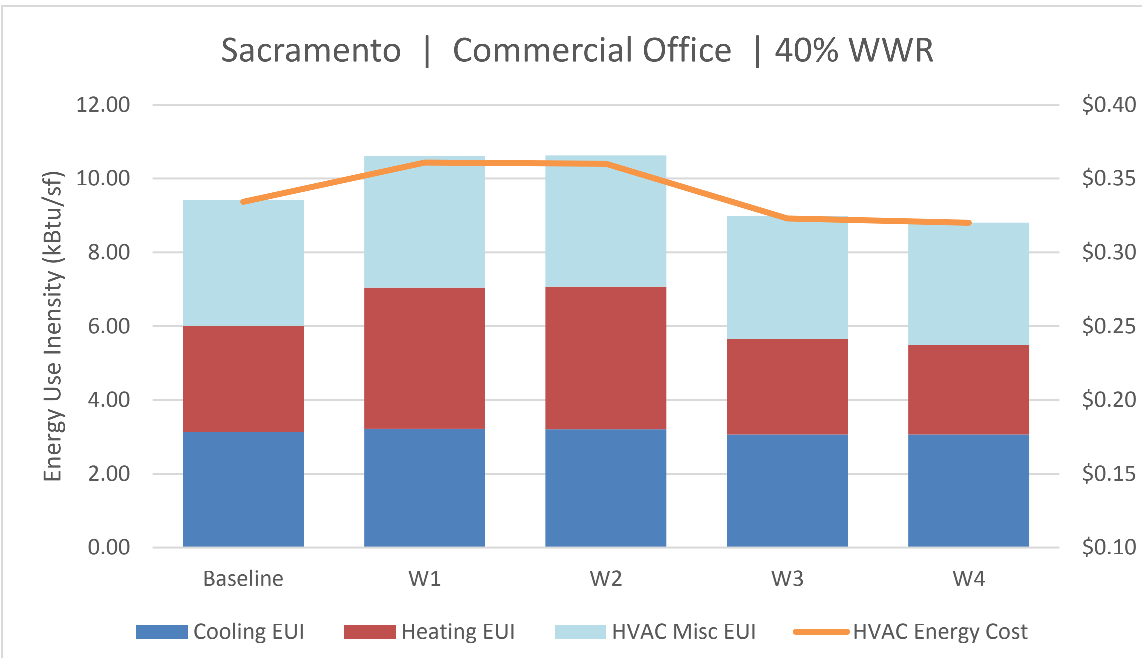
3.1.2 Sacramento

The climate in Sacramento is evenly driven by cooling and heating energy. Sacramento both experiences warm weather in the summer and cooler temperatures in winter.

Under all WWR options assessed in the standard construction assemblies (W1 and W2) used more energy compared the CCAPP system (W1 & W2). The CCAPP systems performed better than the baseline Title 24 envelope with a 40% WWR. The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~30% compared to typical construction assemblies (W1 & W2). In general, the addition 1" of continuous insulation included in W4 did not have a significant impact on building efficiency compared to W3.

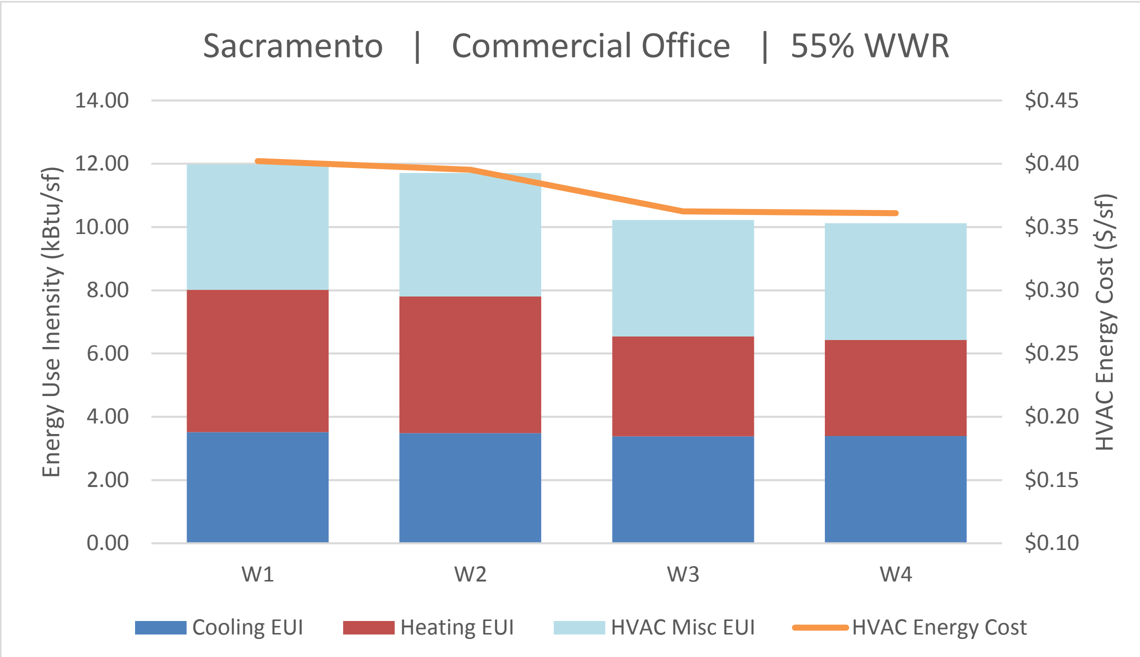
The CCAPP envelope system can reduce HVAC energy use/cost by up to 10% compared to conventional envelope designs.

40% WWR & Code Baseline



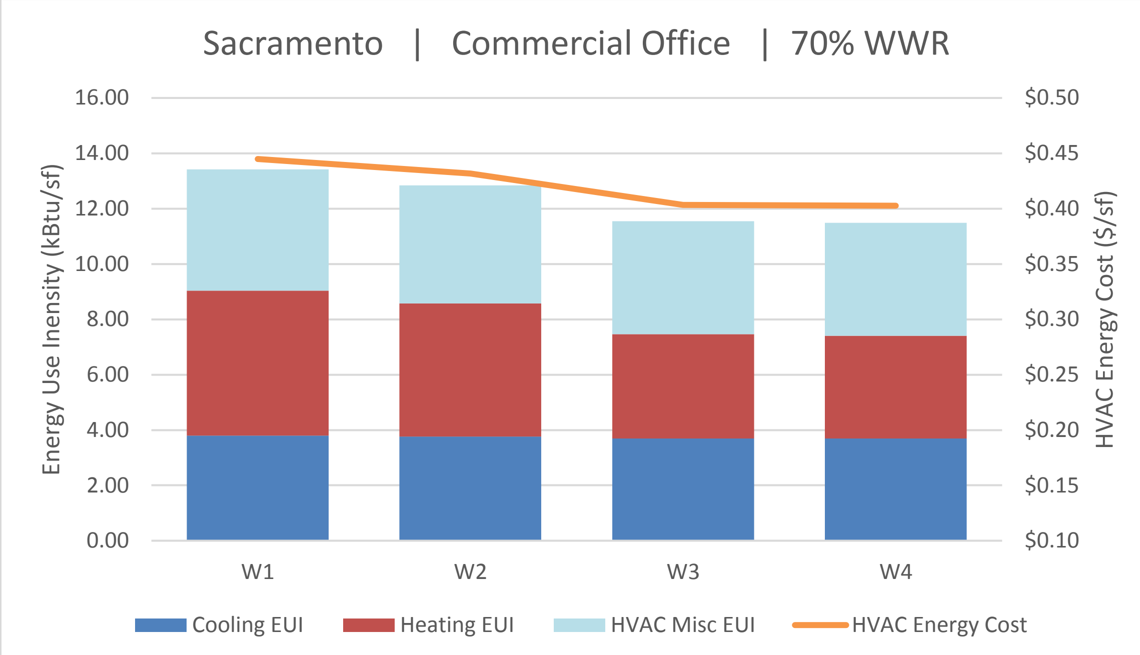
Sacramento | Commercial Office | 40% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	3.13	-	2.89	-	3.40	-	9.42	-	$0.33	-
W1	3.22	*-3%*	3.82	*-32%*	3.57	*-5%*	10.61	*-13%*	$0.36	*-8%*
W2	3.20	*-2%*	3.87	*-34%*	3.55	*-4%*	10.63	*-13%*	$0.36	*-8%*
W3	3.06	*2%*	2.59	*10%*	3.32	*2%*	8.97	*5%*	$0.32	*3%*
W4	3.06	*2%*	2.43	*16%*	3.31	*3%*	8.81	*7%*	$0.32	*4%*

55% WWR



Sacramento | Commercial Office | 55% WWR										
	Cooling EUI		Heating EUI		HVAC Misc EUI		HVAC EUI		Energy Cost	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	3.51	-	4.50	-	3.96	-	11.98	-	$0.40	-
W2	3.49	*1%*	4.32	*4%*	3.91	*1%*	11.71	*2%*	$0.40	*2%*
W3	3.38	*4%*	3.15	*30%*	3.69	*7%*	10.23	*15%*	$0.36	*10%*
W4	3.39	*4%*	3.04	*32%*	3.69	*7%*	10.12	*16%*	$0.36	*10%*

70% WWR



Sacramento | Commercial Office | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	3.80	-	5.24	-	4.37	-	13.42	-	$0.44	-
W2	3.76	*1%*	4.81	*8%*	4.27	*2%*	12.84	*4%*	$0.43	*3%*
W3	3.69	*3%*	3.78	*28%*	4.08	*7%*	11.55	*14%*	$0.40	*9%*
W4	3.70	*3%*	3.71	*29%*	4.09	*7%*	11.49	*14%*	$0.40	*9%*

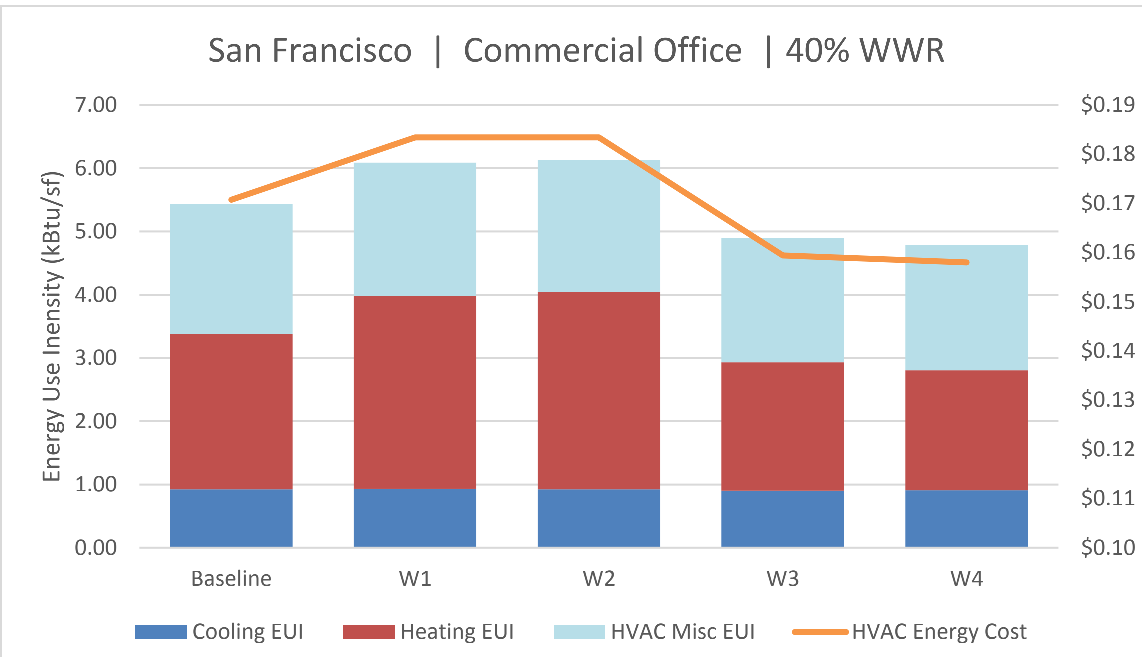
3.1.3 San Francisco

San Francisco's climate is very temperate. Energy costs are over 50% lower compared to Los Angeles and Sacramento. Heating is required in winter months, with limited solar heat gains during these periods. The mild temperatures throughout the year allow for 100% outside air economizers to be used frequently which greatly reduce the cooling energy required.

Under all WWR options assessed in the standard construction assemblies (W1 and W2) used more energy compared the CCAPP system (W1 & W2). The CCAPP systems performed better than the baseline Title 24 envelope with a 40% WWR. The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~30% compared to typical construction assemblies (W1 & W2). In general, the addition 1" of continuous insulation included in W4 did not have a significant impact on building efficiency compared to W3.

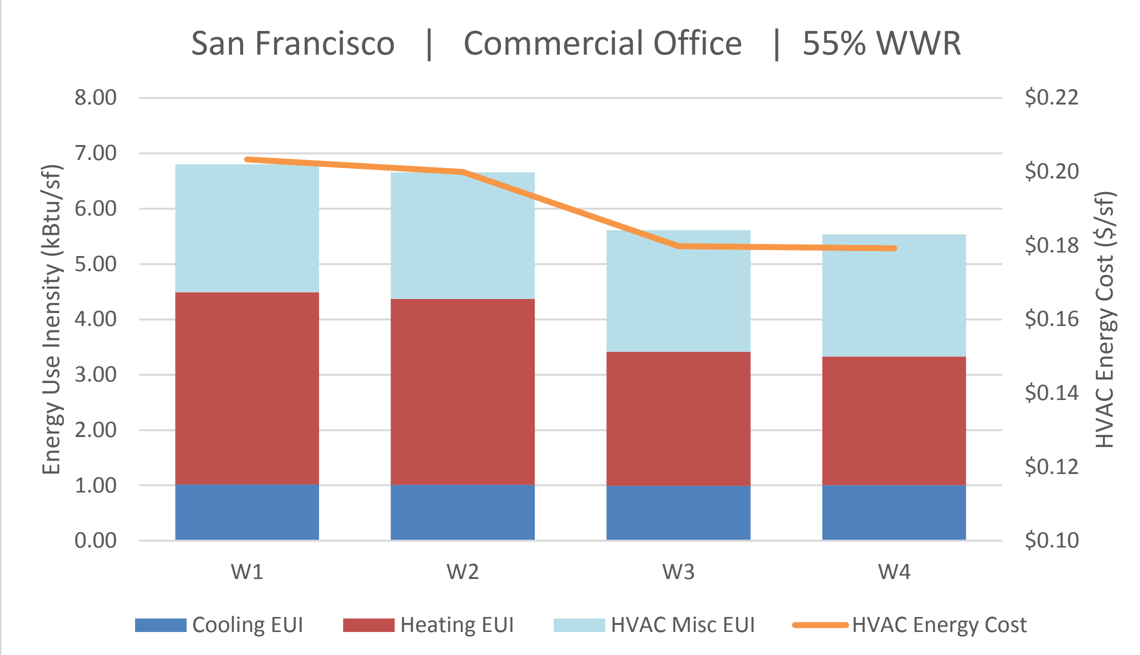
The CCAPP envelope system can reduce HVAC energy use/cost between 10-20% compared to conventional envelope designs. It is most effective on the building with higher WWR due to the higher performance windows.

40% WWR & Code Baseline



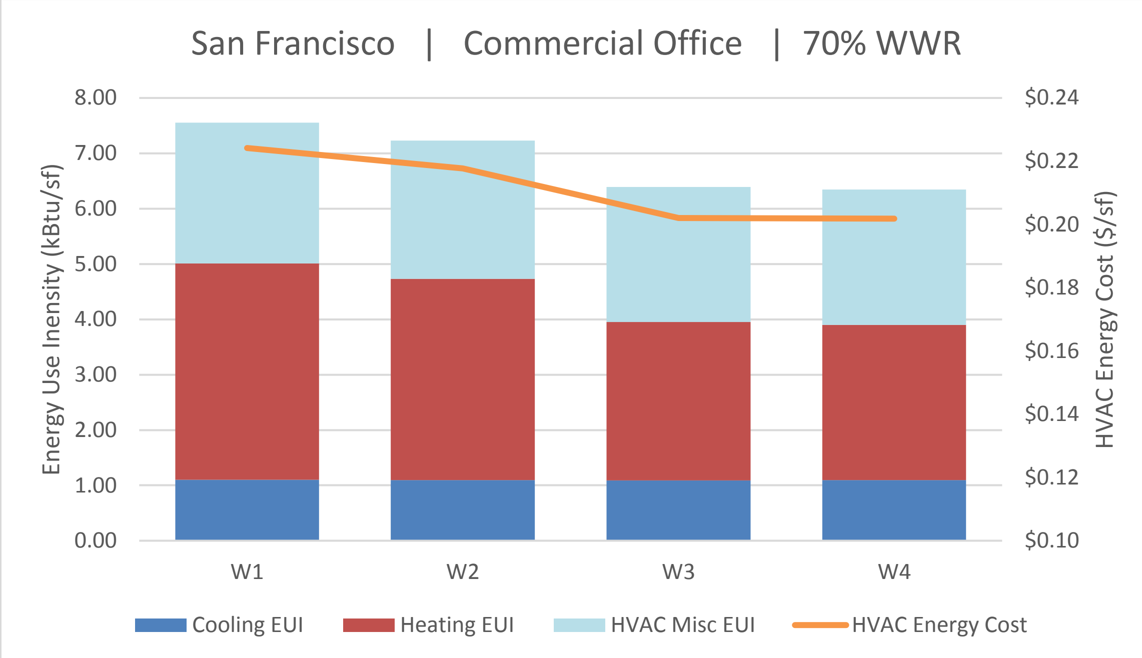
San Francisco | Commercial Office | 40% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	0.92	-	2.46	-	2.05	-	5.43	-	$0.17	-
W1	0.93	*-1%*	3.05	*-24%*	2.10	*-3%*	6.09	*-12%*	$0.18	*-7%*
W2	0.92	*0%*	3.12	*-27%*	2.09	*-2%*	6.13	*-13%*	$0.18	*-7%*
W3	0.90	*2%*	2.03	*18%*	1.97	*4%*	4.90	*10%*	$0.16	*7%*
W4	0.91	*2%*	1.89	*23%*	1.98	*3%*	4.78	*12%*	$0.16	*7%*

55% WWR



San Francisco | Commercial Office | 55% WWR										
	Cooling EUI		Heating EUI		HVAC Misc EUI		HVAC EUI		Energy Cost	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	1.02	-	3.47	-	2.32	-	6.80	-	$0.20	-
W2	1.01	*1%*	3.36	*3%*	2.29	*1%*	6.66	*2%*	$0.20	*2%*
W3	0.99	*2%*	2.42	*30%*	2.20	*5%*	5.61	*18%*	$0.18	*12%*
W4	1.00	*1%*	2.33	*33%*	2.21	*5%*	5.54	*19%*	$0.18	*12%*

70% WWR



San Francisco | Commercial Office | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	1.10	-	3.91	-	2.54	-	7.55	-	$0.22	-
W2	1.10	*1%*	3.63	*7%*	2.50	*1%*	7.23	*4%*	$0.22	*3%*
W3	1.09	*1%*	2.86	*27%*	2.44	*4%*	6.39	*15%*	$0.20	*10%*
W4	1.10	*0%*	2.80	*28%*	2.45	*4%*	6.35	*16%*	$0.20	*10%*

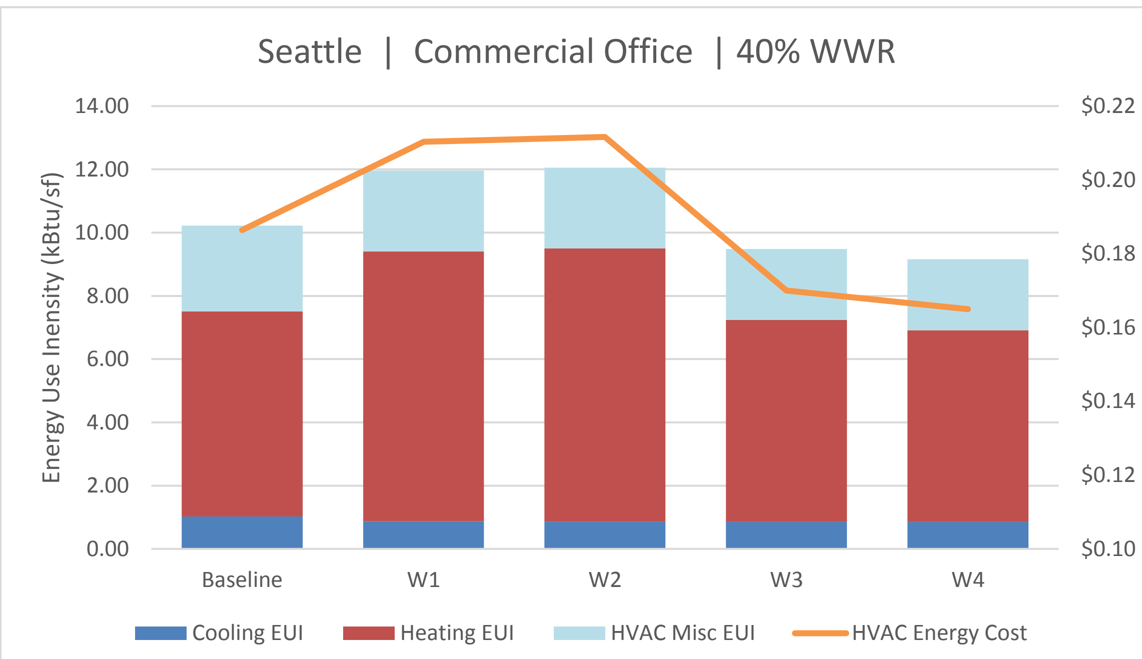
3.1.4 Seattle

The climate in Seattle is heating driven and therefore the CCAPP system performs the best in this region.

The heating dominated Seattle climate has a baseline that requires 3" of continuous insulation. For this reason, the CCAPP systems do not display as significant savings compared to the baseline envelope system. Under all WWR options assessed in the standard construction assemblies (W1 and W2) used more energy compared the CCAPP system (W1 & W2). The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~25% compared to typical construction assemblies (W1 & W2). In general, the addition 1" of continuous insulation included in W4 did not have a significant impact on building efficiency compared to W3.

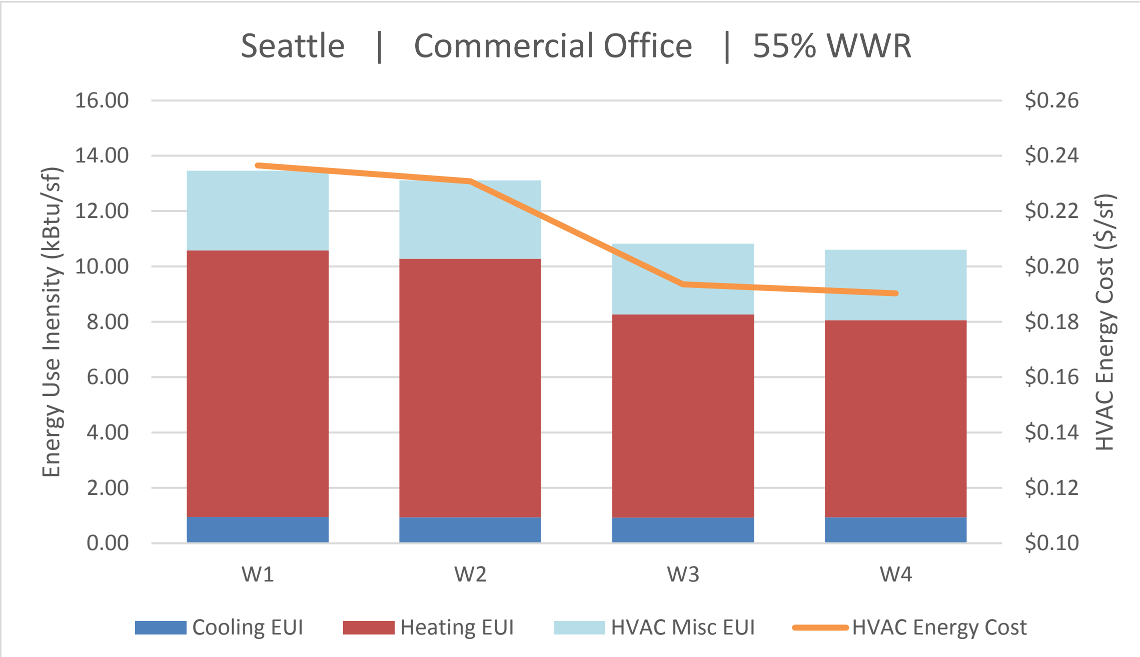
The CCAPP envelope system can reduce HVAC energy use/cost by up to 10-20% compared to conventional envelope designs. It is most effective on the building with higher WWR due to the higher performance windows.

40% WWR & Code Baseline



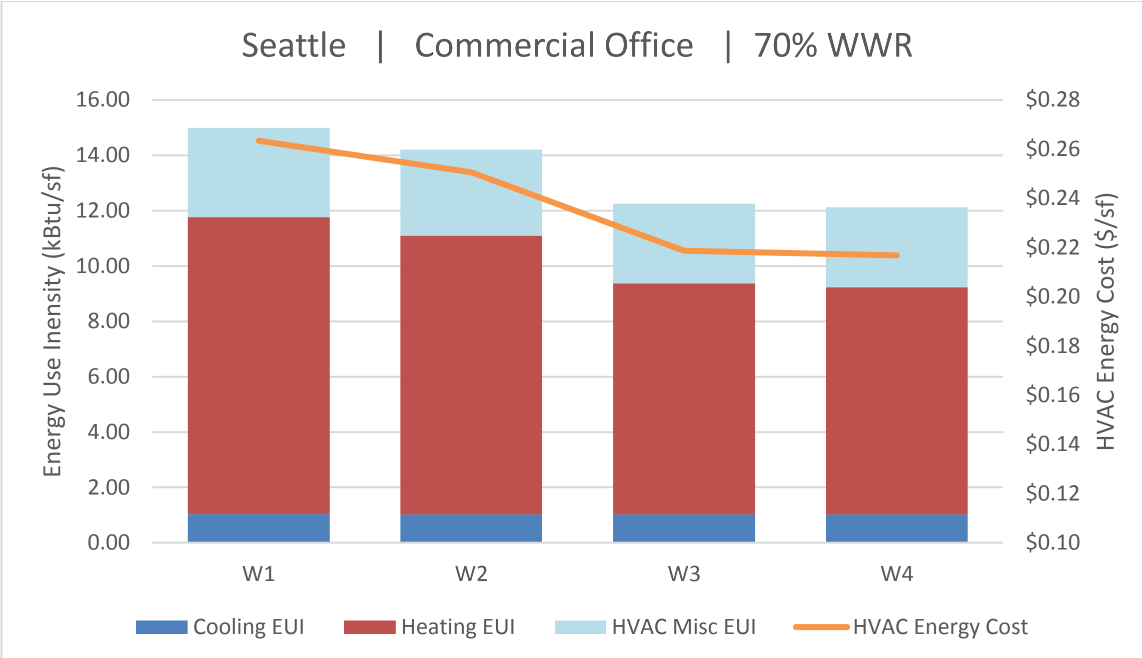
Seattle | Commercial Office | 40% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	1.02	-	6.49	-	2.71	-	10.22	-	$0.19	-
W1	0.87	*15%*	8.53	*-32%*	2.55	*6%*	11.96	*-17%*	$0.21	*-13%*
W2	0.87	*15%*	8.64	*-33%*	2.55	*6%*	12.05	*-18%*	$0.21	*-14%*
W3	0.85	*17%*	6.38	*2%*	2.25	*17%*	9.49	*7%*	$0.17	*9%*
W4	0.85	*17%*	6.06	*7%*	2.24	*17%*	9.16	*10%*	$0.16	*11%*

55% WWR



Seattle | Commercial Office | 55% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	0.95	-	9.63	-	2.88	-	13.46	-	$0.24	-
W2	0.94	*1%*	9.34	*3%*	2.83	*2%*	13.11	*3%*	$0.23	*2%*
W3	0.93	*2%*	7.34	*24%*	2.56	*11%*	10.83	*20%*	$0.19	*18%*
W4	0.94	*2%*	7.12	*26%*	2.55	*11%*	10.61	*21%*	$0.19	*20%*

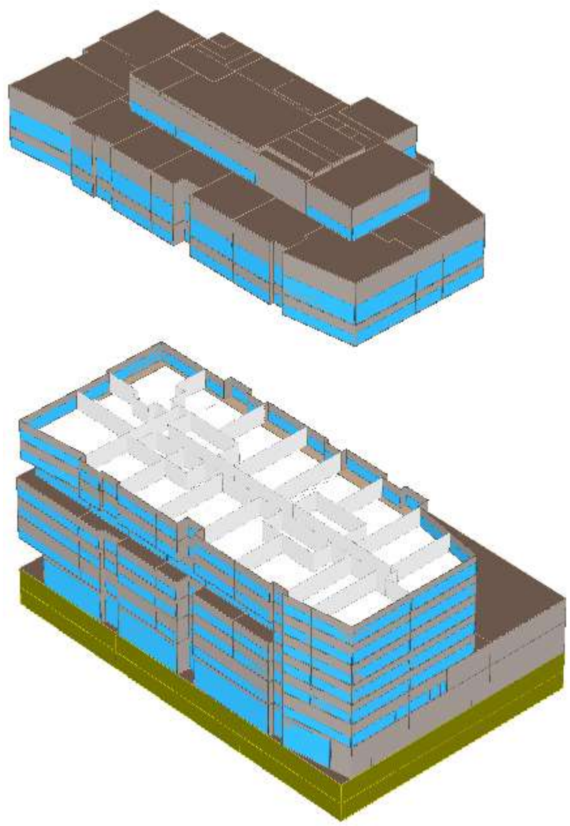
70% WWR



Seattle | Commercial Office | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	1.03	-	10.73	-	3.22	-	14.99	-	$0.26	-
W2	1.03	*1%*	10.06	*6%*	3.12	*3%*	14.21	*5%*	$0.25	*5%*
W3	1.02	*2%*	8.35	*22%*	2.88	*11%*	12.25	*18%*	$0.22	*17%*
W4	1.03	*1%*	8.21	*23%*	2.88	*11%*	12.12	*19%*	$0.22	*18%*

4 RESIDENTIAL BUILDING RESULTS

The comparative residential building utilized in this study is a 26-story, 435,000 square foot, high-rise residential building, with two stories of underground parking. The ground and first floor podium consist of retail and office spaces, and a 24-story residential tower above includes of a range of studio, one bedroom and two-bedroom apartment. The HVAC system conditioning the building was modeled after the ASHRAE 90.1 Appendix G system type and is representative of a typical HVAC system for a high-rise residential building of this size. All modeled parameters are identified below the Results section. In order to reduce energy model simulation duration, multipliers were applied to common residential level, as outline in the Figure below.



4.1 Simulation Results

Results will be organized by Climate Zone and then the modeled Window-Wall-Ratio (WWR).

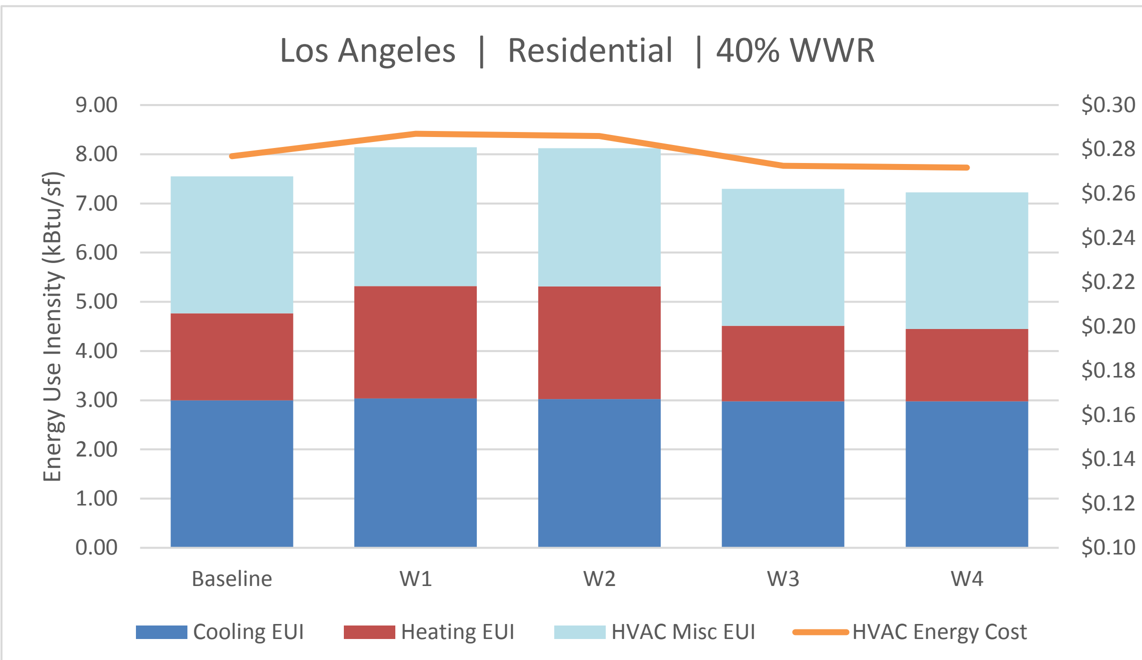
4.1.1 Los Angeles

The climate in Los Angeles is primarily cooling. There were benefits for adding the CCAPP system for all WWR scenarios that were assessed. Although the benefits are great for buildings with a higher WWR.

The energy usage for W1 and W2 are worse than the baseline Title 24 envelope design for the 40% WWR building. The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~30% compared to typical construction assemblies (W1 & W2). The CCAPP system had a minimal impact on reducing cooling and miscellaneous HVAC energy use. In general, the addition 1" of continuous insulation included in W4 does not have a significant impact compared to W3 in Los Angeles.

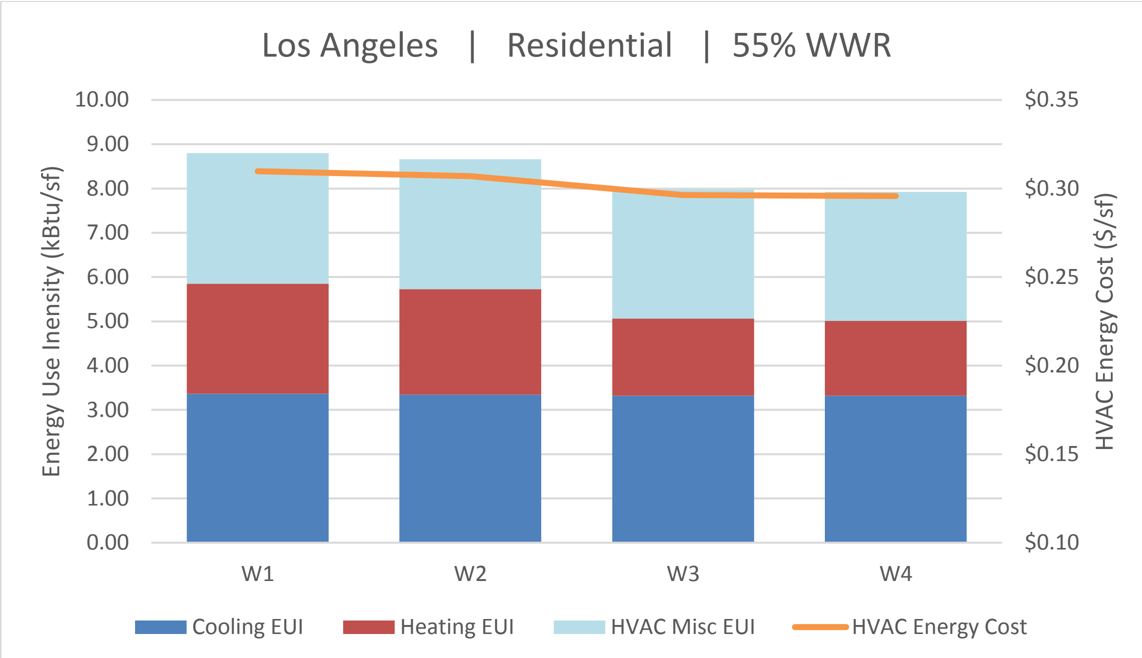
The HVAC EUI and energy cost for a CCAPP system are roughly 10% lower compared to standard constructions and 5% lower compared Title 24 prescriptive baseline constructions.

40% WWR & Code Baseline



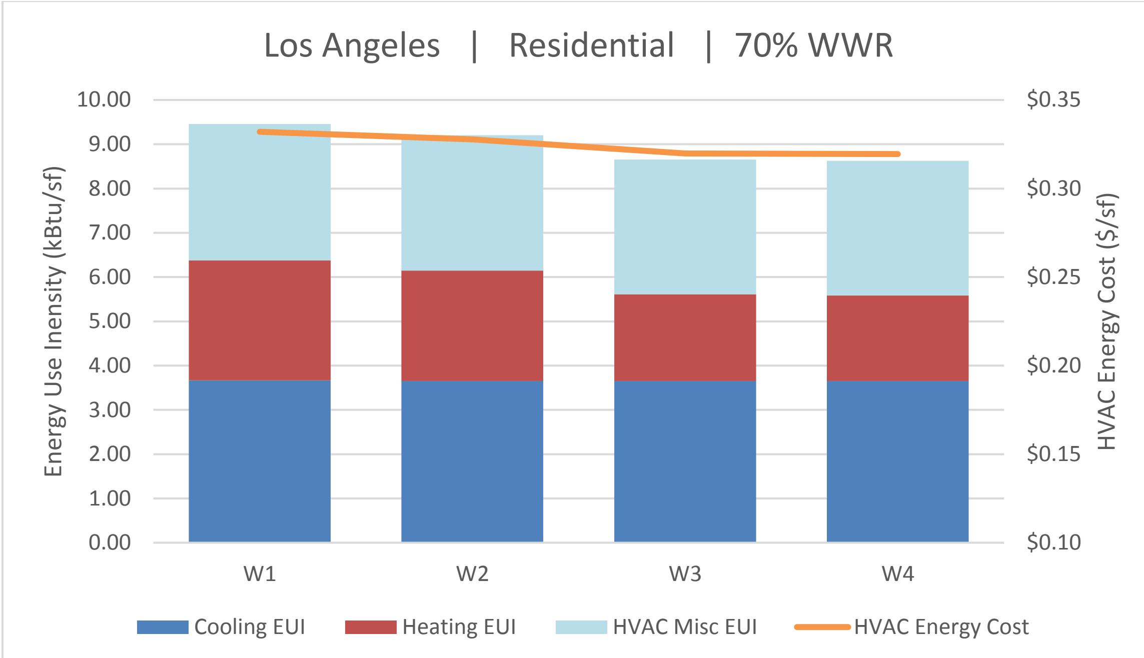
Los Angeles | Residential | 40% WWR										
	Cooling EUI		Heating EUI		HVAC Misc EUI		HVAC EUI		Energy Cost	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	3.00	-	1.77	-	2.79	-	7.55	-	$0.28	-
W1	3.04	*-1%*	2.28	*-29%*	2.82	*-1%*	8.14	*-8%*	$0.29	*-4%*
W2	3.02	*-1%*	2.29	*-30%*	2.81	*-1%*	8.12	*-8%*	$0.29	*-3%*
W3	2.98	*1%*	1.54	*13%*	2.78	*0%*	7.29	*3%*	$0.27	*2%*
W4	2.98	*1%*	1.47	*17%*	2.78	*0%*	7.23	*4%*	$0.27	*2%*

55% WWR



Los Angeles | Residential | 55% WWR										
	Cooling EUI		Heating EUI		HVAC Misc EUI		HVAC EUI		Energy Cost	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	3.36	-	2.49	-	2.95	-	8.80	-	$0.31	-
W2	3.34	*1%*	2.38	*4%*	2.94	*0%*	8.66	*2%*	$0.31	*1%*
W3	3.32	*1%*	1.74	*30%*	2.91	*1%*	7.97	*9%*	$0.30	*4%*
W4	3.32	*1%*	1.69	*32%*	2.91	*1%*	7.92	*10%*	$0.30	*5%*

70% WWR



Los Angeles | Residential | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	*%*	kBtu/sf	*%*	kBtu/sf	*%*	kBtu/sf	*%*	$/sf	*%*
W1	3.67	-	2.71	-	3.08	-	9.46	-	$0.33	-
W2	3.66	*0%*	2.49	*8%*	3.06	*1%*	9.21	*3%*	$0.33	*1%*
W3	3.65	*0%*	1.96	*28%*	3.04	*1%*	8.65	*9%*	$0.32	*4%*
W4	3.66	*0%*	1.93	*29%*	3.04	*1%*	8.62	*9%*	$0.32	*4%*

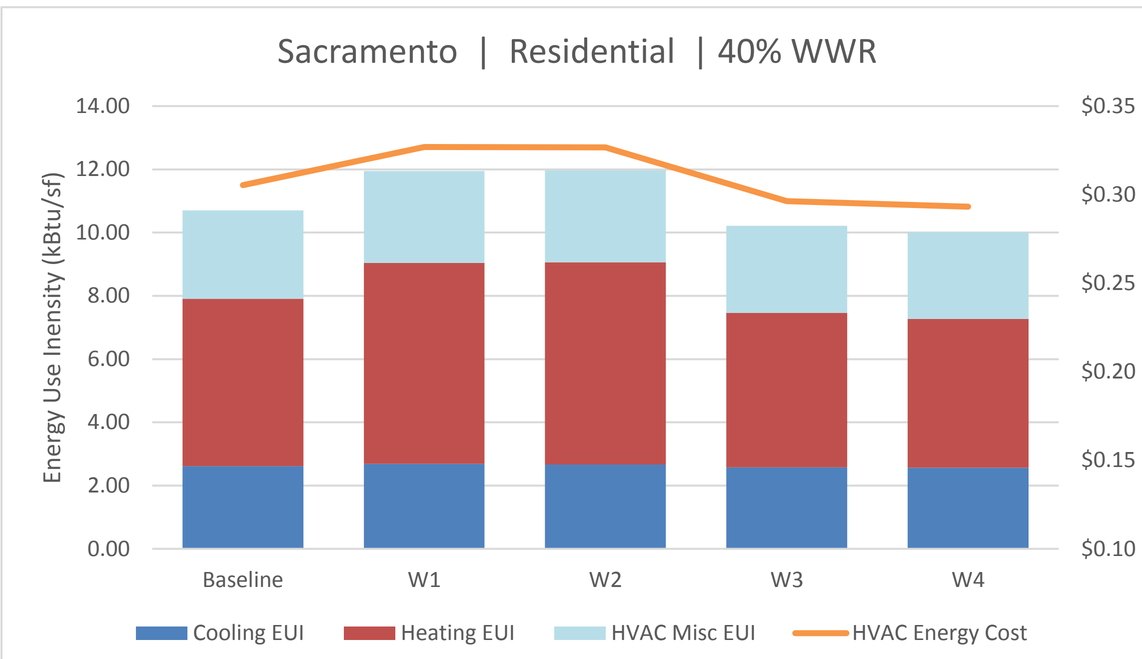
4.1.2 Sacramento

The climate in Sacramento is evenly driven by cooling and heating energy. Sacramento both experiences warm weather in the summer and cooler temperatures in winter. Residential buildings which operate 24/7 will use more energy to heat the building than to cool it.

Under all WWR options assessed in the standard construction assemblies (W1 and W2) used more energy compared the CCAPP system (W1 & W2). The CCAPP systems performed better than the baseline Title 24 envelope with a 40% WWR. The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~20-25% compared to typical construction assemblies (W1 & W2). In general, the addition 1" of continuous insulation included in W4 did not have a significant impact on building efficiency compared to W3.

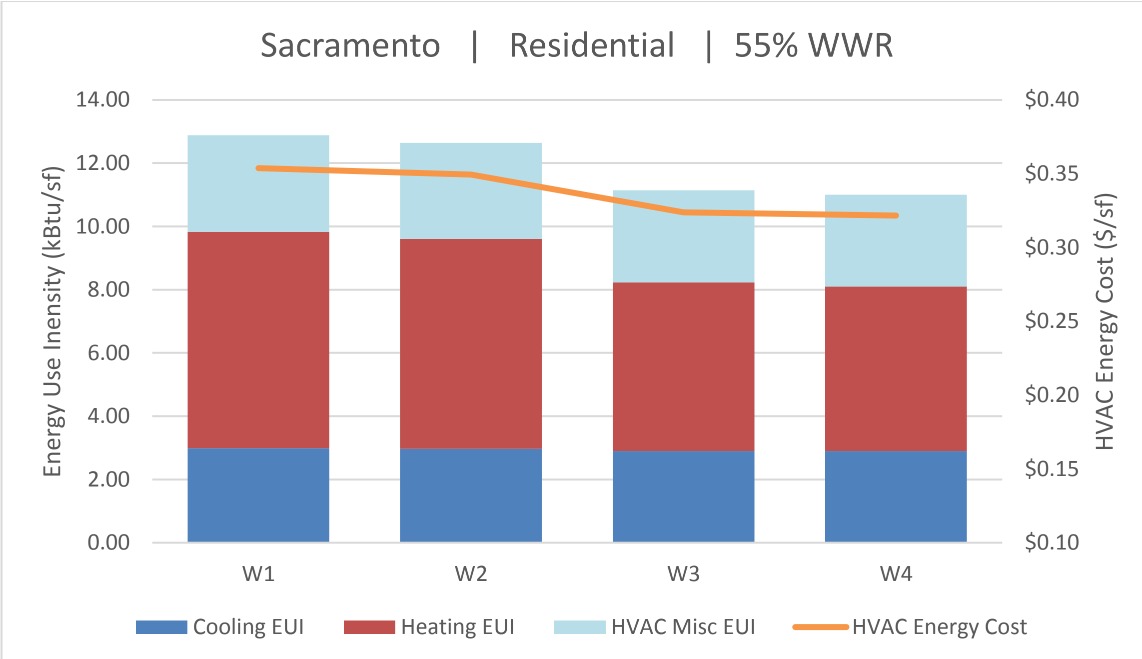
The HVAC EUI and energy cost for a CCAPP system are roughly 13% lower compared to standard constructions and 5% lower compared Title 24 prescriptive baseline constructions.

40% WWR & Code Baseline



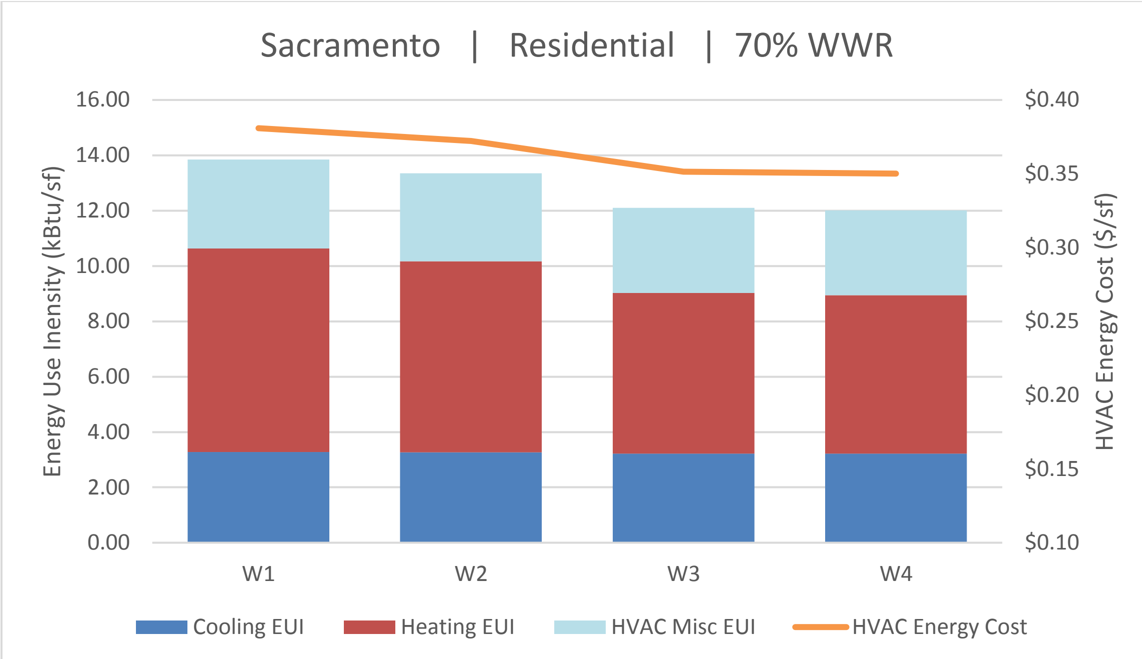
Sacramento | Residential | 40% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	2.61	-	5.29	-	2.80	-	10.70	-	$0.31	-
W1	2.68	*-3%*	6.36	*-20%*	2.90	*-4%*	11.94	*-12%*	$0.33	*-7%*
W2	2.67	*-2%*	6.39	*-21%*	2.90	*-4%*	11.96	*-12%*	$0.33	*-7%*
W3	2.57	*2%*	4.89	*8%*	2.76	*1%*	10.21	*5%*	$0.30	*3%*
W4	2.57	*2%*	4.70	*11%*	2.75	*2%*	10.02	*6%*	$0.29	*4%*

55% WWR



Sacramento | Residential | 55% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	2.99	-	6.85	-	3.05	-	12.89	-	$0.35	-
W2	2.97	*1%*	6.64	*3%*	3.04	*1%*	12.64	*2%*	$0.35	*1%*
W3	2.90	*3%*	5.33	*22%*	2.92	*4%*	11.15	*13%*	$0.32	*8%*
W4	2.89	*3%*	5.20	*24%*	2.91	*5%*	11.01	*15%*	$0.32	*9%*

70% WWR



Sacramento | Residential | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	3.28	-	7.35	-	3.22	-	13.85	-	$0.38	-
W2	3.26	*1%*	6.91	*6%*	3.18	*1%*	13.35	*4%*	$0.37	*2%*
W3	3.22	*2%*	5.81	*21%*	3.08	*4%*	12.10	*13%*	$0.35	*8%*
W4	3.22	*2%*	5.72	*22%*	3.07	*5%*	12.01	*13%*	$0.35	*8%*

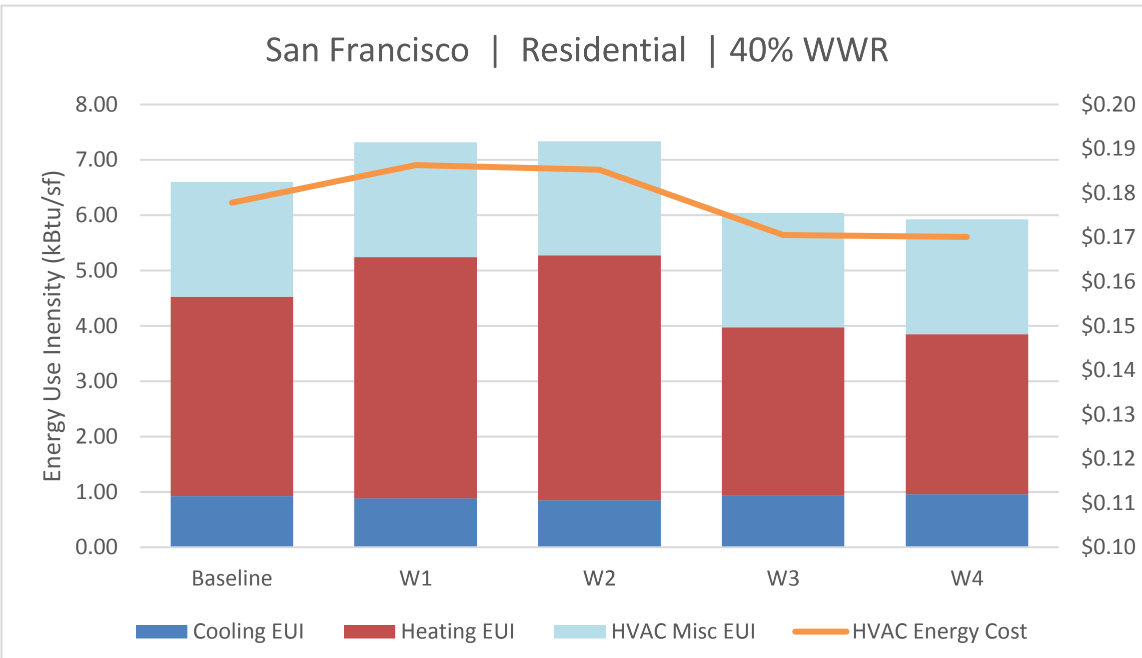
4.1.3 San Francisco

San Francisco's climate is very temperate. Heating is required in winter months, with limited solar heat gains during these periods.

Under all WWR options assessed in the standard construction assemblies (W1 and W2) used more energy compared the CCAPP system (W1 & W2). The CCAPP systems performed better than the baseline Title 24 envelope with a 40% WWR. The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~30% compared to typical construction assemblies (W1 & W2). In general, the addition 1" of continuous insulation included in W4 did not have a significant impact on building efficiency compared to W3.

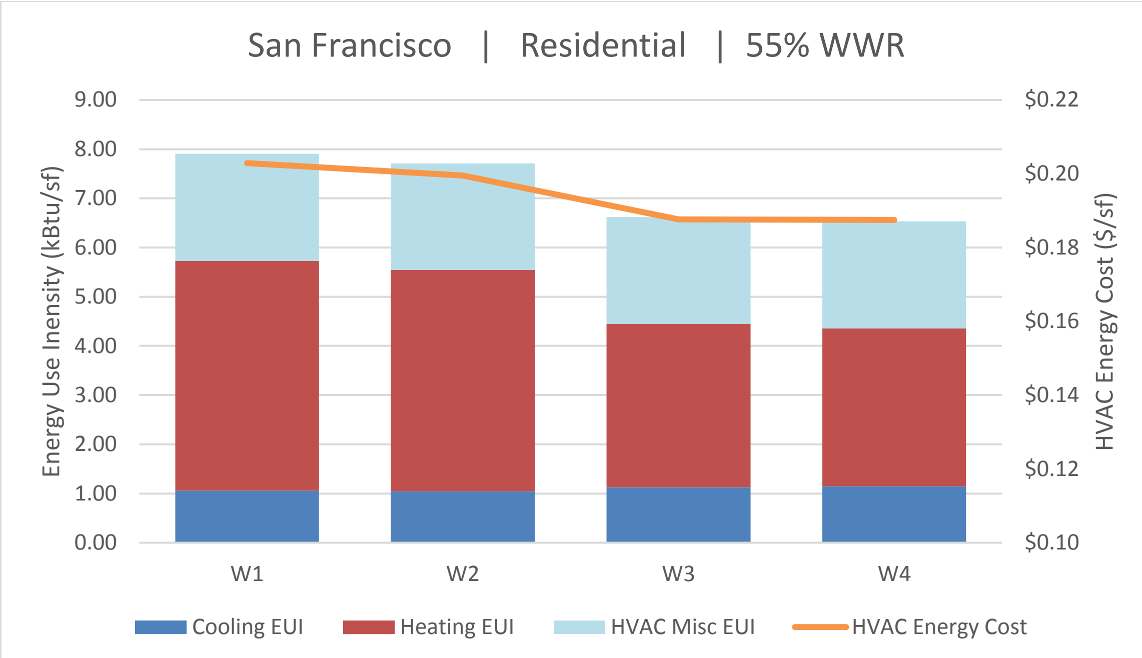
The HVAC EUI and energy cost for the CCAPP system is roughly 10-15% lower compared to standard constructions and 10% lower compared Title 24 prescriptive baseline constructions. It is most effective on the building with higher WWR due to the higher performance windows.

40% WWR & Code Baseline



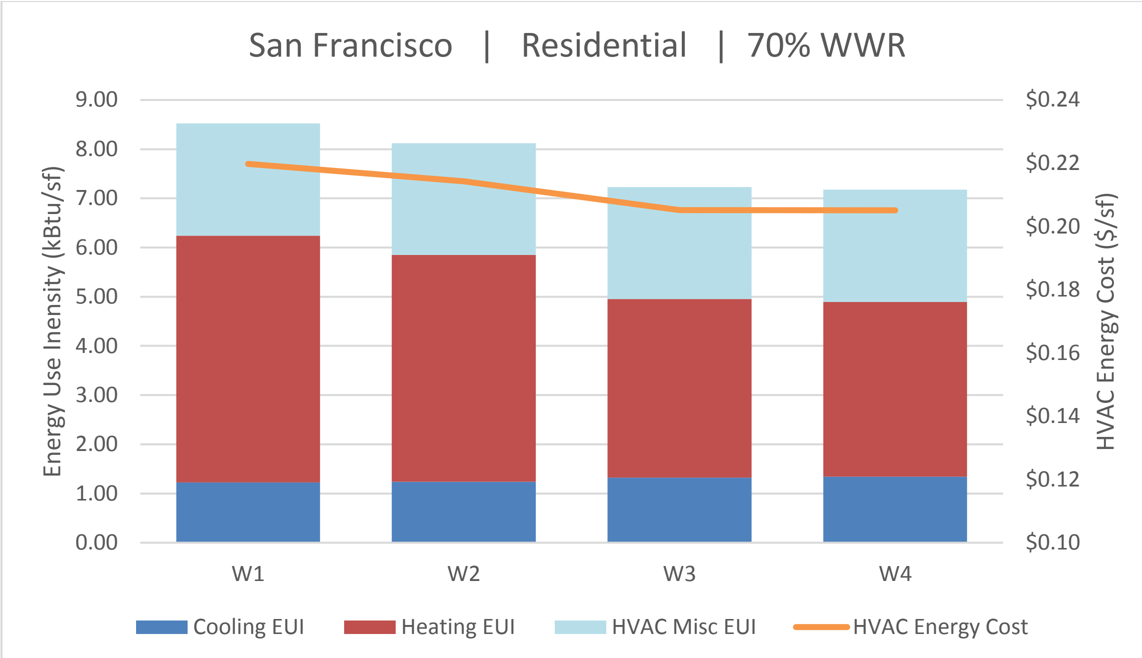
San Francisco | Residential | 40% WWR										
	Cooling EUI		Heating EUI		HVAC Misc EUI		HVAC EUI		Energy Cost	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	0.92	-	3.61	-	2.07	-	6.60	-	$0.18	-
W1	0.88	*4%*	4.36	*-21%*	2.08	*0%*	7.32	*-11%*	$0.19	*-5%*
W2	0.85	*8%*	4.42	*-23%*	2.07	*0%*	7.34	*-11%*	$0.19	*-4%*
W3	0.93	*-1%*	3.04	*16%*	2.07	*0%*	6.04	*8%*	$0.17	*4%*
W4	0.96	*-4%*	2.89	*20%*	2.08	*0%*	5.93	*10%*	$0.17	*4%*

55% WWR



San Francisco | Residential | 55% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	1.06	-	4.67	-	2.18	-	7.91	-	$0.20	-
W2	1.05	*1%*	4.50	*4%*	2.17	*1%*	7.71	*2%*	$0.20	*2%*
W3	1.13	*-7%*	3.32	*29%*	2.17	*0%*	6.62	*16%*	$0.19	*8%*
W4	1.15	*-9%*	3.20	*31%*	2.18	*0%*	6.54	*17%*	$0.19	*8%*

70% WWR



San Francisco | Residential | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	1.23	-	5.01	-	2.28	-	8.53	-	$0.22	-
W2	1.24	*-1%*	4.61	*8%*	2.27	*1%*	8.12	*5%*	$0.21	*2%*
W3	1.33	*-8%*	3.63	*28%*	2.28	*0%*	7.23	*15%*	$0.21	*7%*
W4	1.34	*-9%*	3.55	*29%*	2.28	*0%*	7.17	*16%*	$0.21	*7%*

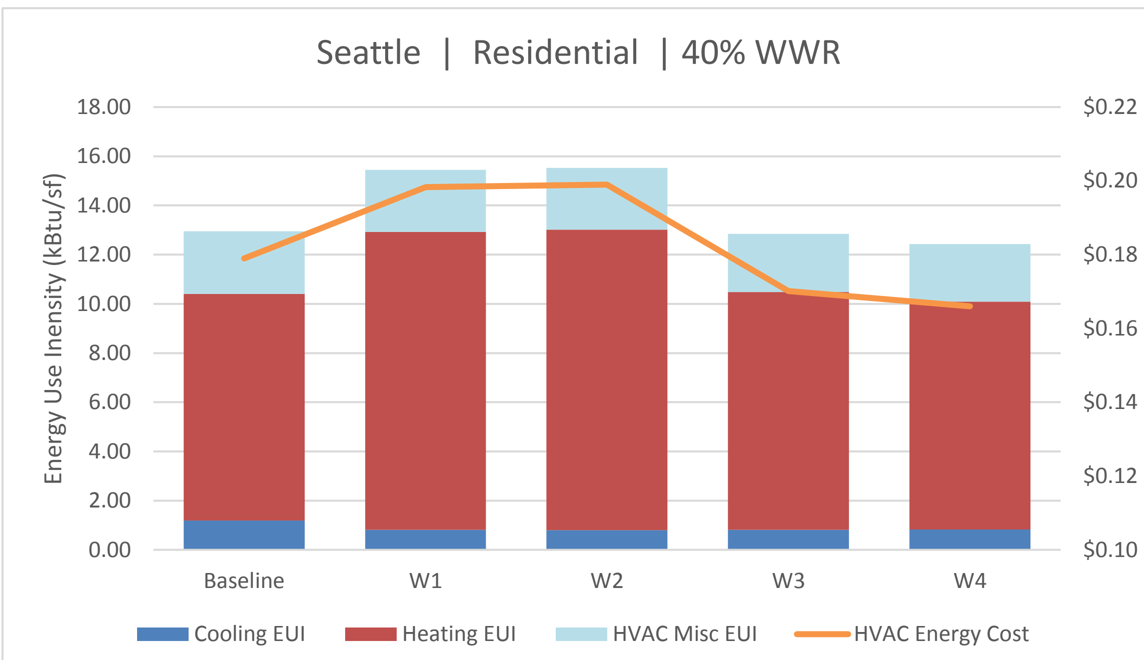
4.1.4 Seattle

The climate in Seattle is heating driven and therefore the CCAPP system performs the best in this region.

The heating dominated Seattle climate has a baseline that requires 3” of continuous insulation. For this reason, the CCAPP systems do not display as significant savings compared to the baseline envelope system. Under all WWR options assessed in the standard construction assemblies (W1 and W2) used more energy compared the CCAPP system (W1 & W2). The CCAPP systems perform better than the other envelope options by reducing the amount of heating energy by ~20% compared to typical construction assemblies (W1 & W2). In general, the addition 1” of continuous insulation included in W4 did not have a significant impact on building efficiency compared to W3.

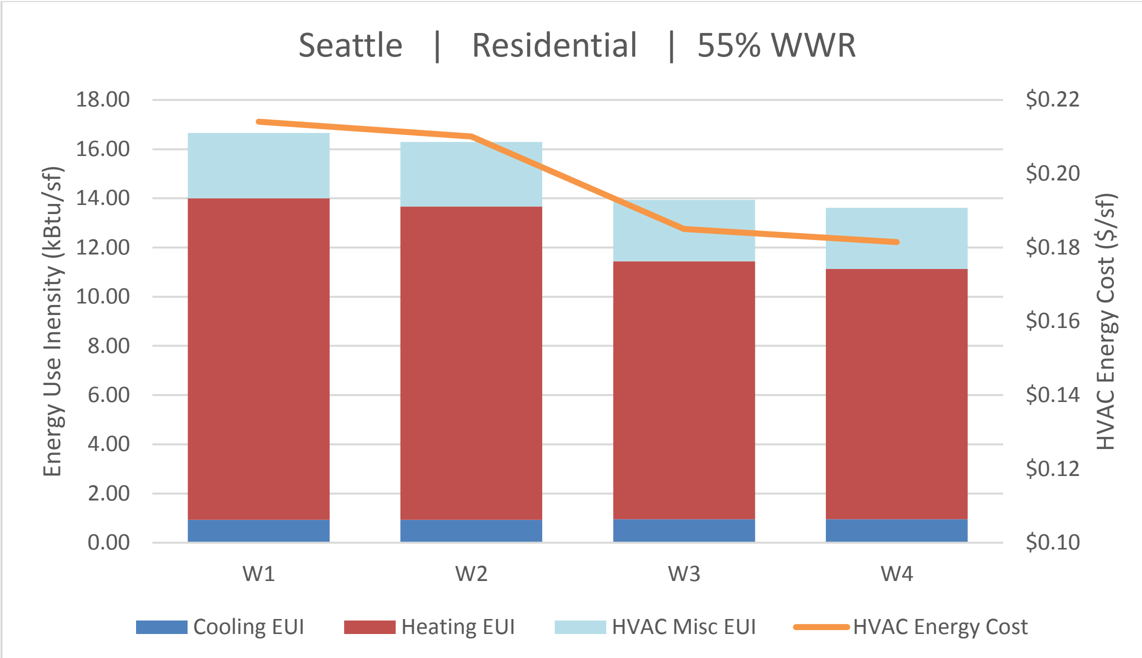
The HVAC EUI and energy cost for the CCAPP system is roughly 10-18% lower compared to standard constructions and 4% lower compared Seattle prescriptive baseline constructions. It is most effective on the building with higher WWR due to the higher performance windows

40% WWR & Code Baseline



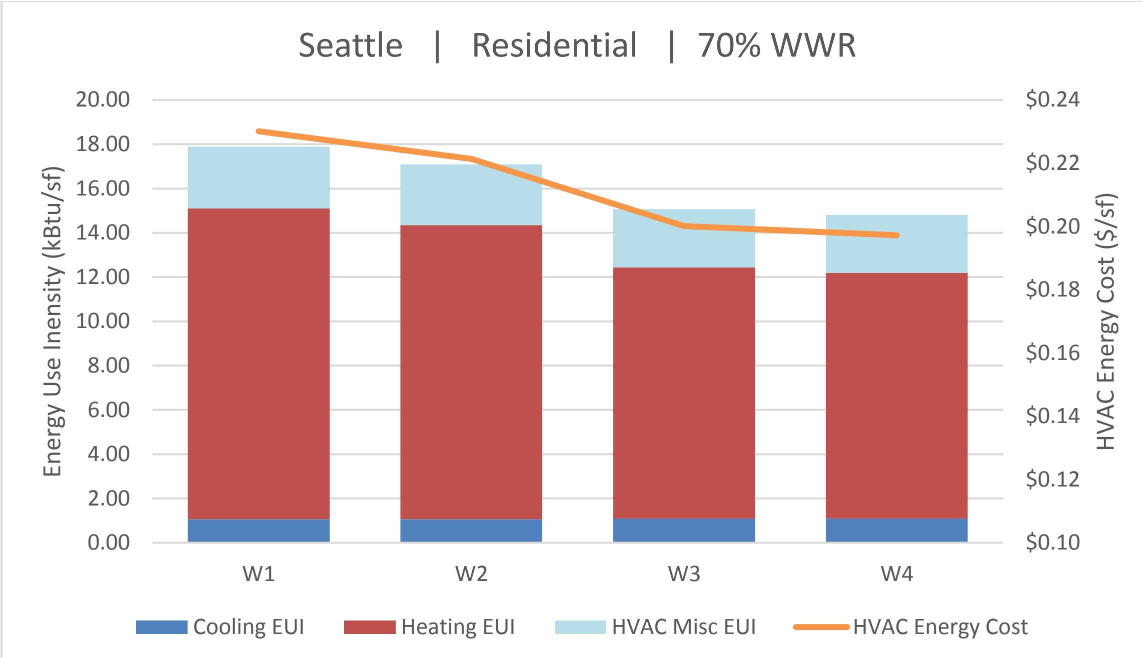
Seattle | Residential | 40% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
Baseline	1.19	-	9.21	-	2.55	-	12.95	-	$0.18	-
W1	0.81	*32%*	12.12	*-32%*	2.52	*1%*	15.44	*-19%*	$0.20	*-11%*
W2	0.80	*33%*	12.22	*-33%*	2.52	*1%*	15.53	*-20%*	$0.20	*-11%*
W3	0.82	*31%*	9.66	*-5%*	2.36	*7%*	12.84	*1%*	$0.17	*5%*
W4	0.83	*30%*	9.26	*-1%*	2.34	*8%*	12.44	*4%*	$0.17	*7%*

55% WWR



Seattle | Residential | 55% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	0.93	-	13.07	-	2.66	-	16.66	-	$0.21	-
W2	0.93	*0%*	12.73	*3%*	2.63	*1%*	16.30	*2%*	$0.21	*2%*
W3	0.96	*-3%*	10.49	*20%*	2.50	*6%*	13.94	*16%*	$0.19	*14%*
W4	0.96	*-3%*	10.17	*22%*	2.48	*7%*	13.61	*18%*	$0.18	*15%*

70% WWR



Seattle | Residential | 70% WWR										
	Cooling EUI		**Heating EUI**		**HVAC Misc EUI**		**HVAC EUI**		**Energy Cost**	
	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	kBtu/sf	%	$/sf	%
W1	1.06	-	14.04	-	2.79	-	17.89	-	$0.23	-
W2	1.06	*0%*	13.28	*5%*	2.75	*2%*	17.08	*5%*	$0.22	*4%*
W3	1.09	*-4%*	11.34	*19%*	2.63	*6%*	15.07	*16%*	$0.20	*13%*
W4	1.09	*-4%*	11.10	*21%*	2.61	*6%*	14.80	*17%*	$0.20	*14%*

5 GENERAL ENERGY MODEL PARAMETERS

This section outlines the information that was applied to both building types similarly, based on climate zone. This will include:

- Weather information
- Envelope construction properties
- Utility rates
- Economization limits
- Internal loads

The thermal properties of the roof, walls, floors, slabs and windows were evaluated and defined by climate zone per Title 24 Part 6, 2016 & Seattle Energy Code 2015.

The utility rates used in this study were estimated based on state wide average costs.

5.1 Climate Zones

Four (4) different climate zones were evaluated in this analysis:

- Climate Zone 1 - Sacramento, CA
    - *TMY3 - CA_Sacramento_Metropolitan*
- Climate Zone 2 - San Francisco, CA
    - *TMY3 - CA_San_Francisco_Intl_AP*
- Climate Zone 3 - Los Angeles, CA
    - *TMY3 - CA_Burbank-Glendale-Pasadena*
- Climate Zone 4 - Seattle, WA
    - *TM3 - WA_Seattle_Seattle-Tacoma*

Table 1 shows envelope properties, utility rates and mechanical design parameters, including economizer requirements and limit temperatures:

Table 1: General Modeling Parameters

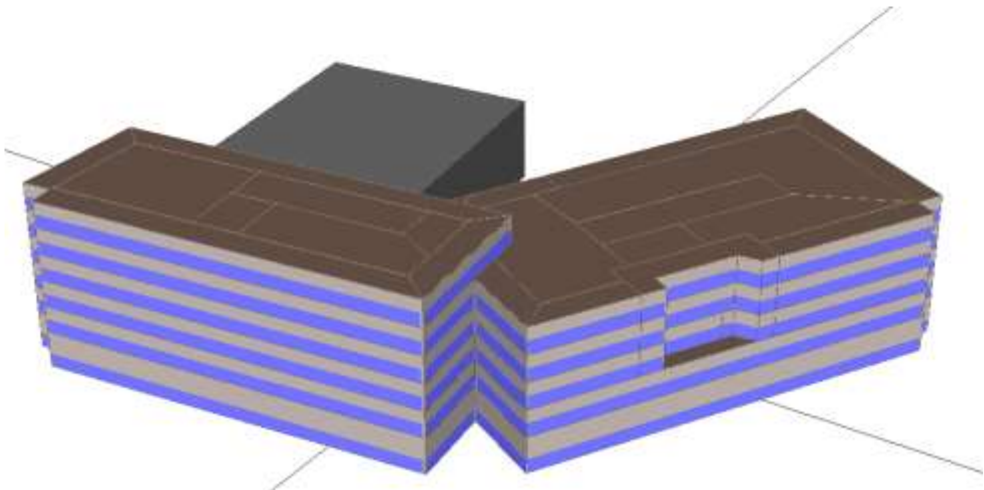
The following design parameters were used per ASHRAE design guidelines.

	Sacramento, CA	San Francisco, CA	Los Angeles, CA	Seattle, WA
Climate Zones	1A	2B	3C	5A
Humidity Type	Dry	Marine	Marine	
Temperature Type	Warm	Warm	Warm	Cool
Cooling Design Day DB (°F)	97	78	95	81
Cooling Design Day WB (°F)	68	62	69	64
Heating Design Day DB (°F)	30	37	39	23
Electricity ($/kWh)	$0.15	$0.15	$0.15	$0.08
Natural Gas ($/therm)	$0.85	$0.85	$0.85	$0.81

6 OFFICE ENERGY MODELING PARAMETERS

6.1 Building Geometry

This 6-story, boomerang-shaped office building is approximately 235,000 square feet. The following images provide a 3-D representation of the analyzed building.



6.2 Mechanical Systems

The mechanical system was based on construction documents from fully designed and constructed projects. The capacity and sizing of these systems were allowed to adjust based on changes to the design conditions in various climate zones. The office building is served by Variable Air Volume (VAV) boxes located in each thermal zone. Supply air for each zone is provided by Air Handling Units (AHUs), located on every level. Chilled water for each AHU is provided by two water cooled centrifugal chillers, which reject heat to a two cell, open cooling tower. Hot water for VAV reheat coils is provided by two natural gas condensing hot water boilers.

6.3 Internal Loads

Per ASHRAE 90.1-2013, ASHRAE 62.1-2013 ASHRAE Fundamentals Handbook and additional resources, the internal loads were compiled and used in models consistently throughout all building types, HVAC types and climate zones. As seen on the following page, Table 3 includes the following internal loads which were used in models: the lighting power density per space type (W/sf), equipment power density per space type (W/sf), ventilation by occupancy (cfm/ person), ventilation by area (cfm/ sf), people per 1000 ft, occupancy density (sf/ person), sensible heat per person and latent heat per person.

Space Type	LPD (w/sf)	EPD (w/sf)	OCC (sf/ person)	CFM/SF - OSA	Infiltration (ACH)	Sensible	Latent
Break Rooms	1.10	0.50	40	0.30	0.4	250	200
Conference	1.10	0.50	20	0.50	0.4	250	200
Corridor	0.50	0.20	300	0.15	0.4	250	200
Lobby	0.90	0.50	100	0.30	0.4	250	200
IDF/MDF/MPOE	0.60	5.00	-	-	0.4	250	200
Office	0.90	1.10	200	0.15	0.4	250	200

6.4 Schedules

The office building assumes a that the HVAC systems will operate from 7am to 7pm, Monday through Friday, and 4 hours total over the weekend for afterhours use. During these periods each zone has a cooling and heating setpoint of 75 F and 70 F respectively.

The lighting/ occupancy schedule assumed people in general work from 9am to 5pm with some people coming in early and some staying late. Occupancy over the weekend is limited to 4 hours on Saturday only. Building equipment schedules follow a similar trend to that of the occupancy schedules, however remain higher outside of business hour to account for computers and equipment remaining powered overnight.

The operating and HVAC schedules were kept constant for all simulations.

6.5 Envelope Assemblies

The following envelope assemblies were held consistent among all residential parametric simulations. The exterior wall and window values varied depending on the envelope system being assessed.

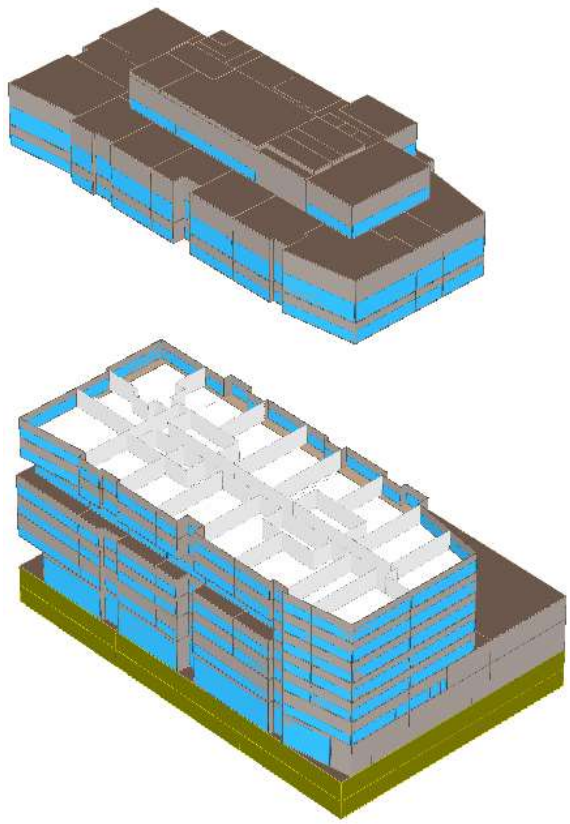
	Description	U-Factor
Roof	R-28 rigid insulation	0.034
Exterior Floor	R-8.4 c.i.	0.073

7 Residential Energy Modeling Parameters

7.1 Building Geometry

This 24-story, rectangular shaped building is approximately 53,000 square feet. It has a central corridor with apartments on either side. The window-to-wall ratio (WWR) is approximately 20%. The ASHRAE 90.1-2013, Table G3.1.1.1-1 can be found in the Appendix as a reference.

The following images provide a 3-D representation of the analyzed building. Multipliers were used for floors with similar floors plans.



7.2 Mechanical System

The mechanical system was based on construction documents from fully designed and constructed projects. The capacity and sizing of these systems were allowed to adjust based on changes to the design conditions in various climate zones.

Heating and cooling for the residential building is provided by a condenser water loop, which serves individual Water Source Heat Pumps (WSHP) in each residential unit. Outside air is provided to each WSHP from restroom exhaust fans through louvers on façade of the building. A constant volume, Dedicated Outside Air System (DOAS) provides ventilation for the corridors in the residential tower and contains a Direct Expansion (DX) refrigeration coil and a gas furnace for heating. The podium is served by constant volume, single zone water sources heat pumps which are provided ventilation air through directly through the façade.

7.3 Internal Loads

Per ASHRAE 90.1-2013, ASHRAE 62.1-2013 ASHRAE Fundamentals Handbook and additional resources, the internal loads were compiled and used in models consistently throughout all building types, HVAC types and climate zones. As seen on the following page, Table 3 includes the following internal loads which were used in models: the lighting power density per space type (W/sf), equipment power density per space type (W/sf), ventilation by occupancy (cfm/ person), ventilation by area (cfm/ sf), people per 1000 ft, occupancy density (sf/ person), sensible heat per person and latent heat per person.

Space Type	LPD (w/sf)	EPD (w/sf)	sf/ person	OSA (CFM/SF)	Infiltration (ACH)	Sensible	Latent
Apartment	0.91	1.25	378	0.12	0.4	250	200
Amenity Space	0.60	1.00	30	0.3	0.4	250	200
Conference	1.46	1.00	30	0.5	0.4	250	200
Corridor	1.14	0.20	100	0.15	0.4	250	200
Lobby	0.67	0.50	30	0.3	0.4	250	200
Mechanical / Electrical	0.80	3.00	-	0.15	0.4	250	200
Office	0.97	1.00	100	0.2	0.4	250	200
Parking	0.11	-	-	0.15	0.4	250	200
Retail	1.20	1.00	30	0.23	0.4	250	200
Stair	0.36	-	-	-	0.4	250	200
Storage	0.36	-	-	-	0.4	250	200

7.4 Schedules

The residential building schedules were based on the EnergyStar Multifamily energy modeling guidelines. This assumes an occupancy schedule typical of a residential property, with maximum occupancy overnight and at the weekend. Equipment and lighting schedules follow a similar trend to that of the occupancy schedules. The podium level operates on a number of different schedule representing retail and office operating hours.

The residential WSHPs are is scheduled to operate constantly and maintain a cooling and heating setpoint of 75 F and 70 F respectively. The operating and HVAC schedules were kept constant for all simulations.

7.5 Envelope Assemblies

The following envelope assemblies were held consistent among all residential parametric simulations. The exterior wall and window values varied depending on the envelope system being assessed.

	Description	U-Factor
Roof	R-28 rigid insulation	0.034
Exterior Floor	R-8.4 c.i.	0.073