Image: Ankrom Moisan Architects / Jeremy Bitterman

Energy Trust of Oregon Net Zero Fellowship Research

Approaching Net Zero for Today's Buildings

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Agenda

1. Research Goals
2. Research Approach
3. Case Study #1
4. Case Study #2
5. Conclusions

The Net Zero Fellowship aims to address potential barriers slowing the widespread adoption of net-zero design and to grow the community constructing these remarkable buildings.

Possible topics may include technical research, policy implications, economic benefits, market barriers and community-based net-zero projects.

Inaugural Net Zero Fellowship Research Goal

Identify the most cost-effective energy improvements to approach net zero energy use for two real case study buildings:

Midrise Multifamily

Low-to-Midrise Office

Research Approach

- Analyze **existing buildings that were designed for high performance** and completed within last five years to understand their current and potential operational performance.

- Evaluate strategies to achieve net zero energy performance and **analyze cost premiums, as well as overall economic feasibility,** through a pro forma that includes operational energy savings.

Costing Approach

- Pricing is the direct cost of construction materials and labor, including standard markups.
- Work is priced in 2018 dollars in the City of Portland.
- Pricing assumes a competitive bid process with at least 3 bidders and no preference for union or non-union labor.

SOURCE

Market Context – Construction Costs are HIGH

Image: Federal Reserve Bank of St. Louis

Market Context – Construction Costs are HIGH

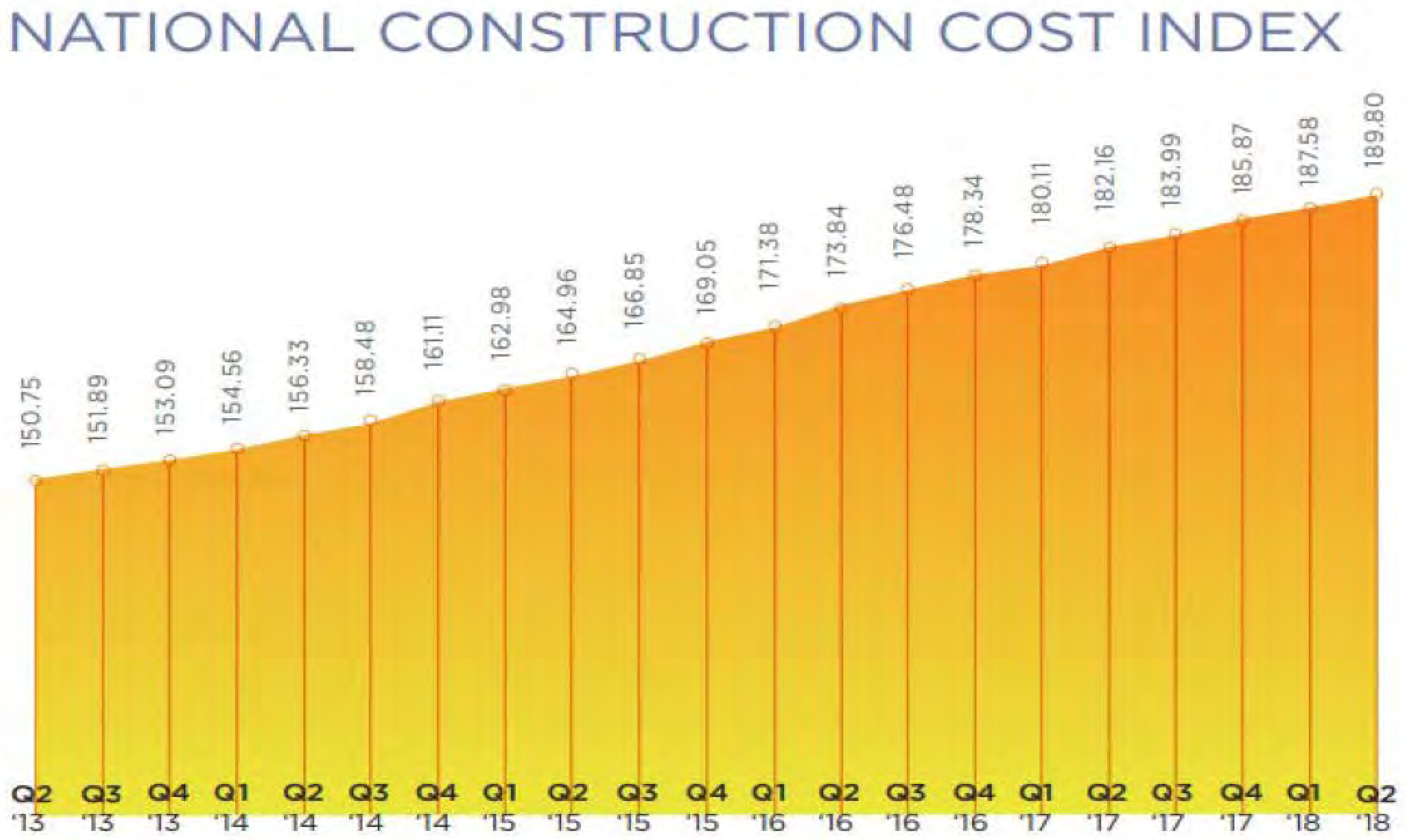


Image: Rider Levett Bucknall, Quarterly Construction Cost Report, Second Quarter 2018

Market Context – Construction Costs are HIGH

City	April 2017	July 2017	October 2017	January 2018	April 2018	Annual % Change
• Boston	20,835	20,989	21,176	21,325	21,563	3.49%
• Chicago	20,414	20,652	20,905	21,177	21,394	4.80%
• Denver	14,097	14,187	14,337	14,513	14,649	3.92%
• Honolulu	24,060	24,050	24,058	23,663	23,804	-1.06%
• Las Vegas	13,510	13,614	13,777	13,922	14,081	4.22%
• Los Angeles	19,997	20,326	20,586	20,874	21,010	5.07%
• New York	24,499	24,698	24,927	25,104	25,387	3.62%
• Phoenix	13,785	13,900	14,080	14,248	14,442	4.77%
• Portland	14,830	15,044	15,302	15,524	15,768	6.32%
• San Francisco	24,039	24,546	24,760	25,151	25,704	6.93%
• Seattle	16,419	16,654	16,804	17,017	17,250	5.06%
• Washington, DC	19,774	19,884	20,054	20,212	20,437	3.35%

Image: Rider Levett Bucknall, Quarterly Construction Cost Report, Second Quarter 2018

Financial Analysis - Basics

- Key variables for a project to move forward or “pencil”:
  - Cost to build ($$$ paid by owner)
  - Income/Rents ($$$ to owner)
- Project must provide enough economic return to attract investors
- $Return = \frac{Net\ Income\ (Rents)}{Net\ Cost}$
- Rents must be high enough and cost must be low enough to generate return
- Net Cost is cost less subsidies, grants, tax credit equity, etc.

Financial Assumptions

- Timing: the projects are in today's construction costs with today's rents
- Location: building location stays the same
- No additional rent premium for Path to NZ building versus Baseline LEED Platinum buildings
- However, we DO assume utility savings benefits proforma

Case Study 1:
Midrise Office

Image: Ankrom Moisan Architects

Midrise Office Case Study: Vestas Headquarters

Meier and Frank Building:

- 170,679 square feet
- 5 floors
- Commercial office tenants: GE, Vestas, Urban Shift
- Certified LEED Platinum in 2012
- Historic renovation operational since 2013

SOURCE

Vestas Headquarters Sustainability Features

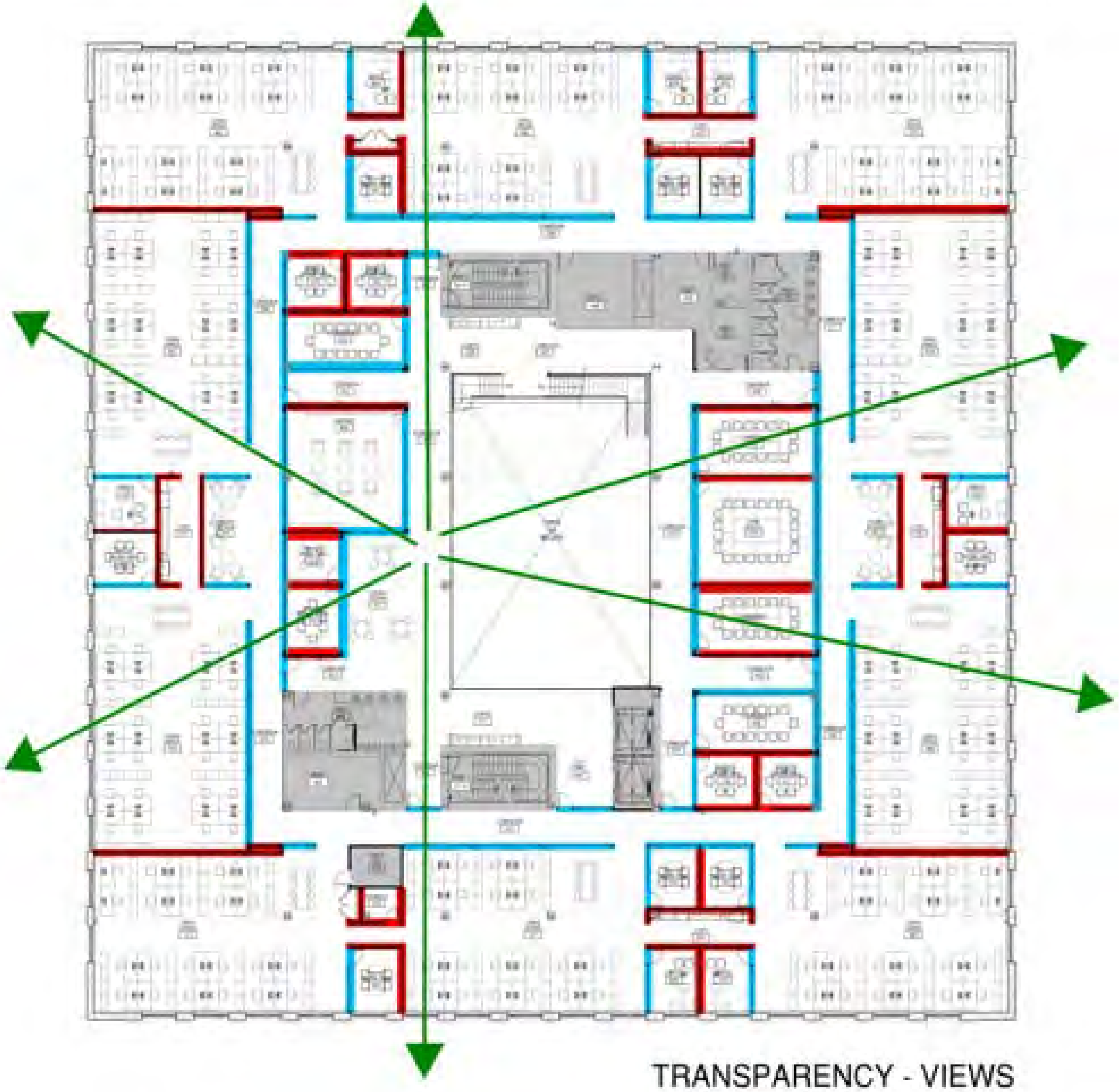
Envelope

- Thermal Mass – Exposed Concrete Floors
- Well-Insulated Roof (R30) Over Concrete
- Operable Windows

Efficient and Natural Lighting

- Daylighting through interior atrium
- Lighting controls and occupancy sensors
- Lower lighting power density 0.54 W/sf

Vestas Headquarters Sustainability Features



TRANSPARENCY - VIEWS

Windows: Benefits and Challenges

HVAC and Renewables

HVAC: Level 1

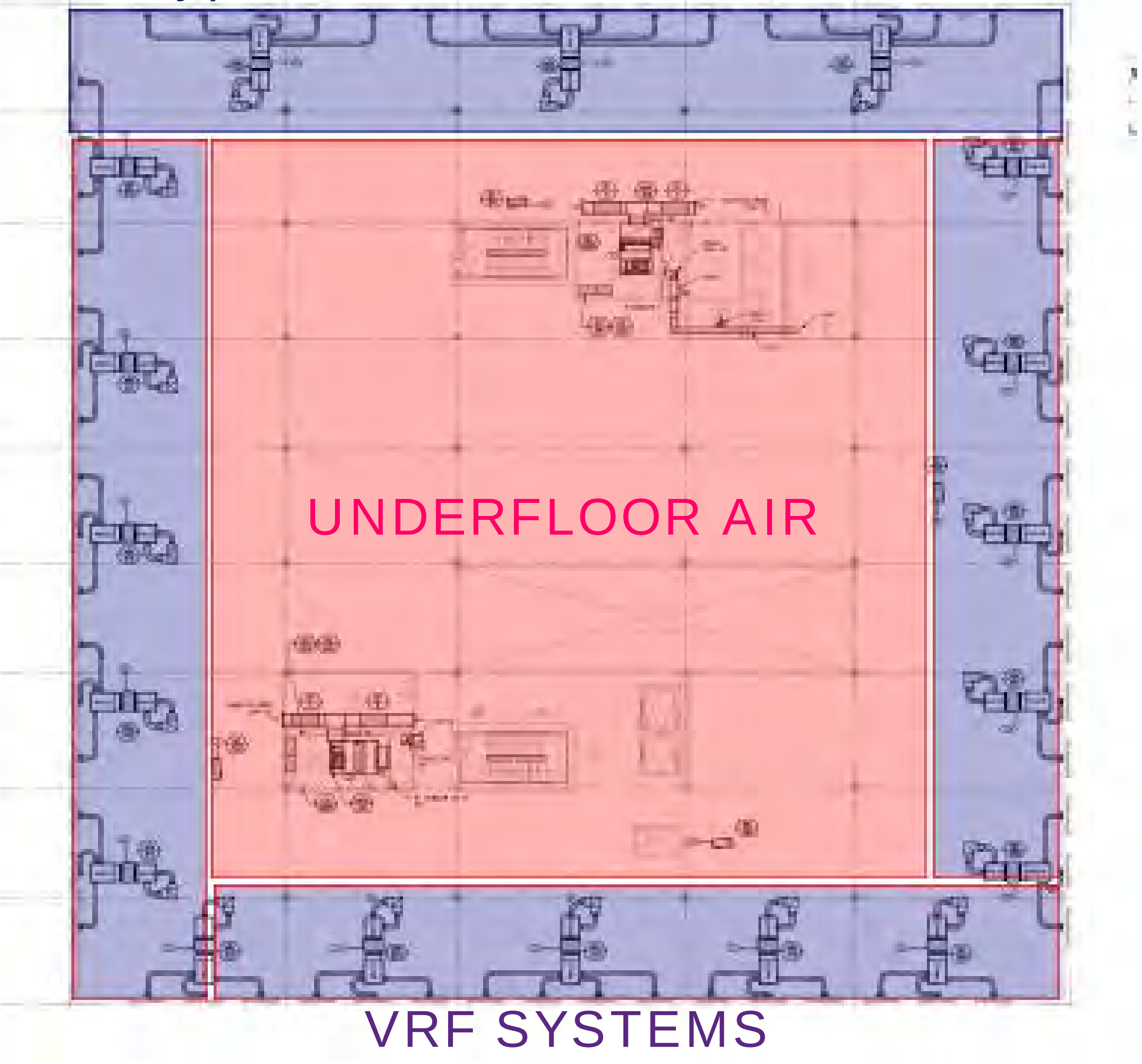
- Water source heat pumps
- Energy Recovery on Ventilation Air System

HVAC: Levels 3-5

- Underfloor Air Distribution (window height challenge)
- VRF with water cooled condensers in perimeter areas

Rooftop Solar 125 kW PV Array

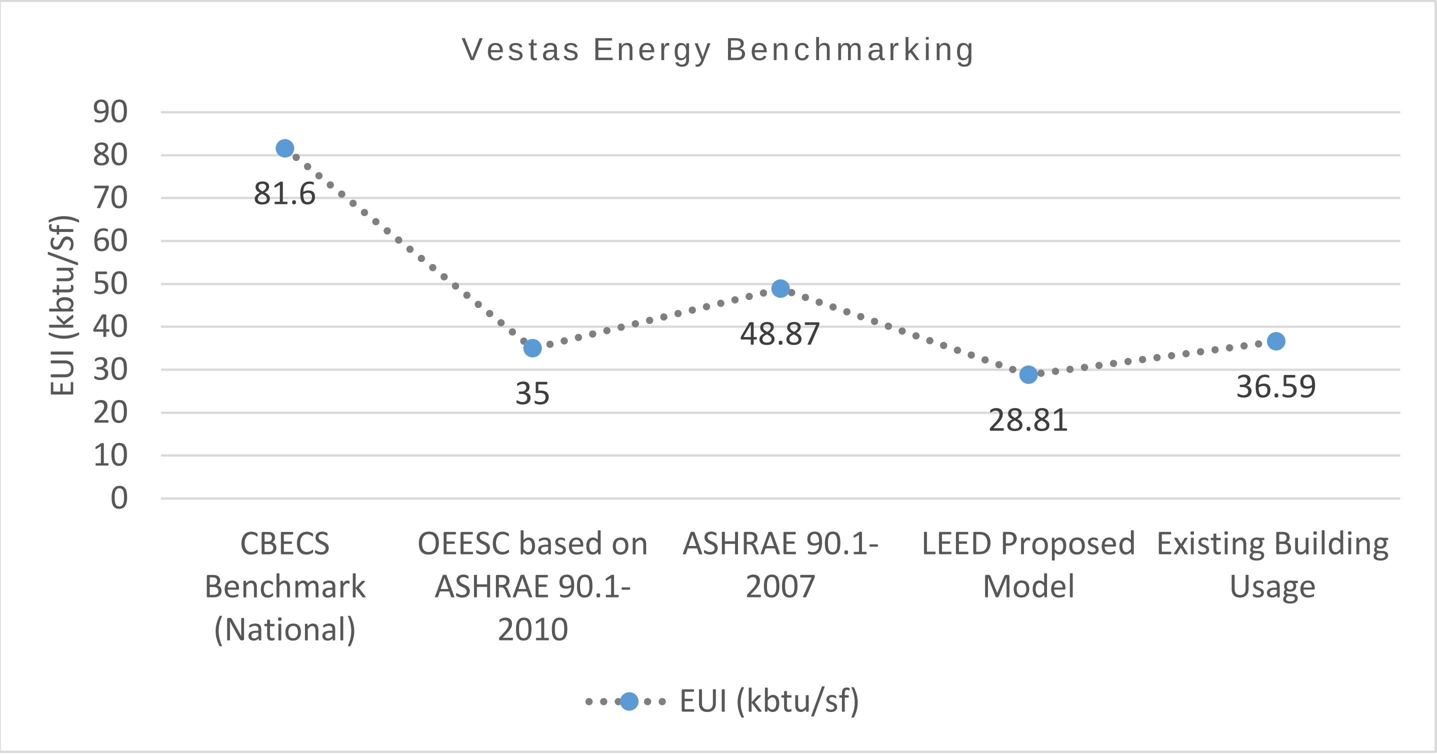
Typical Floor Plan Floors 3-5



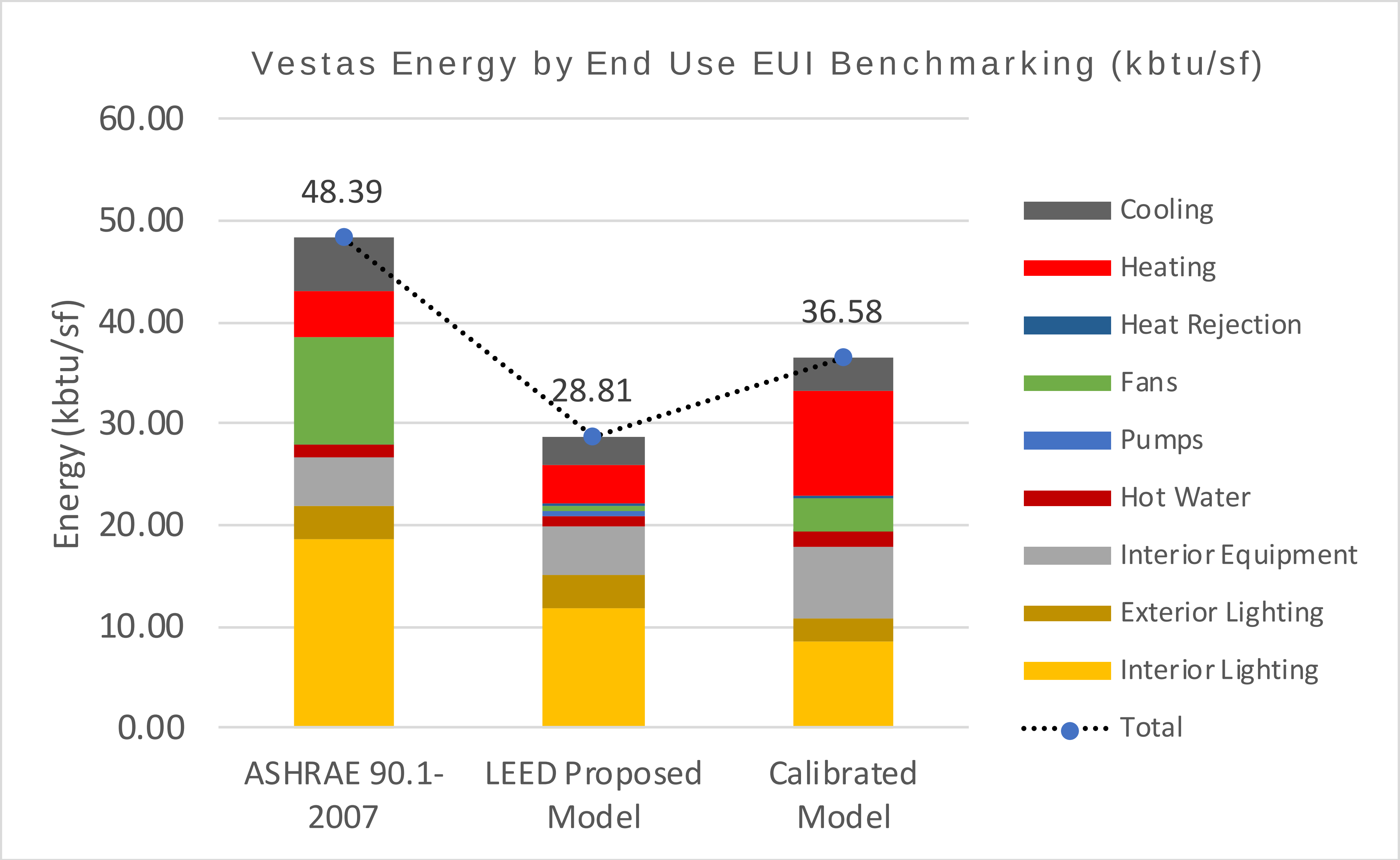
Establishing Baseline

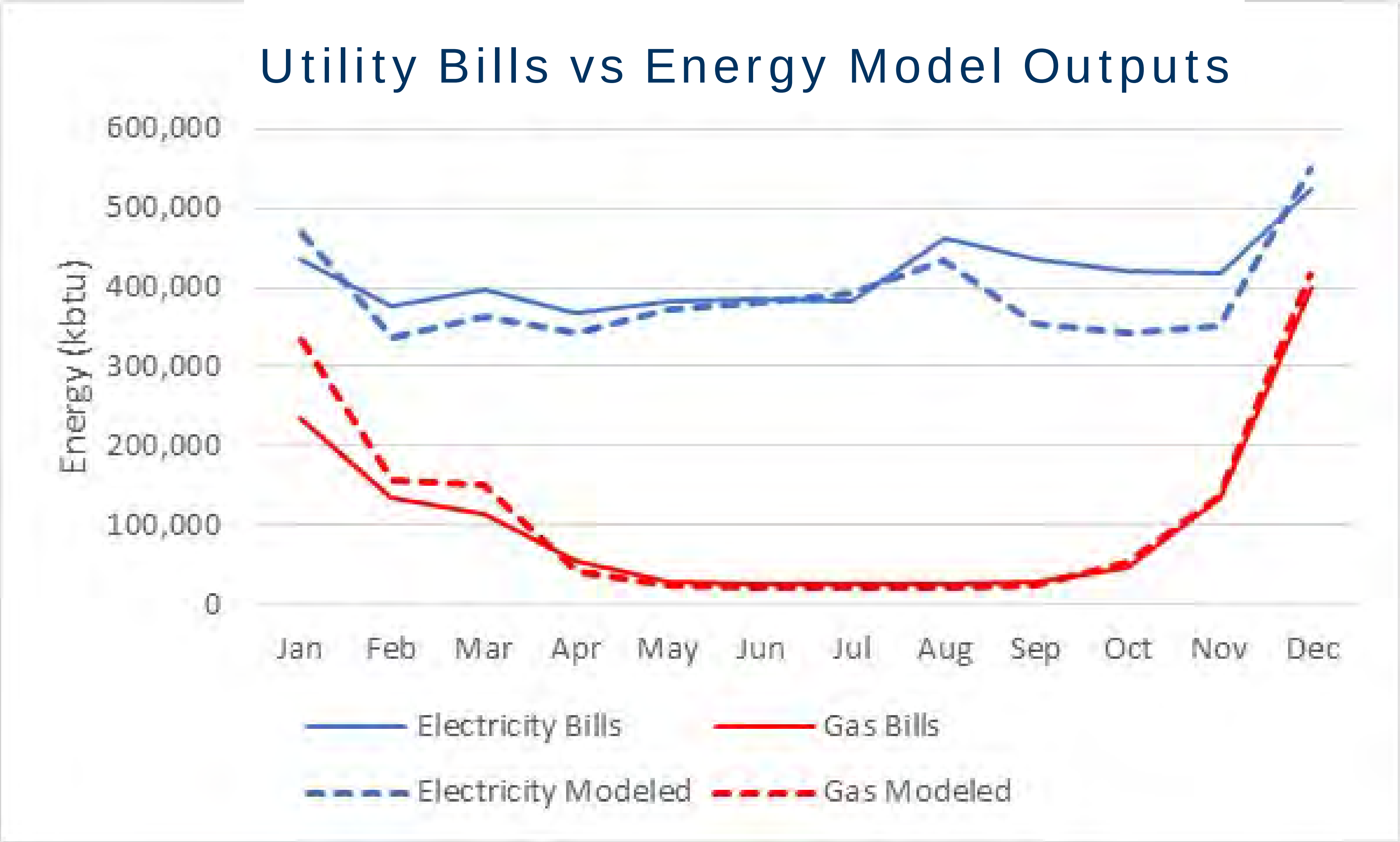
Vestas Energy Benchmarking – EUI 36.58 kbtu/sf

- Verified through utility bills
- Gap between predicted and measured energy performance is 21.2%
- Onsite PV generation offsets 6-9% of building electricity usage

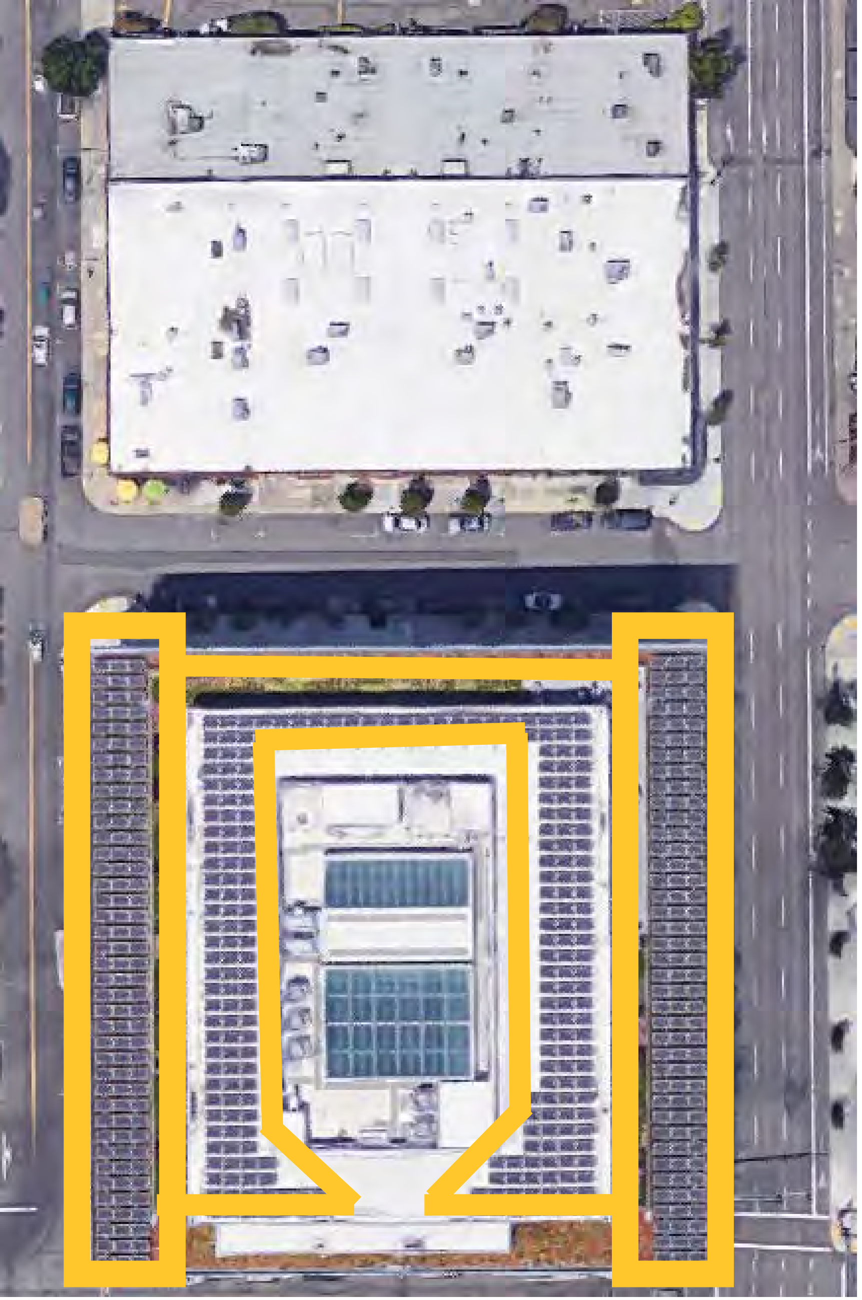


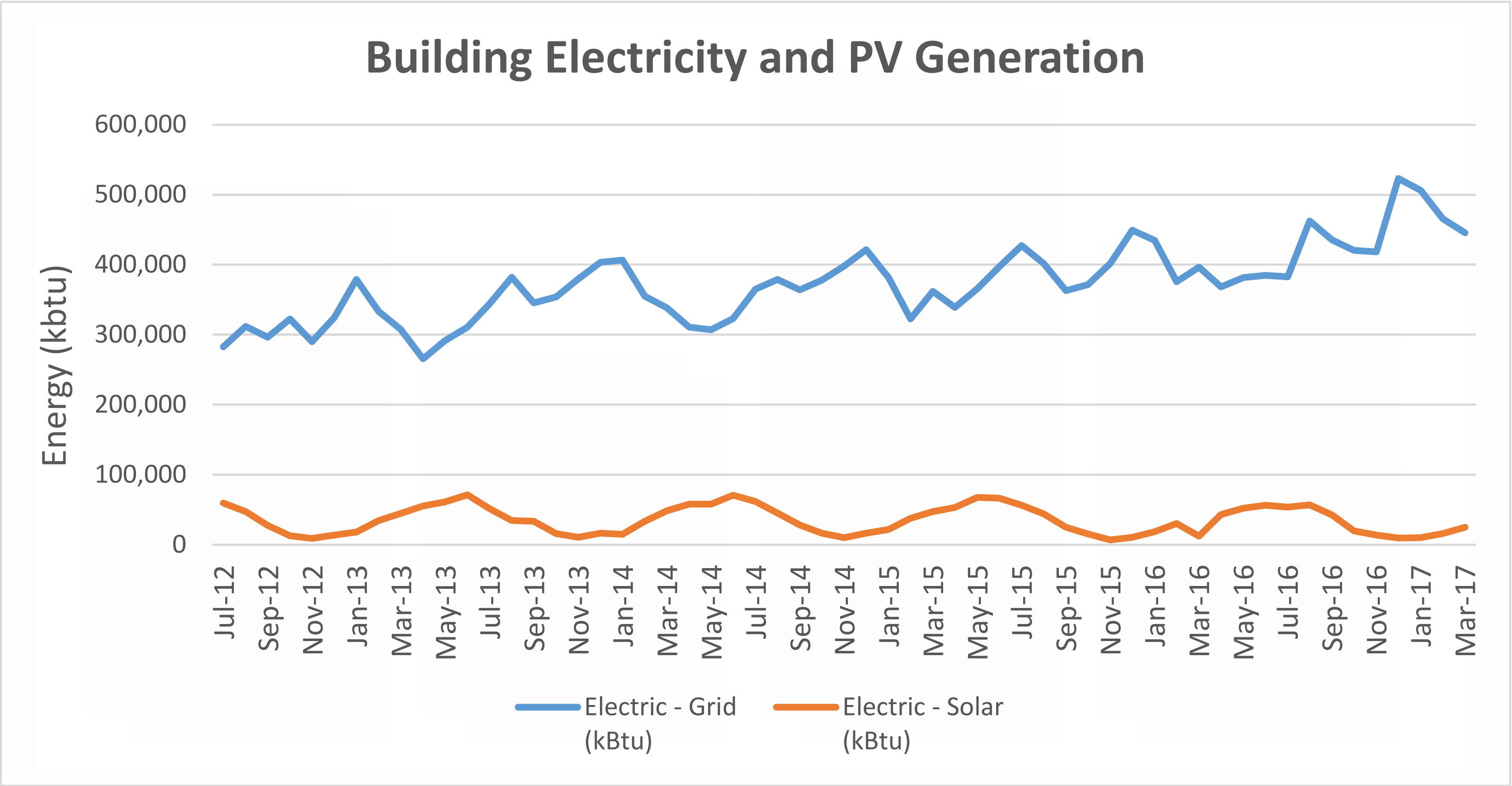
Establishing Baseline



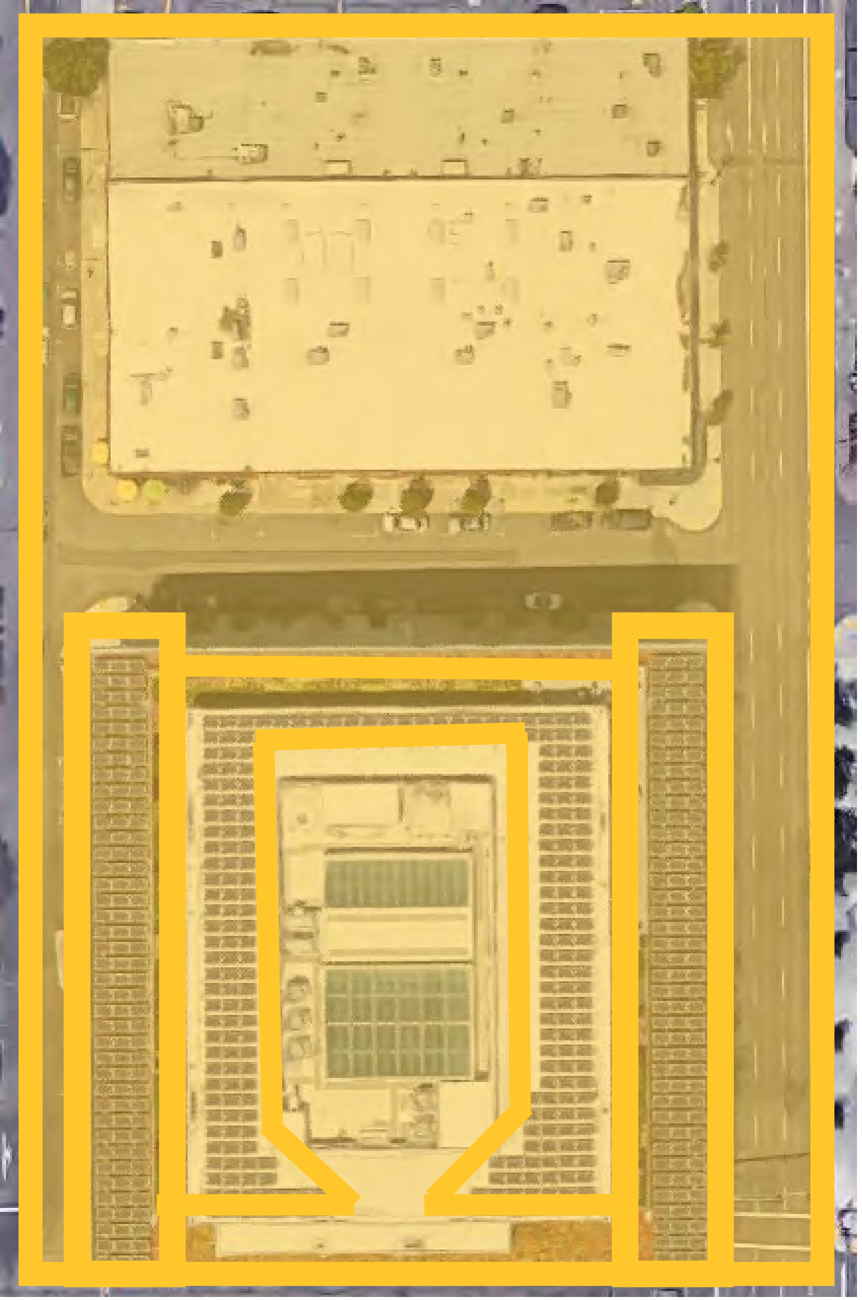


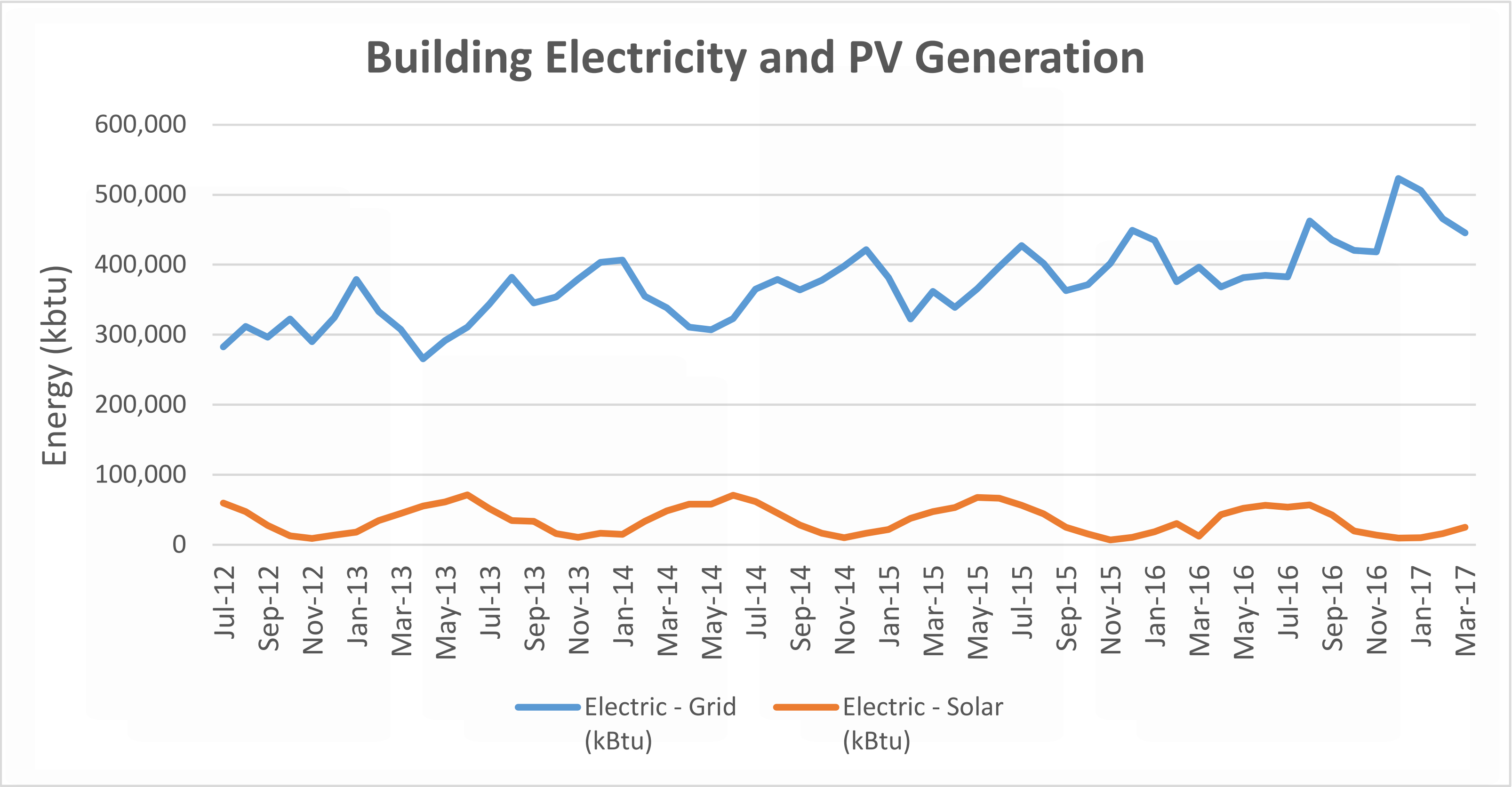
Model calibrated within 5-12% range of electricity and gas reported in utility bills for 2016.





Vestas Existing Solar – 125 kW





Solar Needed – 750 kW, or 3x available rooftop

Vestas Existing Solar – 125 kW

Efficiency Strategies Considered

Envelope:

- Increase thermal performance of walls and windows
- Reduce window wall ratio
- Increase roof insulation
- Reduce glazing U value

Shading:

- Solar heat gain coefficient (SHGC)
- Use dynamic glass
- Automated blinds
- Increase shading on south/west facades

Daylight/Lighting:

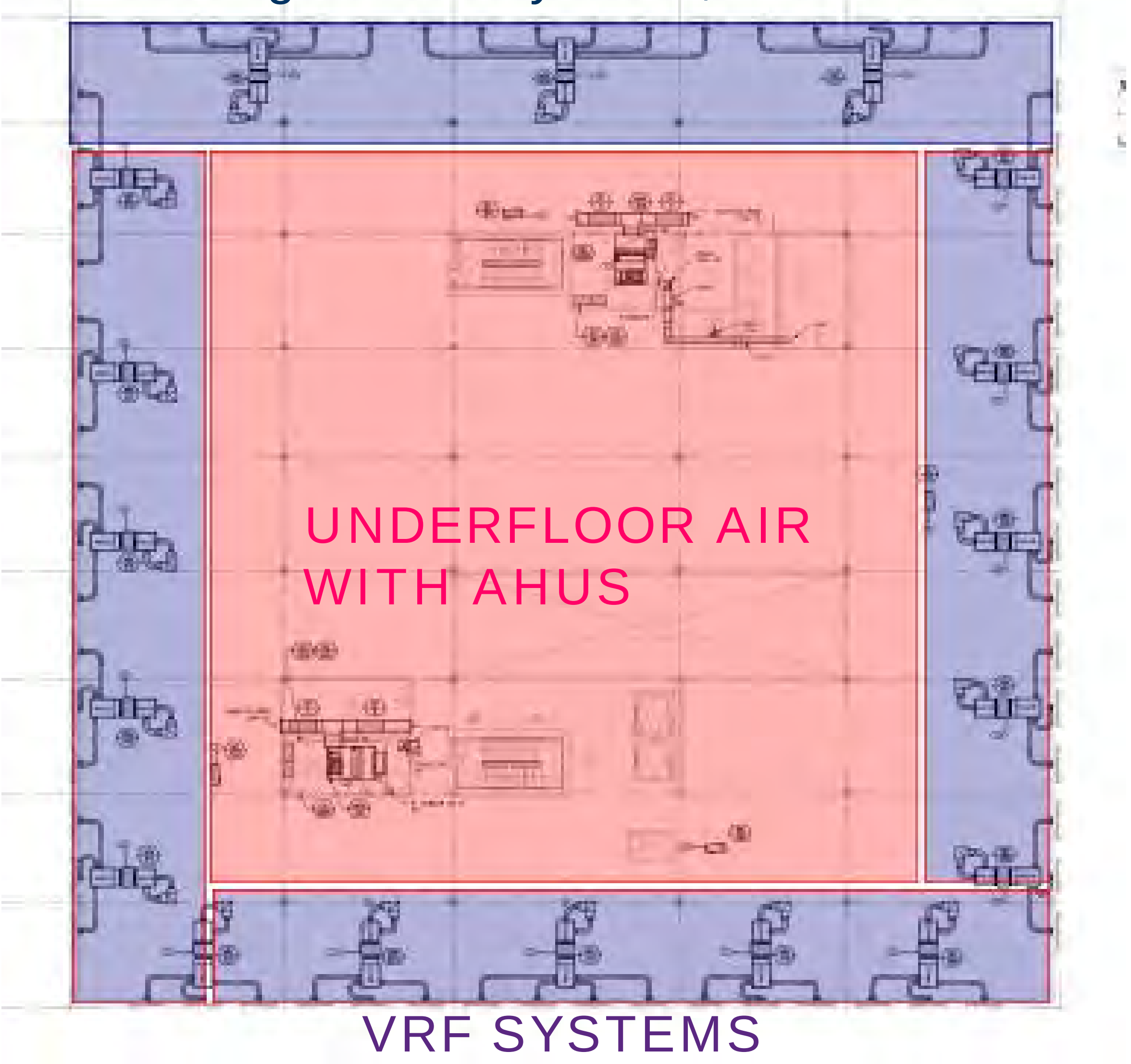
- Switch from fluorescent to LED fixtures to reduce lighting power density from .57W/sf to .4W/sf
- Add skylight on Level 5

HVAC:

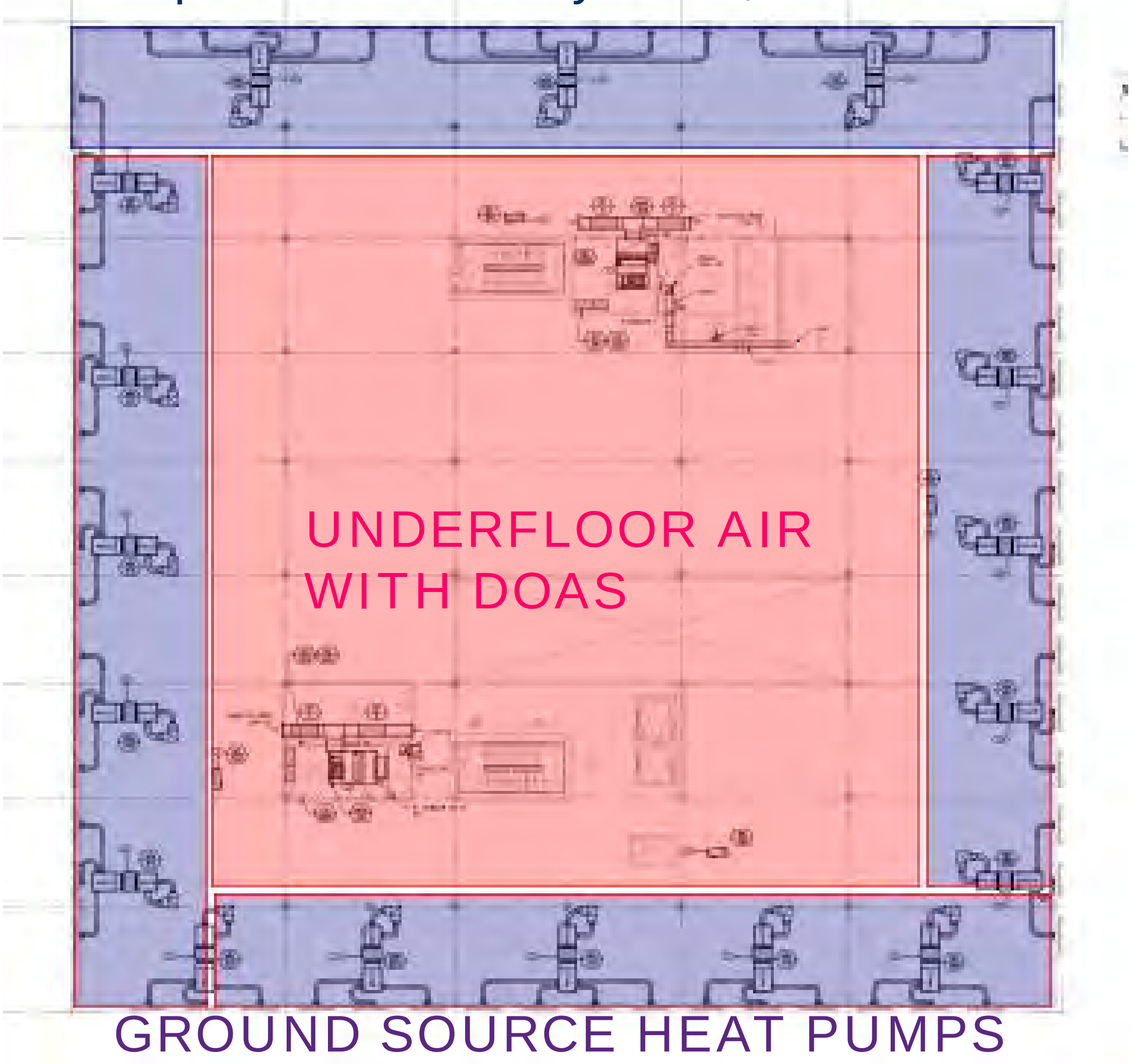
- Convert water heater from gas fired to heat pump
- Switch boiler/fluid cooler system to geothermal
- Radiant heating and cooling

HVAC Upgrades

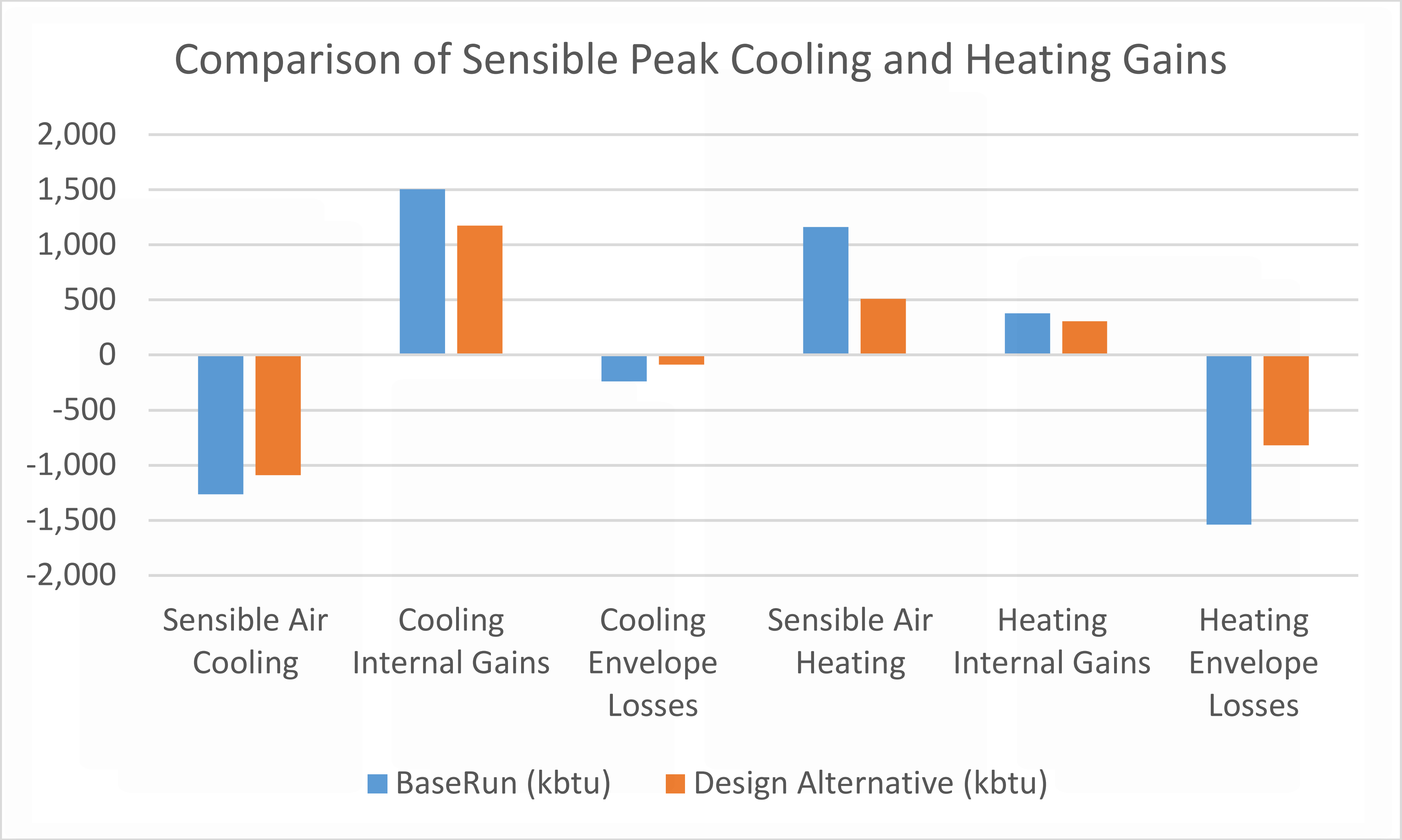
Existing HVAC System, Floors 3-5



Proposed HVAC System, Floors 3-5



Goal: Reduce EUI to Under 20 kbtu/Square Foot



EUI Reduction Strategies With Costs

Bundled Strategies	EUI (kbtu/sf)	Annual Energy Savings	Annual Cost Savings	First Cost	Cost/sf	Cost/EUI/sf
Building As Is	36.12	-	-	-	-	-
1: Envelope Upgrade	34.97	3.19%	$13,432	$1,034,718	$6.06	$5.28
2. Shading	35.38	2.05%	$8,182	$259,038	$1.52	$2.06
3. Lighting/Plug Load Reductions	33.90	6.14%	$7,261	$270,124	$1.85	$0.84
4. Heat Pump Water Heater	35.97	0.41%	-$4,057	$11,466	$.07	$0.46
5. Ground Source Heat Pump	22.67	37.23%	$44,395	$1,526,850	$8.95	$0.67
All Strategies, Bundled	20.50	43.25%	$54,062	$3,148,117	$18.44	$1.18

Resulting Economics – Vestas Office Building

- Target Return on Cost for Portland Office: 7.00%

Vestas Office Building	No Historic Tax Credits		Path to Net Zero	
Feasibility	Baseline	Path to Net Zero	Premium	$/GSF
Total Costs in 2018 dollars	**$82,080,000** $454/GSF	**$85,490,000** $473/GSF	4%	$473
Additional Capital Incentives /GSF	**$52.43**	**$66.51**		$14.08

Vestas Office Building	With Historic Tax Credits		Path to Net Zero	
Feasibility	Baseline	Path to Net Zero	Premium	$/GSF
Total Costs in 2018 dollars	**$82,390,000** $456/GSF	**$85,800,000** $475/GSF	4%	$475
Additional Capital Incentives /GSF	**$15.54**	**$28.02**		$12.48

Case Study 2:

Multifamily Residential

Image: Holst Architecture

Multifamily Residential Case Study

Beech Street Apartments

- 36,742 square feet (Building owned and managed by Home Forward)
- 4 floors
- 32 units of affordable housing for women and children
- New Construction (2014)
- LEED for Homes Platinum certified

SOURCE

Beech Street Apartments Sustainability Features

Envelope

- Exterior walls insulated to R16, roof to R50
- Low window wall ratio (16%) and high performance glazing

Efficient HVAC Systems

- VRF fan coil units and air cooled condensing units
- Make up air unit with heat recovery system

Lighting

- Fluorescent lighting, good daylight and operable windows

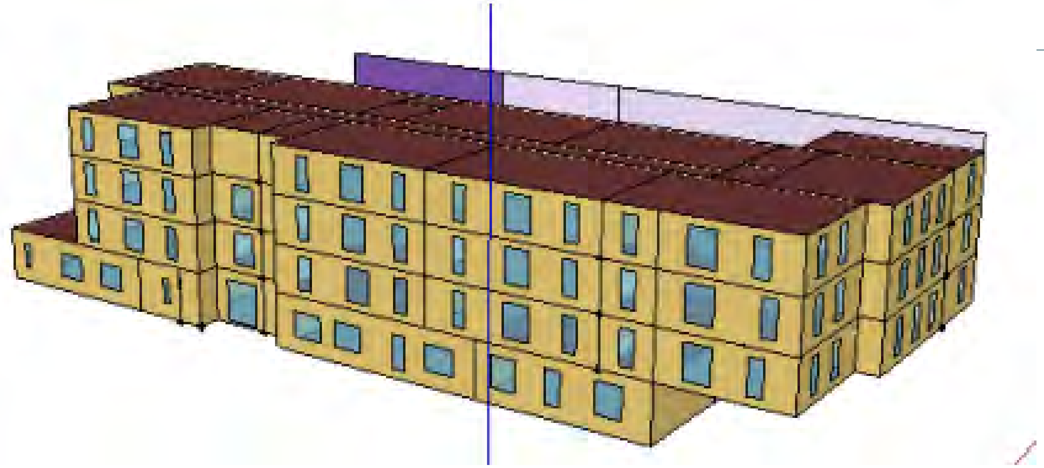
Beech Street Apartments Sustainability Features

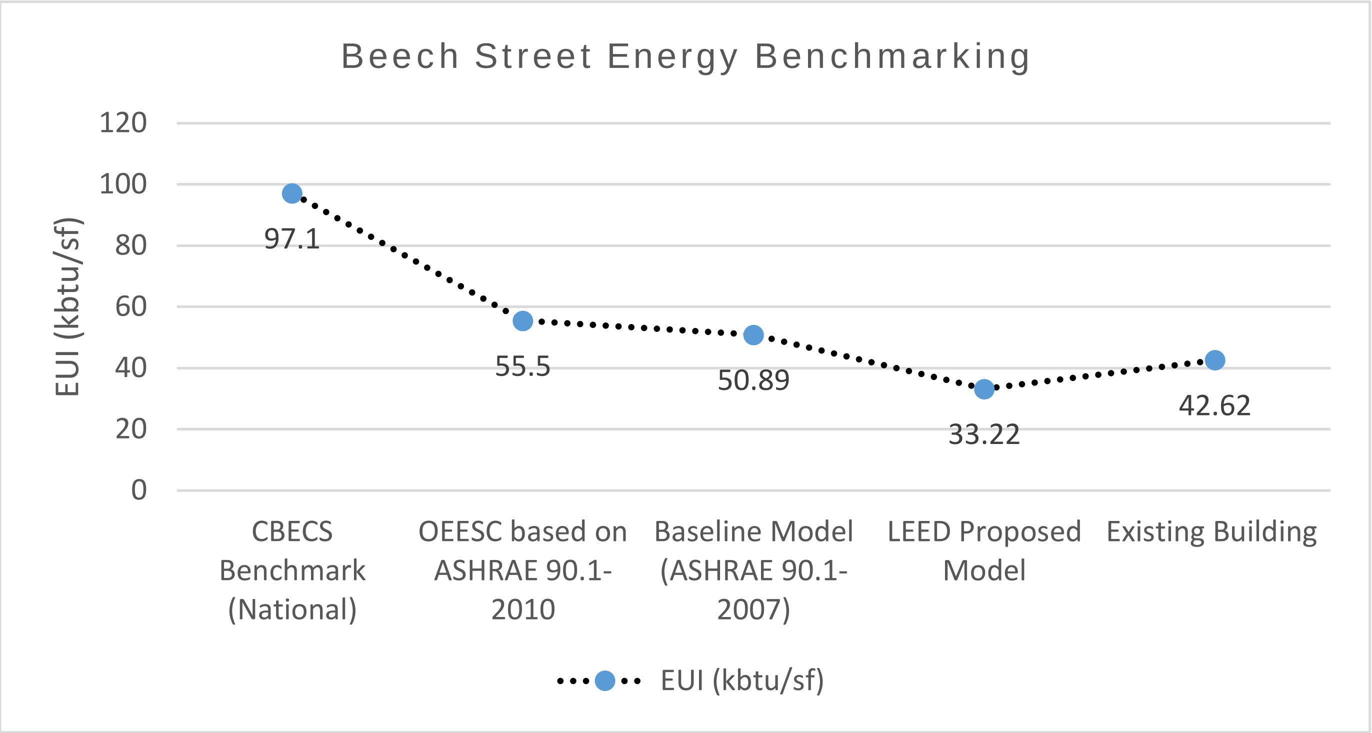
Awning Window Ventilation Challenges

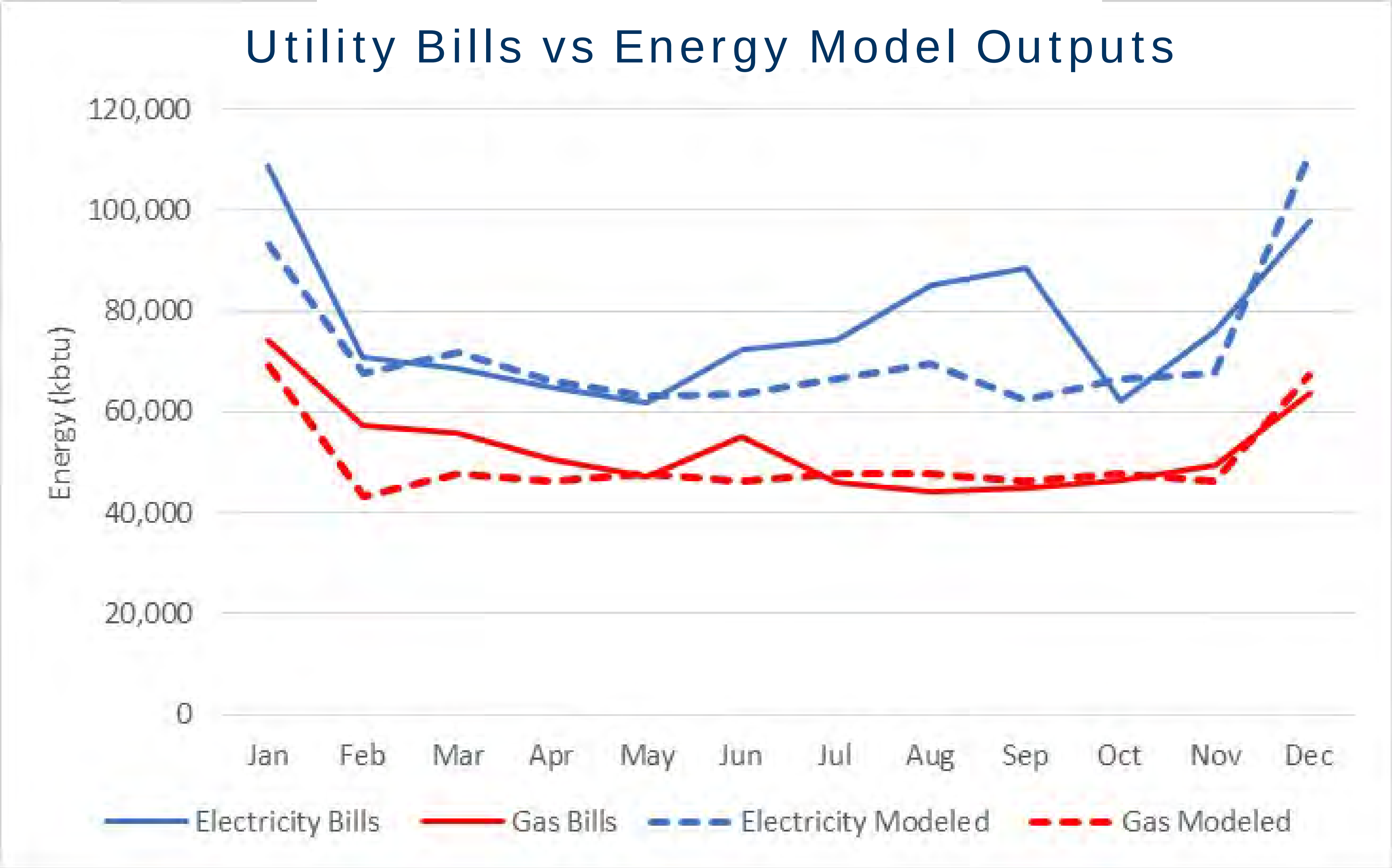
Establishing Baseline

EUI 42.62 kbtu/sf

- Verified through utility bills
- Gap between predicted and measured energy performance is 22%

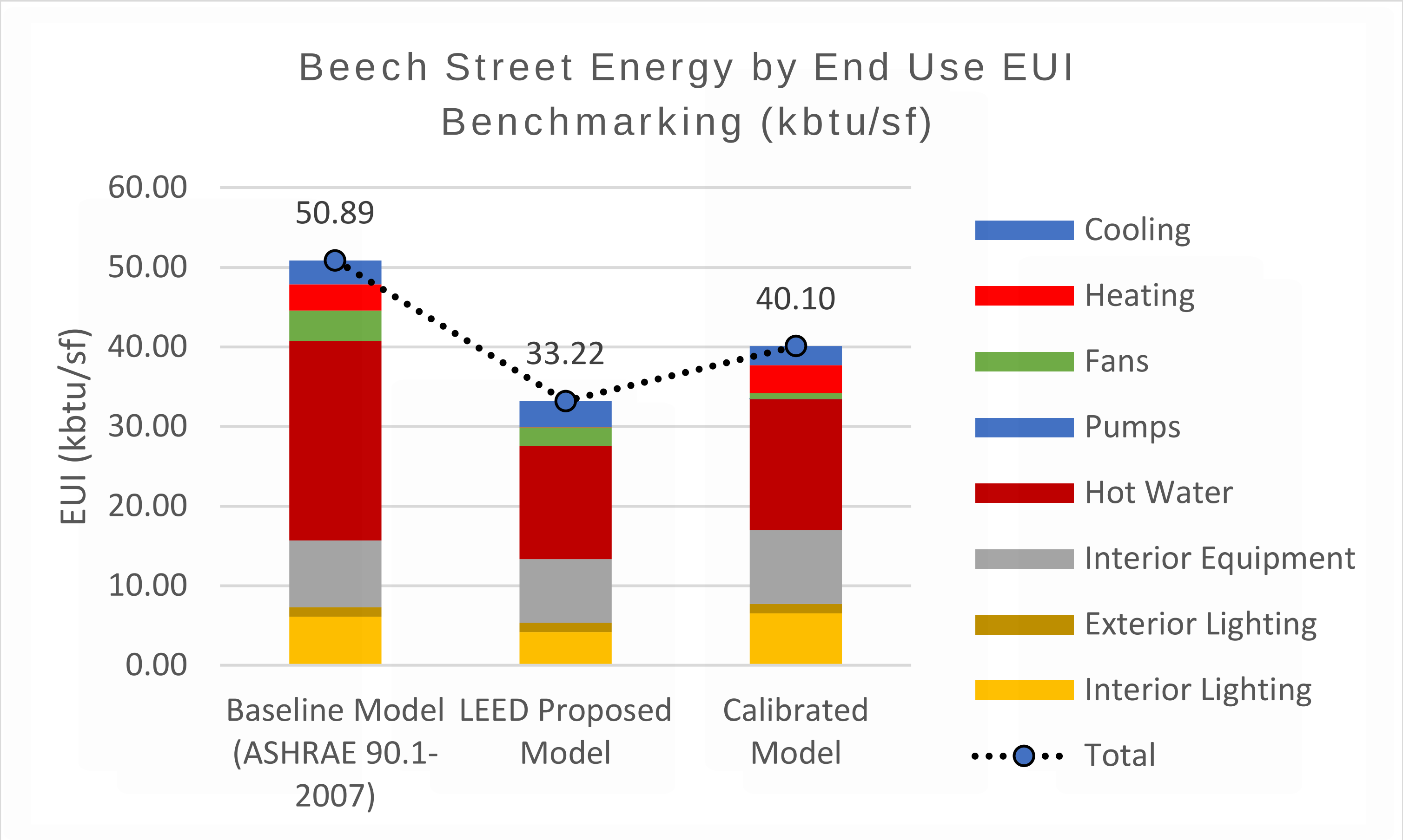






Model calibrated within 5-10% range of utility bill data for 2016.

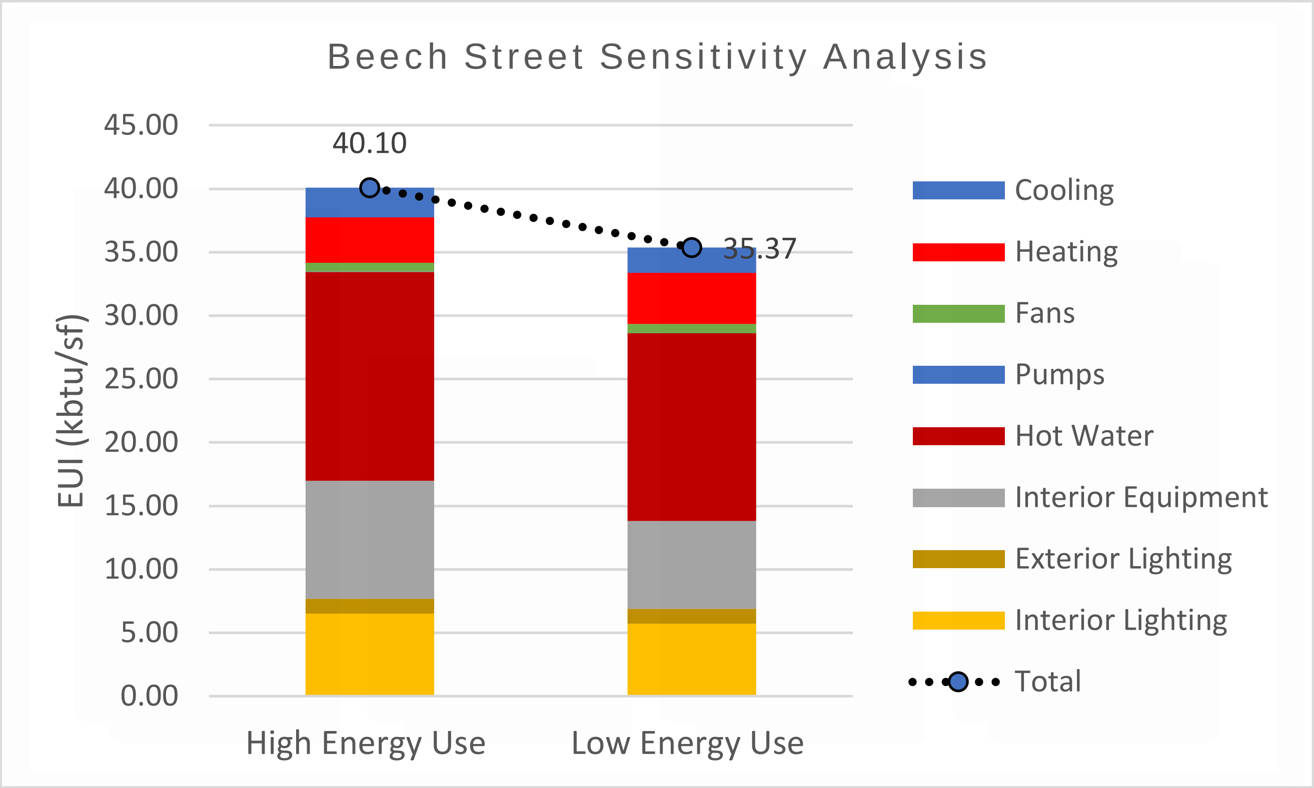
Establishing Baseline



Sensitivity Analysis

Sensitivity Analysis, Adjusted For:

- Lighting operational hours
- Plug load operational hours
- Water schedule

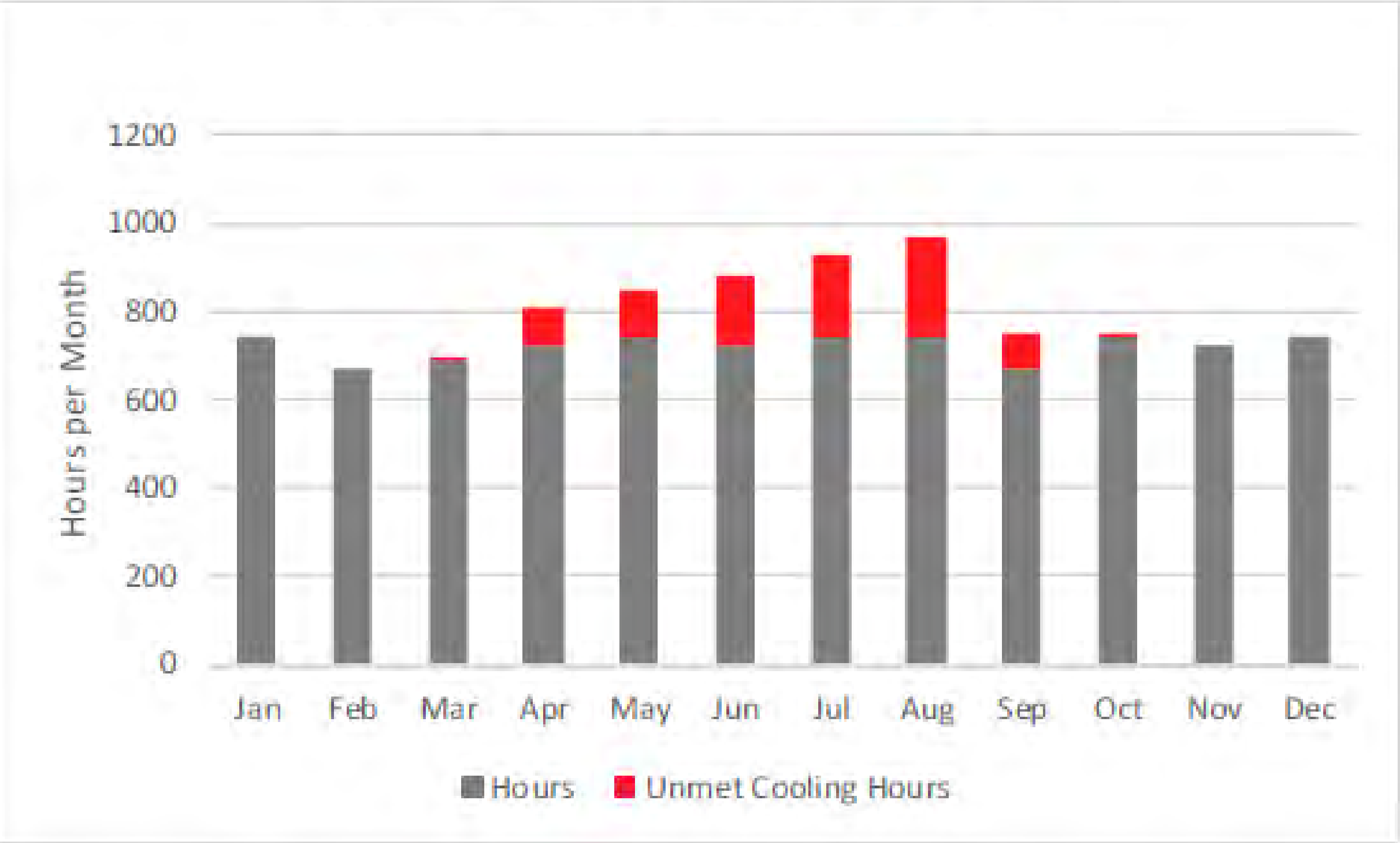


(Re) Establishing Baseline for Cooling/Comfort

Occupant Feedback:

- 100% of occupants surveyed felt summer indoor air temperatures needed improvement
- Cooling added to the Baseline

Unmet Cooling Hours for Sample Unit 151



Efficiency Strategies Considered

Envelope:

- Insulate walls
- Insulate roof
- Window Wall Ratio
- Increase air tightness, .25 cfm/sf, 0.08 cfm/sf

Shading:

- Add shading devices on south/west facades
- Solar Heat Gain Coefficient
- Select low U value glazing

Daylight/Lighting:

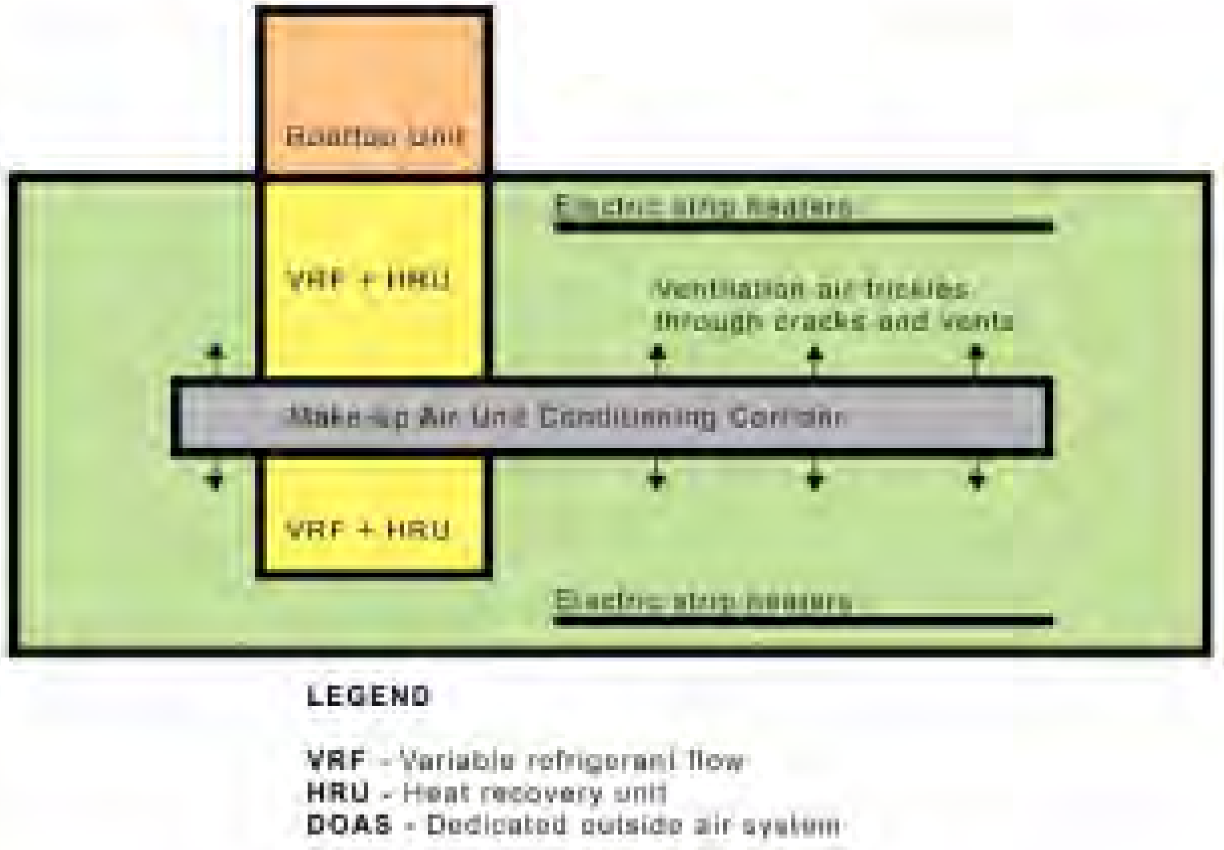
- Replace fluorescent fixtures with LEDs to lower lighting power density from .65W/sf to .5W/sf.
- Turn off nighttime equipment use
- Add light shelves to units

HVAC/Hot Water

- Convert gas fired water heater to heat pump water heater
- Reduce hot water usage
- Use heat recovery ventilators (HRVs) in units
- Use radiant heating and cooling in units
- Solar thermal to offset hot water heating

HVAC Upgrades

Existing HVAC System



Proposed HVAC System

Beech St Apts - EUI Reduction Strategies With Costs

Bundled Strategies	EUI (kbtu/sf)	Annual Energy Savings	Annual Cost Savings	First Cost	Cost/sf	Cost/EUI/sf
Building As Is	36	-	-	-	-	-
1: Envelope Upgrade	35	3.55%	$1,162	$425,621	$11.58	$9.78
2. 20% Lighting Reduction	35	3.29%	$1,153	$40,301	$1.10	$0.93
3. Nighttime Plug Load Reduction	35	2.36%	$828	$119,480	$3.25	$3.83
4. Heat Pump Water Heater and Hot Water Reduction	27	23.83%	-$1,539	$23,318	$0.63	$0.07
5. Add DOAS w/ HRU/VRF in Units	35	2.18%	$765	$342,576	$9.32	$11.91
All Strategies, Bundled	24	33.02%	$1,361	$951,297	$25.89	$2.24

Resulting Economics – Beech Street Apartments

- Target Return on Cost for Portland Multifamily: 5.75%

Beech Street Apartments	Market Rate		Path to Net Zero	
Feasibility	Baseline	Path to Net Zero	Premium	$/GSF
Total Costs in 2018 Dollars	$13,000,000	$14,020,000	8%	$380
Additional Capital Incentives/GSF	$104.76	$132.24		$27.49

Conclusions

Image: Holst Architecture

Conclusions of the Study

- Energy models predict building performance, not people. The initial gap to Net Zero was larger than predicted/designed.
- Typical project process doesn't leave time for early energy analysis – but it probably should.
- The baseline for multifamily housing (especially affordable housing) does not currently include cooling. That creates increased energy draws from personal cooling solutions, *and* uncomfortable conditions for residents. Energy Trust is actively exploring these issues.
- The research provides new information about net zero strategies for common building types that the market is not designing to net zero – comparable net zero buildings were very hard to find.

Conclusions – Costing

- Commercially available technology today is readily available to build net zero buildings. The market conditions are not quite there yet.
- Increasing baseline standards for code or comfort will make the relative premium costs smaller.
- The current construction market pricing makes net zero buildings challenging. New financing options can make a difference.

Conclusions – Financial

- Increased demand on labor and materials, combined with not enough supply, has skyrocketed construction costs.
  - *Opportunity*: if/when costs settle down relative to market rents, the gap may not be as expensive. Subsidies or other gap financing would help make these project achievable.
- The relative costs for more energy efficient upgrades is still high.
  - *Opportunity: as R&D continues and scale decreases relative cost of measures, Net Zero becomes more achievable.*
- Making a net zero building design a reality can be a complex challenge in today's construction market. Financial subsidies and technical resources can help, but there is still a gap.

EnergyTrust of Oregon

CITY OF PORTLAND, OREGON 1851

PACENow Financing Energy Efficiency

Thank you!

Image: Ankrom Moisan Architects / Jeremy Bitterman

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