Designing for Net Zero Energy Building Using Energy Modeling

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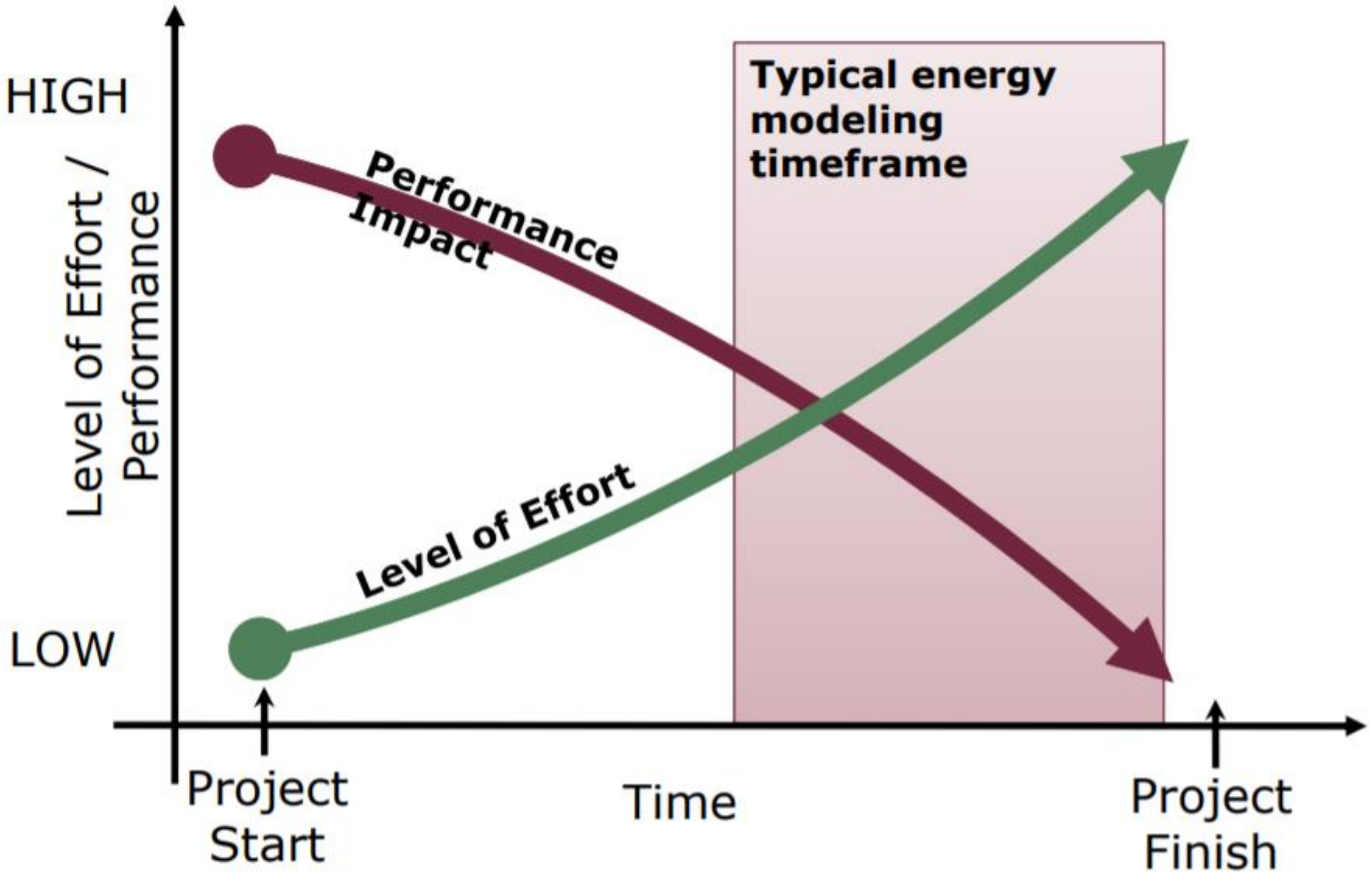
KARPMAN CONSULTING

The AIA 2030 Commitment 2014 Progress Report - Takeaways

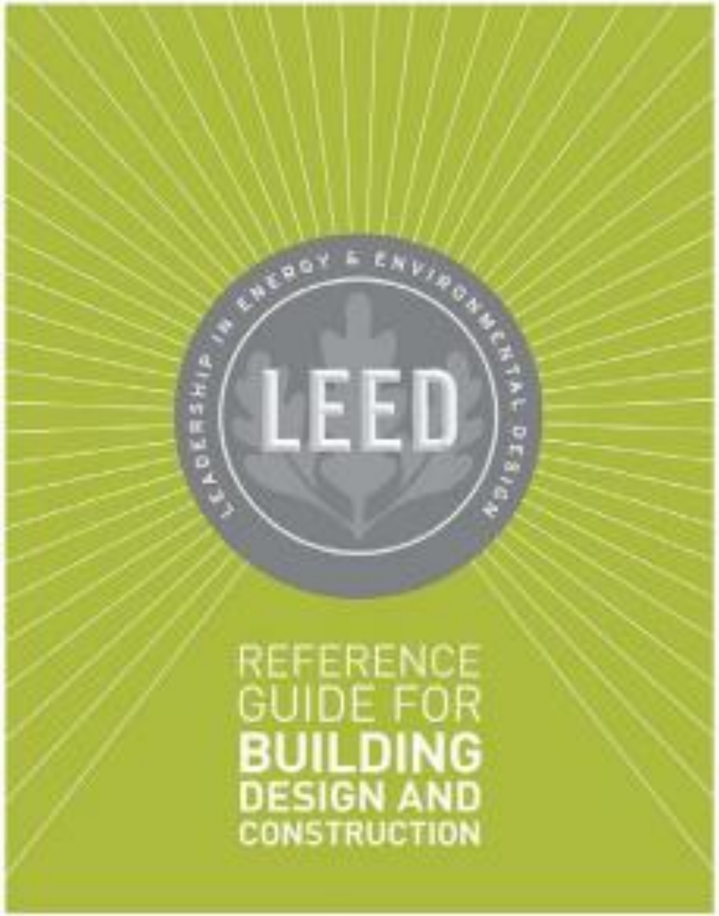
"…… A standout finding from 2015 is the **critical role of energy modeling** in improving building design. Modeling **early in the process** helps ensure that there is greater interplay in the decision making between efficiency and aesthetics from the initial stages of a project. This negates the need to either undo design decisions that have already been made in exchange for improved performance, or altogether forgo those options because the project is too far down the road."

When is Energy Modeling Typically Used?



Energy Modeling to Achieve Net Zero

- The responsibility of the building energy modeler is to inform project design decisions that affect building energy performance.
  - Site, Exposure & Building Shape Optimization
  - Operational Parameters
  - Thermal Envelope & Air Tightness
  - Advanced Lighting Designs, Daylighting & Controls
  - Process Energy Reduction
  - High Performance HVAC Systems & Controls
  - Ventilation Strategies
  - Service Hot Water Improvements
  - Renewable Systems
- LEED v4 Integrative Process Credit
  - By the end of SDs, use “simple box” energy model to explore how to reduce energy loads.



BSR/ASHRAE Standard 209P

Public Review Draft

Energy Simulation Aided Design for Buildings except Low-Rise Residential Buildings

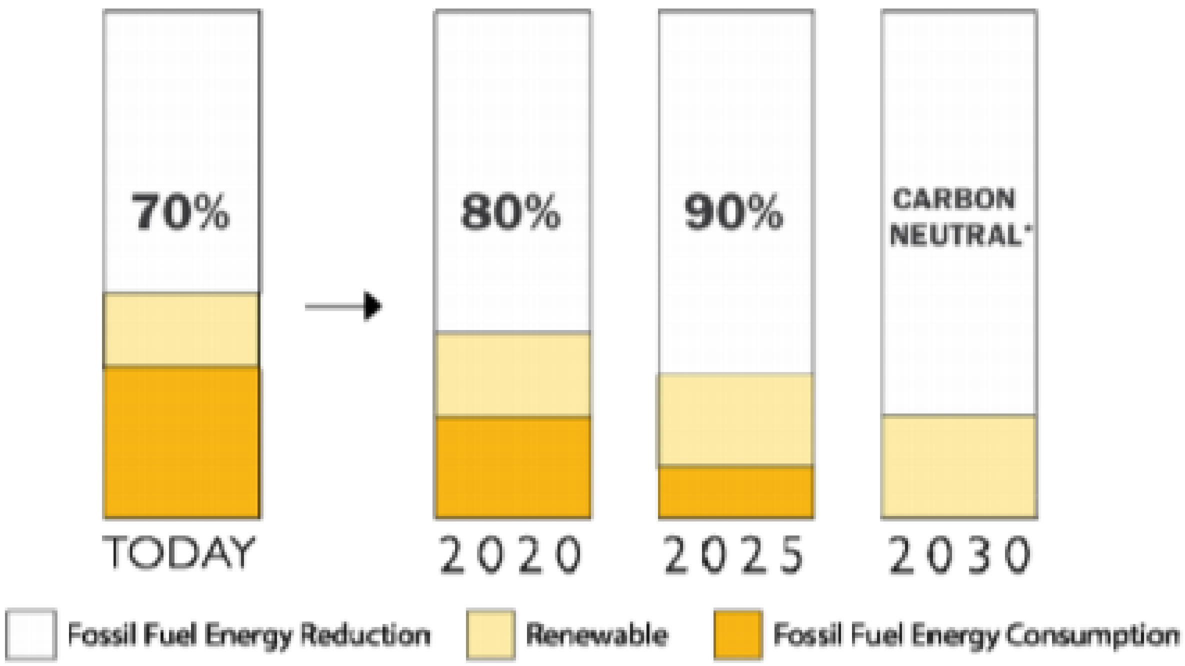
- Describes a methodology to apply building energy modeling to the design process
- Recognizes that building energy simulation is most useful when it informs the design process
- Created to advance the use of timely building energy modeling to quantify how design decisions can affect building energy use when those design decisions are being made

Standard 209 Structure

- Climate & Site Analysis
- Benchmarking
- Energy Charette
- Energy Performance Goals in Owners Project Requirements
- Modeling Cycle Types
  - Simple Box & Conceptual Design
  - Load Reduction
  - HVAC System Selection & Mapping
  - Design Refinement, Integration & Optimization
  - Energy Simulation Aided Value Engineering
  - As-Designed Energy Performance
  - Addendum/Change Orders
  - As-Built Energy Performance
  - Post-Occupancy Energy Performance Comparison (M&V)

Benchmarking & Energy Goals

- Determine expected Site EUI (kBtu/SF) for code compliant design based on building type.
- Evaluate which energy end uses are expected to be largest energy consumers.
- Does the project have a ceiling for renewable energy capacity?
- Does owner have a targeted EUI prior to renewables?



CBEC Typical Energy by End Use by Building Type (kbtu/ft^2)

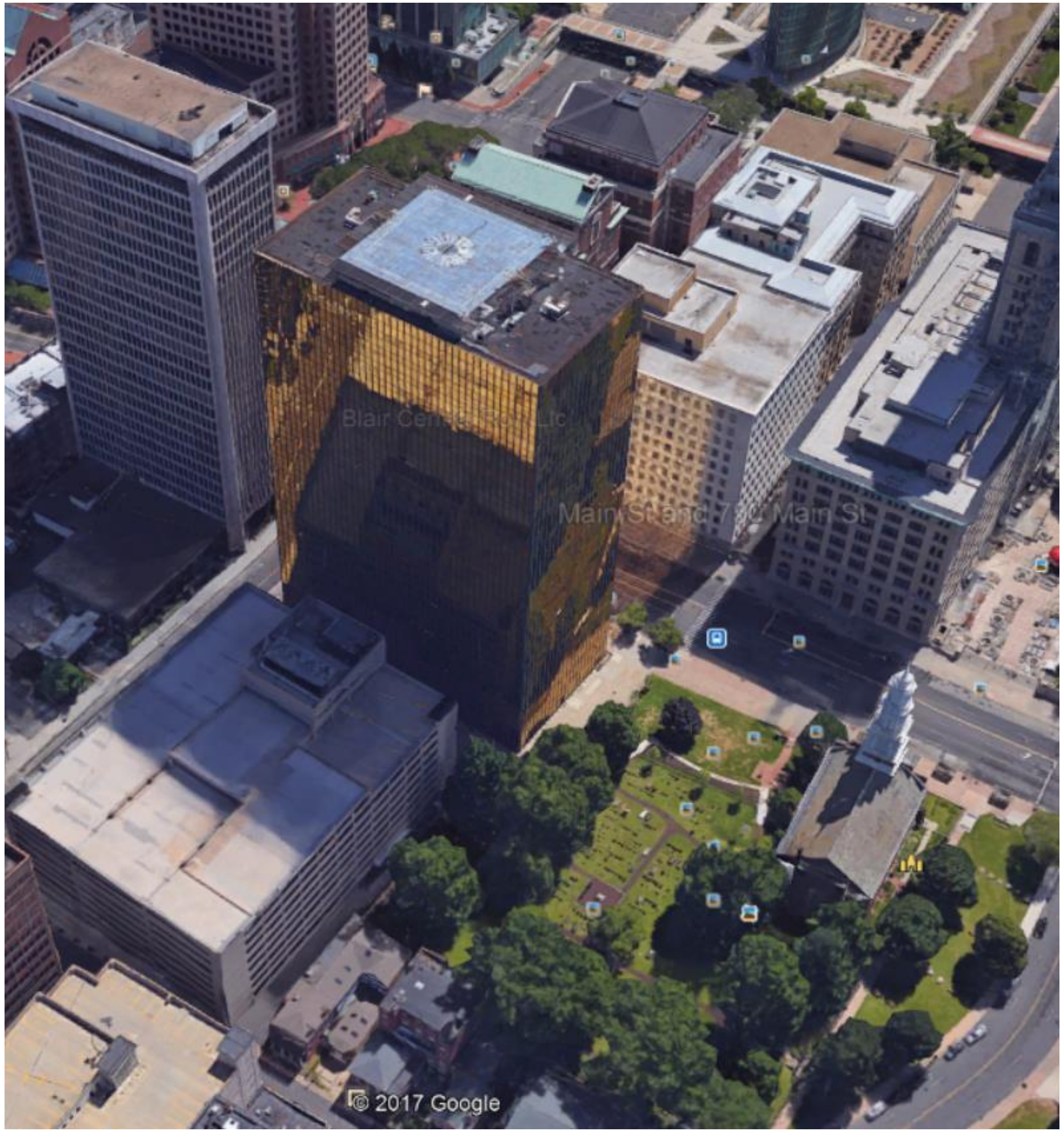
	Space Heating	Cooling	Ventilation	Water Heating	Lighting	Process & Plug	Total
Education	39.4	8.0	8.4	5.8	11.5	10.1	83.2
Food Sales	28.9	9.8	5.9	2.9	36.7	115.6	199.8

Energy Simulation Aided Design for Buildings: Process Flow

- **Conceptual Design**
  - #1 Simple Box Modeling
  - #2 Conceptual Design Modeling
- **Schematic Design**
  - #3 Load Reduction Modeling
  - #4 HVAC System Selection
- **Design Development**
  - #5 Design Refinement
  - #6 Integration & Optimization
- **Construction Documents**
  - #7 Energy-Simulation-Aided Value Engineering

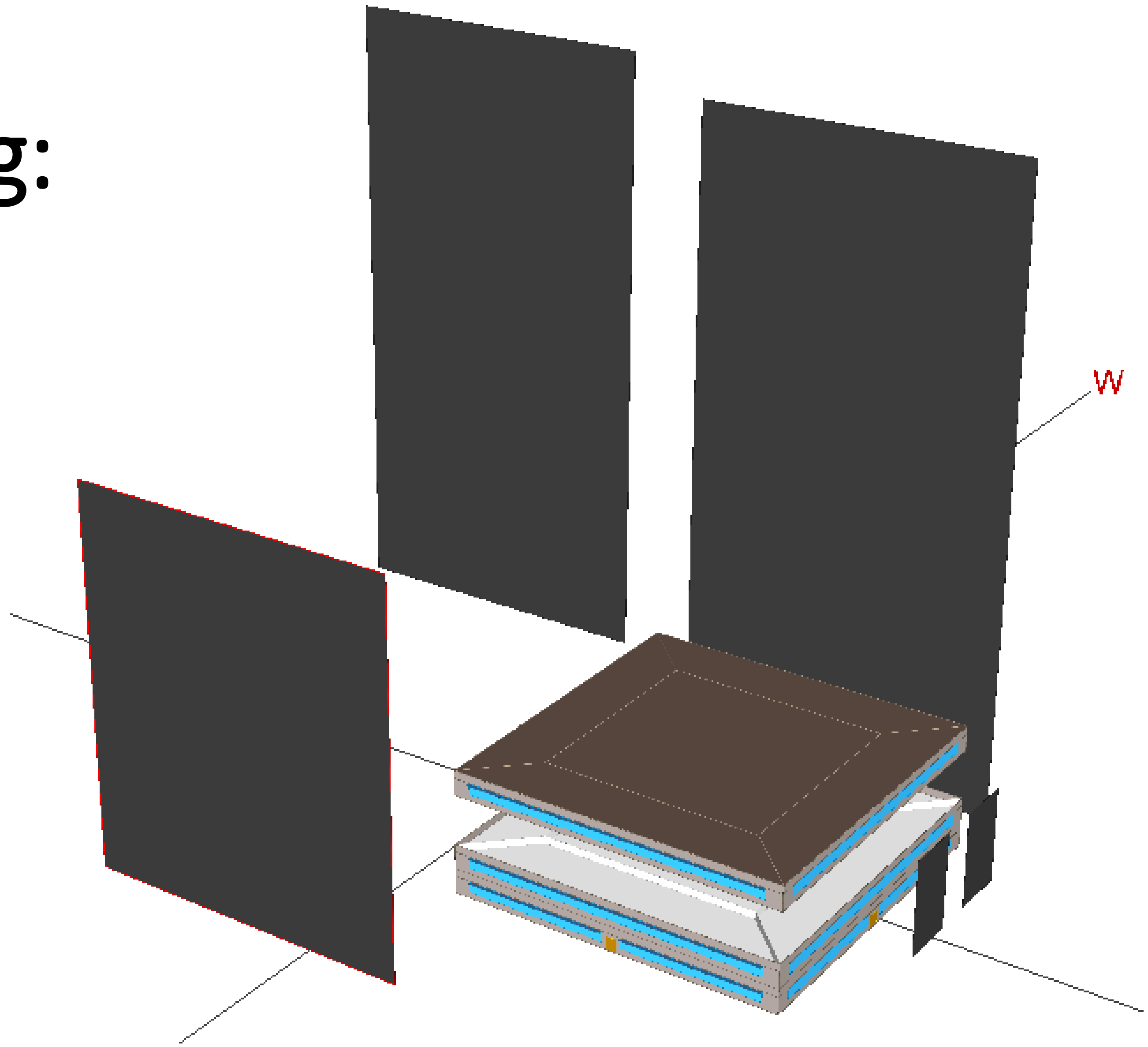
Site Analysis Modeling: Shading by Adjacent Structures

- Evaluate the energy impacts of surrounding structures.
- Case study of shading effects by One Financial Plaza building in downtown Hartford.
- Building to be analyzed highlighted includes electric heat & daylighting controls



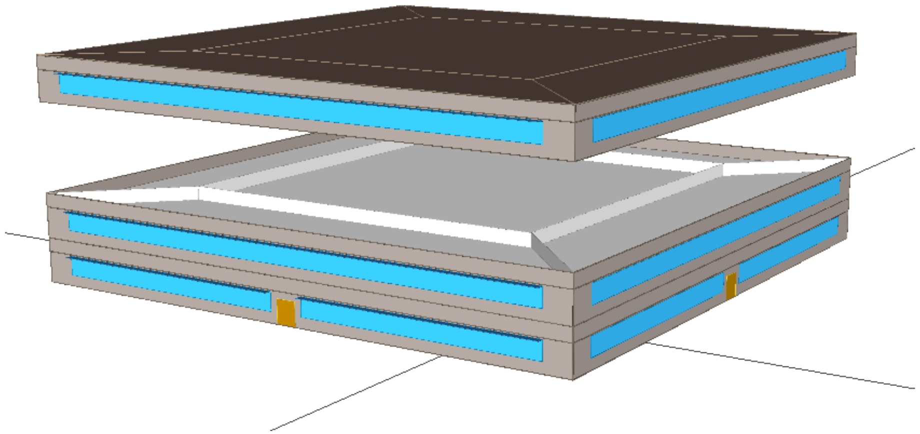
Site Analysis Modeling: Shading by Adjacent Structures

- 3D View in Simulation Software
- Reduces daylighting opportunities
- Less solar gain decreases cooling energy and increasing heating energy

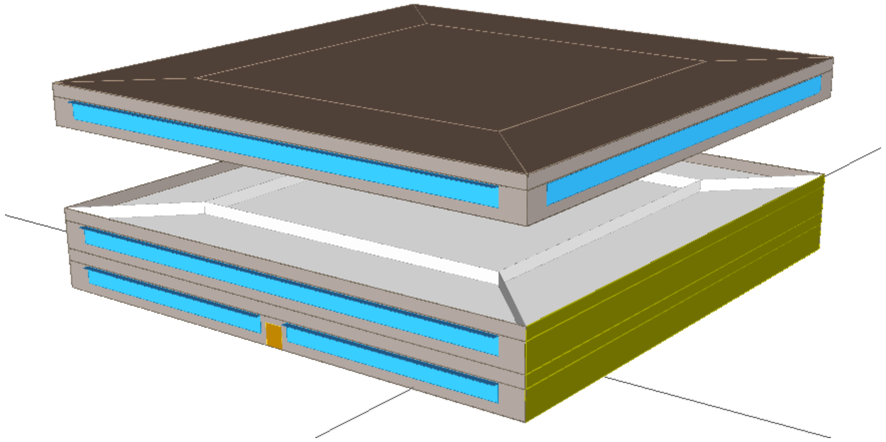


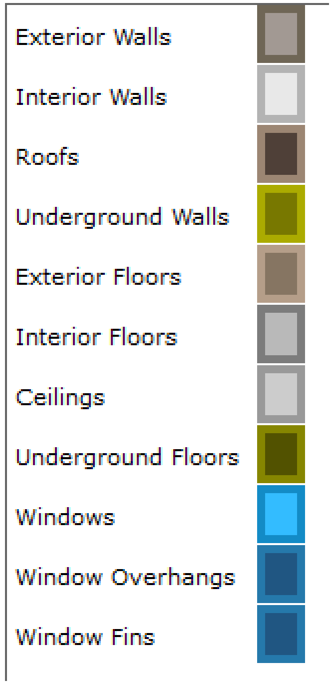
Site Analysis, Load Reduction & Conceptual Design Modeling

Base Case



Below Grade Alternative

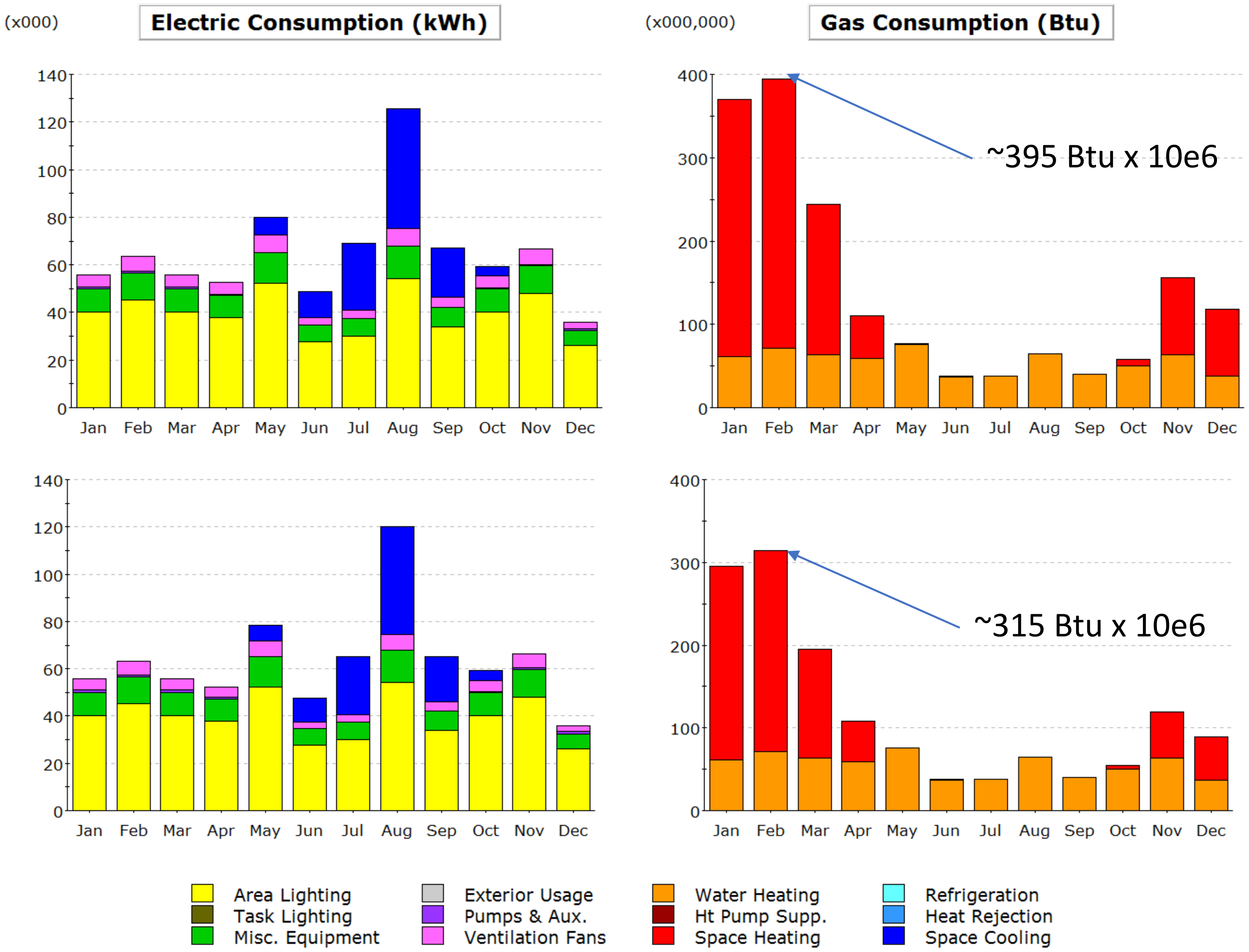




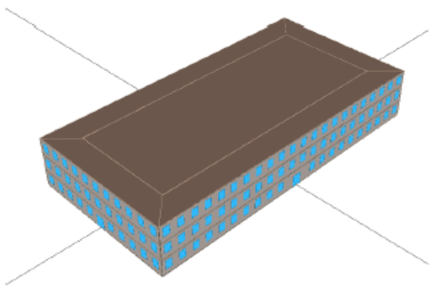
- Identical internal loads & operations and both served by traditional VAV with HW reheat.
- Below grade floor geometry reduces heating and cooling loads by eliminating 10% of above grade wall and window area, resulting in 1.9% reduction in overall building energy.
- Below Grade Alternative presents reduced daylighting opportunities which can be offset by installing Tubular Daylighting Skylights.
- Spaces that are not regularly occupied and with high internal loads are good candidates for below grade wall exposure. Ex. Data Centers & IT Rooms

Base Case

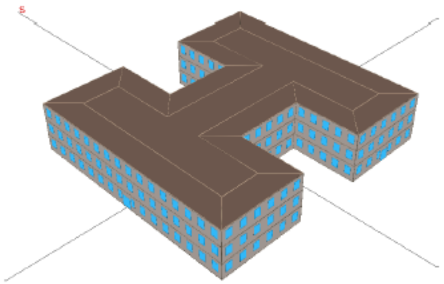
Below Grade Alternative



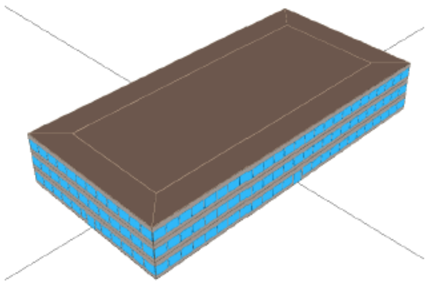
Simple Box/Load Reduction Modeling: Window to Wall Ratio & Geometry



Base Case:
- Rectangle
- 3 story
- 2:1 aspect ratio
- 25% window to wall ratio (WWR)
- daylight dimming control



Alternative 1:
- Same as base case, but H-Shape

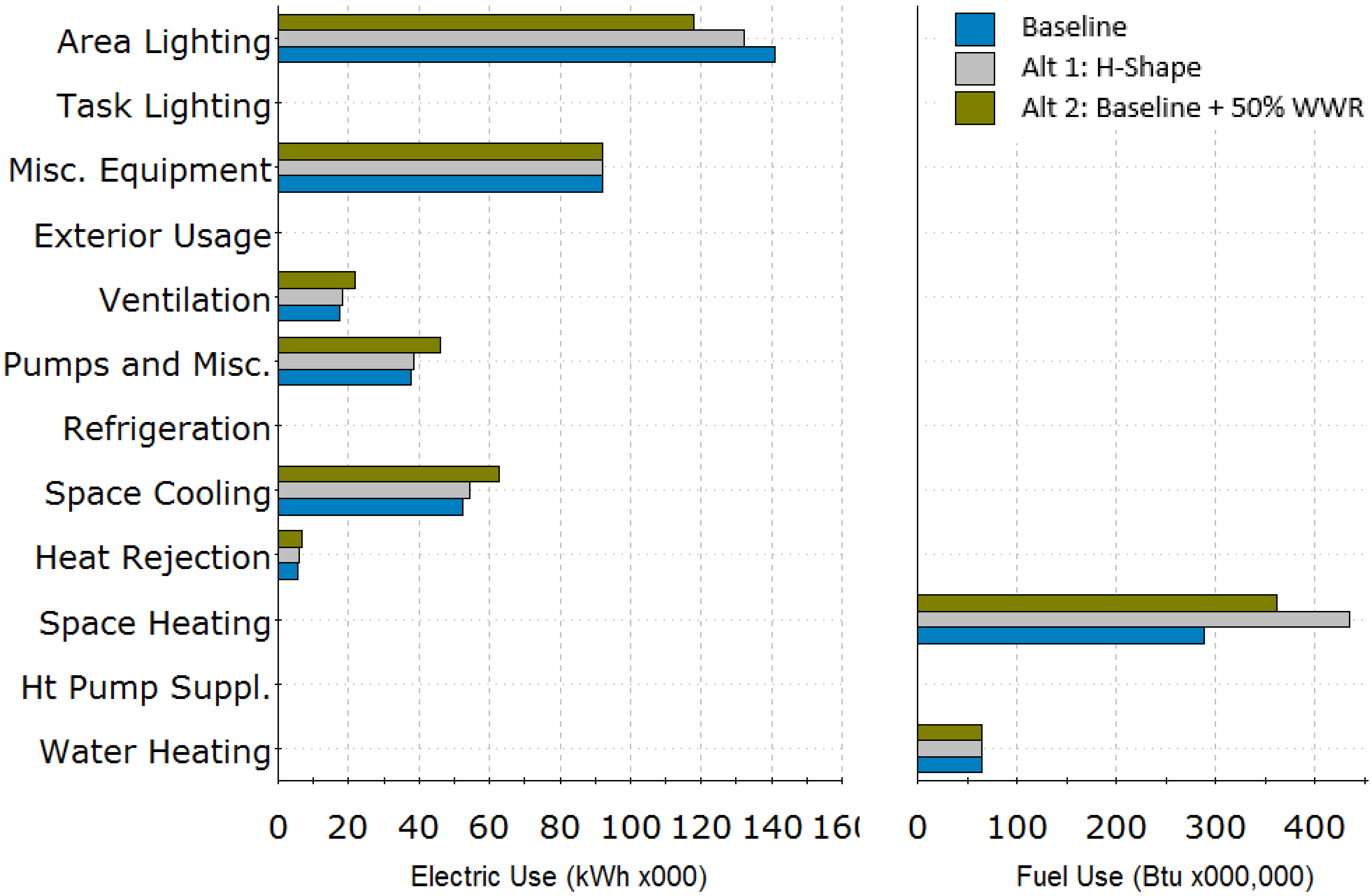


Alternative 2:
- Same as base case, but 50% WWR

Which Alternative is More Efficient?

	Conditioned Floor Area, SF A	Surface Area, SF B	Area Ratio C=B/A
Base Case	50,000	33,097	0.66
Alternative 1	50,000	38,598	0.77
Alternative 2	50,000	33,097	0.66

	Window Area SF
Base Case	3,667
Alternative 1	4,907
Alternative 2	7,365



Area Lighting
Task Lighting
Misc. Equipment
Exterior Usage
Ventilation
Pumps and Misc.
Refrigeration
Space Cooling
Heat Rejection
Space Heating
Ht Pump Suppl.
Water Heating
0 20 40 60 80 100 120 140 16(
Electric Use (kWh x000)
Baseline
Alt 1: H-Shape
Alt 2: Baseline + 50% WWR
0 100 200 300 400
Fuel Use (Btu x000,000)

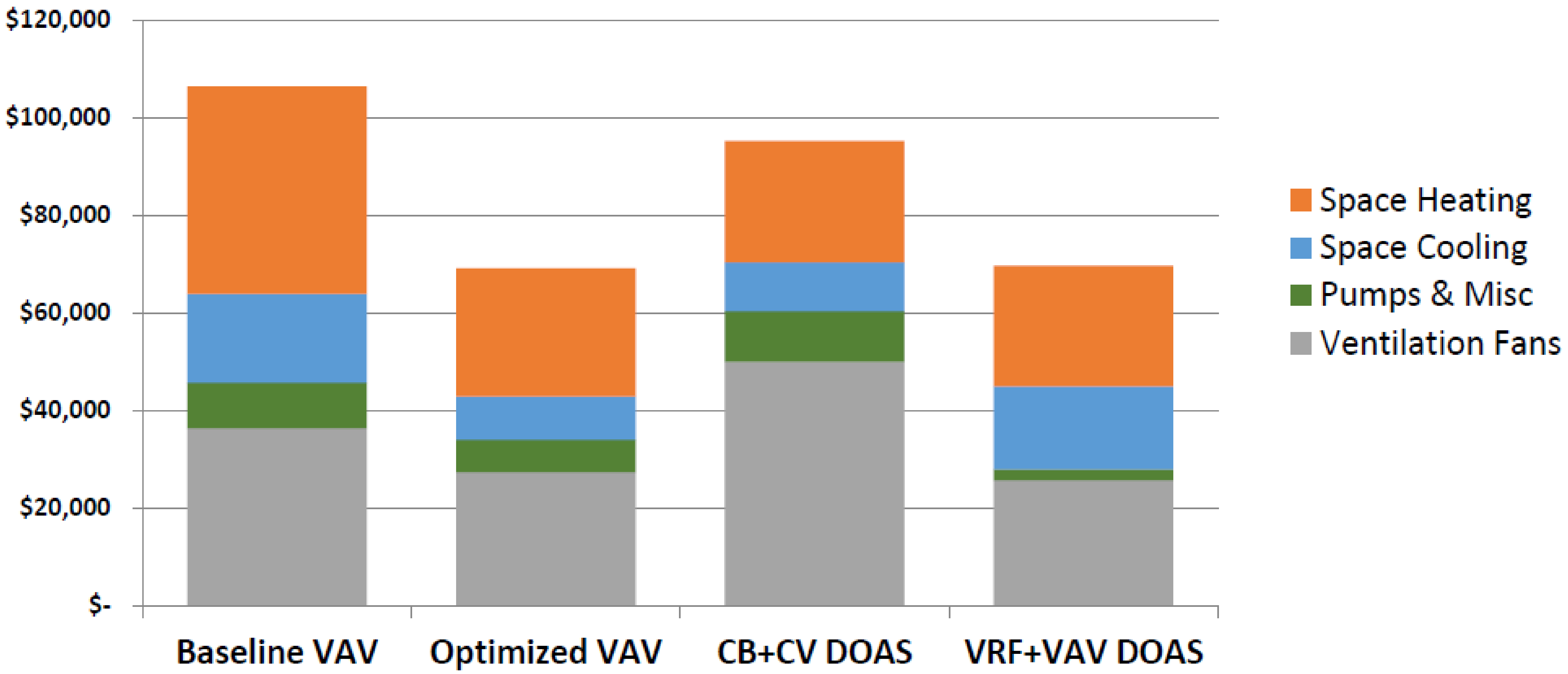
HVAC System Selection Modeling: HVAC System Type Alternatives

- **Baseline VAV**: Variable Air Volume (VAV) air handlers, water cooled chillers and conventional hot water (HW) boilers
- **Optimized VAV**: VAV with HW condensing boilers and air-cooled, magnetic bearing chillers, & improved controls
- **CB + DOAS**: Chilled beams (CB) with condensing boilers and air-cooled magnetic bearing chillers, a constant volume dedicated outdoor air system (DOAS)
- **VRF + DOAS**: Variable refrigerant flow (VRF) heat pumps and a variable volume DOAS

HVAC System Selection Modeling

- High Performance HVAC system such as geo-thermal heat pumps and combination VAV DOAS + VRF are the leading HVAC designs to achieve net zero energy.
- HVAC System Type
  - Ventilation Strategies
    - Comprehensive energy recovery
    - Demand based ventilation
    - Ventilation effectiveness
    - Economizers, natural ventilation strategies
  - Demand based thermostat controls
  - Variable speed fans & pumps
    - Static pressure reset controls for VSD fans
  - Intermittent/cycling indoor unit fan operation

Annual HVAC Cost Comparison



Design Refinement Modeling: HVAC Mapping for Dedicated System for Critical Zone

Case Study

- The Proposed Design has two multi-zone VAV units (MZ-VAV) split up to serve the north and south ends of the building.
- The system minimum ventilation ratio & the minimum supply flow ratio both dictated by the ventilation requirements of the critical zone in each system.
- Critical zones such as the workshop area have the highest ventilation requirements, and the system minimum supply ratio is governed by these spaces during peak occupancy.

Design Refinement Modeling: HVAC Mapping for Dedicated System for Critical Zone

Unit Tag	Spaces Served	Color
AHU-1	Classrooms & Support	Yellow
AHU-2	Workshop - Critical Zone	Orange
AHU-3	Seminar	Blue

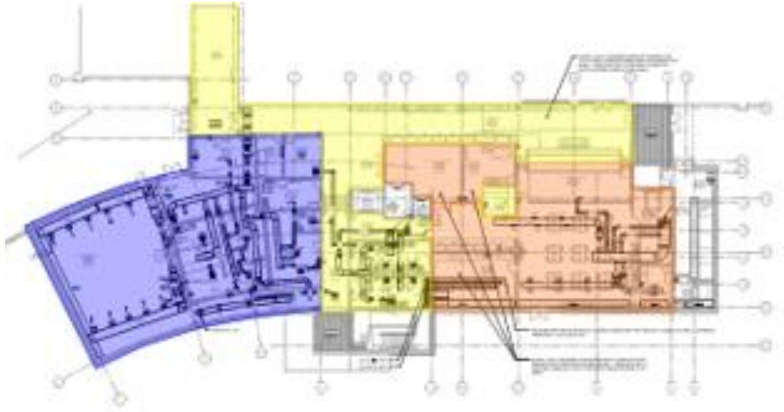


Figure 1: First Floor

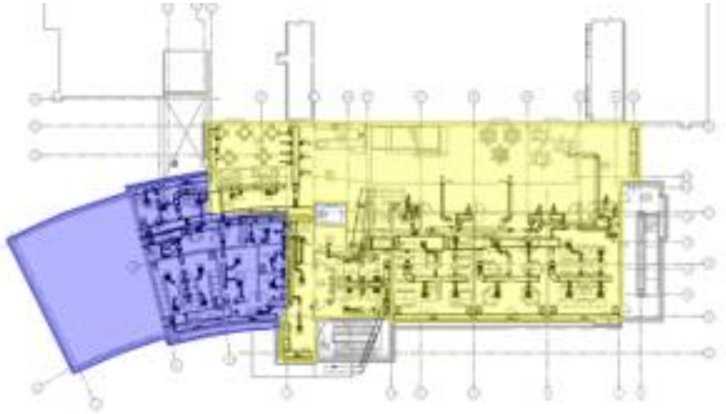


Figure 2: Second Floor

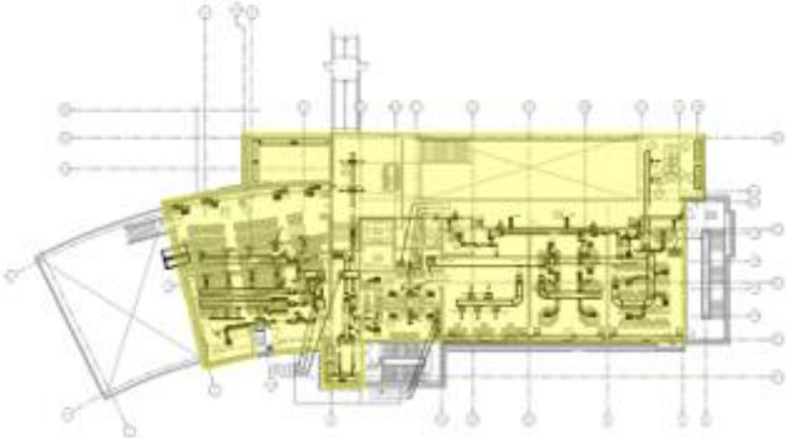


Figure 3: Third Floor

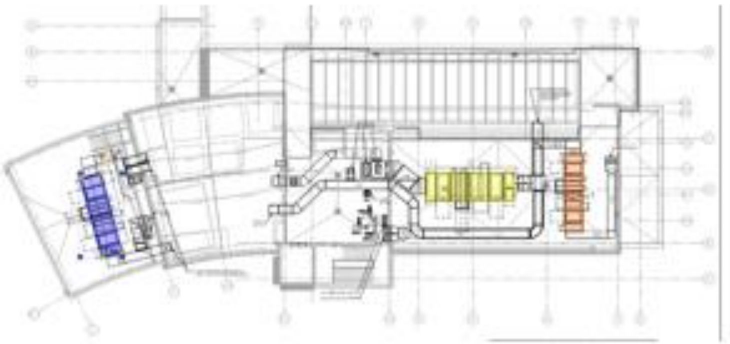


Figure 4: Unit Roof Locations

Design Refinement Modeling: HVAC Mapping for Dedicated System for Critical Zone

- SZ-VAV achieves fan, heating and cooling energy savings by providing dedicated HVAC systems to serve critical zones that reduces the minimum supply flow ratios for the remaining zones served by the MZ-VAV systems.
- SZ-VAV systems will also have a reduced design fan power due to the reduced static pressure from removing zone reheat coils.
- Relatively small pumping energy penalties are expected to accommodate the additional hot water and chilled water coils.

Measure Name	kWh Savings	Therms Savings	Utility Energy Cost Savings ($)
Proposed + SZ-VAV	17,455	998	3,844

Figures 1 & 2: Hourly Simulation Results Comparison

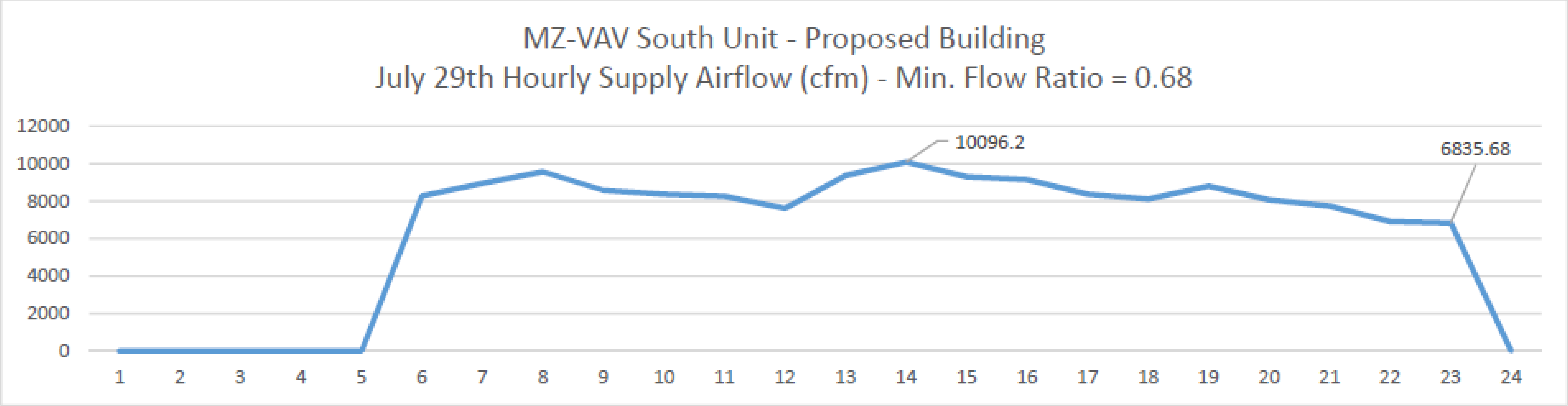


Figure 1: Proposed Design

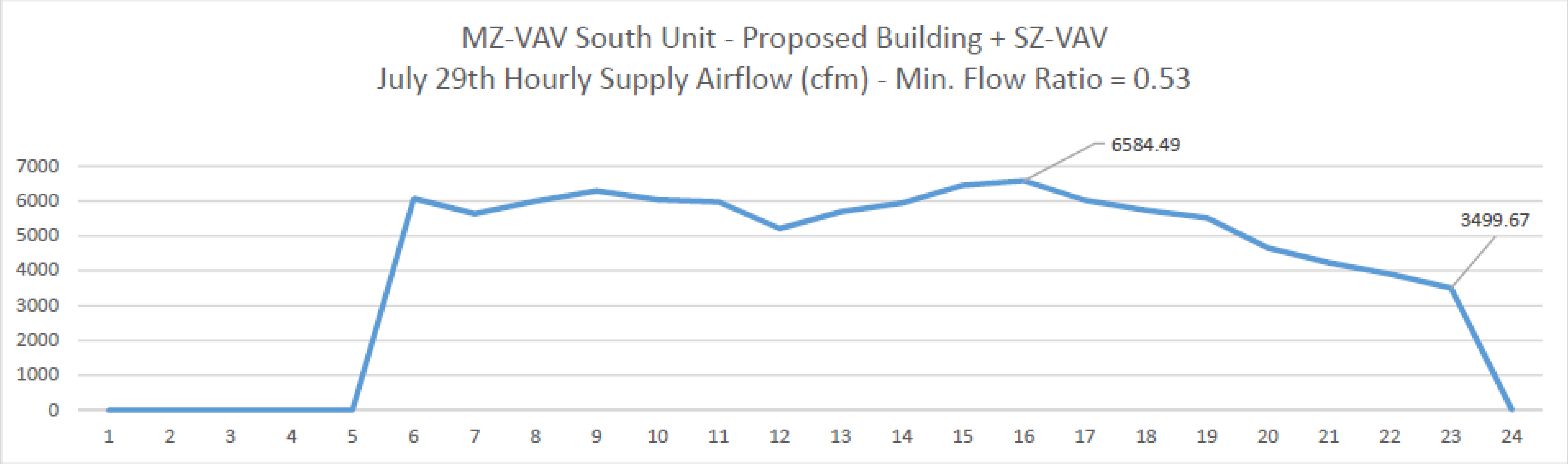


Figure 2: Proposed + SZ-VAV

Design Integration & Optimization Modeling: Individual Measure Modeling

- Quantify & map the energy performance of each building design aspect that contributes towards overall project performance.
- Identify each building design aspect that contributes an energy penalty.
- Provide measure recommendations or alternatives to further enhance building design.
- Case Study: University Lab Building
  - Each baseline, designed and recommended aspects for the building.
  - Saving of each specified & recommended design aspect.
  - Narratives & Diagrams to illustrate recommendations

Design Integration & Optimization Modeling

Component		Baseline	Proposed (based on DD set)	Recommendations
Envelope	Roof	R20 continuous insulation	R30 continuous insulation	NA
	Above Grade Walls	R13 steel frame wall + R7.5 continuous insulation	U-0.053	NA
	Windows	Metal framing, curtain wall / store front NFRC U-Factor = 0.45 / SHGC 0.40	Not specified	NA Windows U-0.39, SHGC-0.38
	Window to Wall Ratio	17%		NA
	Slab on grade	R-10 for 24"	Not specified	R-10 for 24" **Note 8**
Internal Loads	Whole Building (WB) Interior LPD	1.2 W/ft^2	0.73 W/ft^2	**Note 9**
	WB Plug Loads	1.0 W/ft^2		**Note 10**
	Maker Space, Studio	5.0 W/ft^2		
	Auditorium	0.5 W/ft^2		
	Data Closet	50.0 W/ft^2		
	Exterior Lighting	2,020 Watts	867 Watts	NA

Design Integration & Optimization Modeling

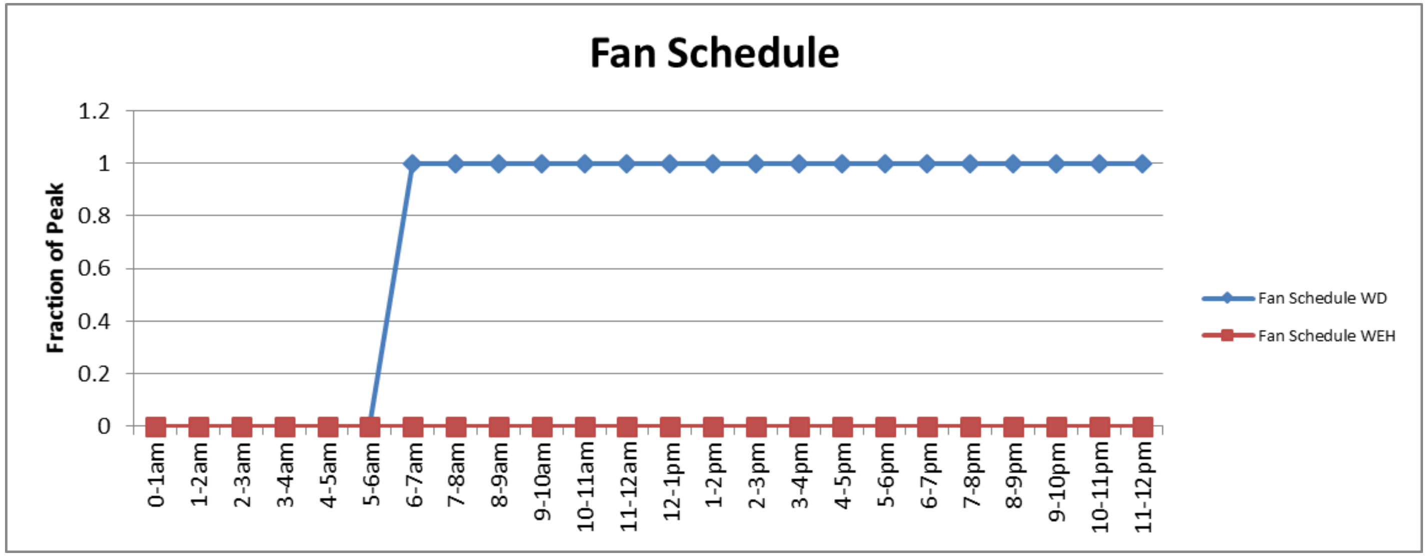
Component		Baseline	Proposed (based on DD set)	Recommendations
HVAC	System Description	(3) PVAVS, one air handler per floor. (2) PSZ in maker space Packaged AC (PSZ) for telecom rooms & gas fired unit heaters	(2) Multizone VAV units serving most of the building with radiant panels on perimeter zones. (1) Single zone VAV unit serving the maker space & HW radiant panels. Packaged AC for telecom rooms & HW unit heaters	**Notes 1 & 2**
	Ventilation Strategy	Continuous ventilation when building is occupied. No Ventilation when building is unoccupied. Air-side economizer, DB limit of 70F	VAV units run continuously when building is occupied and provide ventilation air to each zone.	**Note 4** Enthalpy Wheels on AHU-1,2,3 w/ 75% Effectiveness
	DCV	Auditorium	Auditorium, classrooms & maker	**Note 5**
	Total OA CFM	19,000 CFM		NA
	Fan Power	MZ VAV 1.28 W/CFM SZ CV 0.74 W/CFM Total 51.4 kW	MZ VAV 1.58 W/CFM SZ VAV 1.41 W/CFM Total 66.1 kW	NA
	Fan Control	PVAV run continuously at variable air volume, 0.4 cfm/sf min; all other CV; All systems cycle to meet load in unoccupied mode	VAV run continuously at variable air volume, 0.51 cfm/sf min flow; AC & UH run continuously All systems cycle to meet load in unoccupied mode (all controls are assumed)	**Note 6** 30% Minimum Flow Ratio & VSD Fans based Static Pressure Reset
	Supply Airflow	38,000 CFM	47,000 CFM (Primary HVAC)	NA

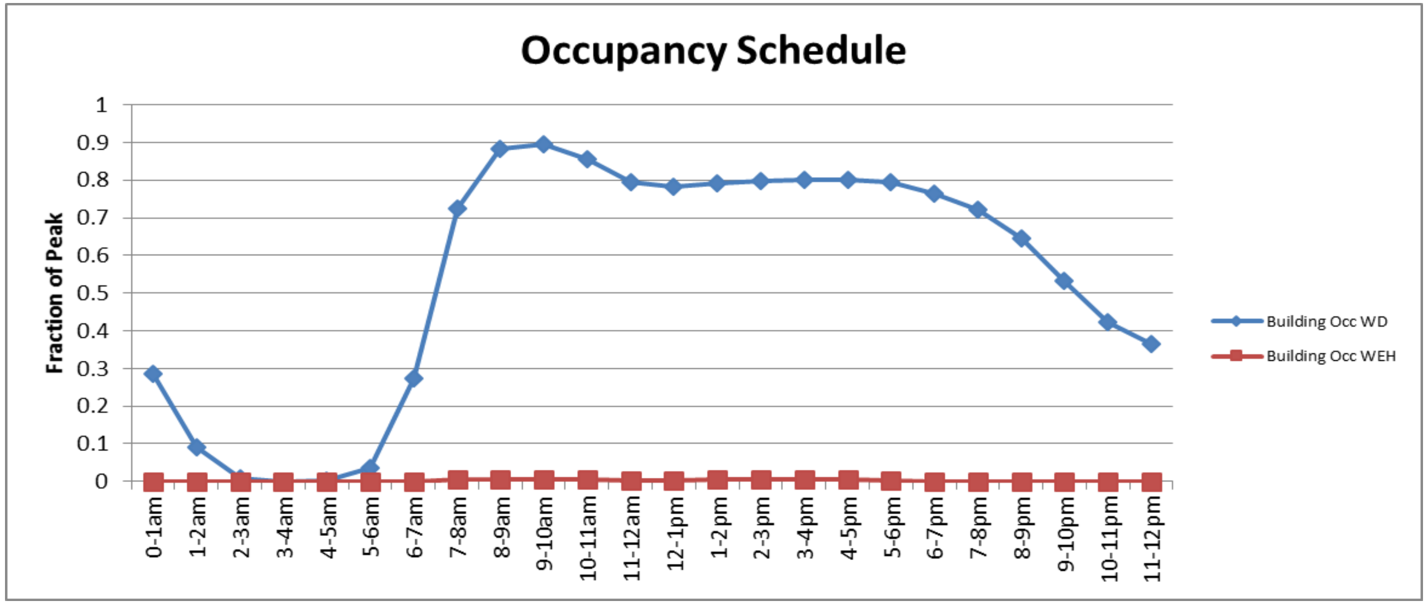
Design Integration & Optimization Modeling

Component		Baseline	Proposed (based on DD set)	Recommendations
HVAC	Pump Power	19 W/GPM hot water loop pump power, for a total of 1.54 kW Riding the Pump Curve	FP-HW AHU-1,2,3: 9.4 W/GPM CHW AHU-1,2,3: 11.3 W/GPM Each equipped with VSDs	NA
	Cooling Efficiency	13 SEER Data Closet AC 11.0, 9.8 EER PSZ 9.5, 9.8 EER PVAVS	10.1 EER/15.2 SEER Data Closets AC 3.1 COP, 4.2 IPLV Air-Cooled Chiller	**Note 7** 12 EER/17 SEER AC 3.4 COP, 4.6 IPLV Chiller
	Heating Efficiency	80 Et Natural Draft Boilers & Furnaces	95% Rated Condensing Boilers	NA
	Circulation Loops	HW supply of 180F, delta T 50F. OA reset supply to 150F	HW supply of 150F, delta T 40F CHW supply of 44F, delta T 12F OA reset supply to 100F & 54F, HW & CHW, respectively.	NA
DHW	Gas Heater Et	80%	Not specified	95% Condensing
	Fixture Flow Rate	Lavatory: 2.20 GPM	Lavatory: 0.50 GPM	NA

Design Integration & Optimization Modeling

The occupancy schedule of the auditorium is assumed to be a consistent with the rest of the space in the building, which implies that the auditorium acts as a lecture hall with regular attendance. However, the actual anticipated schedule should be established, to understand if energy recovery or DCV or a combination of both is best suited.





Individual Measure Modeling: As-Designed

Measure #	Measure Name	kWh Consumption	Gas Consumption (Therms)	Utility Energy Cost ($)	Increment Savings ($)	Cumulative Savings ($)	Cumulative % Savings
Base	Baseline Design	604,978	21,381	166,371	-	-	
1	Baseline + Proposed HVAC Mapping	690,333	17,189	178,795	(12,424)	(12,424)	-7.5%
2	Above Grade Walls	686,355	16,935	177,597	1,198	(11,226)	-6.7%
3	Roof	682,374	15,987	175,598	1,999	(9,227)	-5.5%
4	Windows	681,440	15,805	175,160	438	(8,789)	-5.3%
5	LPD Reduction	618,576	15,810	160,078	15,082	6,293	3.8%
6	Lighting Controls	607,584	16,001	157,647	2,431	8,724	5.2%
7	Daylighitng Controls	602,416	16,043	156,249	1,398	10,122	6.1%
8	Exterior Lighting Reduction	598,739	16,043	155,799	450	10,572	6.4%
9	VSD AHU CHW & HW Pumps	592,072	16,134	154,603	1,196	11,768	7.1%
10	Demand Control Ventilation	587,634	12,893	150,335	4,268	16,036	9.6%
11	Enthalpy Wheels	569,605	6,509	138,216	12,119	28,155	16.9%
12	Condensing DHW Heater	569,605	6,335	138,038	178	28,333	17.0%
13	**Low Flow Fixtures**	**569,605**	**6,092**	**137,790**	**248**	**28,581**	**17.2%**

Design Integration & Optimization Modeling

- The total designed daylighting controlled wattage is 3,818 watts based on the primary sidelight zone area (see figure 5).
- Advanced multi-zone daylighting controls are available to exceed the 90.1-2010 minimum controlled wattage and achieve additional energy savings.
- Once installed and combined with a field calibration, the multi zone daylighting receiver can uniquely dim up to 4 rows of lighting fixtures based on each row's unique availability of natural daylight.

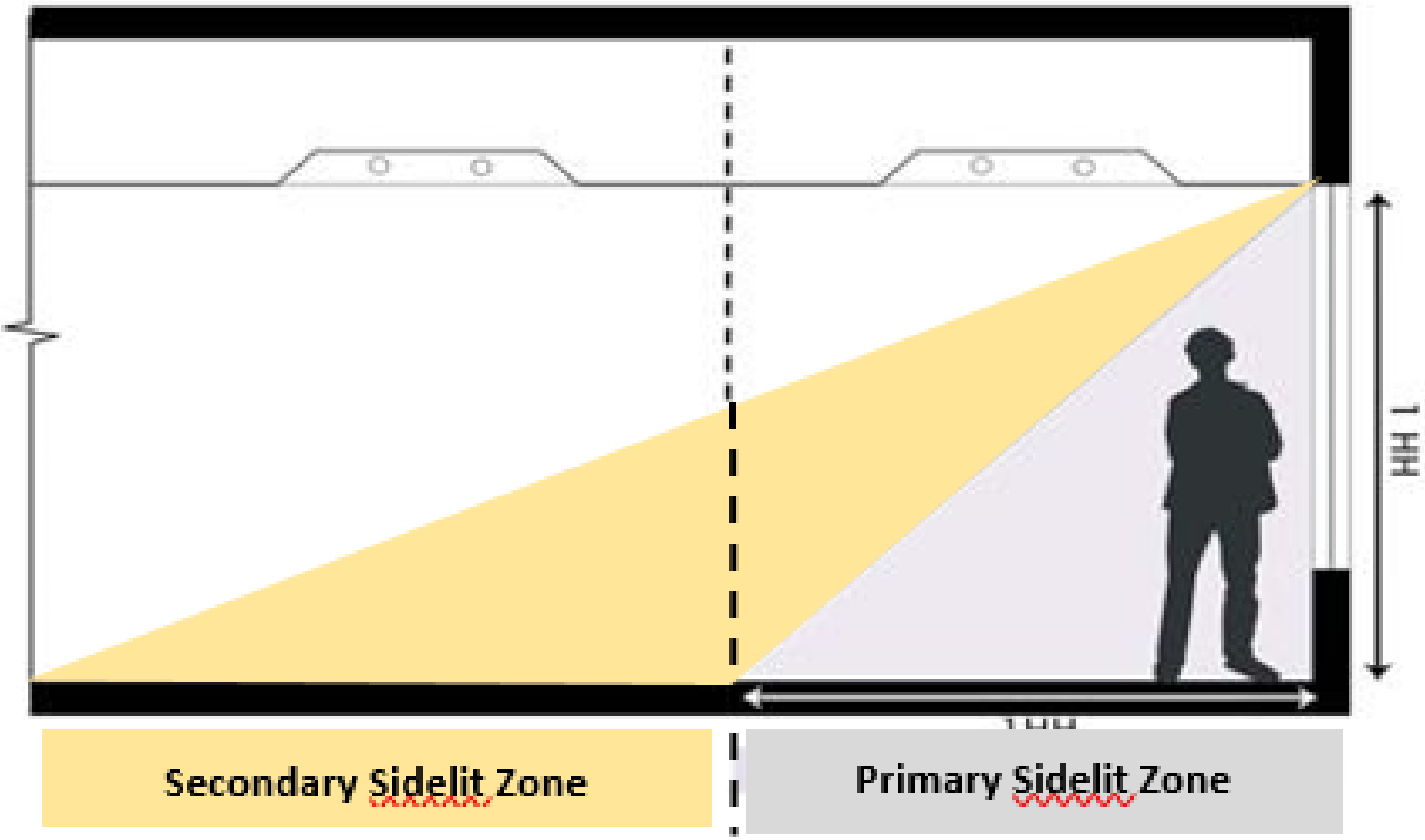
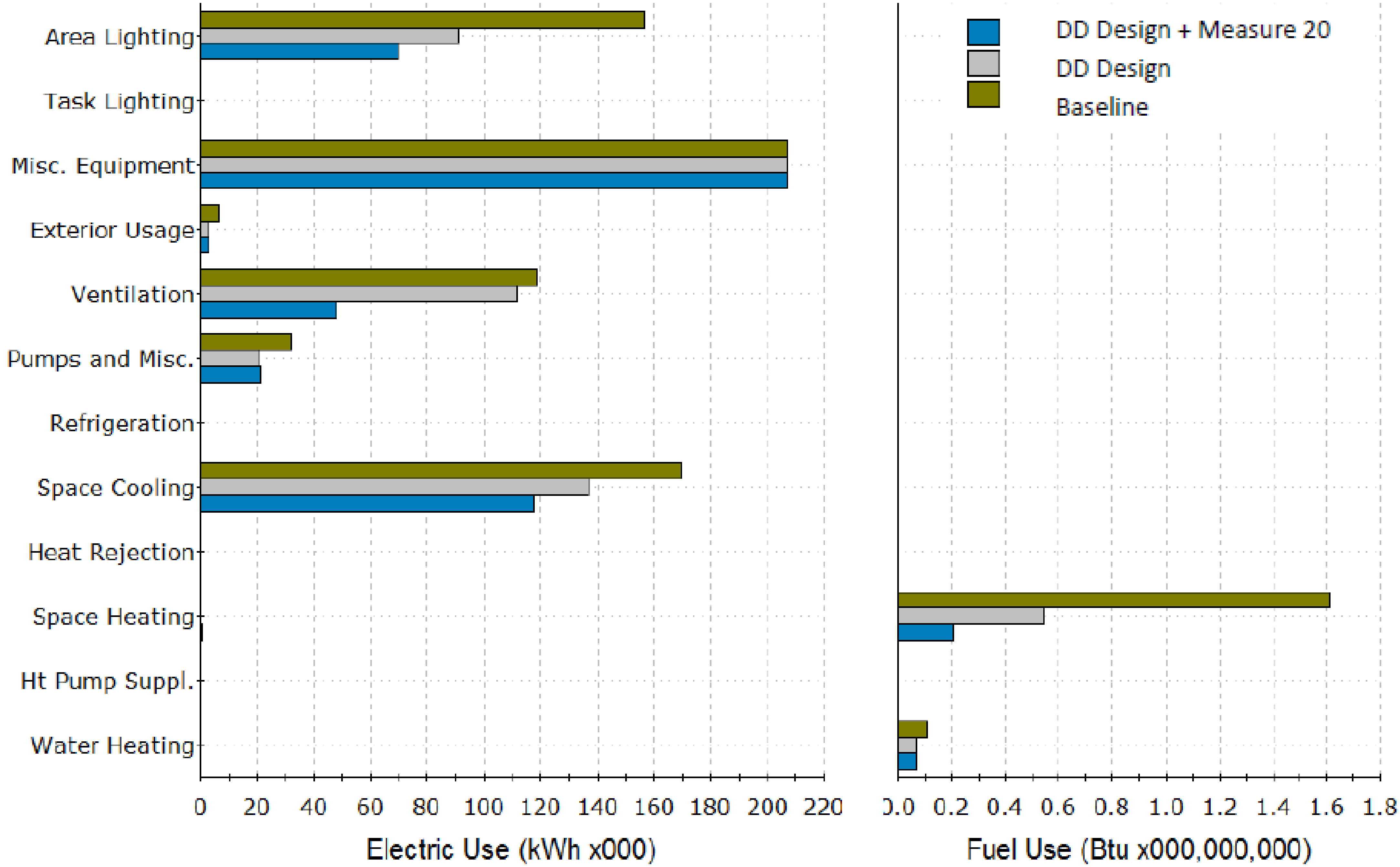


Figure 5: Single Zone & Multi Zone Daylighting Controls

Individual Measure Modeling: As-Designed + Recommendations & Alternatives

Measure #	Measure Name	kWh Consumption	Gas Consumption (Therms)	Utility Energy Cost ($)	Increment Savings ($)	Cumulative Savings ($)	Cumulative % Savings
13	**Low Flow Fixtures**	**569,605**	**6,092**	**137,790**	**248**	**28,581**	**17.2%**
14	Bi-Level Stairwell Lighting Controls	562,763	6,192	136,271	1,519	30,100	18.1%
15	Advanced Daylighting Controls	545,420	6,413	131,733	4,538	34,638	20.8%
16	3.4 COP Air Cooled Chiller	534,472	6,413	129,205	2,528	37,166	22.3%
17	Condensing Boiler Plant	537,086	4,400	127,578	1,627	38,793	23.3%
18	VAV 30% Min Flow Ratio	485,208	2,688	117,365	10,213	49,006	29.5%
19	VSD Fans Static Pressure Reset Controls	466,361	2,710	112,956	4,409	53,415	32.1%
20	12 EER/17 SEER Data Closet ACs	464,200	2,710	112,418	538	53,953	32.4%



Area Lighting
Task Lighting
Misc. Equipment
Exterior Usage
Ventilation
Pumps and Misc.
Refrigeration
Space Cooling
Heat Rejection
Space Heating
Ht Pump Suppl.
Water Heating
0 20 40 60 80 100 120 140 160 180 200 220
Electric Use (kWh x000)
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
Fuel Use (Btu x000,000,000)
DD Design + Measure 20
DD Design
Baseline

Energy Modeling for Low Energy Projects: Examples

UN City, Copenhagen

- Climate Zone 5A
- 544,823 ft^2
- Office occupancy with public spaces and cafeteria
- Completed construction in 2014
- Received European Commission's Green Building Award for New Buildings, and LEED v3.0 Platinum

Completed Modeling Cycles

- As-designed Energy Performance
  - Modeling and report in support of LEED v3 Energy and Atmosphere Credit 1 and Prerequisite 2

Energy cost savings (%)	56.35
EA Credit 1 points documented	19

- Post-occupancy energy performance comparison
  - M&V plan in support of LEED v3 Energy and Atmosphere Credit 5 – Measurement and Verification Option D (calibrated simulation)
  - Calibrated simulation and M&V report with the actual achieved savings

Design Features

Envelope:

U-0.018 walls, U-0.026 roof, U-0.18 curtain wall, 54% window to wall ratio

HVAC:

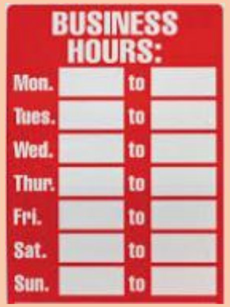
- Chilled beams, radiant heating panels, variable volume DOAS in office areas
- VAV with demand control ventilation in cafeteria, auditorium, and meeting areas
- Fans run continuously during occupied hours, off during unoccupied hours
- Energy recovery with 75% effectiveness on all units
- Chillers COP 6.5 with seawater heat exchangers used as heat sink and water-side economizer
- Purchased hot water from the city system

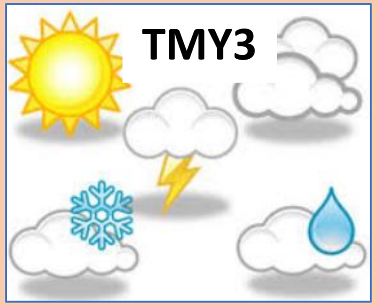
Lighting: LED with daylighting and occupancy sensors throughout

Renewables: PV with the estimated annual electricity production of 350 MWh

LEED Modeling

Assumed Operating Conditions

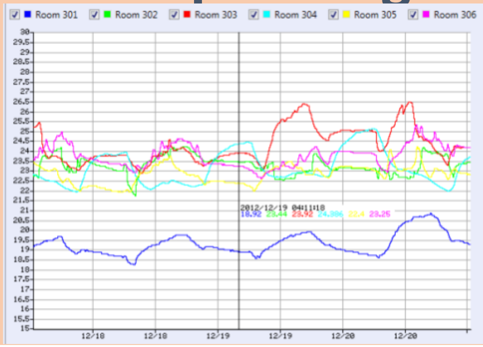


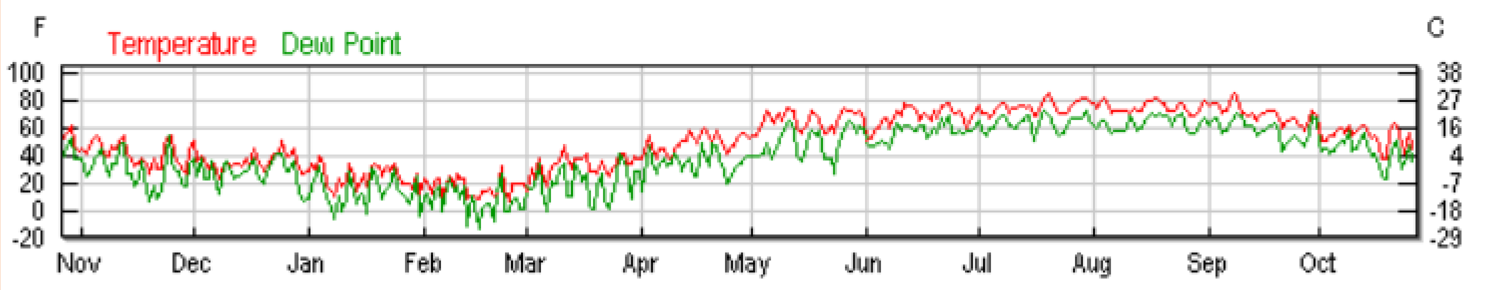


Energy Savings = **Baseline Energy Use** – **Proposed Energy Use**

IPMVP Option D – Calibrated Simulation

Actual operating conditions and weather during M&V period





Energy Savings = **Calibrated Baseline Energy Use** – **Measured Energy Use**

Key Adjustments to the Baseline Model

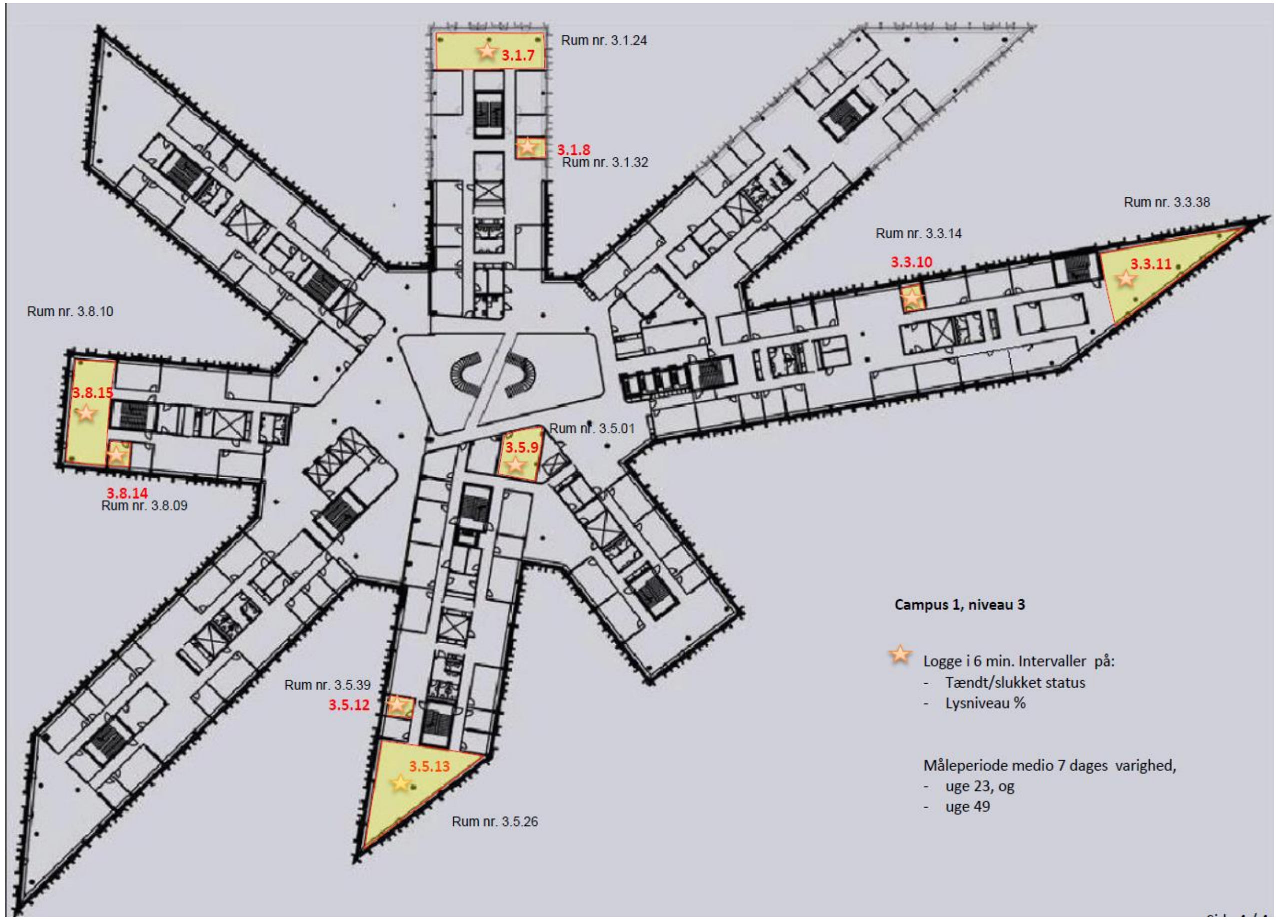
- Weather file with actual conditions for M&V period
- Thermostat setpoints and schedules based on measurements
- Occupancy based on actual
- Service water heating consumption as measured
- Miscellaneous equipment based on the difference in the total measured electricity use for the building, and the measured HVAC and lighting electricity use

Site Measurements

- BMS and metering capabilities required by Danish building regulations and Danish/European standards was sufficient to support majority of metering
- Commissioning to meet requirements of EA Prerequisite 1 (fundamental commissioning) and EA c3 (enhanced commissioning)

#	Equipment	Point Description	Source Type	Source ID	Units	Notes
1a	Outdoor conditions	Dry bulb temperature	Temperature sensors, BAS		°C	Record at 6 min intervals.
2	Electric	Total building electric energy	Electric meters, BAS (All main meters)		kWh	Record at 6 min intervals. Sub-meter or main breaker, provide both kW and kWh to BAS for entire building. The measurement may be obtained by combining readings from several meters, but must represent the total electricity consumption of the building
3	Solar cells (PV)	Electricity generation	Sub-meter Energy, BAS		kWh	Record at 6 min intervals
4	Thermal (hot water from DES)	Thermal energy from DES	Pulse from main district heating meter, BAS		kWh	Record cumulative daily usage. Include space and service water heating, total delivered to the building from DES.
5a	Service water heating (SWH) *aka Domestic Hot Water (DHW)*	Purchased energy for SWH	Sub-meter Energy, BAS		kWh	Record at 6 min intervals.
5b		Total hot water consumed	Sub-meter Water, BAS		m³	Daily logs
6	Cold water	Total cold water consumed in the building	Main cold water meter, BAS		m³	Daily logs
7a	Seawater to chilled water heat exchangers, supply side (PH1-PH4)	Seawater supply temperature	Temperature sensor, BAS	K2_HV00_TF1	°C	Record at 6 min intervals.
7b		Seawater return temperature	Temperature sensor, BAS	K2_HV00_TR1	°C	Record at 6 min intervals.
8	Chilled water plant	Total electricity consumption	Electric meter, BAS		kWh	Record at 6 min intervals; must include consumption of chillers and associated equipment such as primary chilled water loop pumps and condenser water loop pumps.
9a	Secondary chilled water loop, demand side after mixing, per loop (5 total)	Supply water temperature	Temperature sensor, BAS		°C	Record at 6 min intervals.
9b		Return water temperature	Temperature sensor, BAS		°C	Record at 6 min intervals.
9c		Chilled water flow	BAS		m³	Record at 6 min intervals.
9d		Delivered energy	Sub-meter, BAS		kWh	Record at 6 min intervals
10	Free Cooling	Delivered energy	Sub-meter, BAS		kWh	Record at 6 min intervals, free cooling delivered by-passing the chillers
11a	VE01-VE17: Collect the following data points for each AHU	Return air temperature	Temperature sensor, BAS		°C	Record at 6 min intervals; will be used to estimate average indoor temperatures.
11b		Supply air temperature (after energy recovery)	Temperature sensor, BAS		°C	Record at 6 min intervals.
11c		Total AHU electricity usage (supply, return, exhaust fans)	Sub-meter, BAS		kWh	Record at 6 min intervals; kWh calculate as average of hourly kW
		Heating val[illegible]	BAS Command			
			[illegible] Command			

Lighting Fixture Sampling Examples

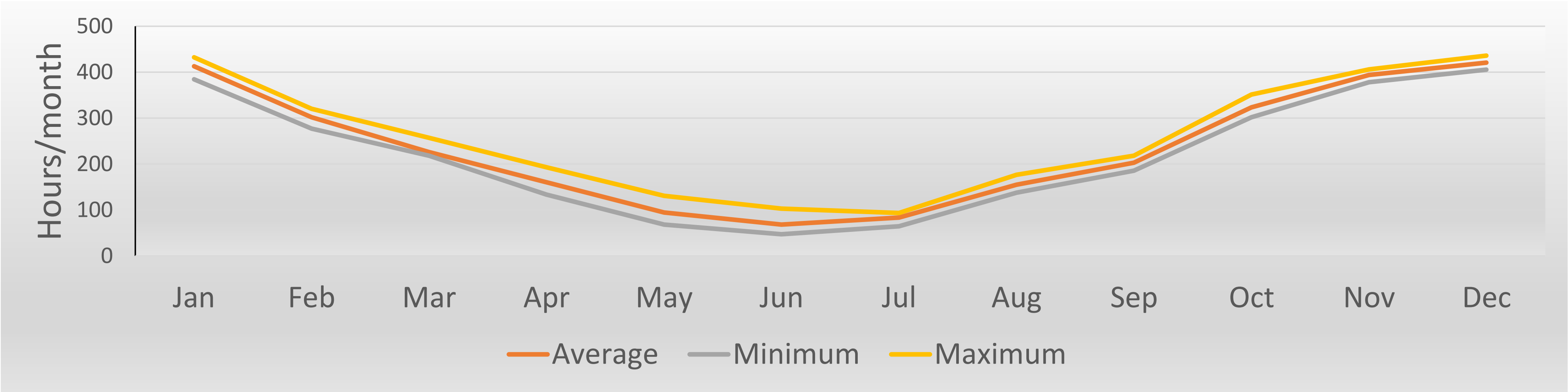


Sample Measured Operating Conditions

- Occupied 6am – 7pm during weekdays
- Thermostat setpoints

		Cooling	Heating
Occupied Periods	Occupants present	75 F	72 F
	No occupants	77 F	70 F
Unoccupied Periods		81 F	68 F

- Exterior lighting runtime hours based on sample of fixtures

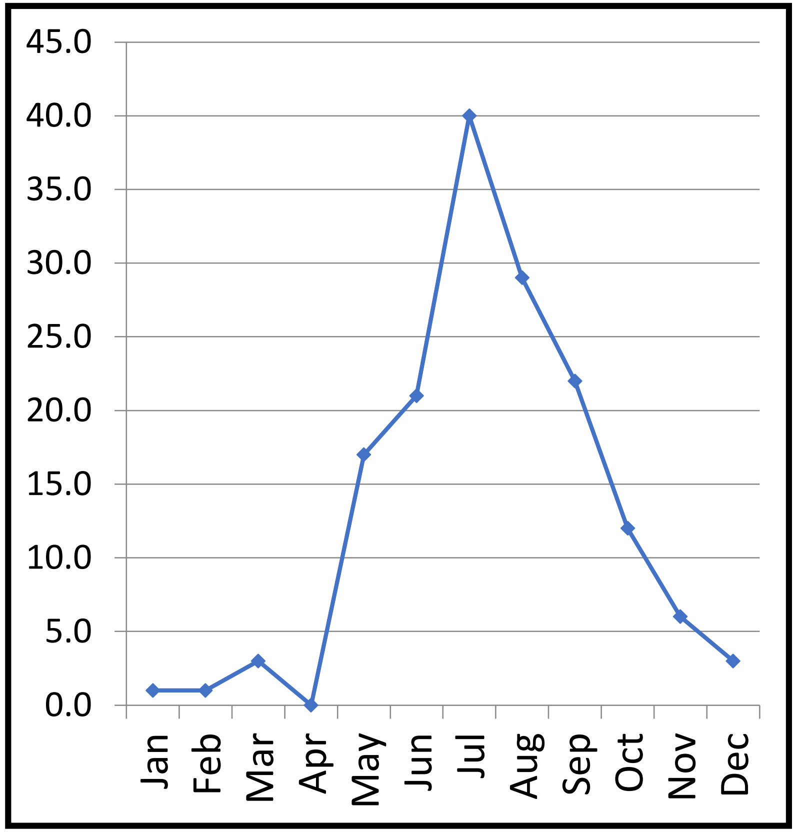


Sample Measurements Affecting Proposed Design

Ocean Water Temperature

Month	Projected Temperature C	Actual Temperature C
Jan	2	5.9
Feb	1.2	4.1
Mar	1.7	7.3
Apr	5	8.5
May	10	17.2
Jun	14.5	19.5
Jul	17.5	23.4
Aug	17.4	21.4
Sep	15	18.2
Oct	11.1	15.7
Nov	7.4	12.2
Dec	4.4	9.0

Measured Chiller MWh



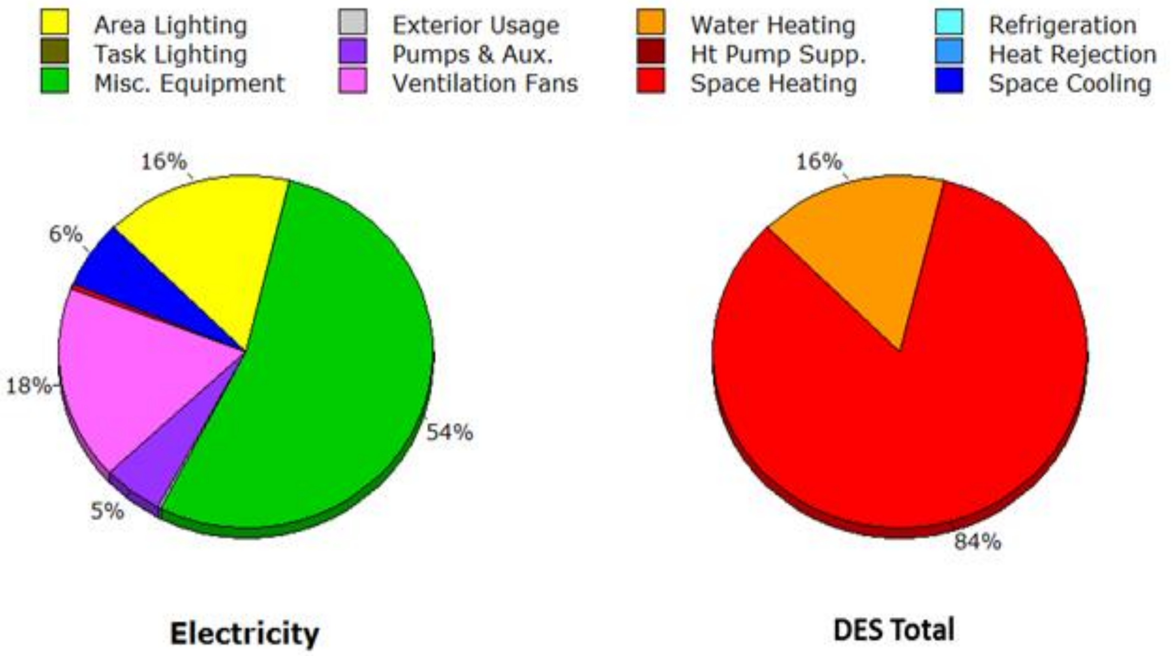
PV Power Generation, MWh

Months	Projected	Actual
January	6	4
February	15	9
March	27	24
April	46	43
May	57	50
June	53	51
July	57	57
August	47	44
September	31	31
October	19	12
November	7	5
December	3	3
Total	**365**	**332**

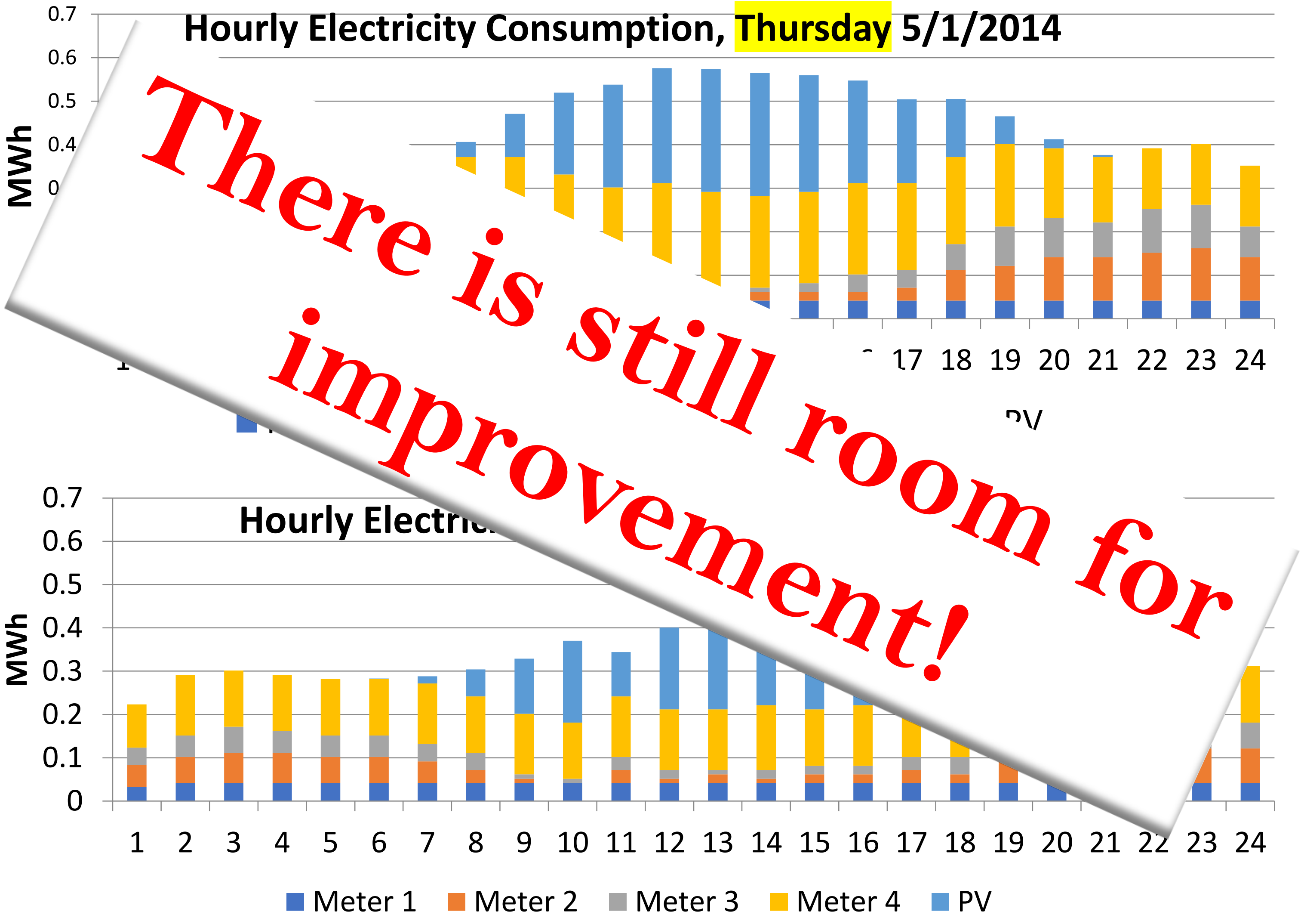
Projected versus Actual Performance

- LEED models projected **50% site EUI savings**, **56% cost savings** relative to baseline, and **40 kBtu/SF site EUI** including renewables
- Site EUI during 1 year M&V period was **29 kBtu/SF**

Calibrated Proposed Design: Consumption by End Use



Sample Findings



- Based on the measurements, the building is occupied 7AM - 7 PM on weekdays
- Air-handlers and lighting were confirmed to be off during unoccupied hours with some minor exceptions
- Electricity consumption during unoccupied hours is 50% of the peak, indicating opportunity for added savings by reducing miscellaneous loads (e.g. IT) during unoccupied hours

Stetson Court Residence Hall, Williams College

- New ~27,000 square feet dormitory building for ~ 60 students
- Fully occupied except for 4 weeks a year

Completed Modeling Cycles

- Load Reduction (Schematic Design stage)
- HVAC system selection, design refinement, integration, and optimization (Design Development)
- As-design energy performance (Construction Documents)
- As-built Energy Performance (Final energy model and LEED documentation)

Energy Charette

PROJECT #:	PROJECT NAME:	MEETING#:	DATE:	LOCATION:
14523	WC New Residence Hall	#1	06.30.14	Williams College Field House

SUSTAINABILITY GOALS

- WC's goal for all new construction is LEED Gold for New Construction v 3.
- The energy target is 25 KBTU/SF/Year annual energy load before renewables.
- The EUI target should be compared to national and/or state standards.
- Emission goal of reducing or not increasing energy-related emissions cannot be met by this building, since is a new load and new SF.
- Future goal for the campus is 100% renewable energy.

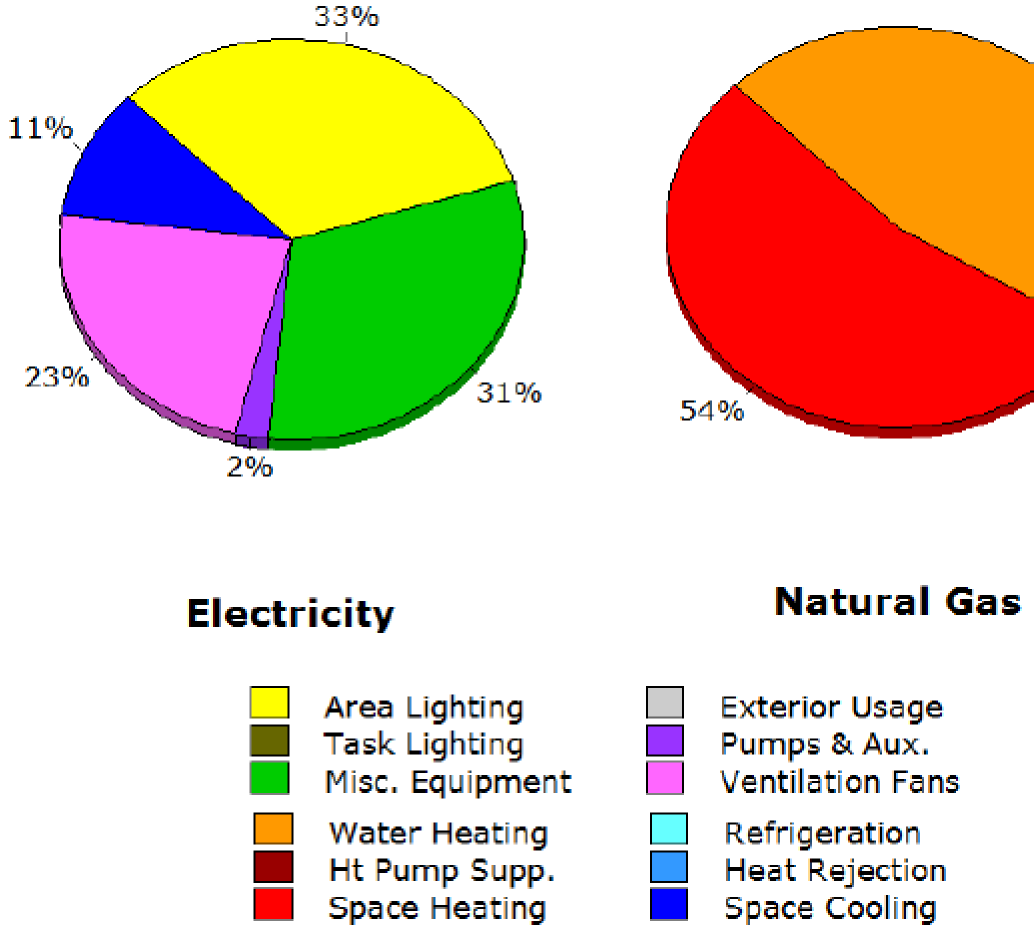
Benchmarking

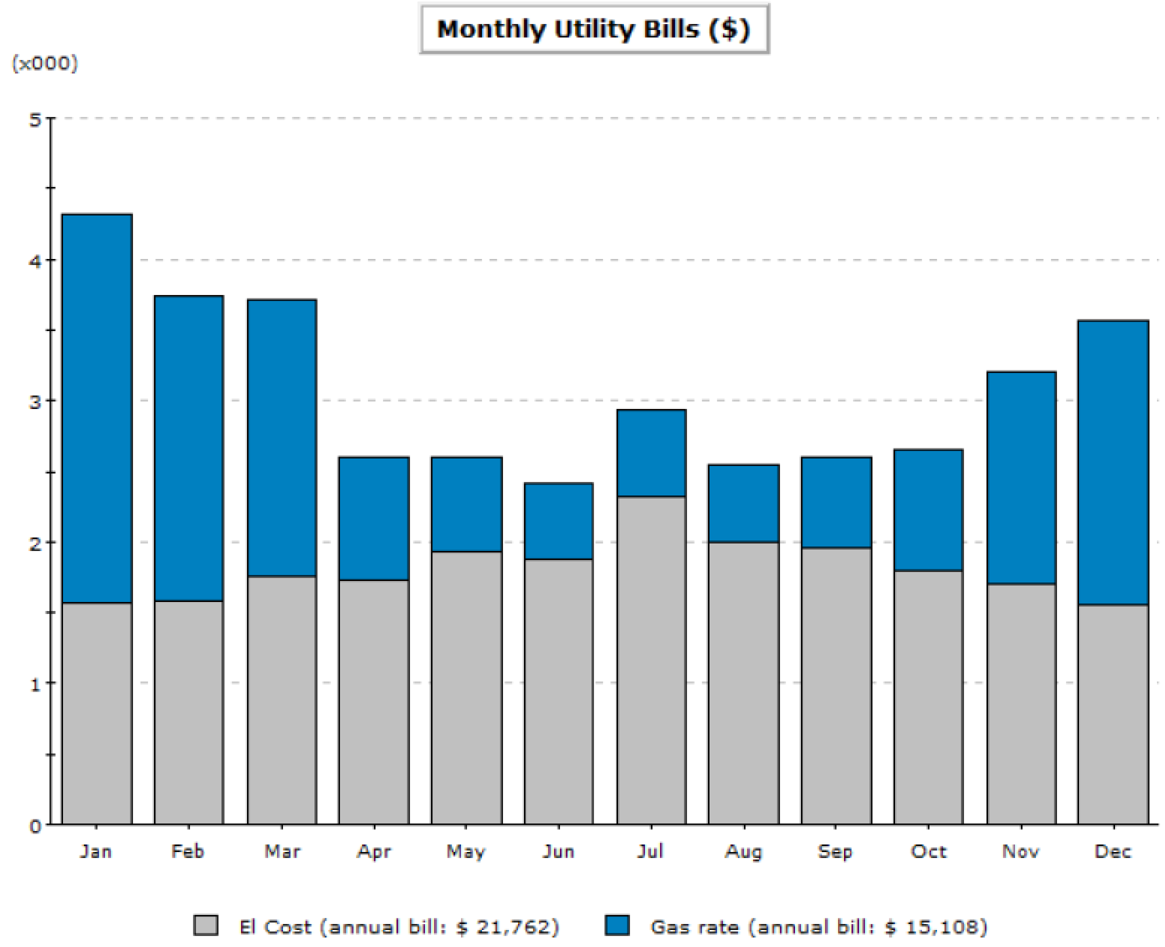
Metric	Design Target*	Median Property*
ENERGY STAR score (1-100)	75	50
Source EUI (kBtu/ft²)	150.2	201.4
Site EUI (kBtu/ft²)	91.4	122.5
Source Energy Use (kBtu)	3,906,245.6	5,236,400.0
Site Energy Use (kBtu)	2,375,691.0	3,185,000.0
Energy Cost ($)	45,692.90	61,258.76
Total GHG Emissions (Metric Tons CO2e)	155.7	208.7

Operating Conditions from the Owner

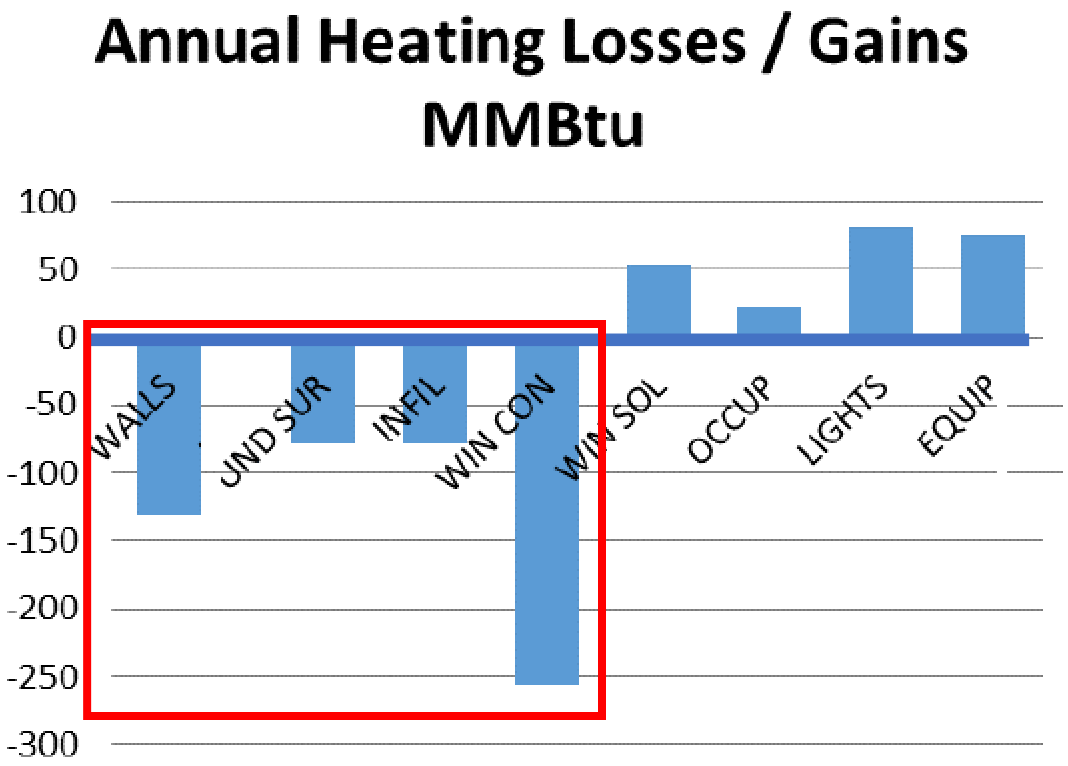
- HVAC systems modeled in occupied mode 24/7, except during vacation periods (4 weeks per year)
- In occupied mode, thermostat setpoint/setback is 68F/64F for heating and 76F/82F for cooling
- Hot water use of 25 gal/person/day. Higher than typical for dormitory, but below typical for multifamily
- Steam from campus plant must be used for space and service water heating

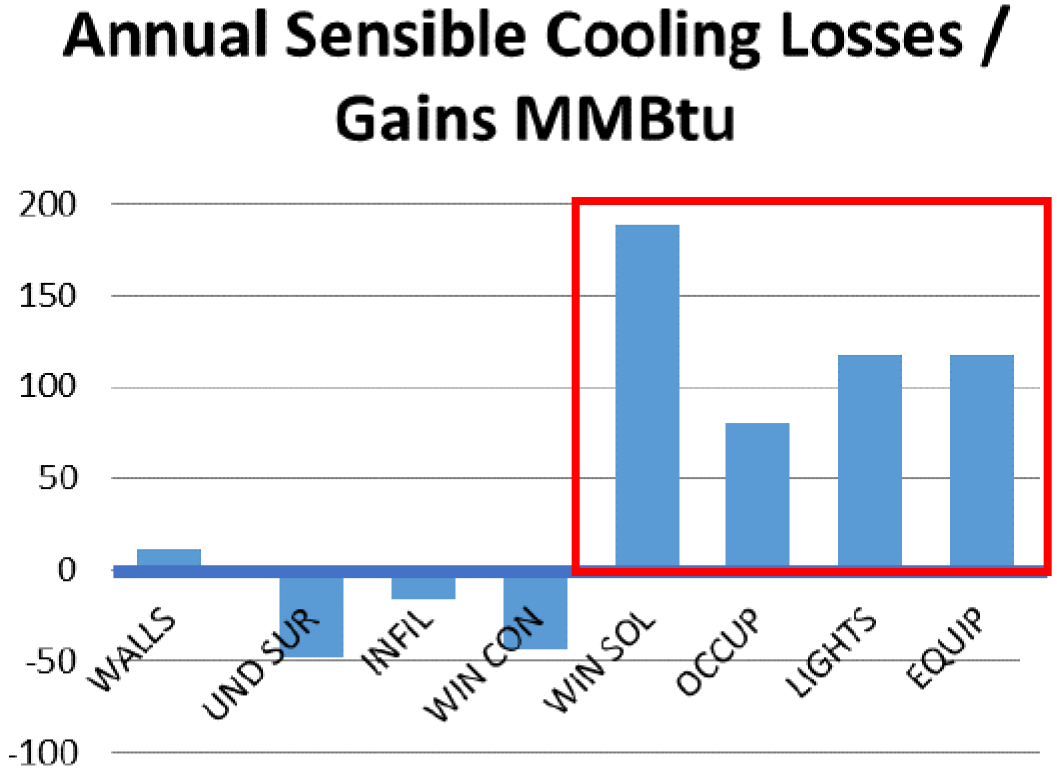
Establishing Load Reduction Priorities Based on Simple Box Model of LEED Baseline





Heating and Cooling Load Components





Load Reduction Targets

Component	Baseline	Recommended Target
Roof	R20 continuous insulation	R60 continuous insulation
Above Grade Walls	R13 steel frame wall + R7.5 continuous insulation	R40 continuous insulation
Windows	NFRC U-Factor = 0.55 / SHGC 0.4	Triple Pane Glazing NFRC U-Factor = 0.24 / SHGC 0.41
Window to Wall Ratio	25%	14%
Infiltration	0.4 CFM/SF @ 75Pa	0.25 CFM/SF @ 75Pa (Note 1)
Slab on grade	R-10 for 24"	R-20 for 24"

Note 1: Measured infiltration was 0.11 CFM at 75PA

Load Reduction and HVAC System Selection

	Baseline	Recommended Target
Lighting		
Whole Building LPD	1.0 W/ft^2	0.6 W/ft^2
Lighting Occupancy Sensors	Classrooms	Restrooms, lounges, dining room, storage areas
HVAC		
HVAC Description	PTAC units in each zone with a hot water coil served by a natural draft boiler plant and a DX cooling coil	Hot water baseboards served by steam to hot water heat exchanges from campus system
Ventilation Strategy	PTAC units run continuosly and provide ventilation air to each zone	2 constant volume DOAS units with 75% energy recovery effectiveness; 1 VAV DOAS unit serving dining area and lounges

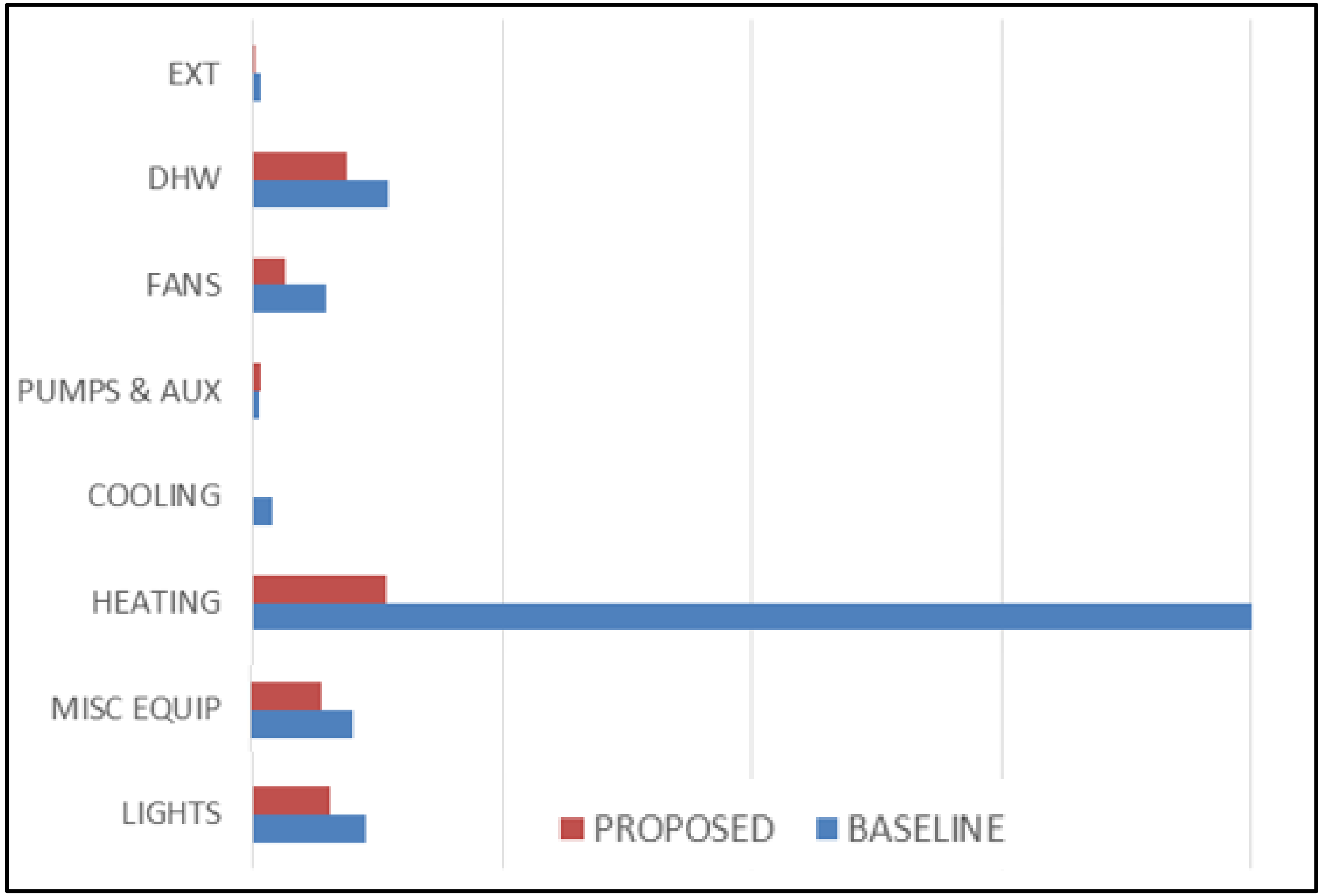
Design Optimization: ECM Analysis

Measure #	Measure Name	Cumulative Savings ($)	Cum.%
Base	Baseline Design		
1	Base + Energy recovery units + fin-tube	11,741	21%
2	1 + R-40 exterior walls	13,281	23%
3	2 + R-60 roof	14,238	25%
4	3 + R-20 below-grade walls	14,948	26%
5	4 + R-10 under-slab insulation	15,107	27%
6	5 + Triple glazed windows	17,502	31%
7	6 + Double glazed glass doors	17,717	31%
8	7 + Infiltration reductions	24,551	43%
9	8 + Exterior Lighting	24,926	44%

ECM Analysis (continued)

Measure #	Measure Name	Cumulative Savings ($)	Cum.%
10	9 + Reduced LPD	27,169	48%
11	10 + Occupancy sensors	27,595	49%
12	11 + Daylighting controls	27,656	49%
13	12 + Low flow fixtures	29,462	52%
14	13 + Washer and dishwasher DHW	29,543	52%
15	14 + Pump VFD	29,721	52%
16	15 + ERU DCV and VAV	31,992	57%
17	16 + Thermostat occupancy sensors	32,116	57%
18	17 + Cooling Off	34,376	61%
19	18 + Window shading	34,640	61%

Site Energy by End Use



Site Energy Use Intensity Results

	EUI (kbtu/ft^2)
Proposed Design, LEED	30
Actual Proposed before PV (w/o cooling, with manual shades)	27
Actual Proposed with PV	16

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Acknowledgements

- ASHRAE Standard 209P “Energy Simulation-Aided Design for Buildings”
- ASHRAE Standard 209 presentation at IBPSA-USA Summer Meeting St. Louis - June 25, 2016, by Jason Glazer and Erik Kolderup