A NET-ZERO APPROACH FOR SMALL OFFICE BUILDINGS

A Feasibility Study For Market Competitive High Performance Small Office Buildings

October 1, 2015 - DRAFT


SUSTAINABLE ENERGY FUND
Re:Vision

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This study was comissioned by the Sustainable Energy Fund to assess feasibility for the design and construction of a net-zero energy multi-tenant office building in the Lehigh Valley area of Pennsylvania.

We’ve seen net-zero energy (NZE) large office buildings.

NREL RESEARCH SUPPORT FACILITY
Location: Golden, Colorado
Design: RNL Design with Stantec
Construction: Haselden Construction

Size: 220,000 sf
EUI*: 35 kBTU/ft^2/year
Cost**: $57.4m ($260/ ft^2)

Net-Zero Energy Certified 2011

**Energy Use Intensity - EUI is a common metric which will be referred to throughout this report. Unless noted otherwise all EUI values are “site” values. This means the amount of energy used on site. “Source” EUI, where noted, accounts for the “site” value plus transmission losses.*

*** Published Construction Cost*


DRINK
JUICE
EAT
ORGANIC

And we’ve seen NZE medium office buildings.

BULLITT CENTER
Location: Seattle, Washington
Design: Miller Hull Partnership
Construction: Schuchart Construction

Size: 50,000 sf
EUI*: 16 kBTU/ft^2/year
Cost**: $18.5m ($370/ft^2)

Net-Zero Energy Certified 2015

**Energy Use Intensity - EUI is a common metric which will be referred to throughout this report. Unless noted otherwise all EUI values are “site” values. This means the amount of energy used on site. “Source” EUI, where noted, accounts for the “site” value plus transmission losses.*

*** Published Construction Cost*


WESTFALIA
Re:Vision ARCHITECTURE
ACTIVE DRIVEWAY DO NOT PARK HERE
WORK IN PROGRESS
FPV-0518

Precedents for NZE small office buildings are harder to come by.

RE:VISION ARCHITECTURE, Philadelphia, Pennsylvania
5,000 sf
EUI (site) - 24 kBTU/ft^2/year
LEED-EB Platinum

Approximately 1/3* of all commercial office square footage in the United States is found in buildings under 25,000 total square feet. Small office buildings vary wildly in age, context, quality and use.

**2012 Commercial Buildings Energy Consumption Survey*

SYNERGIS TECHNOLOGIES, Quakertown, Pennsylvania
23,000 sf
Adaptive reuse of 100 year old manufacturing building


BERKS COUNTY COM
PAST
PRESENT
FUTURE

This study focuses on a specific kind of small office building - multi-tenant with owner occupancy - and the market feasibility of achieving NZE within this typology.

The short story:
it can work.
For the longer story, read on...

BERKS COUNTY COMMUNITY FOUNDATION, Reading, PA
14,800 sf
LEED-NC Platinum

01 | What is NZE?

The Net-Zero Energy equation is simple:
ENERGY GENERATED ≥ ENERGY USED

Getting there is more complicated though.

The “net” in Net-Zero refers to the annual period in which energy is calculated. It is acceptable to import energy in some months as long as excess generation in others balances out over the course of a year.

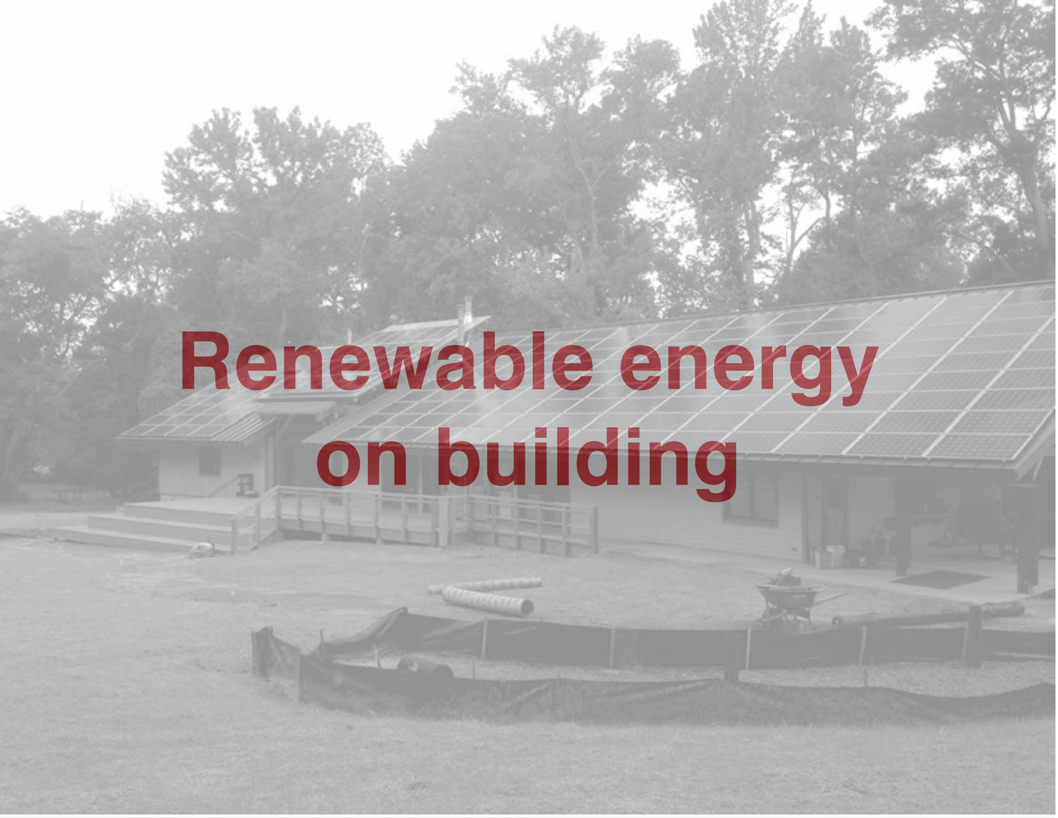
NREL defines the NZEB (net-zero energy building) renewable energy supply heirarchy in descending order as:

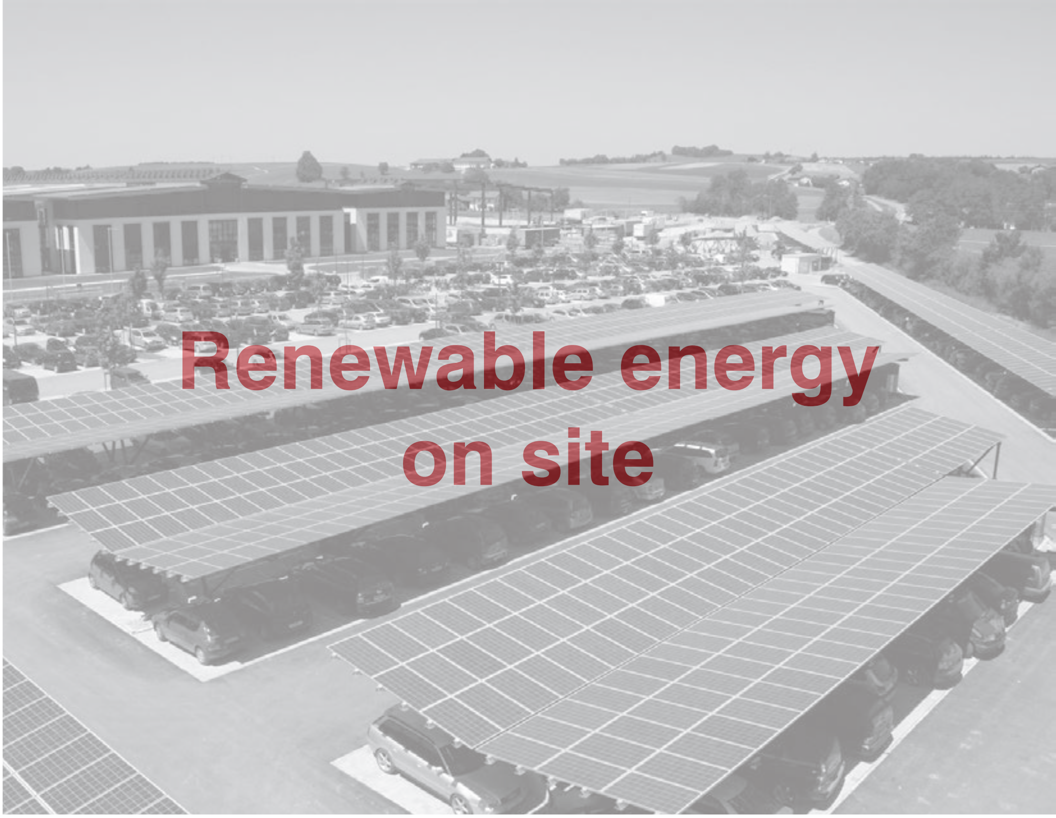
0. Reduce energy demand
1. Generate energy within the building footprint
2. Generate energy within the project site
3. Generate energy from off-site resources
4. Purchase off-site renewable energy sources

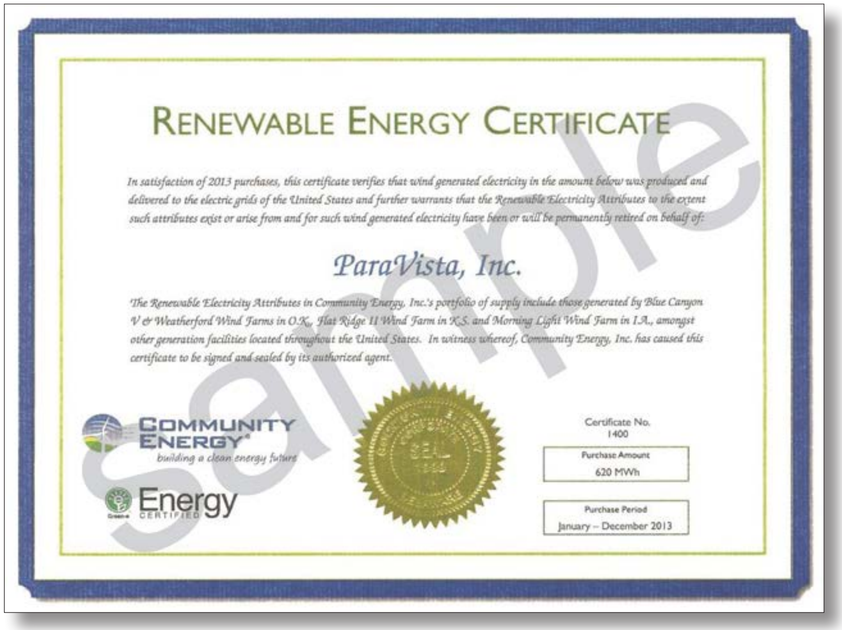
Similarly, NREL classifies NZEB’s as follows:

NZEB:A	Uses renewable energy sources within the building footprint.
NZEB:B	Uses renewable energy sources within the project site. (NZEB:A sources may also be used.)
NZEB:C	Includes renewable energy sources off-site to generate energy on site.
NZEB:D	Includes purchased green energy.

If a building does not import any energy in any form (i.e. it is “off-grid”) it is classified as ZEB:A Plus







RENEWABLE ENERGY CERTIFICATE

In satisfaction of 2013 purchases, this certificate verifies that wind generated electricity in the amount below was produced and delivered to the electric grids of the United States and further warrants that the Renewable Electricity Attributes to the extent such attributes exist or arise from and for such wind generated electricity have been or will be permanently retired on behalf of:

ParaVista, Inc.

The Renewable Electricity Attributes in Community Energy, Inc.'s portfolio of supply include those generated by Blue Canyon V & Weatherford Wind Farms in O.K., Flat Ridge II Wind Farm in K.S. and Morning Light Wind Farm in I.A., amongst other generation facilities located throughout the United States. In witness whereof, Community Energy, Inc. has caused this certificate to be signed and sealed by its authorized agent.

COMMUNITY ENERGY®
building a clean energy future

Green-e Energy CERTIFIED

Certificate No.
1400

Purchase Amount
620 MWh

Purchase Period
January – December 2013

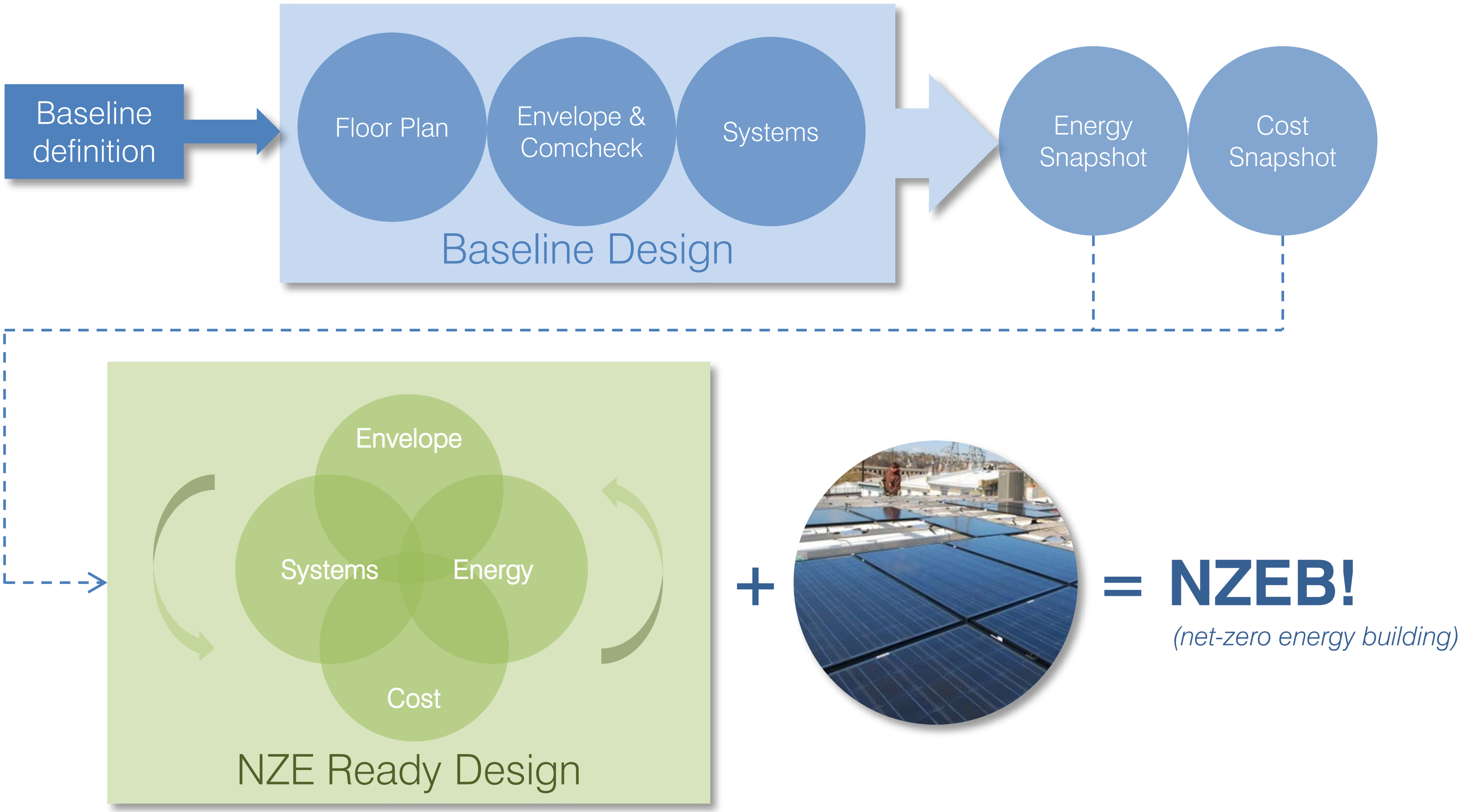
02 | Study Methodology

To isolate variables and provide a true apples-to-apples comparison, a **“baseline”** and “**NZE Ready”** version of the same office building program were studied.

The **baseline design** was created in the linear process often used in the marketplace: the architect designs the spatial components to meet the program requirements and then the buidling systems components are overlayed and adapted. Typically, energy modelling is not performed on buildings of this nature. When prescriptive code requirements are not met, ComCheck is used to verify and modify the design performance requirements.

For the pupose of this study,the baseline design was run through a full energy model to provide an energy profile that the design team could assess when designing the NZE ready version of the building. The baseline design was also cost estimated.

Armed with a baseline understanding of energy and cost, the Architect, Systems Engineer, and Construction Manager worked in an unusually integrated and iterative process to arrive at a **NZE Ready** design which balanced energy demand reduction, construction cost, and cost of on site renewable energy generation required for NZE. This version of the design is referred to as “NZE Ready”; the renewable energy system which will make it a net-zero energy building (NZEB) is carried separately in the cost model.



Baseline definition

Floor Plan

Envelope & Comcheck

Systems

Baseline Design

Energy Snapshot

Cost Snapshot

Envelope

Systems

Energy

Cost

NZE Ready Design

+

= **NZEB!**

(net-zero energy building)

03 | Baseline Definition

What is the market standard (“baseline”) version of a 15,000 sf, owner occupied, multi-tenant building in the Lehigh Valley region?

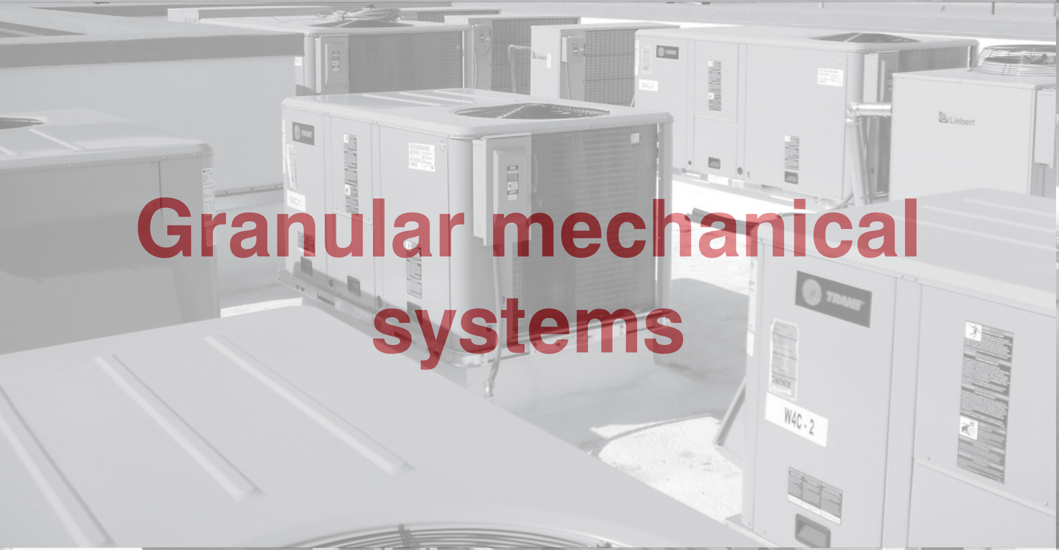
To define the baseline, the Design Team reached out to the real estate and development community to get a real world perspective on what actually happens in this particular market. We spoke with : *Brandywine Realty Trust, CBRE, Dermody Properties, Gorski Engineering, Hankin Group, Jones Lang LaSalle, Kaiserman Company, Liberty Property Trust, and NAI.*

Observations and suggestions about broad design ideas, preferences, technological integration, and cost management emerged from the interviews with commercial real estate brokers, builders and developers. Many comments centered around the ability of the building to be flexible for changing tenants over time. Six primary requirements were identified for the baseline design:

1. **Single Story, “Sliced Loaf of Bread”** - The most flexible way to handle reconfiguring tenant spaces over time is a bar shaped building with a rhythmic facade and structure that can be easily reconfigured. All respondents noted that a building of this size is best as a single story unless it is site constrained.
2. **As much glass as possible** - This was communicated by developers as one of the most desirable features of a space to a prospective tenant. As discussed later, there are better ways of providing daylight and connection; however, the market standard is to provide as much glazing as possible.
3. **Granular mechanical systems** - The standard is for many small systems to allow for different space conditioning needs of tenants as well as the ability to reconfigure units as tenant spaces change.
4. **Rentable area = useable area** - In the small tenant market, paying rent for portions of common spaces is undesirable.
5. **Individual suite entrances** - This is a desirable feature for a small tenant as it allows them to appear more professional to their clientele. This also allows for the elimination of internal, shared corridors.
6. **Individual suite kitchens and bathrooms** - This is a market standard condition.

Single story, "sliced loaf of bread"

As much glass as possible



Granular mechanical systems

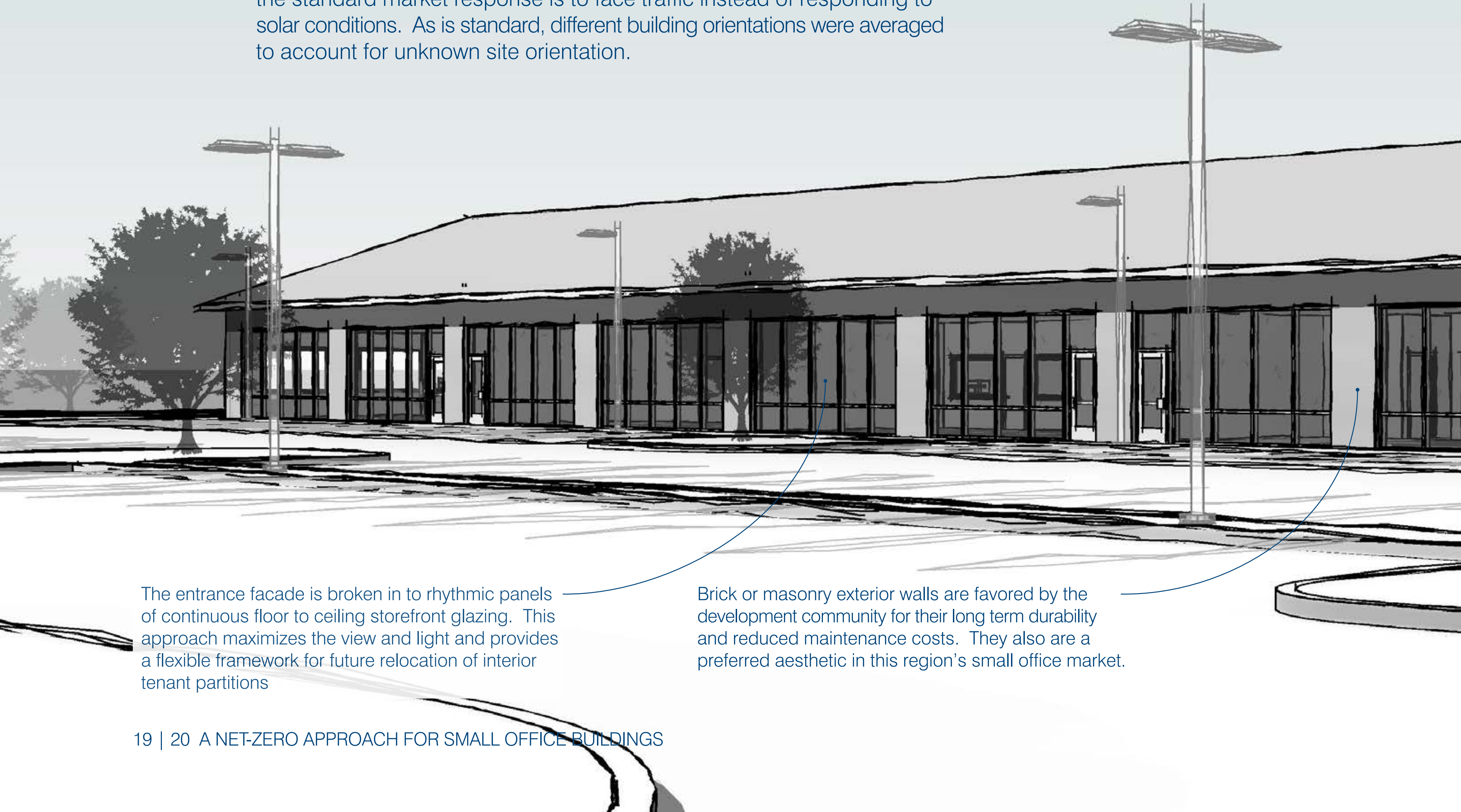
Rentable area = useable area

Individual suite entrances

Individual suite kitchens and bathrooms

04 | Baseline Design

The baseline design for the 15,000 sf owner occupied, multi-tenant building in the Lehigh Valley is a one story bar shaped building. Its form is primarily based on the need for flexibility but also responds to regional market aesthetic preferences. For the purpose of the study, the baseline design building orientation is assumed to be towards the street becuase the standard market response is to face traffic instead of responding to solar conditions. As is standard, different building orientations were averaged to account for unknown site orientation.

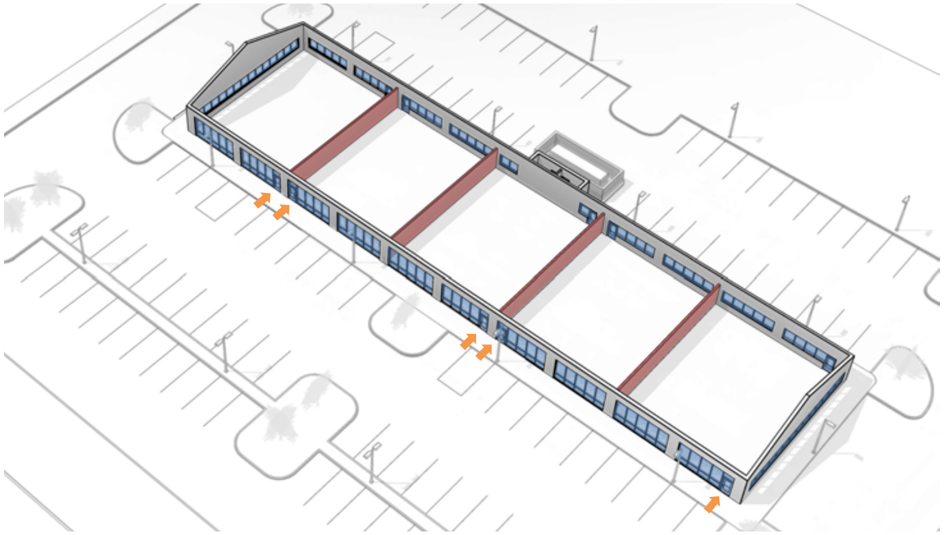


The entrance facade is broken in to rhythmic panels of continuous floor to ceiling storefront glazing. This approach maximizes the view and light and provides a flexible framework for future relocation of interior tenant partitions

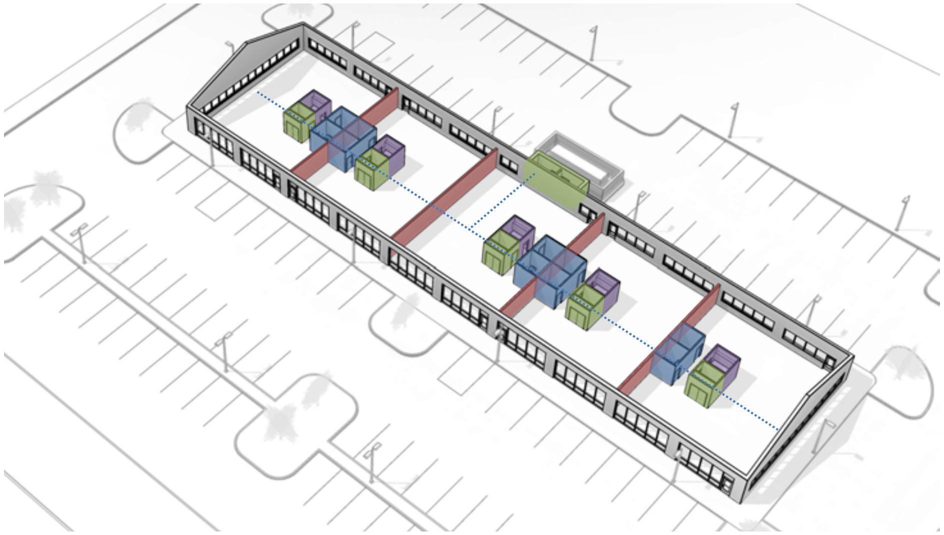
Brick or masonry exterior walls are favored by the development community for their long term durability and reduced maintenance costs. They also are a preferred aesthetic in this region's small office market.

Pitched roofs are preferred in this market for single story buildings. They give an otherwise small building an increased visual presence from the street and respond to the region's vernacular architecture.

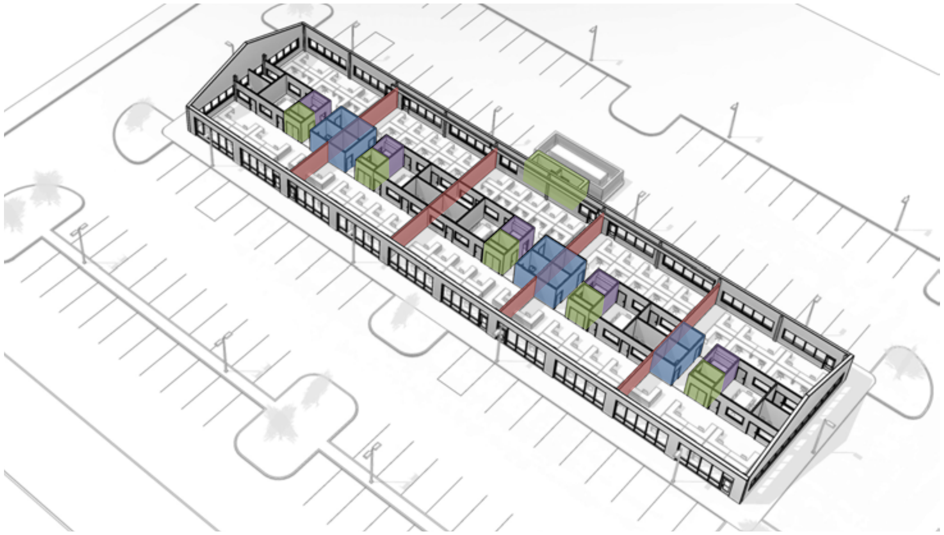
This building has 42% of it's exterior walls glazed, which is more than the prescriptive code requirement. In order to meet the performance code, continuous "ribbon" windows are used on the end and rear facades to manage the overall building glazing percentage and the glass used has a slightly improved performance specification from code minimums.



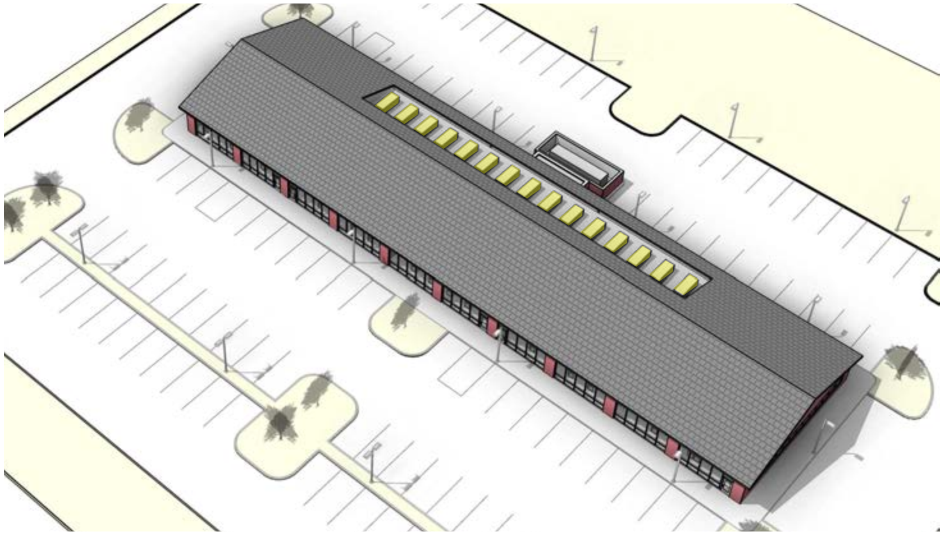
The bar shaped building can easily be re-demised over time due to the rhythmic facade. Glazing is plentiful - so much so that it exceeds prescriptive code requirements. The building only passes for performance if certain specifications are modified. Each suite can easily have its own entrance.



A central utility trench runs the length of the building. Restrooms (blue), kitchens (purple) and utility space (green) can be relocated along this trench as space is re-demised.



For the purpose of energy analysis, sample fit outs were designed to each include open office seating for 16-20, two private offices, and a conference room.



Each 3,000 sf tenant is provided (3) 3-4-ton constant volume packaged rooftop air-to-air heat pumps for perimeter and core zones. The total system size is 55 tons. The units are located on the rear side of the roof in a flat cut-out.

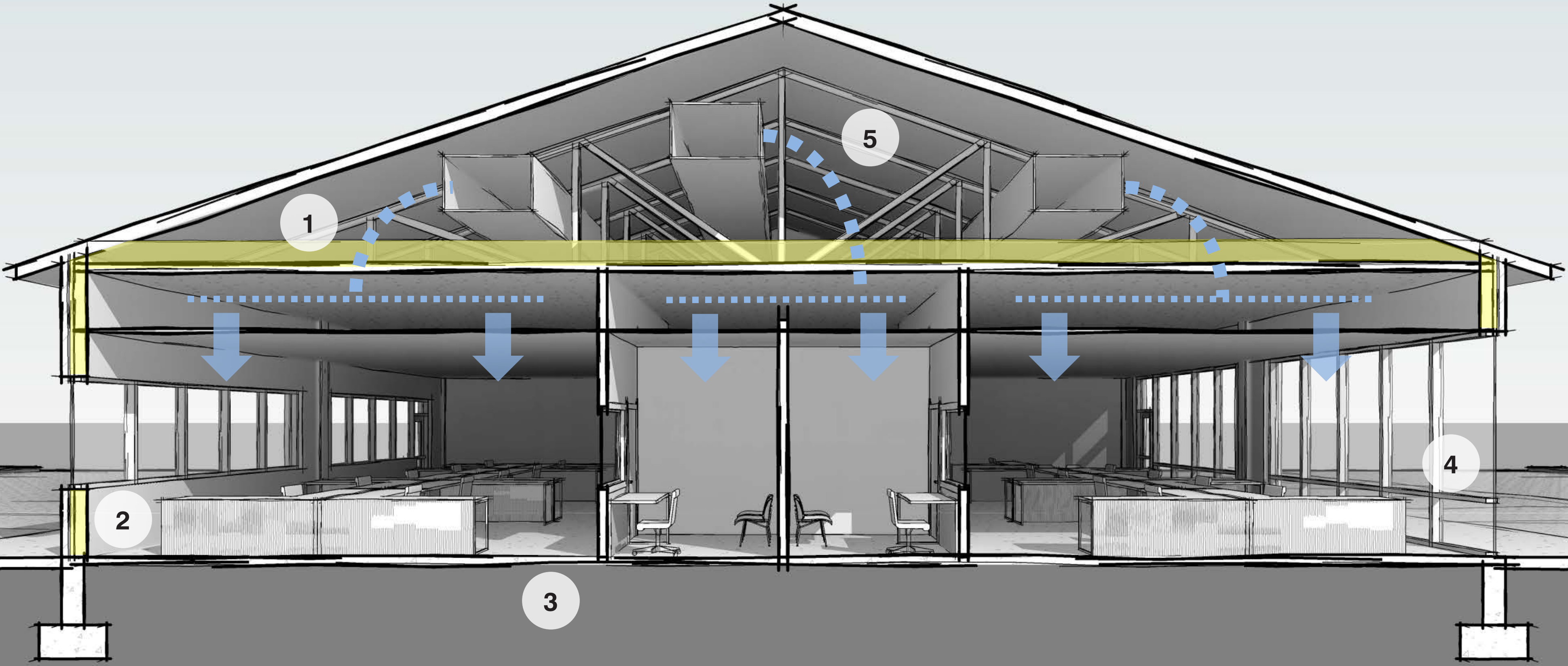
Baseline Design Building Envelope Assemblies

1. Roof - Asphalt shingles with plywood roof sheathing, steel roof trusses, R-38* fiberglass attic insulation at base of trusses over drywall ceiling.
2. Opaque walls - Brick veneer w/ 1½" continuous exterior XPS R-7.5, metal studs w/ R-13 fiberglass batt insulation*.
3. Uninsulated 4" concrete slab.
4. Thermally broken aluminum storefront with 1" Low-E insulated glass. No operable windows.

* - *Code Minimum*

Baseline Design HVAC Distribution

5. Insulated trunks from RTUs extend through the attic plenum space and drop down through the drywall ceiling to branches in the plenum space above dropped ceilings; ceiling diffusers are located as required throughout finished spaces.



Carrier

Mechanical Systems

The baseline HVAC system is constant volume packaged rooftop air-to-air heat pump units. Units are mounted on the rear side roof in a flat roof area notched out of the sloped roof. Three 3-4 ton units are provided per tenant space, one for the interior zone and one for each perimeter zone. Unit sizes are based on standard developer capacity of 300 sf/ton and preliminary load calculations. The total building system size is 55 tons.

Insulated supply and return ducts are run through the vented, unconditioned attic (continuous for the length of the building) to individual insulated ceiling plenums within the tenant spaces. Supply ductwork is distributed to ceiling diffusers in each space. Return air is via the ceiling plenum in each tenant space back to the return riser and up to the RTU. Ventilation to spaces will be provided via the RTUs.

Plumbing Systems

All tenant fixtures are standard code compliant fixtures. The following are the fixture flow rates:

Lavatory	0.5 gpm
Kitchen Sink	2.2 gpm
Mop Sink	2.5 gpm
Water Closet	1.6 gpf
Site Irrigation	Yes

Electrical Systems

Tenant services are sized based on the following anticipated tenant space loads:

HVAC	11.0 w/sf
Equipment/Plug Loads	1.0 w/sf
Lighting	1.0 w/sf
Water Heating	0.15 w/sf

Tenant lighting is as follows:

Office space - (3) lamp T8 parabolic fixture
Restrooms - CFL downlights and a fluorescent sconce
Workstations - desk light with a T8 lamp
Exterior lfixtures - LED

All lighting controls are standalone vacancy sensors with wall switches. Site lighting is controlled by a time clock.

05 | NZE Ready Design

The NZE Ready design for the 15,000 sf owner occupied, multi-tenant building in the Lehigh Valley is a one story bar shaped building. Its form, while based on the need for flexibility, also responds to its solar orientation. For the purpose of the study, this building is oriented with the long entrance facade slightly east of South. This orientation supports "passive solar" design concepts and also points the roof in the optimal direction for maximum annual generation of photovoltaic systems.

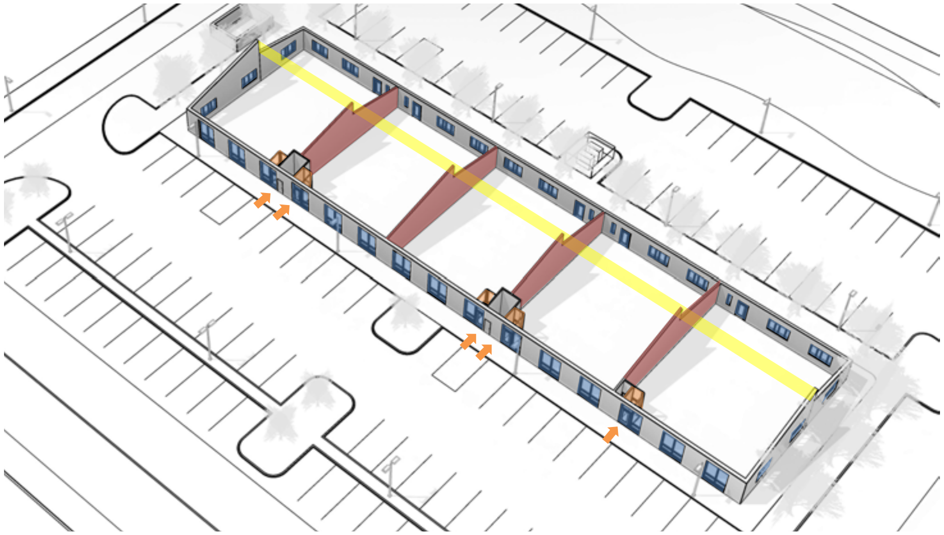
Similar to the baseline design, the entrance facade is broken up rhythmically to facilitate future reconfiguration of space. However, the NZE Ready design has floor to ceiling punched openings with operable windows instead of continuous glazing. This approach optimizes the view and natural light while reducing unwanted heat gain and losses through excess glazing.

Exterior walls are metal structural insulated panels (SIPs). These prefabricated assemblies provide high insulative value, airtight construction, reduced thermal bridging and a durable metal finish. Field installation time and overall assembly cost are both reduced over the market standard.

The south facing roof is sloped on an angle to achieve a balance between PV generation and interior space volume. The roof overhang on the south facade provides full shading of the windows during summer months when the sun is high in the sky.

This building has 25% of its exterior walls glazed, which meets the prescriptive code requirement. The north, east and west facades have smaller openings than the south to reduce direct solar gain on the east and west and thermal transfer through the windows on the north.

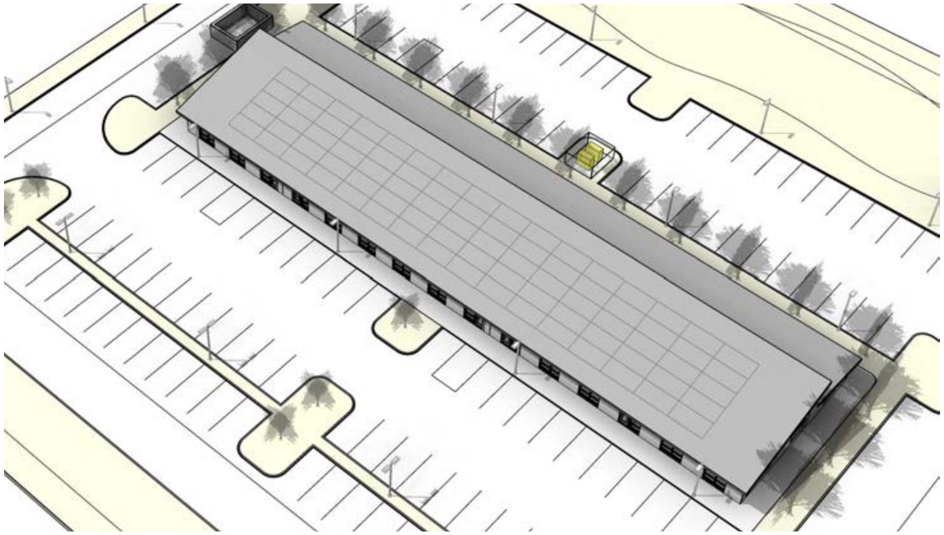
Additional trees have been added on the east and west sides to provide shading for the windows.



Similar to the baseline design, the NZE Ready design can easily be re-demised over time due to the rhythmic facade. Glazing is optimized - instead of continuous floor to ceiling glazing and ribbon windows, openings are utilized as well as a clerestory (yellow). Each suite can easily have its own entrance.

A central utility trench, similar to that in the baseline design, runs the length of the building. Restrooms (blue), kitchens (purple) and utility space (green) can be relocated along this trench as space is re-demised.

To ensure that the energy analysis is an accurate comparison to the baseline, the sample fit outs were designed to include the same quantity of open office seating, private offices, and conference rooms.



A twinned 10+8 ton variable refrigerant flow (VRF) system is used for heating and cooling. The units are located on grade behind the building. Additional trees have been planted on the north, east and west facades to reduce solar heat gain on the building.

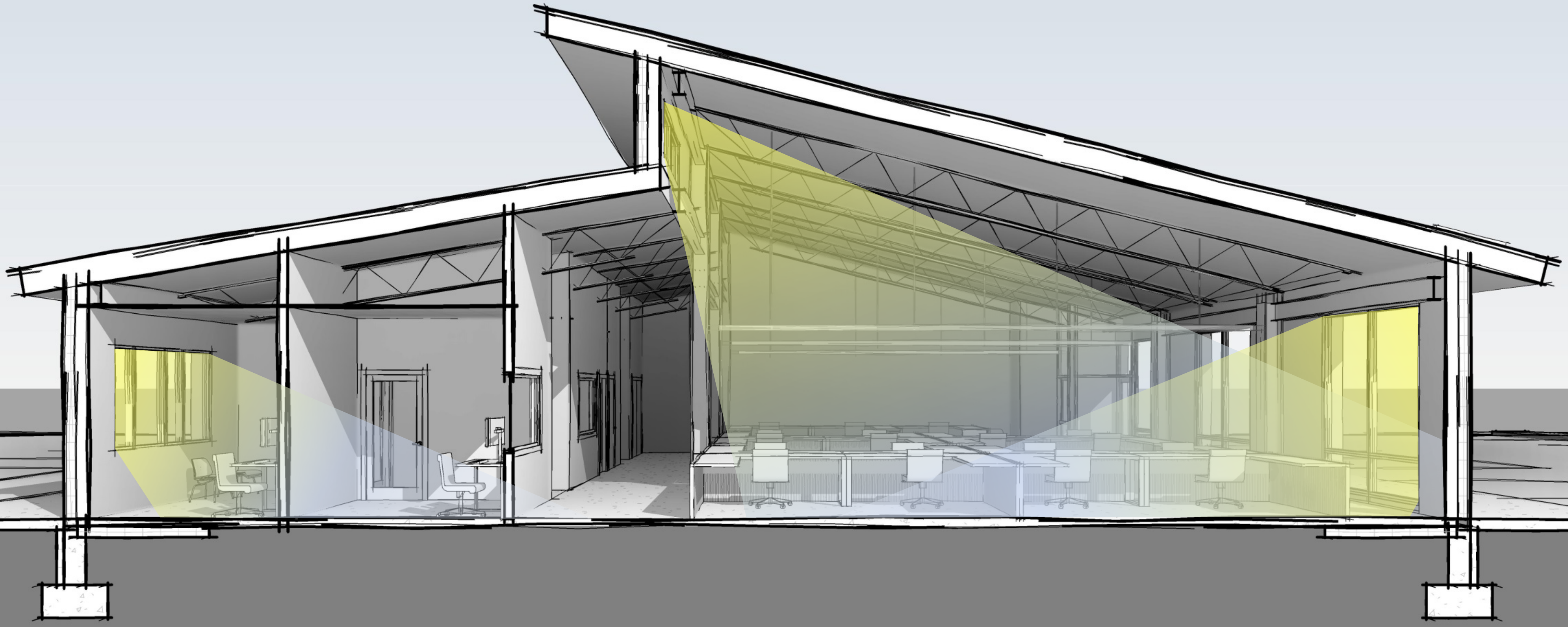
Daylighting

One of the most common misconceptions of office design is that a continuous wall of glass will create the best work conditions. In reality, this approach creates uncomfortable glare conditions as well as thermal comfort issues near the glazing.

The goal of effective daylighting is to evenly distribute light deep in to a space from multiple sides. Clerestory windows are an effective way to provide light deep in a space to balance levels. They also promote passive ventilation when operable and combined with operable windows on the main facade..

Adequate daylight reduces the energy demand and heat production of electric lights while improving worker performance and well being.

A beautifully daylit space is in high demand among most tenants.



Multiple building envelope types were studied to determine the sweet spot for energy demand reduction and cost.

	BASELINE	NZE READY		
		"Good" Envelope	**"Better" Envelope**	**"Best" Envelope**
Envelope Assemblies		*Shaded fields are the final design utilized in the energy and cost model*		
ROOF INSULATION	**R-38** - Uninsulated roof cavity w/ insulated attic R-38 loose fill cellulose insulation	**R-29** - 8¼" EPS SIPs	**R-41 -** 6½" Polyurethane SIPs	**R-52** - 12¼" Graphite enhanced EPS SIPs
WALL INSULATION *Notes:* *1. R-Values in this chart are not degraded for thermal bridging. The energy model does, however, degrade assemblies based on thermal bridging.* *2. Metal SIPs do not receive additional exterior cladding; they are the exterior finish.*	**R-14.4** - 1½" XPS exterior rigid insul, sheathing, 6" metal studs w/R-13 fiberglass batt insulation	**R-28 -** 3½" Metal EPS SIPs w/ 2x3 interior wall	**R-40** - 5" Metal EPS SIPs* w/ 2x3 interior wall	**R-48** - 6" Metal EPS SIPs* w/ 2x3 interior wall
		R-26.9 - 5½" semi rigid mineral wool w/6" fiberglass clips, sheathing, 2x6 metal studs w/o insulation	**R-47.0** - 5½" semi rigid mineral wool w/6" fiberglass clips, sheathing, 2x6 wood studs w/4" closed cell spray foam	**R-54.3** - 5½" semi rigid mineral wool w/6" fiberglass clips, sheathing, 2x6 wood studs w/5½" closed cell spray foam **R-52.6** - cladding, sheathing,11 7/8" TJI's @ 24" o.c. w/ dense packed cellulose insulation, sheathing, 2x3 interior wall
WINDOWS	Thermally broken extruded aluminum storefront w/ 1" IGU w/ Low-E on face 2	Insulated fiberglass frame windows w/ ultra-wide IGU w/ suspended film	High performance insulated fiberglass frame windows w/ ultra-wide IGU w/ twin suspended film	High performance insulated fiberglass frame windows w/ ultra-wide IGU w/ twin suspended film
SLAB ON GRADE INSULATION	No insulation	R-10 6' from perimeter	R-10 Continuous	R-10 Continuous
ENVELOPE COST	Highest	Lowest*	Mid-range	High

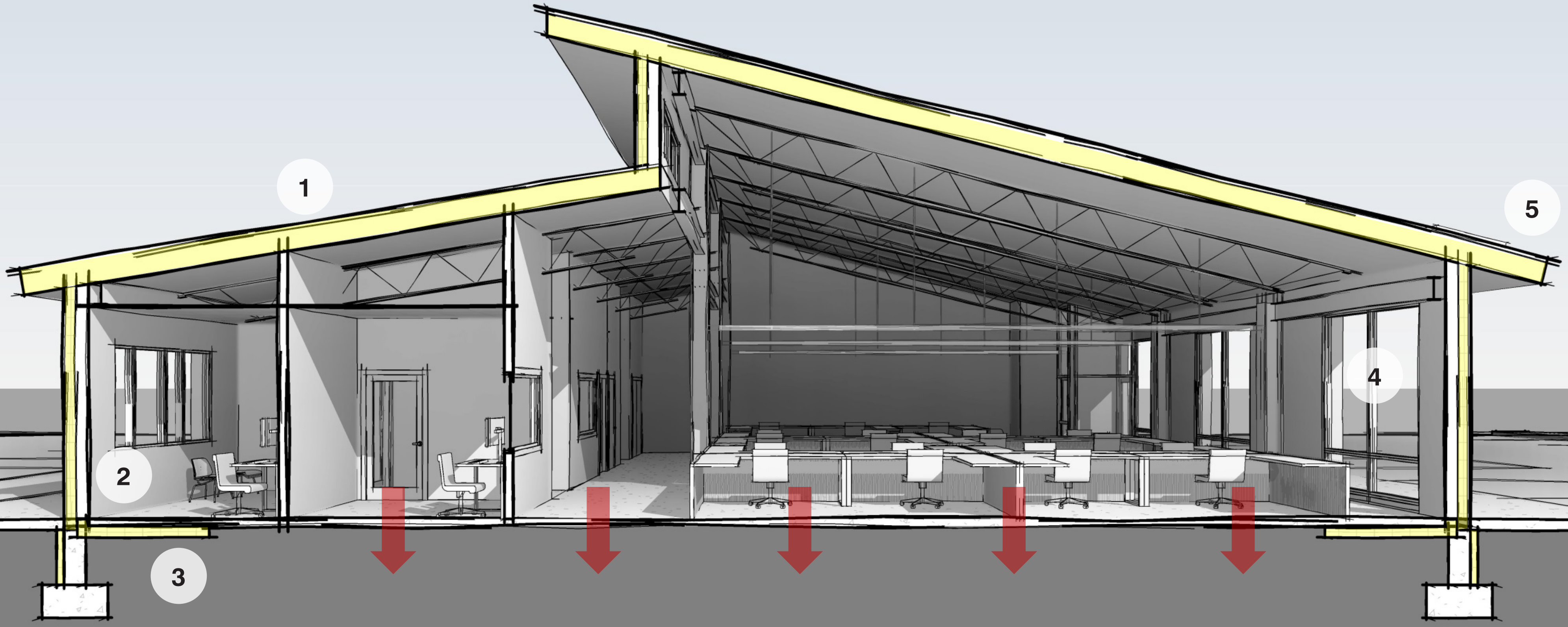
** - Significant cost savings were realized by utilizing a prefabricated high performing wall system instead of a multi-component site assembled system. It should be noted that the character/aesthetic of the wall is changed.*

Envelope Energy Analysis

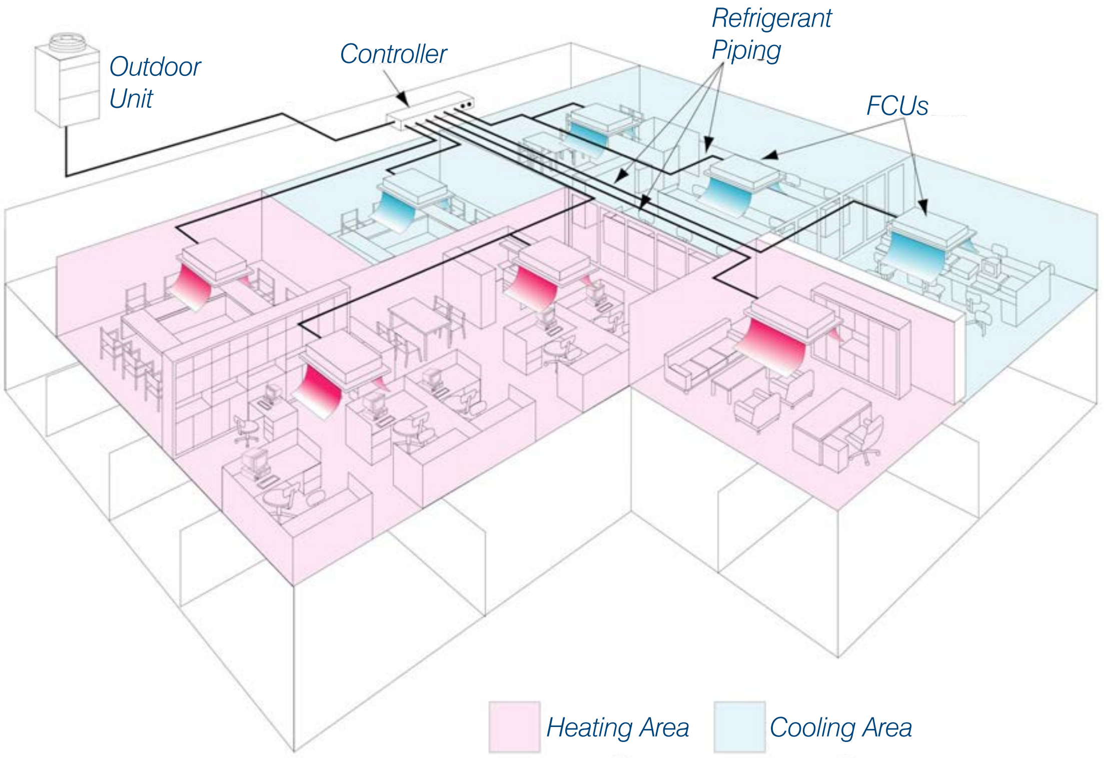
Year 1 Envelope Energy Savings %	-	6.0%	7.8%	8.1%
Year 1 Envelope Energy Savings (kWh)	-	14,047	18,100	18,924
Year 1 Envelope Energy Savings ($)	-	$1,663.74	$2,132.24	$2,227.49
30 yr Envelope Energy Savings ($)	-	$81,469.12	$103,760.25	$108,292.18
NZE PV 1st Cost Savings from Envelope	-	$15,816.85	$20,380.51	$21,308.33

Building Envelope

1. Roof - By insulating the roof instead of the attic the unconditioned plenum in the baseline is eliminated. This allows for the full volume of the space to be open which facilitates better daylighting and passive ventilation strategies.
2. Opaque walls - SIP construction achieves a higher insulative value and reduced air infiltration compared to the baseline stick built assemblies.
3. The outer 6' of the concrete slab foundation is insulated for improved thermal comfort and eliminating perimeter space heaters required in the baseline design. Because the building is internally load dominated, the interior of the slab is not insulated so heat can dissipate to the earth.
4. High performance windows are used to reduce solar heat gain in the summer and thermal conduction in the winter.
5. Windows and walls are passively shaded by roof overhangs on the south and trees on the east, west and north.



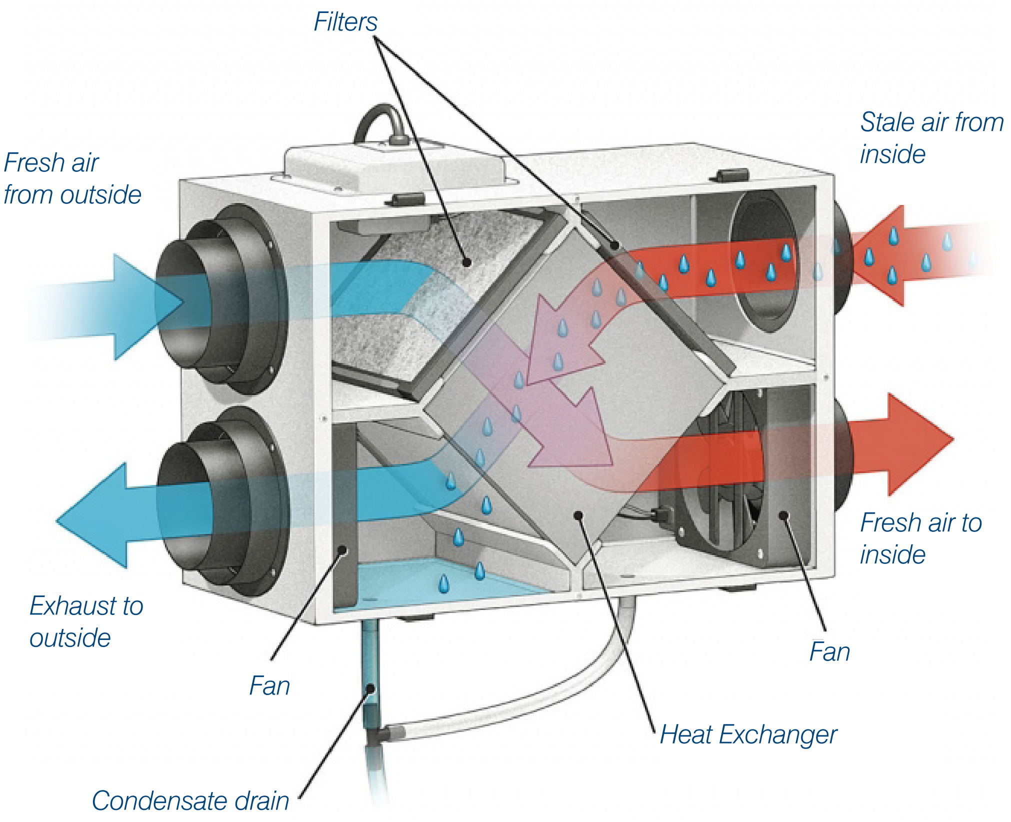
Instead of many small heat pumps pushing air independently through the building, the NZE Ready design more efficiently pumps refrigerant directly from a single outdoor unit to conditioning points.



A variable refrigerant flow system (VRF) conditions refrigerant in an outdoor unit and then circulates it through the building to multiple fan coil units (FCUs). VRF systems offer substantial energy savings over conventional air systems as refrigerant requires much less energy to move through a building than does air. Further, a variable speed motor is used allowing for deeper energy savings over a constant volume system.

Because VRF systems can control multiple indoor branches with different demands from the same outdoor unit, the system can be “rightsized” instead of oversized.

Energy Recovery Ventilators (ERV) are installed in each tenant unit to provide fresh air. These ultra-efficient systems exchange heat between stale air being exhausted and incoming fresh air.



Because VRF systems do not move air through a building one of their drawbacks is that fresh air ventilation must be supplied independently.

In the NZE ready design each tenant unit has an ERV located in the tenant utility room. Select FCUs are ducted directly from the ERV. This allows fresh air to be distributed to spaces which cannot be served by natural ventilation.

Exhaust fans in toilet rooms and kitchens are connected to the ERVs to capture the heat in the air before it is exhausted.

ERVs are extremely efficient in terms of heat transfer. This allows for increased quantities of fresh air changes per hour with minimal reconditioning of the air from outside.

Mechanical Systems

The HVAC system for the optimized building is a variable refrigerant flow (VRF) system with heat recovery. Fan coil units (FCU) provide heating and cooling to each space and zone. Up to 50 FCUs can be connected to the system. The outdoor unit consists of twinned 10 and 8 ton units located on grade for a total system capacity of 18 tons. The VRF system controls allow for individual tenant BTU tracking for billing purposes. Each tenant space has a dedicated 210 cfm ERV to provide ventilation for areas not served by operable windows. Select FCUs are connected to the ERV system for fresh air as required for zone ventilation with the remainder of ventilation air provided directly to the space. Approximately 30% of each tenant space requires fresh air; the rest is naturally ventilated. Ductwork typically is run exposed in the open office space and concealed above the ceiling in the rest of the spaces.

Plumbing Systems

All tenant fixtures are high efficiency fixtures. The following are the fixture flow rates:

Lavatory	0.25 gpm *(50% reduction)*
Kitchen Sink	2.2 gpm *(32% reduction)*
Mop Sink	1.5 gpm *(40% reduction)*
Water Closet	1.6 gpf *(32% reduction)*
Site Irrigation	No - The NZE Ready building has native and adaptive site plantings which do not require permanent irrigation. This is a water, energy, and cost savings over the baseline, which is irrigated.

Electrical Systems

Tenant services are sized based on the following anticipated tenant space loads:

HVAC	9.5 w/sf *(20% reduction)*
Equipment/Plug Loads	0.75 w/sf *(25% reduction)*
Lighting	0.45 w/sf *(55% reduction)*
Water Heating	0.15 w/sf *(no change)*

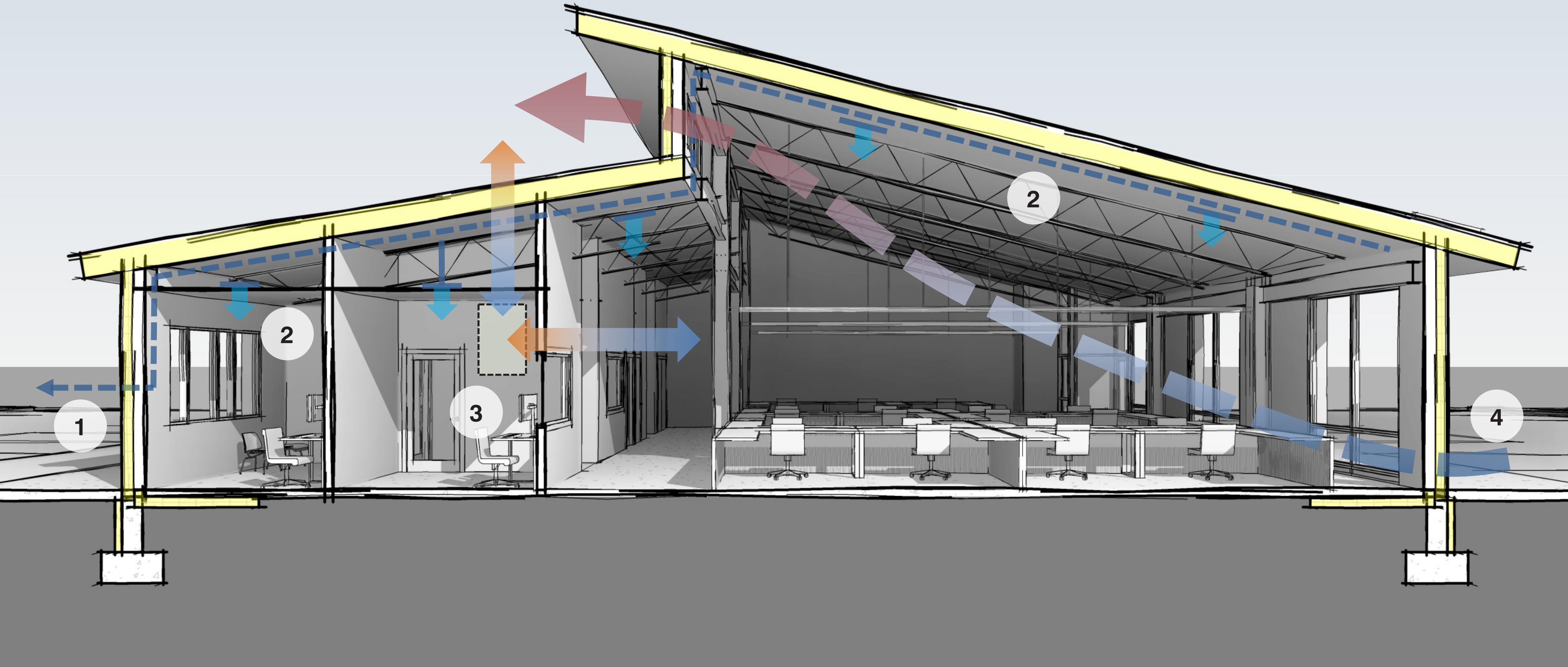
Tenant lighting is as follows:

Open office space - LED Indirect/direct pendants
Private offices - LED high performance troffers
Restrooms - LED downlights and a fluorescent sconce
Workstations - desk light with a LED lamp
Exterior lfixtures - LED

All lighting controls are networked with vacancy sensors, wall dimmers and daylight dimming. Site lighting is controlled by a time clock.

Heading, Cooling and Ventilation

1. An exterior twinned 18 ton unit conditions refrigerant for the building VRF system.
2. Refrigerant is piped through the building to FCUs where air is pulled across the refrigerant and blown into the space.
3. Each tenant space has an ERV to provide fresh air.
4. Operable windows on the south facade and clerestory promote cross/stack ventilation through the space.



06 | Energy Analysis

Smartly achieving NZE requires a reduction of energy demand to a point where remaining energy use is offset by on-site renewable energy generation. Our study has the added challenge of keeping first costs for a NZE building in line with a typical developer building.

To get to this point, the design team worked iteratively through a design-energy-cost modeling process. Variables were isolated to understand relative impact cost and then modeled together to find synergistic opportunities. In the end, it was the sum total of many energy conservation measures (ECMs) which drove the predicted Energy Use Intensity to its low level. Some of the critical lessons learned for this building in this location were:

- Increased envelope insulation, past the “good” level resulted in diminishing returns. Energy use did decrease but much less than the cost increase of the assemblies and PV offset. We saw that between the code minimum and “good” envelopes the building changed from being externally load dominated to internally dominated. **Understanding building load profiles is paramount to cost-effective energy efficient design decision making.**
- As an internally load dominated building, a fully insulated floor slab did not pencil out. Perimeter underslab insulation was retained for thermal comfort purposes.
- Plug loads were a key driver of the overall energy use. Because individual tenant use and density cannot be prescribed, this number could not be driven down as aggressively as hoped. However, through proper tenant engagement, there is an opportunity to very significantly reduce energy use.
- Building orientation was most influential to PV generation and less so for energy use as the envelope/glazing were already optimized and the building was internally load dominated
- Solar thermal hot water heating had a very minimal energy impact because the hot water demand is minimal. Given the cost increase for the system, the payback was not favorable for this small office application.

Building form & orientation

Glazing quantity, quality & location

Reduced air infiltration

Increased insulation

Efficient lighting

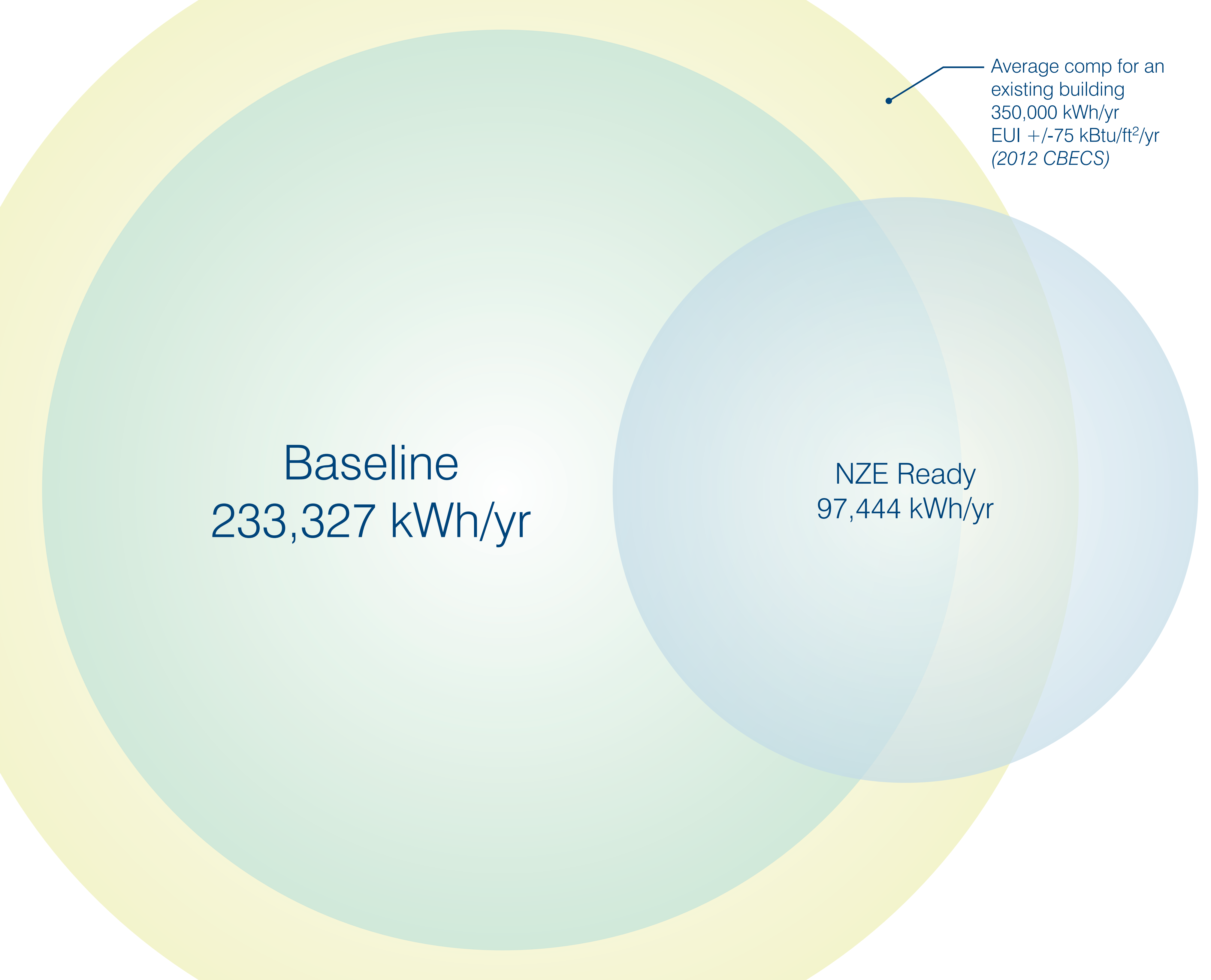
Daylight harvesting

Efficient office equipment

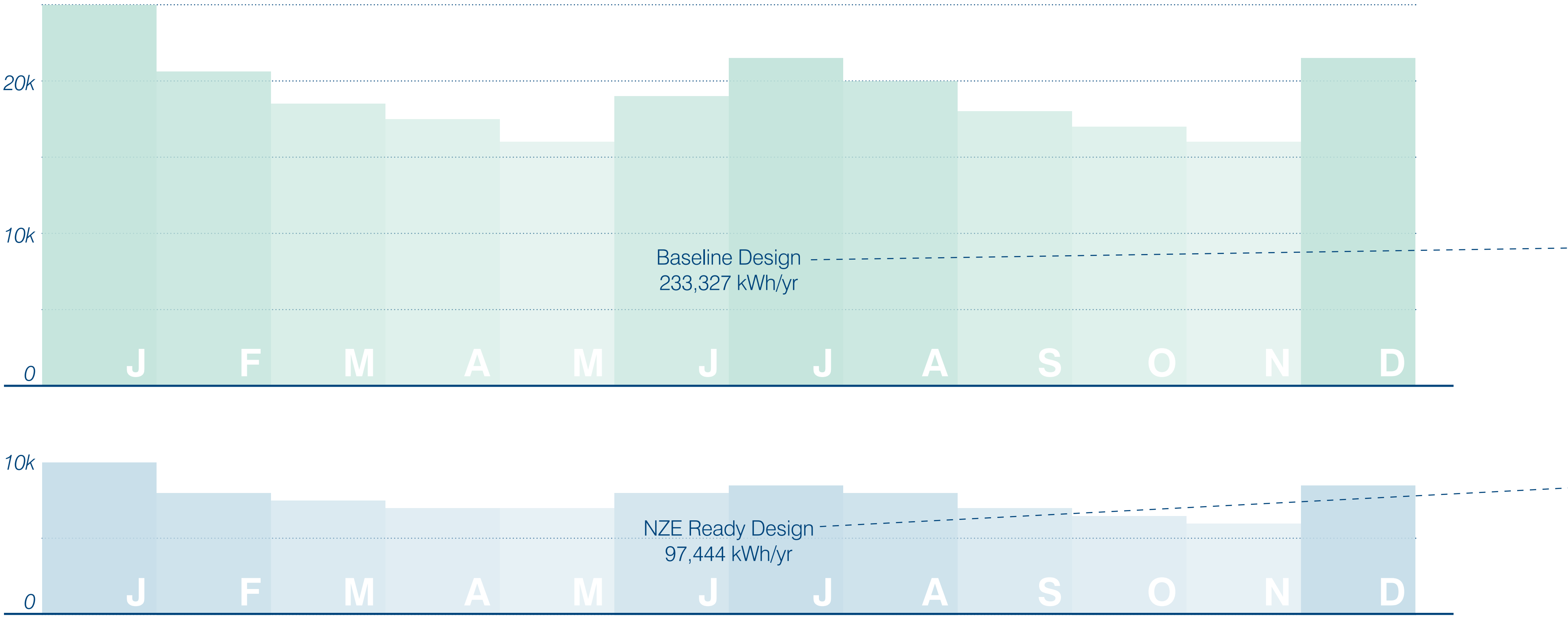
Reduced hot water demand

Efficient & right-sized HVAC

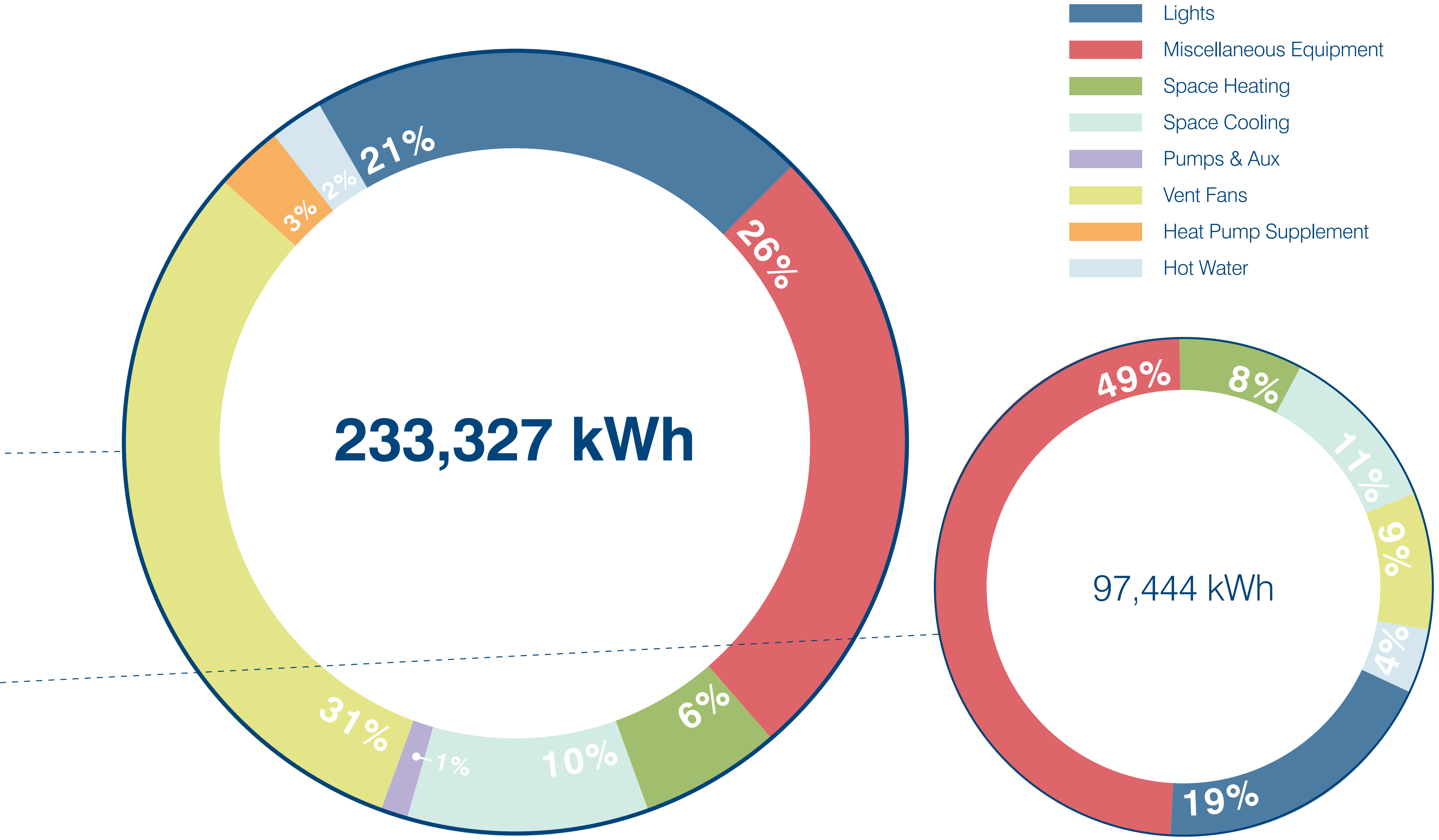
Getting the NZE Ready design to be more energy efficient than the Baseline was straightforward. However, it took numerous iterations to find the sweet spot for energy efficiency and first cost. An EUI of 21 kBtu/ft^2/yr was not the lowest possible, but the "smartest" level balancing first cost with anticipated return.


Average comp for an
existing building
350,000 kWh/yr
EUI +/-75 kBtu/ft²/yr
(2012 CBECS)
Baseline
233,327 kWh/yr
NZE Ready
97,444 kWh/yr

Annual Energy Consumption (kWh)



End-use Comparison

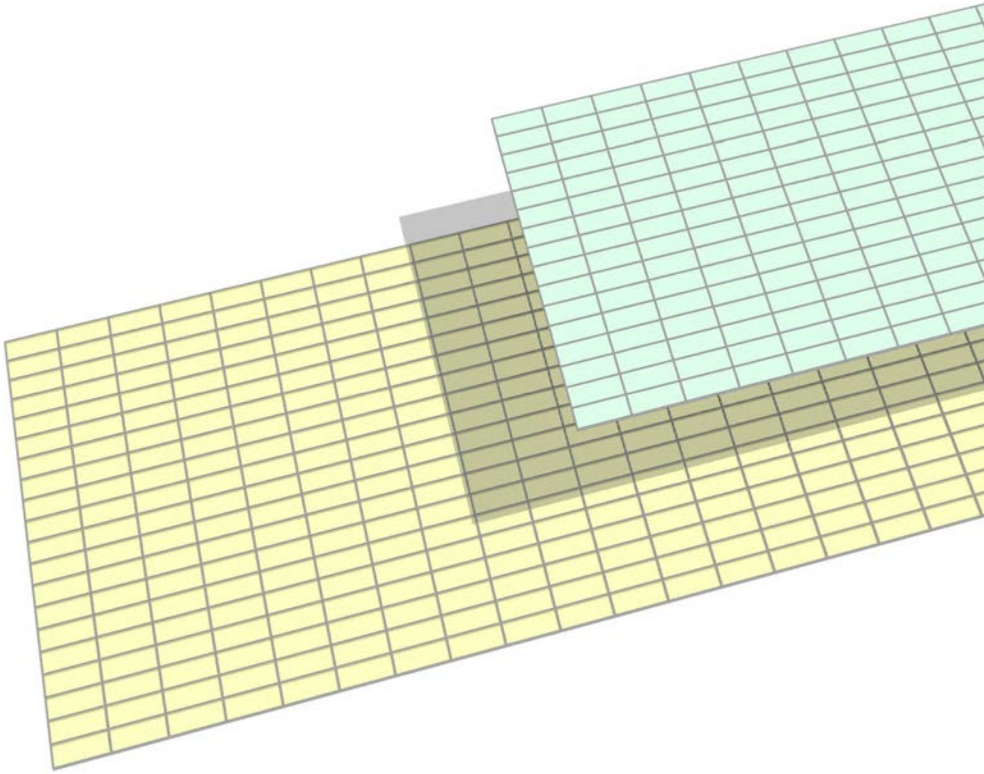


In order to get to NZE a building needs to offset its energy demand with renewable energy generation. The NZE Ready design, through energy demand reduction, is able to comfortably fit the required PV array within it's building footprint.

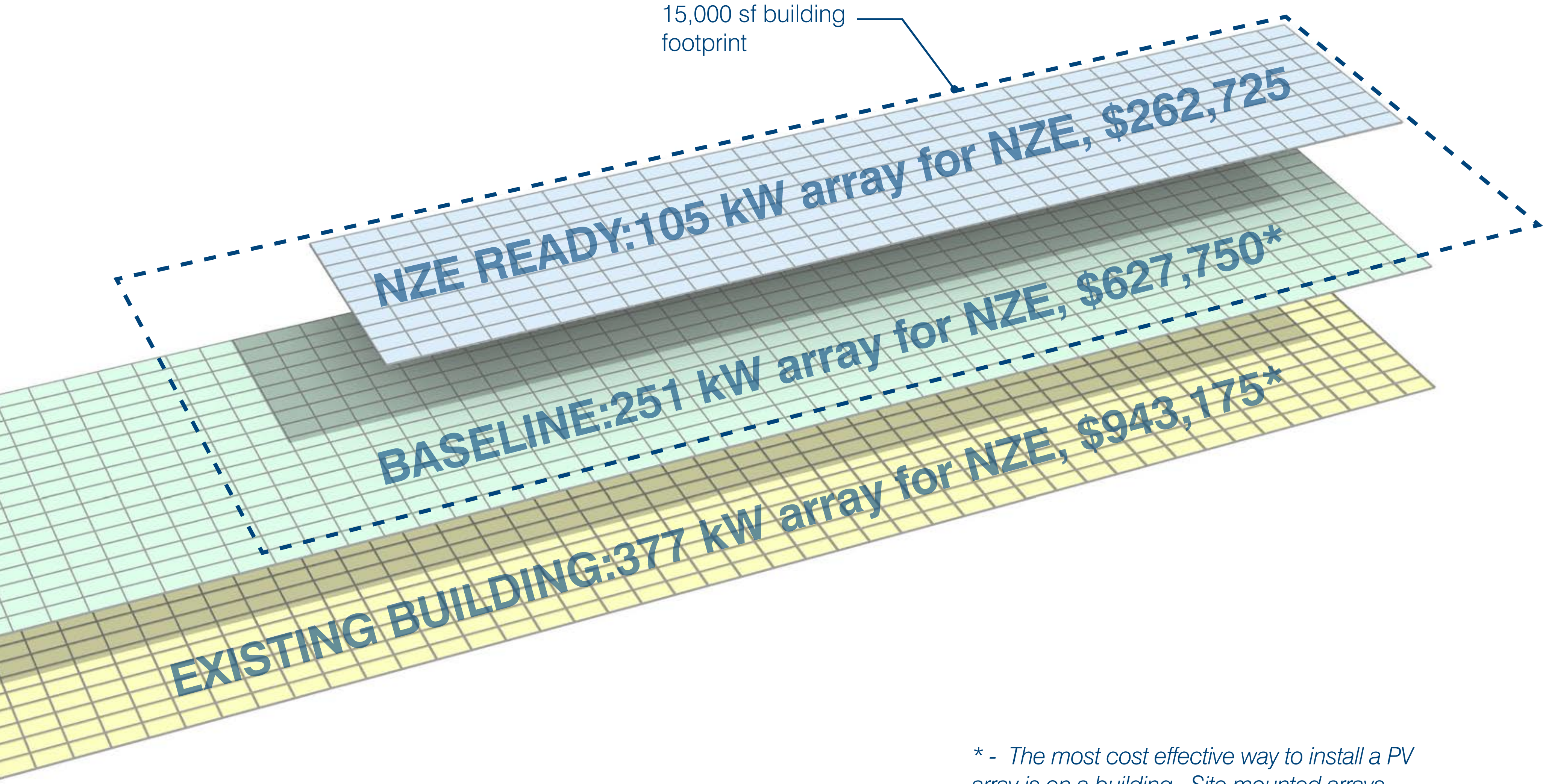
Average Existing Small Office Building - **75 kBtu/ft^2/yr**
377 kW array for NZE, 24,625 sf, **$943,175***

Baseline - **52 kBtu/ft^2/yr**
251 kW array for NZE, 16,467 sf, **$627,750***

NZE Ready Building - **21 kBtu/ft^2/yr**
105 kW array for NZE, **$262,725**



PV Calculation Data
0.31 kW/panel
37.5" x 77.5"
$2.50/watt installed before standard tax credits
(based on pricing at the time of the study)



** - The most cost effective way to install a PV array is on a building. Site mounted arrays cost more due to required structural mounting systems, earthwork, connection distance and access to electrical service, and stormwater management. These costs would be incurred on the baseline and existing comp but are not accounted for in these estimated PV array costs.*

07 | Cost Analysis

At the beginning of this study the question was presented as to whether or not NZE is “market feasible” for the small office. What was found to be critical to this determination is time horizon.

The scale of the project, 15,000 sf, is below the size threshold that most real estate investors in this region will consider. However, it is a realistic and manageable size for an owner-occupant property. In this scenario, the investor as owner/occupant can afford to take a longer view of return on initial investment whereas a developer would typically be looking to recoup their first costs in 5-7 years. This makes all the difference to cost feasibility.

This study has approached cost through three primary lenses:

1. Project first cost
2. Project first cost + energy cost over 30 years
3. Project first cost + PV first cost + energy savings over 30 years

Project First Cost

30 Year Energy Cost

30 Year PV Savings

Baseline Design First Cost Estimate

This cost estimate is based off the baseline design in the previously indicated configuration of (5) tenant units each with (1) meeting room, (2) private offices, (2) restrooms, kitchenette, tenant utility room, and closets. Cost estimate excludes land acquisition costs, demolition of existing structures, furniture, fixtures and equipment.

1. SITEWORK	$ 551,000
Preparation, E&S controls, grading, stormwater management, site utilities, paving, planting, irrigation, site furnishings, site lighting	
2. CONCRETE	$ 153,000
Foundations and slab on grade	
3. SUPERSTRUCTURE	$ 315,000
Steel structural frame with steel roof trusses	
4. ROOFING	$ 193,000
Sloped roof shingles, underlayment & sheathing, venting, soffits, trim, gutters & downspouts Flat roof membrane, cover board, equipment curbs, drains and piping	
5. BUILDING ENVELOPE	$ 357,000
Opaque wall - brick veneer, R7.5 XPS, weather barrier & sheathing, 6” metal studs, fiberglass insulation, painted drywall Storefront - thermally broken extruded aluminum with 1” low-E IGUs Exterior doors - fully glazed, coordinated with storefront Ribbon windows - thermally broken extruded aluminum with 1” low-E IGUs Flashing, lintels, trim, sills, etc.	
6. INTERIOR CONSTRUCTION	$ 387,000
Partitions - framing, drywall, paint, acoustic insulation Ceilings - drywall and insulation under trusses, ACT in all other spaces Doors, frames and hardware Interior windows Flooring - carpet tile typical, ceramic tile at bathrooms, linoleum at kitchens Millwork - kitchen cabinets and counters Specialties - Signage, window coverings, fire extinguisher cabinets, kitchen appliances	
7. HVAC	$ 190,000
Package rooftop air to air heat pumps, ductwork, diffusers, thermostats Bathroom and kitchen ventilation	

8. ELECTRICAL	$ 290,000
Gear, panels, distribution wiring and receptacles Fluorescent T8 interior lighting and lighting controls Telecom and data Fire alarm system including strobes, annunciators and exit signs Security System Backup generator	
9. PLUMBING	$ 113,000
Infrastructure, toilets, lavatory sinks, kitchen sinks, hot water heaters, utility sinks, restroom accessories exterior hose bibs	
10. FIRE PROTECTION	$ 70,000
Sprinklers and pump	
11. GENERAL CONDITIONS	$ 423,120
Construction management, insurance & bonds, permits & fees	
12. CONSTRUCTION CONTINGENCY	$ 261,900
CONSTRUCTION SUBTOTAL	**$ 3,304,020**
CONSTRUCTION COST/SF	**$ 220.27**
13. DESIGN FEES	$ 240,960
Architect, landscape architect, civil engineer, structural engineer, systems engineer	
14. SOFT COSTS	$ 50,000
Survey, soil testing, traffic studies, etc	
15. PROJECT SCOPE CONTINGENCY	$ 130,950
PROJECT FIRST COST TOTAL	**$ 3,725,930**
PROJECT COST/SF	**$ 248.40**

NZE Ready Design First Cost Estimate

This cost estimate is based off of the baseline design in the previously indicated configuration of (5) tenant units each with (1) meeting room, (2) private offices, (2) restrooms, kitchenette, tenant utility room and closets. Cost estimate excludes land acquisition costs, demolition of existing structures, furniture, fixtures and equipment.

1. SITEWORK	$ 553,000
Preparation, E&S controls, grading, stormwater management, site utilities, paving, native and adaptive planting, ~~irrigation~~, site furnishings, site lighting	*+0.4%*
2. CONCRETE	$ 155,000
Foundations and slab on grade	*+1.3%*
3. SUPERSTRUCTURE	$ 315,000
Steel structural frame with steel roof trusses	*0%*
4. ROOFING	$ 245,000
Sloped roof shingles, underlayment & sheathing, furring space, venting, soffits, trim, gutters & downspouts, SIPs structure	*+27%*
5. BUILDING ENVELOPE	$ 270,000
Opaque wall - Metal EPS SIPs with interior 2x3 wall with painted drywall Glazing and doors - Insulated fiberglass frames with ultra-wide IGUs with suspended film. Flashing, lintels, trim, sills, etc. Underslab R-10 insulation 6' from perimeter	*-24.4%*
6. INTERIOR CONSTRUCTION	$ 316,000
Partitions - framing, drywall, paint, acoustic insulation Ceilings - ACT at private offices, meeting room and bathrooms Doors, frames and hardware Interior windows and vestibule storefront Flooring - carpet tile typical, ceramic tile at bathrooms, linoleum at kitchens, walk off tile in vestibules Millwork - kitchen cabinets and counters Specialties - Signage, motorized window coverings, fire extinguisher cabinets, kitchen appliances	*-18.4%*
7. HVAC	$ 293,000
VRF system w/ heat recovery and zoned FCUs - 18 ton ground mounted unit, (1) ERV in each tenant unit, exposed ductwork, BMS control system, bathroom and kitchen ventilation	*+54%*

8. ELECTRICAL	$ 320,000
Gear, panels, distribution wiring and receptacles, LED interior lighting and lighting controls including daylight dimming	*+10.3%*
Telecom and data, Security System, Backup generator	
Fire alarm system including strobes, annunciators and exit signs	
9. PLUMBING	$ 113,000
Infrastructure, toilets, lavatory sinks, kitchen sinks, hot water heaters, utility sinks, restroom accessories	*0%*
exterior hose bibs	
10. FIRE PROTECTION	$ 78,000
Exposed sprinklers and pump	*+11.4%*
11. GENERAL CONDITIONS	$ 429,570
Construction management, insurance & bonds, permits & fees	*+1.5%*
12. CONSTRUCTION CONTINGENCY	$ 265,800
	+1.5%
CONSTRUCTION SUBTOTAL	**$ 3,353,370**
CONSTRUCTION COST/SF	**$ 223.56**
	+1.5%
13. DESIGN FEES	$ 483,430
Architect, landscape architect, civil engineer, structural engineer, systems engineer - enhanced predesign, documentation and CA	*+106%*
Preconstruction Services	
Commissioning	
14. SOFT COSTS	$ 50,000
Survey, soil testing, traffic studies, etc	*0%*
15. PROJECT SCOPE CONTINGENCY	$ 132,900
	+1.5%
PROJECT FIRST COST TOTAL	**$ 4,019,700**
PROJECT COST/SF	**$ 267.98**
	+7.9%

Energy cost escalation over time is a complex equation which values the generation of energy and its transmission differently. Currently, generation is the majority of overall energy cost; however, within the project time horizon, transmission is expected to become the larger cost factor as our energy infrastructure degrades.

What is most illuminating about the energy cost analysis is that while costs rise exponentially for the both the baseline and NZE ready designs, the baseline escalates more significantly. This is due to the anticipated transmission charges on an increased load size.

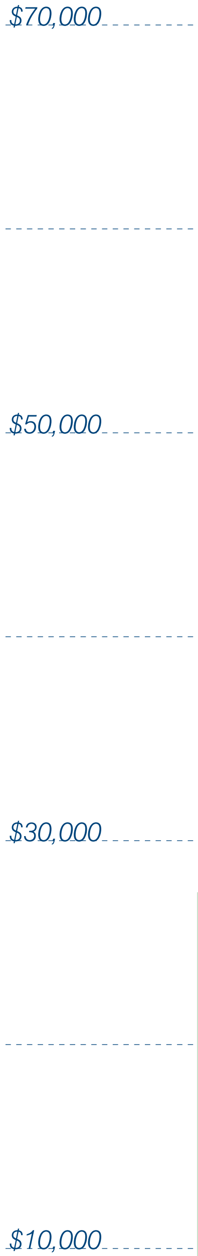
Note:
Energy costs were calculated using the following criteria:

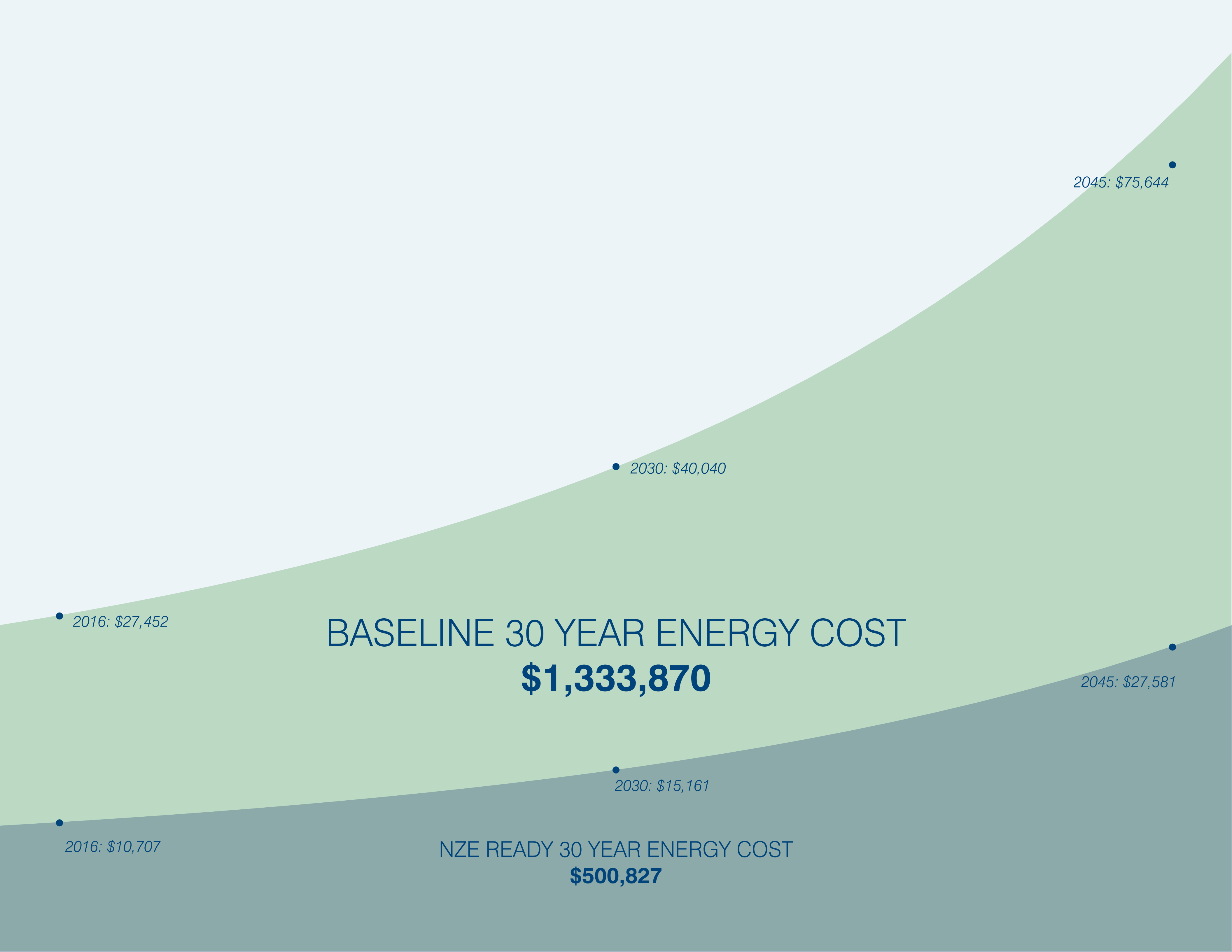
- *PPL GS-3 service*
- *Fixed monthly fee of $40*
- *Distribution charge: $4.192 per kW, 0.6% annual escalation*
- *Generation & Transmission: $0.09198 per kWh, 7.6% annual escalation*

ANNUAL ENERGY COST

BASELINE 🟩

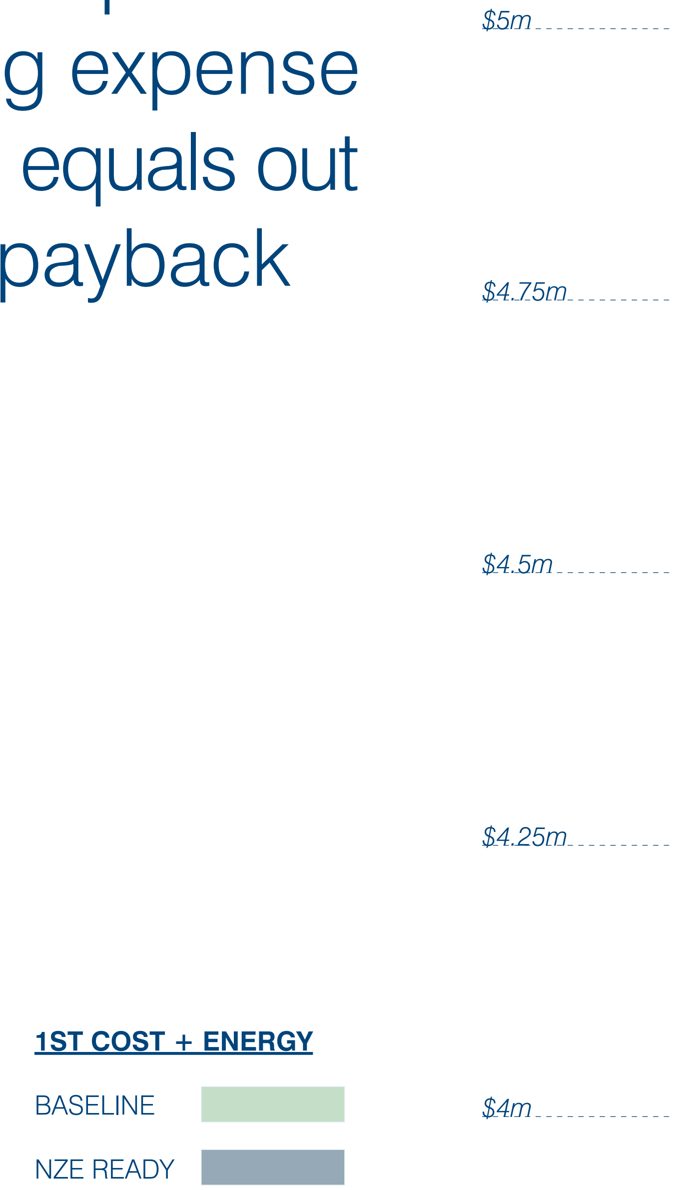
NZE READY ▨

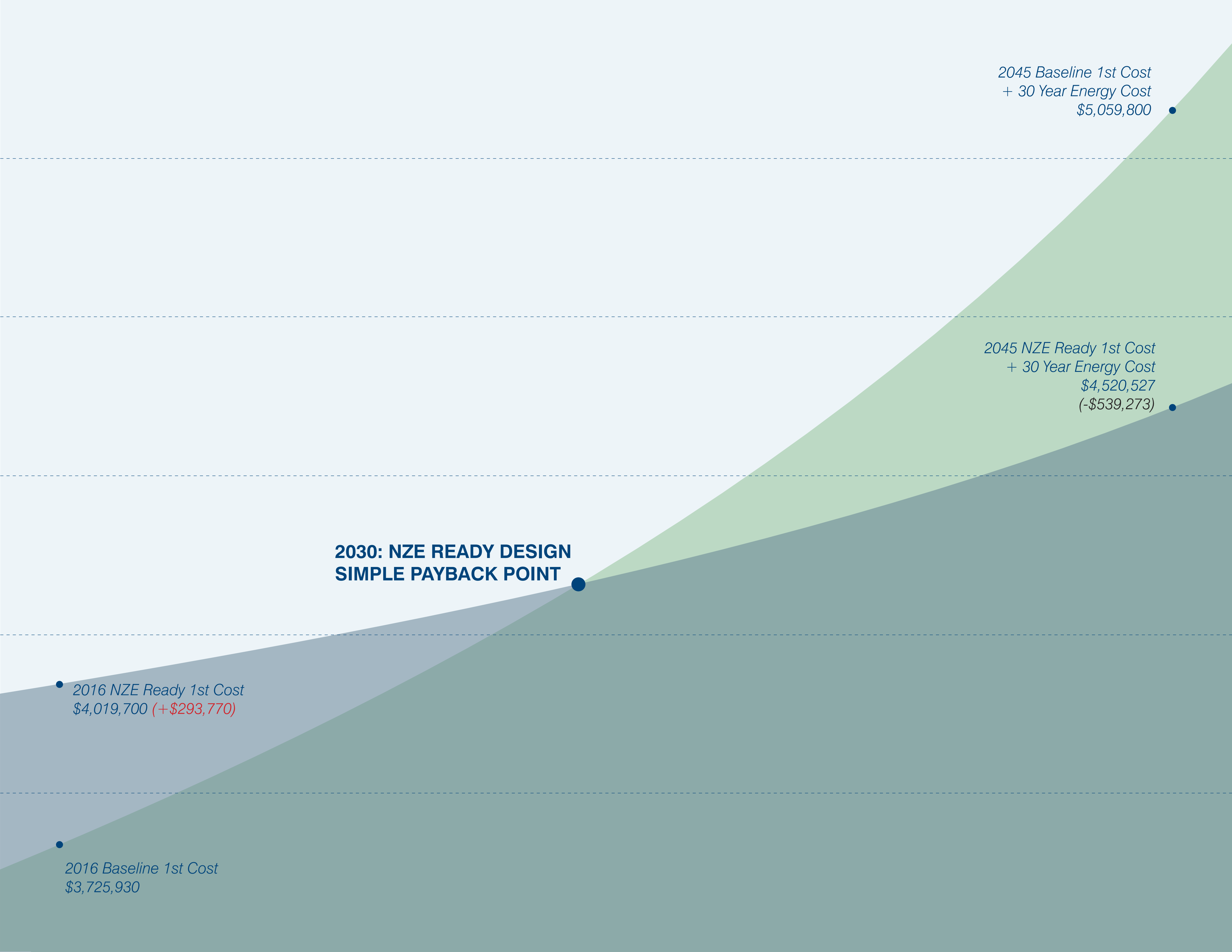



2045: $75,644
2030: $40,040
2016: $27,452
BASELINE 30 YEAR ENERGY COST
$1,333,870
2045: $27,581
2030: $15,161
2016: $10,707
NZE READY 30 YEAR ENERGY COST
$500,827

As annual energy use is compounded upon the initial project cost, the overall building expense for the baseline and optimized designs equals out around 15 years. This is the simple payback period.

For simplicity and isolation of variables, the NZE payback period focuses only on project first cost and 30 year energy use. There are, however, many other costs which factor in to the overall life-cycle cost analysis including but not limited to operations and maintenance fees, system and/or equipment replacement, tenant renovations, tenant vacancies, rental value increases, property taxes, insurance premiums, etc. If these are factored in to the overall financial equation, it is anticipated that the net effect will be of further benefit to the NZE Ready building.

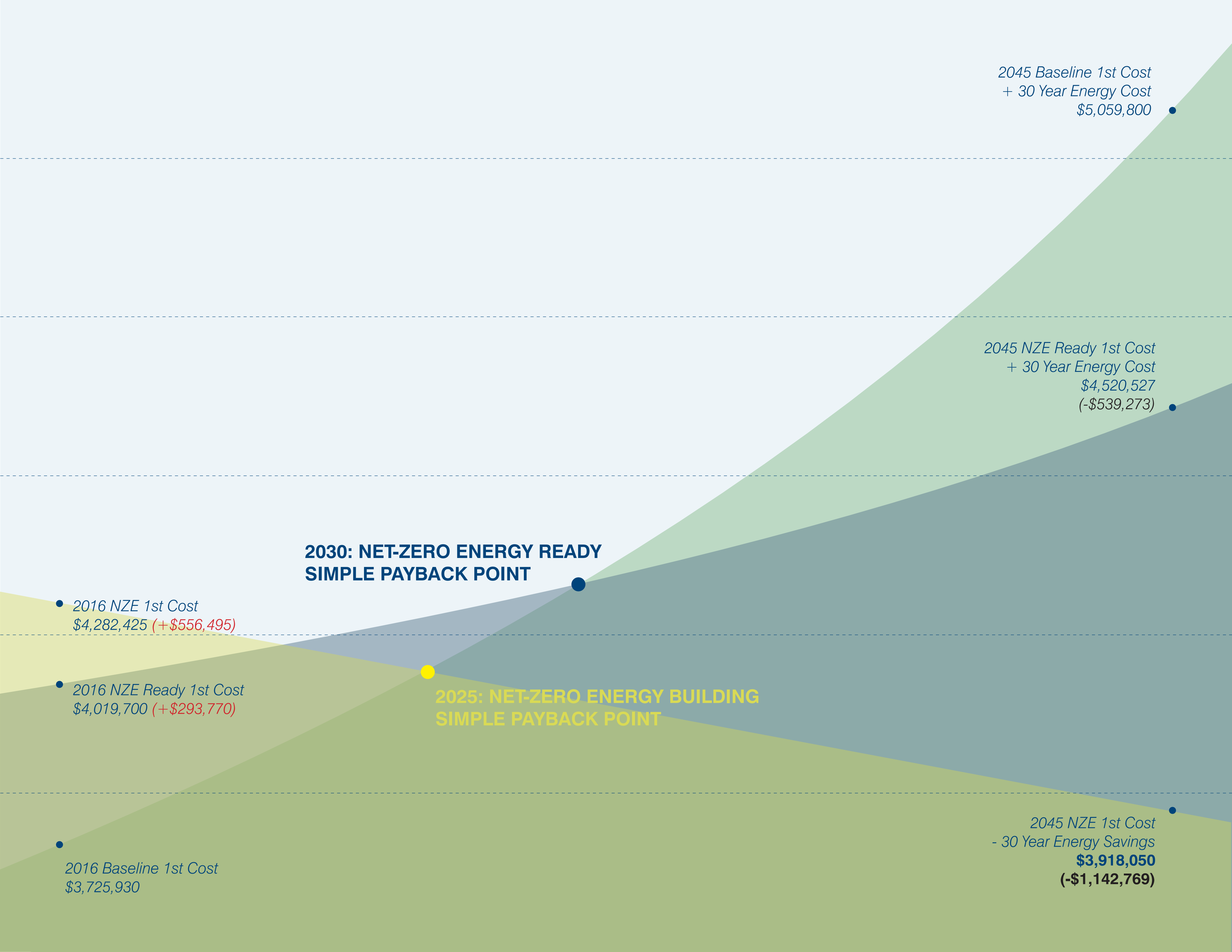



2045 Baseline 1st Cost
+ 30 Year Energy Cost
$5,059,800
2045 NZE Ready 1st Cost
+ 30 Year Energy Cost
$4,520,527
(-$539,273)
2030: NZE READY DESIGN
SIMPLE PAYBACK POINT
2016 NZE Ready 1st Cost
$4,019,700 (+$293,770)
2016 Baseline 1st Cost
$3,725,930

In order to comfortably “guarantee” NZE, the renewable energy system was designed with a healthy contingency of 20%. This means that assuming typical conditions from Day One, the total project cost starts to decrease as excess energy is produced and sold back to the grid.

Although the initial project cost is higher when PV is factored in, the decrease over time actually slides the payback point of the NZE design versus the baseline back even further. The cost and energy modeling performed suggest that this payback period is occuring in the 10th year of operation.

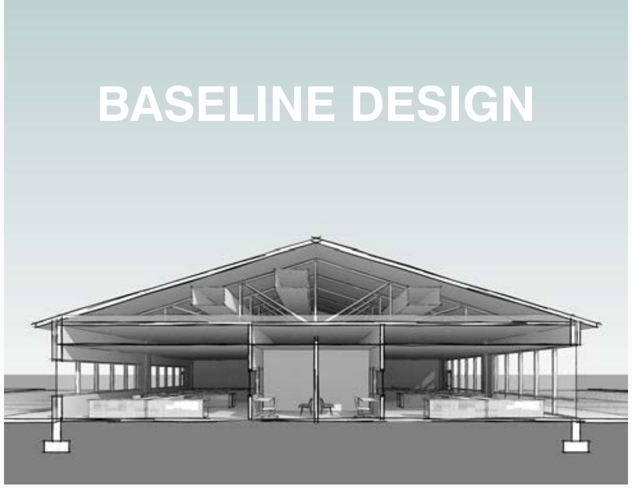
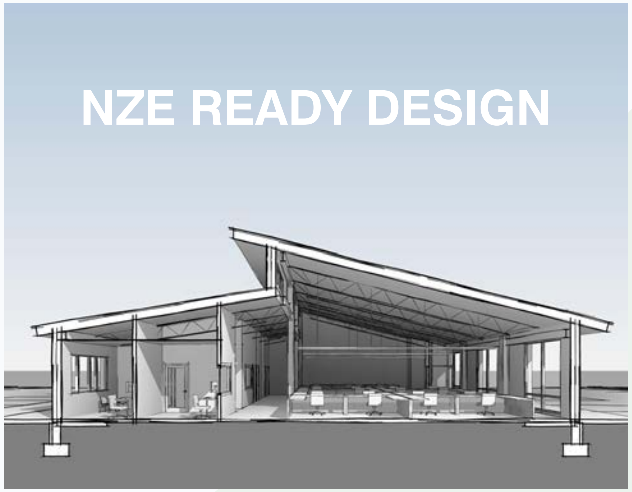
For the PV system cost analysis, federal and state incentives were not included. Incentives such as grants or tax credits will reduce the NZE design first cost further pushing the simple payback point back further.


2045 Baseline 1st Cost
+ 30 Year Energy Cost
$5,059,800
2045 NZE Ready 1st Cost
+ 30 Year Energy Cost
$4,520,527
(-$539,273)
2030: NET-ZERO ENERGY READY
SIMPLE PAYBACK POINT
2016 NZE 1st Cost
$4,282,425 (+$556,495)
2016 NZE Ready 1st Cost
$4,019,700 (+$293,770)
2025: NET-ZERO ENERGY BUILDING
SIMPLE PAYBACK POINT
2045 NZE 1st Cost
- 30 Year Energy Savings
$3,918,050
(-$1,142,769)
2016 Baseline 1st Cost
$3,725,930

08 | Executive Summary

This study set out to provide Sustainable Energy Fund with the data needed to objectively evaluate the added cost and value of constructing an owner occupied Net-Zero-Energy office building for their headquarters in the Lehigh Valley.

For an owner-occupant, the results are promising…

	BASELINE DESIGN 	NZE READY DESIGN 
Building Envelope	Code min. insulation, overglazed w/ conventional windows, no foundation insulation, standard construction	Increased insulation, optimized and improved windows, perimeter foundation insulation, tighter construction
HVAC	Oversized conventional roof top unit system with code minimum ventilation rates	Right-sized energy efficient variable refrigerant flow(VRF) system with ERVs for improved ventilation
Space Quality	Conventional office space with poor thermal comfort at perimeters	Unique space with exposed structure, passive ventilation and improved thermal comfort.
Energy Use Intensity (EUI)	52 kBtu/sf^2/yr	21 kBtu/sf^2/yr
Construction Cost	$ 3,304,020	$ 3,353,370 (+$49,350)
Construction Cost/sf	$ 220.27	$ 223.56 (+1.5%)
Design, Commissioning & Precon	$240,960	$483,430 (+$243,470)
1st Cost + 15 Year Energy Cost	$4,219,405	$4,209,312 (-$10,093)
1st Cost + 30 Year Energy Cost	$5,059,800	$4,520,527 (-$539,273)
Net-Zero Energy Building Payback (Recoup investment over baseline)	-	10 years
30 Year NZEB Savings Over Baseline	-	$1,142,769

In answering ‘whether to’ do NZE, we also made discoveries of ‘how to’ do it smartly.

THE NET-ZERO ENERGY READY APPROACH

The NZE Ready approach orients and optimizes the building to prepare it for renewables that would make it a NZE Building. As shown in the study, the Baseline Building would not be capable of producing its own energy to reach NZE within its footprint; a larger site area for renewable energy generation would also be needed. The bottom line is that the first cost for the Baseline Building plus renewables far exceeds the first cost for the NZE Ready Building plus renewables.

Even if renewables are excluded, the construction cost of the NZE Ready Building is shown to be capable within 1-2% of the Baseline Building. This is occuring even though the overall design and construction quality is higher for the NZE Ready Building. The significant cost premium for the NZE Ready Building is projected to be found in enhanced Design, Commissioning, and Pre-Construction services that facilitate the achievement of this higher quality at market-rate of construction cost.

When comparing total project budgets for the NZE Ready Building with the Baseline Building, the first cost premium for the NZE Ready Building is anticipated to be returned within 15 years or less on energy costs alone; after that point, the energy returns continue to mount annually. Once renewable energy is factored in, turning the NZE Ready Building into a NZE Building, the return actually decreases to less than 10 years.

Although it is beyond the scope of this study and was not accounted for in any payback calculations, other financial returns are expected for the higher-quality, NZE Ready Building, including market-differentiation and increased leasing potential.

LET’S START AT THE VERY BEGINNING, LITERALLY

Early comparative and then iterative spatial design, energy modeling, and cost modeling are requirements for smartly achieving high performance goals within market constraints.

Typically, by the time an owner and their design team begin to critically look at energy issues, a conceptual design has been approved and a line-item budget has been established. This is true even on deep green projects. What this study showed, however, is that the conceptual design phase is exactly the right time to be evaluating, with highly iterative cost and energy data, a whole-building approach to energy efficiency. This kind of iterative modeling is a front-end investment in time and capital, and one example of why a premium was added to the professional fees associated with designing a NZE Building. For this investment, the value is in finding opportunities for reduced construction cost that also enhance quality or performance. The value of this different process unfolded during the study and testing of many design options for the NZE Ready Building; performance targets were improved upon while construction cost was driven down. With each iteration, opportunities and hidden synergies were discovered which led to improved performance and lowered cost.

OPTIMIZATION

The alternatives to taking the time and gathering the data to optimize a building and systems for high-performance are to:

1. accept low-performance, or,
2. conservatively over-design what is really needed to get the desired comfort/efficiency.

Overdesigned NZE is seldom market feasible or a good investment. Optimized NZE is what we need to achieve.

ONE SIZE DOES NOT FIT ALL

As explored in the study's energy modelling, the same building in a different location, with different load profiles, different operating hours and/or different regional materials can perform wildly differently. For market competitive NZE, the "cookie cutter" approach to office design needs be thrown out the window. Illustrating this point, the economies of construction materials and renewable technologies are moving targets which vary wildly from one location to the next and fluctuate as technology advances and policy incentives change. What is considered an "optimized" building envelope for a net-zero-energy project today will change as relative costs of building materials and renewable energy also change.

THE VALUE OF NZE/HIGH PERFORMING BUILDINGS

For an owner/occupant/investor, the project first cost and energy cost is only one part of a complex long term cost equation which extends beyond the scope of this study. In addition to the studied cost equation there are other attributes of NZE/High Performing buildings which add long term value to the investment:

- Distinctive properties command higher rental values and offer market advantage.
- Functional and pleasing spaces increase tenant retention leading to fewer renovations and fewer vacant months.
- Functional, healthy and pleasing spaces increase employee productivity and retention.
- High performing buildings increase asset value against market comps.
- High performing buildings shelter owners from unstable and unpredictable future energy markets.

IS NZE ENOUGH?

Energy is a significant and critical piece of the overall sustainability equation but solving it alone is not enough to address the broader challenge of sustainable and regenerative communities. It is incumbent upon owners, designers, tenants and other stakeholders to also recognize that global sustainability requires attention to issues of land use, transportation, water, biodiversity, human health, lively built environments, and community equity.

09 | Credits

This study was commissioned by the Sustainable Energy Fund in 2015.

SUSTAINABLE ENERGY FUND

John Costlow, President/CEO

RE:VISION
Architecture

Scott Kelly, AIA, LEED Fellow
Jennifer Rezeli, LEED AP
Drew Lavine, RA, LEED AP

IN:POSSE
Systems Design + Energy Modelling

Rob Diemer, PE, LEED AP
Shannon Kaplan, PE, LEED AP
Brendan McGrath, PE, LEED AP

CVMNEXT
Cost Estimating

Chris Boccella, AIA

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JONES LANG LASALLE
THE KAISERMAN COMPANY
LIBERTY PROPERTY TRUST
NAI

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36	Oak Ridge National Laboratory
36	Sloan Valve Company
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Re:Vision

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