INVENERGY NET ZERO PROTOTYPE

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AUGUST 1, 2022

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01 INTRODUCTION

DEFINING NET-ZERO

We were asked to develop recommendations for a Net Zero Energy/Low Carbon office building to be located in various climate zones. For the purposes of this study, we are using the Department of Energy (DOE) definition of Net Zero Energy, that its energy use over the year is offset by onsite generation as measured in power.

We created a baseline model and two alternatives with increasing levels of performance through a series of load reduction and mechanical systems efficiency.

Since we need to offset our energy use, and the most cost effective method is to utilize onsite generation to avoid any transmission losses or extraction costs, it makes sense that the building be designed as all electric with no fuel burning combustion equipment for space heating or hot water heating, with the expectation that onsite generation would be electric.

We then performed an embodied carbon calculation to understand where, if any, could the Net Zero Energy design be further optimized to become a carbon neutral building.

For the calculation of building energy use, the expected use of EV charging stations was not included in the miscellaneous plug loads as that is energy that is used on site but not to service the building.

DOE definition of Net Zero Energy
an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy

Note this definition assumes the “grid” acts as a battery for times when onsite generation exceeds demand or when demand exceeds generation.

PROCESS

Energy Modeling
We used an energy modeling program called Sefaria Systems, which uses Energy+ as the modeling engine and allows rapid iterations for various strategies. We analyzed what we call load reduction strategies then mechanical system strategies, to evaluate the relative benefit of the recommended strategies that will allow the prototype to perform at a low energy level.

Load Reduction
A typical load reduction strategy is one that reduces the base load. An example is a better performing window. It still is a window, but by changing out to a high performance glass and frame, will reduce the basic heating load by some amount. Multiply this by all the windows and you get the base load reduction either in energy or dollars. Most load reduction strategies are material changes or additions, but some more radical involve building orientation and massing.

Mechanical System
A typical mechanical system strategy is either an efficiency strategy or a system change. A system efficiency strategy is simply using a more efficient motor or fan, the system is still essentially the same. A system change strategy is a physical change in the type of system. An example of this would be to change from an Air-cooled Chiller to a Water-cooled chiller.

On-Site Generation
A typical on site generation strategy are those things that create energy. Currently, the two most common are rooftop or ground mounted photovoltaics and ground mounted wind turbines.

Embodied Carbon
To analyze embodied carbon, we utilized a combination of the ATHENA impact estimator, the EC3 database, and other peer reviewed literature.

01 INTRODUCTION

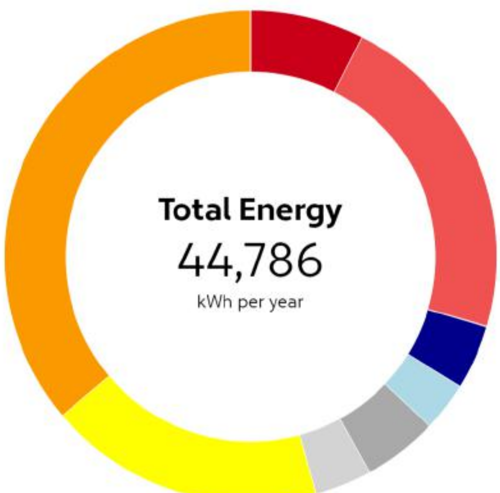
PROJECT BACKGROUND

Location:	Climate Zone 5 (a,b)
Size:	~4,000 sq ft, single stoy
Type:	Office / Semi-heated
Arrangement:	Adjacent
Current Energy Code:	Illinois Energy Conservation Code (IECC 2018)

BASELINE

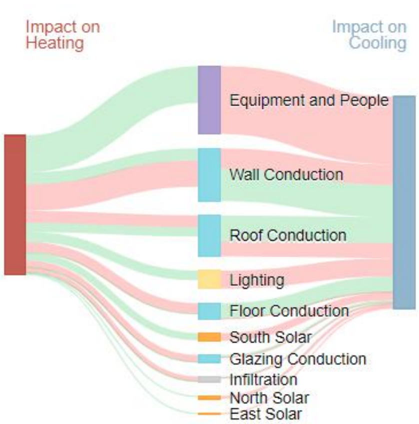
We developed a baseline model (based on the Hardin Site) utilizing the Issue for Construction Drawings, Project Manual and select submittals. In the computer we re-created the building shape, windows, thermal zones, mechanical systems, equipment loads, and occupancy schedules. We then reviewed the results of that model with expected energy use of similar projects and adjusted the model to align with these other projects. The Baseline model geometry, zoning, and energy use are shown in the diagrams below.

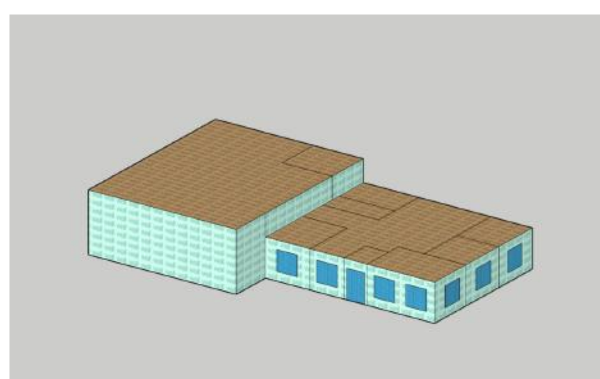
Baseline
Annual Energy Use



Segment	kWh per year	% of total use
Heating	**13,261**	**30 %**
AHU	3,347	7 %
Zones	9,892	22 %
Humidification	22	0 %
Cooling	**3,335**	**7 %**
AHU	1,888	4 %
Heat Rejection	0	0 %
Zones	1,447	3 %
Fans	**3,881**	**9 %**
AHU	2,203	5 %
Zones	1,678	4 %
Interior	**24,309**	**54 %**
Lighting	8,121	18 %
Equipment	16,188	36 %
Pumps	**0**	**0 %**

Invenergy 004 - Baseline - Existing Bldg. Produced by undefined from FARR ASSOCIATES, 10 Feb 2022 @ 15:11:56





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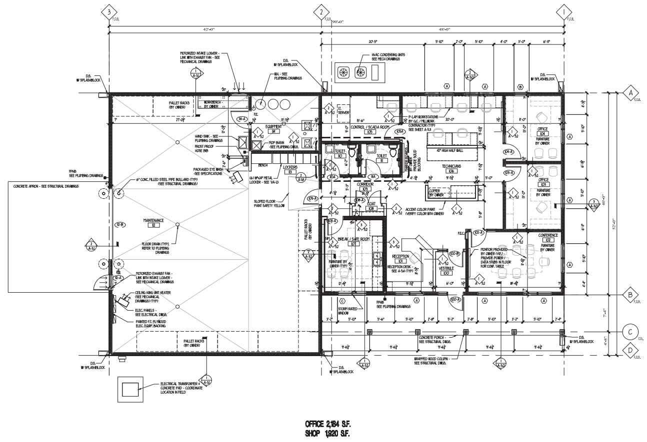
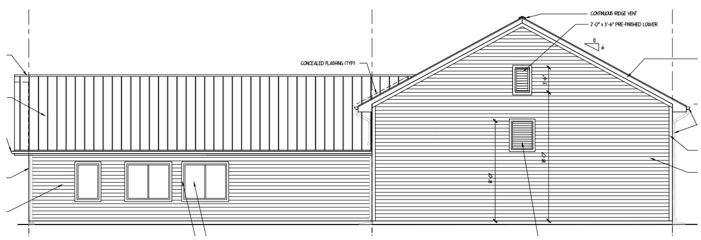
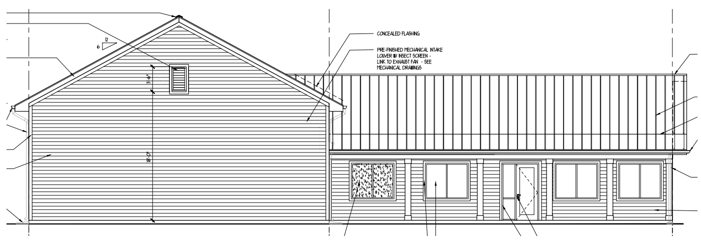
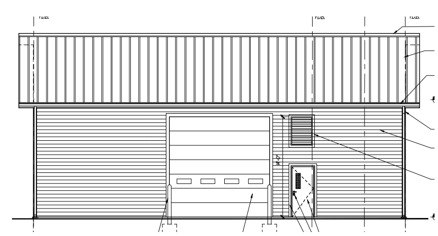
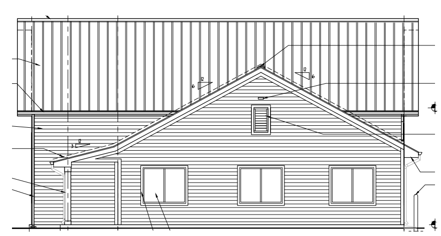










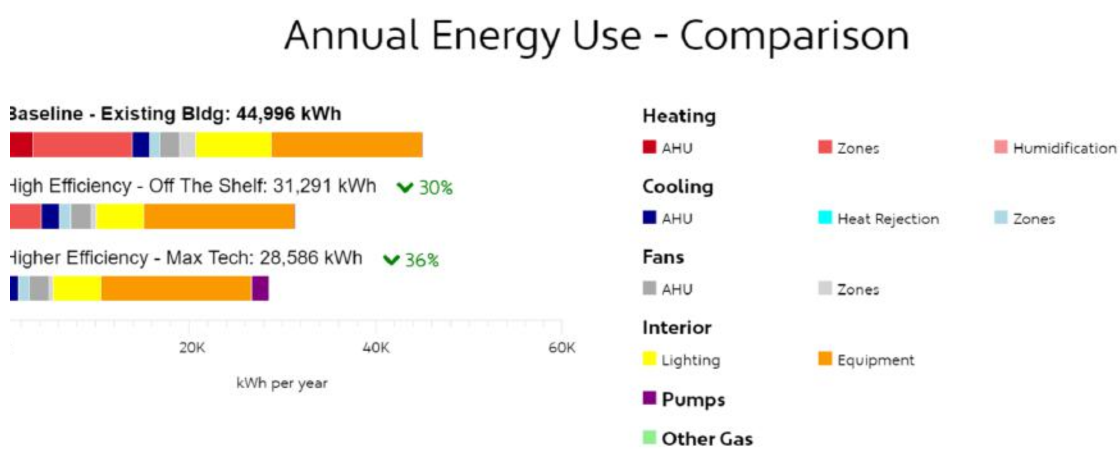
01 INTRODUCTION

PROPOSED DESIGNS

We created two proposed designs, an Off the Shelf concept and a Max Tech concept.

The Off the Shelf model uses - as you might expect - currently available technologies and equipment. The Max Tech concept uses top of the line equipment and modifies some of the building geometry.

Some of these strategies come with increased cost along with increased energy savings, some are cost neutral. These are diagrammed below as massing models and the comparison end-use energy shown here. The individual strategies and recommendations are discussed in the following section.



Off the Shelf

Max Tech

02 ENERGY EFFICIENCY ANALYSIS

02 ENERGY EFFICIENCY ANALYSIS

To better understand how the two proposed design solutions were achieved and to give guidance to the project teams for implementation in future projects, we discuss each strategy below. The table below summarizes the individual Energy Efficiency Measures reviewed and lists cost, impact on embodied carbon, and complexity.

Note: By complexity we mean either complex to implement, purchase, or maintain.

EUI - Energy Use Intensity: a measure of a energy use over a year, measured in Kbtu/sf/sf

	Metric		
Strategy	**Baseline**	**Off the Shelf**	**Max Tech**
Orientation	any	due south	due south
Massing	existing	existing	slightly more compact
Glazing Performance (SHGC)	0.40	0.4	0.4
Glazing Performance (U-factor)	0.38	0.25	0.18
Window to wall ratio	8%	slightly more compact	0.1
Daylighting approach	38% ASE, 3% SDA	87% ASE, 8% SDA (better)	85% ASE, 0% SDA (aggressive)
External shading	partial south	all south 1/2 optimum	all south (optimized)
Air Leakage	0.04 (cfm/ft2@75 Pa)	0.25 (cfm/ft2@75 Pa)	0.15 (cfm/ft2@75 Pa)
Wall (R-value)	R-15.6	R-20	R-40
Roof (R-value)	R-38	R-40	R-60
Thermal Bridging	None	0.003% 0.06 BTU/(hr-ft-F)	0.001% 0.006 BTU/(hr-ft-F)
Lighting power density	0.76	0.6 + Eff + daylight control	0.4 + Eff + daylight control
Office HVAC type	Heat pump with OA direct to unit	DOAS with VRF (air to air)	DOAS, VRF (geothermal)
Maintenance shop HVAC type	(2) 10 kW Electric heater w/ 2500 cfm exhaust fan	DOAS with VRF (air to air)	DOAS,VRF with radiant (geothermal)
Scada room	1.5 ton DX cooling unit	38% ASE, 3% SDA	DOAS, VRF (geothermal)
Add energy recovery to DOAS	N/A	Energy recovery plate on DOAS	Energy recovery plate on DOAS
DX efficiency	11 EER cooling, 2.5 COP heating, 0F ambient heating minimum	13 EER cooling, 3.5 COP heating, -15F ambient heating minimum	18 EER cooling, 5.5 COP heating, ground coupled
DHW	6 kW, 40 gallon	Instantaneous water heater (COP 1)	Heat pump water heater (COP 3)
Plug/process load	N/A	N/A	N/A

02 ENERGY EFFICIENCY ANALYSIS

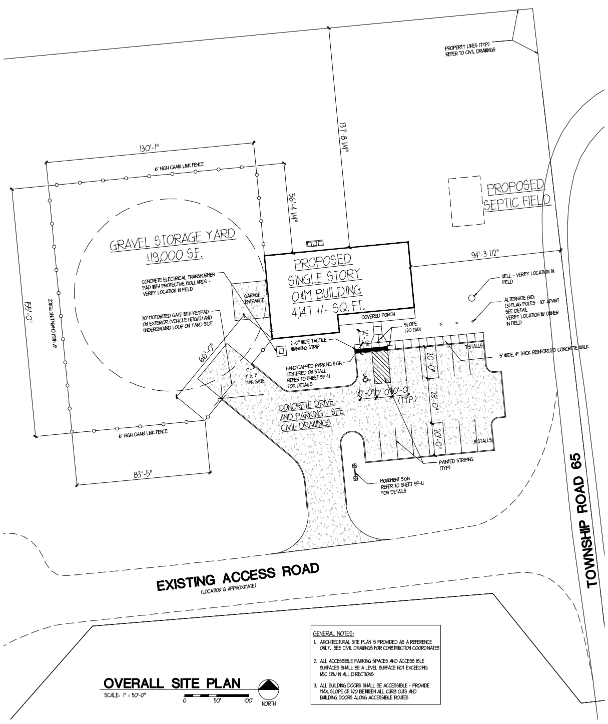
ORIENTATION

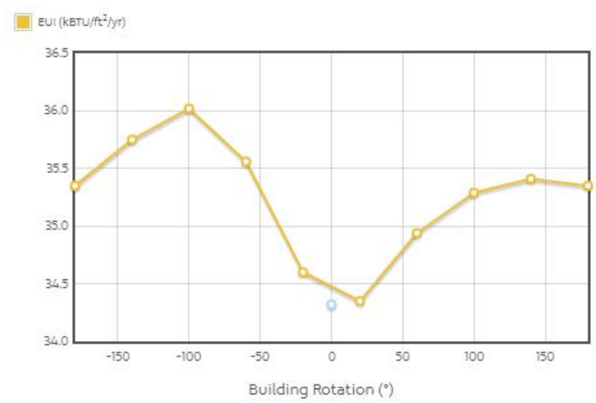
A building's orientation can drastically affect its energy performance. This is primarily due to the passive effects of south facing glass and the undesirable effects of east and west facing glazing. In the chart below you can see the effect of rotating the baseline model 360 degrees (0=south).

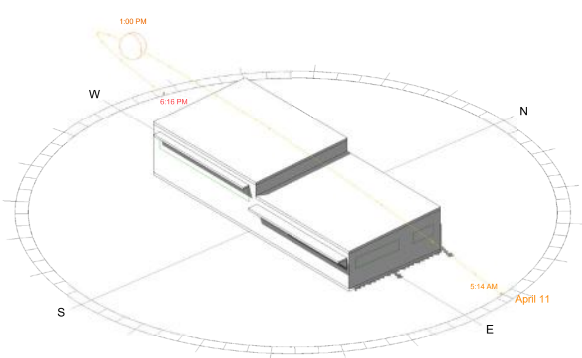
A related factor in building orientation is glass area and glass performance, so, as with all these strategies, they need to be looked at together. We realize not all projects will be able to be oriented due south, but it is clearly a cost effective, low complexity strategy that should be implemented.

This is recommended for both the Off the Shelf concept and the Max Tech concept.

Note: On these charts the vertical axis is Energy Use Intensity (EUI) measured in Kbtu/sf/yr and the horizontal axis is a measure of the metric being analyzed.







02 ENERGY EFFICIENCY ANALYSIS

MASSING

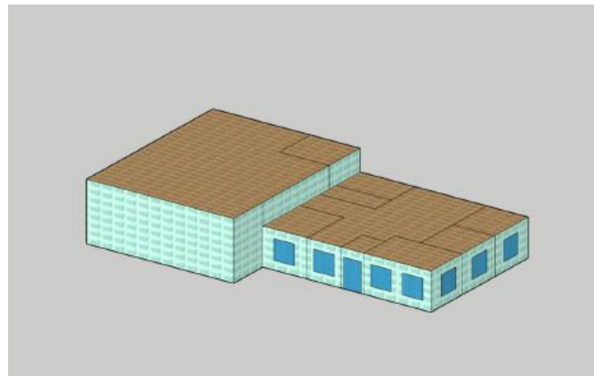
A building's massing affects the heat gain/loss over the year. The current design is fairly compact; however, we wanted to evaluate the effect of a slightly longer / narrower massing primarily to optimize daylight since we are looking at a very low energy building and every move helps reduce the heating/cooling load. Additionally, massing is a very low-complexity, low-cost measure.

Since changing massing may be considered a larger move, we kept the massing the same for the Off the Shelf concept and modified the massing for the Max Tech concept.

Note in the massing images below, the windows and shading devices have also been added, this is because we were looking at all the strategies together.

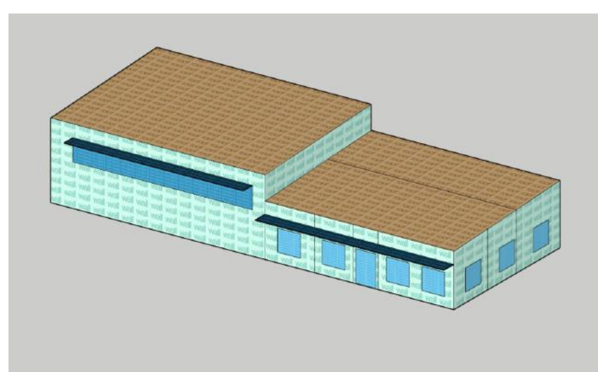
The massing did not make as much impact on direct energy use as a function of heat loss or gain, but does affect Daylight Performance.

See Daylighting for massing recommendations.



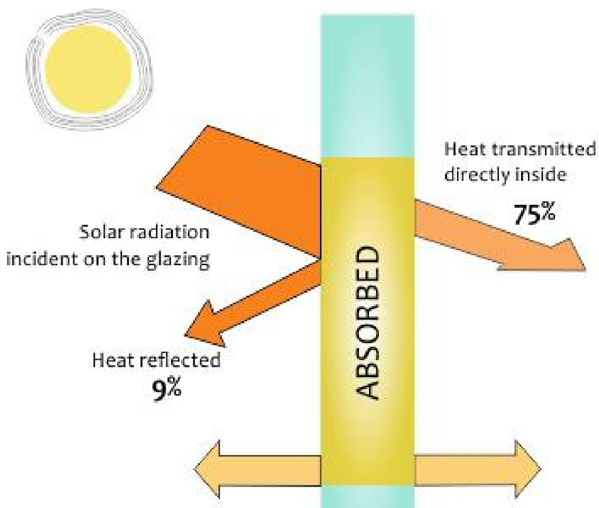
Baseline

Off the Shelf



Max Tech

02 ENERGY EFFICIENCY ANALYSIS



IMPROVED WINDOW PERFORMANCE (SHGC)

SHGC is a measure of how a window rejects solar radiation (heat). Interestingly, this is desirable in the winter when a project can use the heat to help heat the building but undesirable in the summer. A good design balances this winter heating and summer cooling. Seasonal solar heat gain can also be controlled by well designed external shading. Solar heat gain control with glass also needs to be balanced by visible light transmittance. Optimally the Visible Light to Solar Heat Gain Coefficient to Visible Light ratio should be above 1.5.

For Climate Zone 5 SHGC should be high enough to allow for winter passive heating while the summer overheating is controlled with external shading. The proposed SHGCs and Visible Transmittance (VT's) are readily available for all glass packages.

Target SHGC's and VT's are:	SHGC	VT
Baseline (assumed)	0.36	60%
Off the Shelf	0.30	60%
Max Tech	0.24	60%

Note: the SHGC should be looked at in concert with orientation, glazing area, and external shading.

02 ENERGY EFFICIENCY ANALYSIS

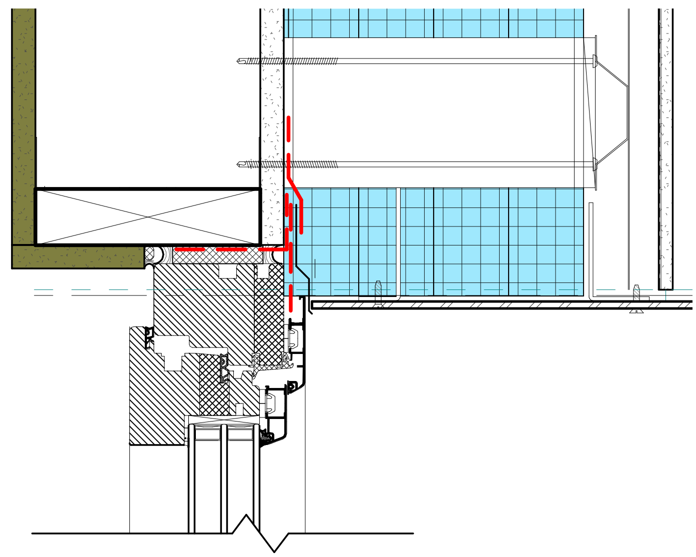
IMPROVED WINDOW PERFORMANCE (U-FACTOR)

U-factor is a measure of how a window resists the flow of heat loss. A lower number is a window with more insulating capacity. This means in the winter, when the project is primarily heating, a lower U-factor is desirable.

Note: R-value is the inverse of U-factor so a higher number is better

For the Off the Shelf concept we targeted the highest performing window with typical dual glazing. For the MaxTech concept, we propose a triple glazed unit. Triple glazed units can get us to U-factors around U-0.16.

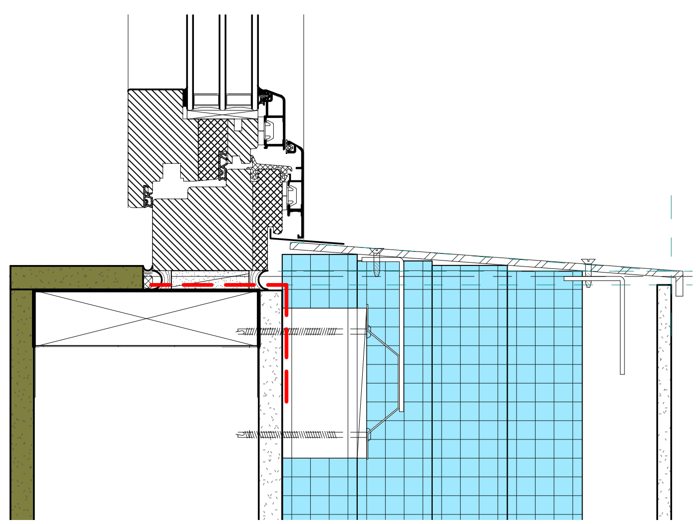
For the purposes of the model we have modeled the doors as windows. In general the same level of efficiency targeted for the windows should be targeted for the doors, although because of the operational nature of doors they tend to have somewhat higher U-factors as there is more “frame” to glass, and the frames are inherently less efficient than the glass.



Recommendations for window U-factor are:

Baseline (assumed)	0.38
Off the Shelf	0.25
Max Tech	0.18

Target systems for the non-standard windows:
Front aluminum storefront - Kwaneer 1600 UT with insupour door with triple glazing
Maintenance Personnel Door - Curries fiberglass door with Trio-E thermally broken frame
Maintenance Overhead door - 3” rigid foam door



When installing the windows in a highly insulated wall it is important to locate the glazing plane in the center of the mass of insulation if possible. Since that is usually proud of the structural framing, clips or bucks must be used (figure a). Alternatively, the insulation can ‘overlap’ the window frame (figure b).

See the discussion on Thermal Bridging.

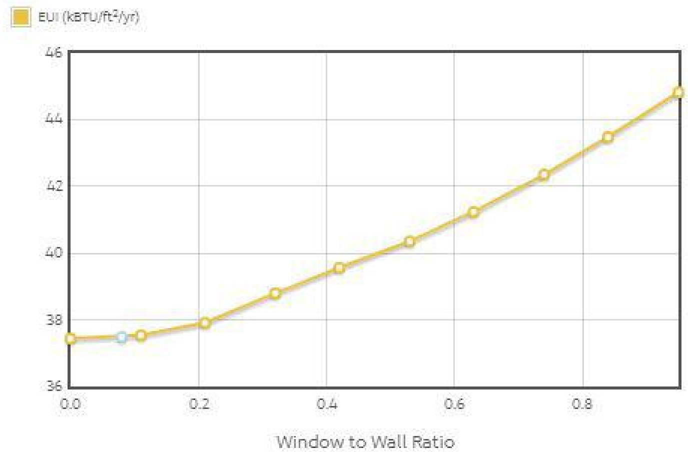
02 ENERGY EFFICIENCY ANALYSIS

WINDOW TO WALL RATIO

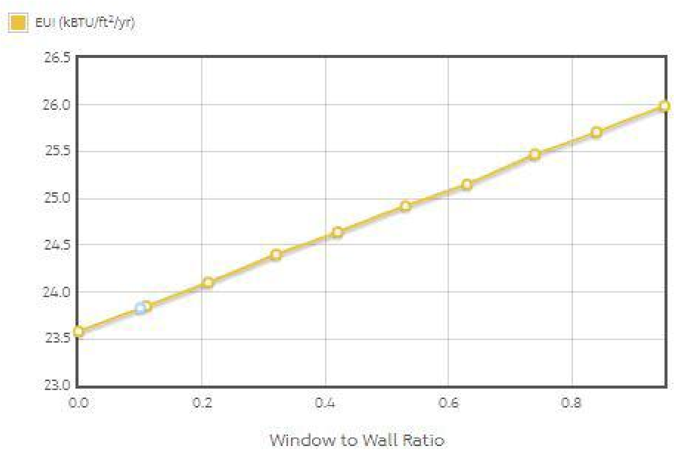
Window to wall ratio is the amount of glazing per wall area. Window area needs to be balanced with both beneficial solar heat gain and glare free daylight. However, in general, for Climate Zone 5, less window area will always outperform more window area. The recommendation is to have about 8%-20% glazing on the South while having just enough glazing on the North, East, and West for optimum daylight.

Since changing glazing area is larger change, we assumed the same glazing for the Baseline as for the Off the Shelf concept and adjusted the glazing in the Max Tech concept.

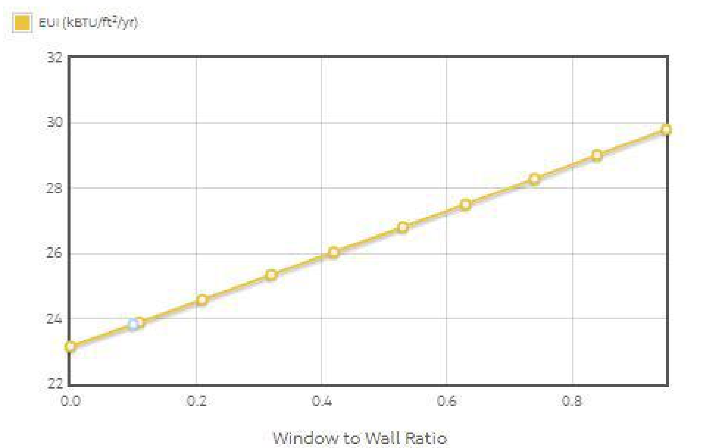
The EUI savings shown are a result of the combined strategies.



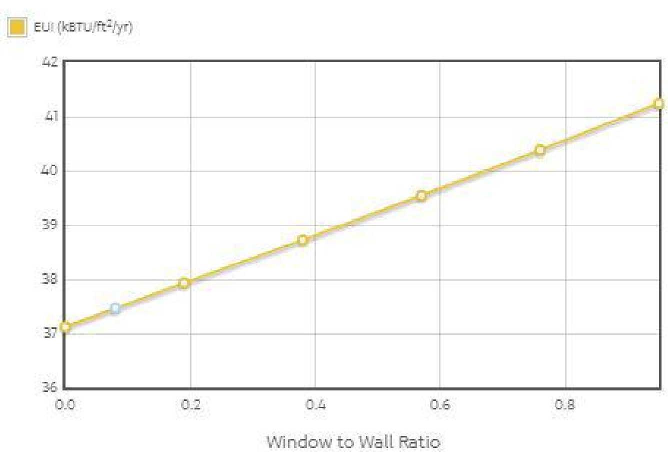
OVERALL - BASELINE



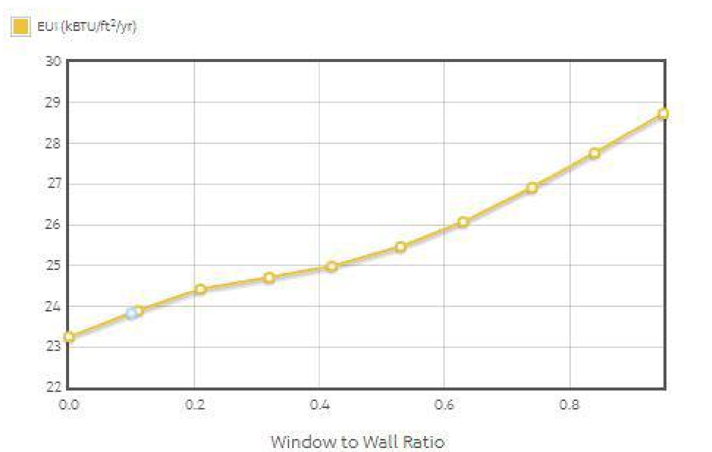
NORTH - BASELINE



EAST - BASELINE



WEST - BASELINE



SOUTH - BASELINE

02 ENERGY EFFICIENCY ANALYSIS

EXTERNAL SHADING

Similar to SHGC, external shading reduces heat gain. The benefit of external shading as opposed to SHGC, however, is it can be tuned to be orientation and seasonally specific. On south facing glass, because the sun location is always known, we can optimize external fins to block unwanted summer sun and let in beneficial winter sun.

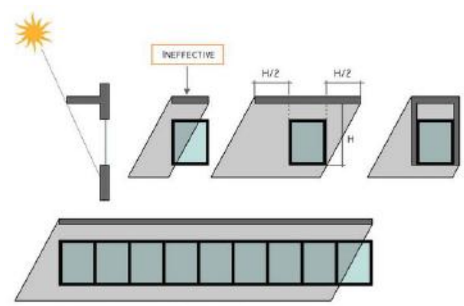
External fins do have a cost and they do weaken the thermal performance of the wall, but the passive winter heating and passive summer shading tend to outweigh those energy losses.

An optimal external shade blocks 100% of the direct sun on the summer solstice and 0% of the winter sun on the winter solstice. This of course has to be balanced with daylighting and glare.

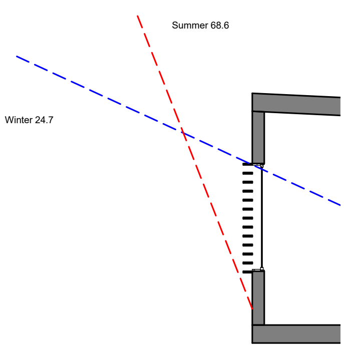
There are two primary types of external fins: (1) one large fin; or (2) a series of small fins.

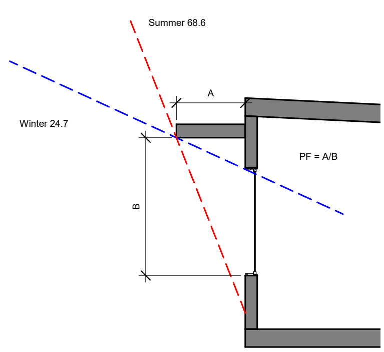
Shading is measured in projection factor (PF). The projection factors analyzed were:

Baseline (existing overhang)	1 (south)
Off the Shelf	.2 (south)
Max Tech	.4 (south)



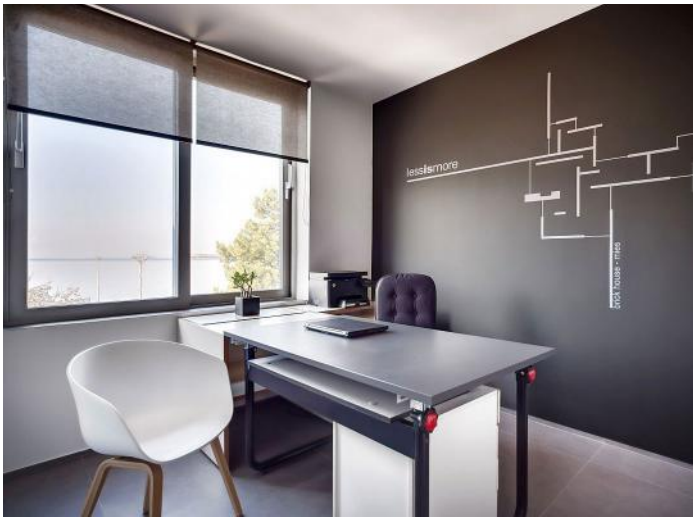
Elevation of Shading Device Configurations for South Facing Facades

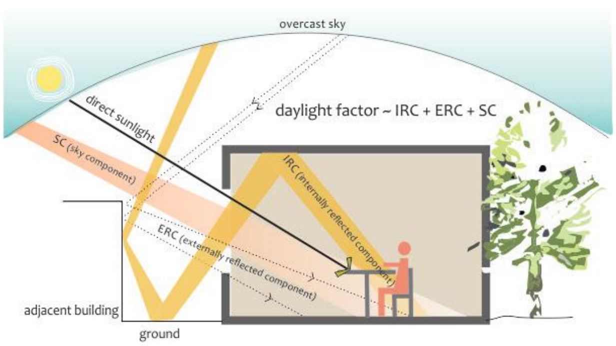




Note: The fins typically should extend past both sides of the window edge in plan for about 20% of the fin length to block angle sun, but in many cases this is not possible as it makes the fin too large.

02 ENERGY EFFICIENCY ANALYSIS





Note: SDA300/50 is a space that receives at least 300 lux of daylight for 50% of the working hours. ASE1000/250 measures the amount of direct sunlight of more than 1000 lux for 250 hours or more of working hours.

DAYLIGHTING

Daylighting is the use of daylight to both enhance the working environment and reduce the energy use of the building. Above we talked about window area, visible light, and heat gain; here we are focusing on the metrics of daylighting to reduce the use of electric lighting. The two metrics we use are ASE and SDA.

SDA300/50 is a measure of usable daylight over the course of the year (answering the question, "is there enough light?"), measured in lux over time. ASE1000/250 is a measure of what is commonly called 'glare' over the course over the year (answering the question, "is there too much light?"), also measured in lux over time.

Note: SDA300/50 is a space that receives at least 300 lux of daylight for 50% of the working hours. ASE1000/250 measures the amount of direct sunlight of more than 1000 lux for 250 hours or more of working hours.

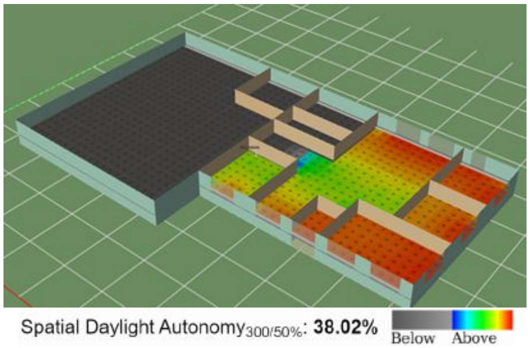
The target daylight metrics are:

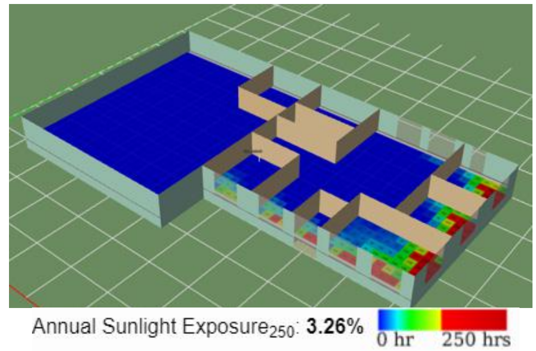
Ideal	SDA>90%	ASE<10%
Baseline (existing)	SDA-38%	ASE-3%
Off the Shelf	SDA-87%	ASE-8%
Max Tech (A & B)	SDA 85%	ASE-0%

These are hard to calculate manually and utilizing a program such as LightStanza is required. The concept layout below, however, shows, the difference between the Max Tech A and Max Tech B is the South Facing glass area. Conceptually, we propose a long continuous row of south facing, shaded glazing and to limit the east facing glazing area, while internally re-arranging the room layout to create a large open, southern facing area with full height internally glazed walls facing that space. The idea that borrowed south facing light is less energy intensive than northern facing windows.

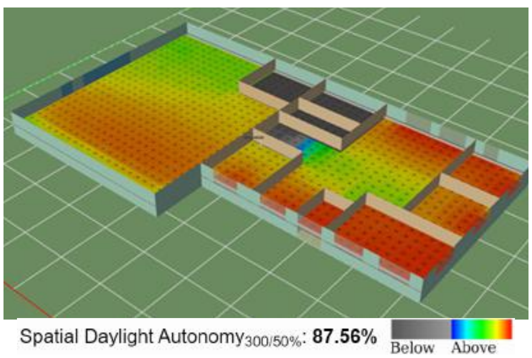
In addition to the shading discussed above, daylight can be optimized with translucent glazing. Translucent glazing addresses glare, but at the expense of views. Commonly translucent glazing is combined with view glazing to maintain the occupants connection to the outdoors.

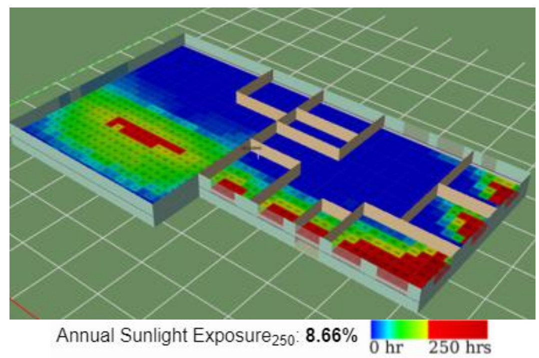
02 ENERGY CONSERVATION MEASURES



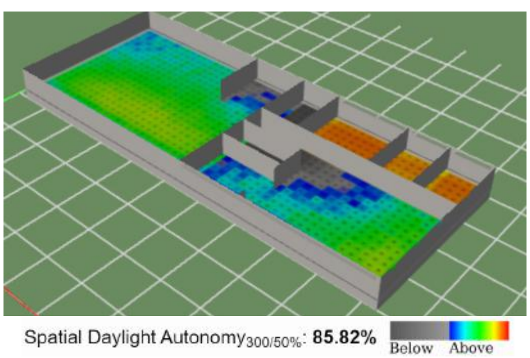


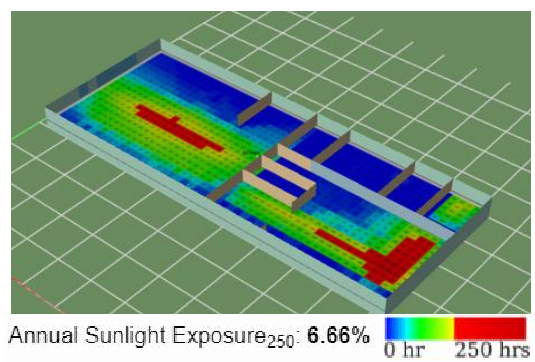
Baseline



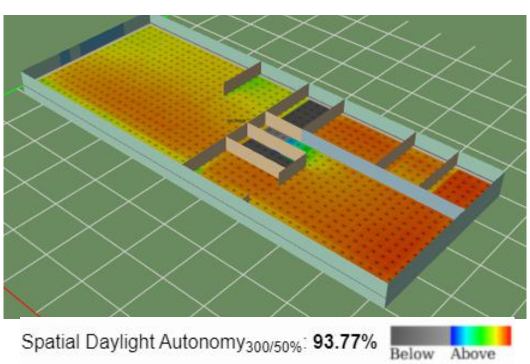


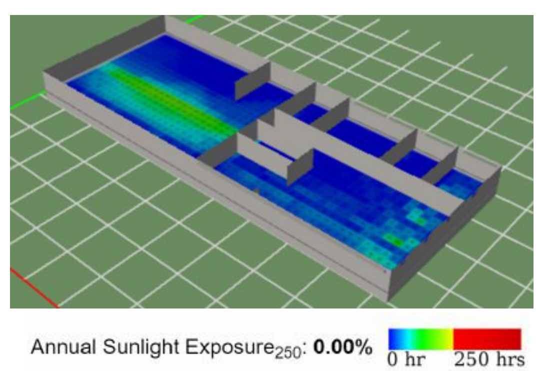
Off the Shelf





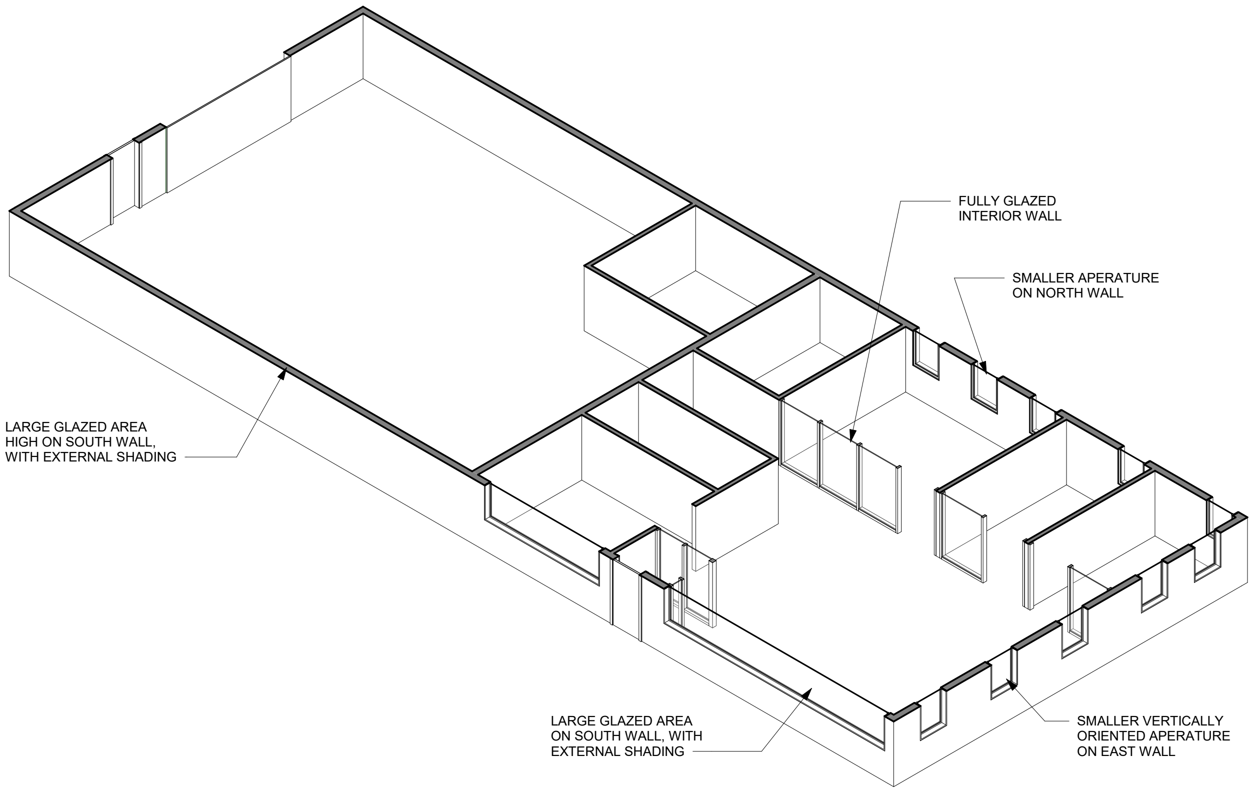
Max Tech A

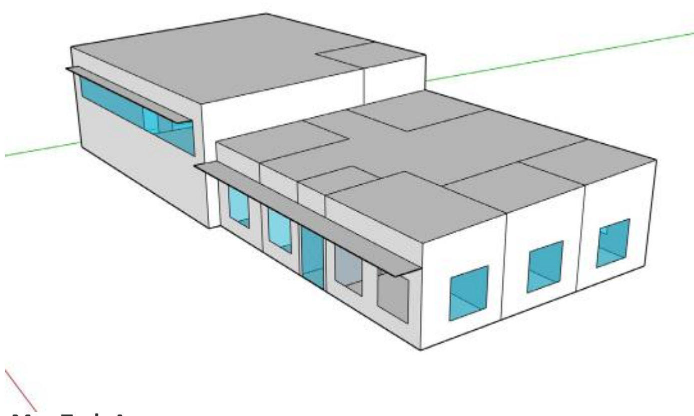




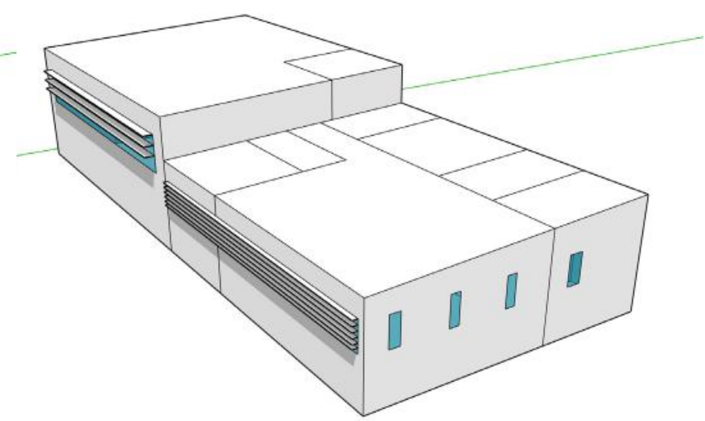
Max Tech B

02 ENERGY CONSERVATION MEASURES





Max Tech A



Max Tech B

02 ENERGY CONSERVATION MEASURES

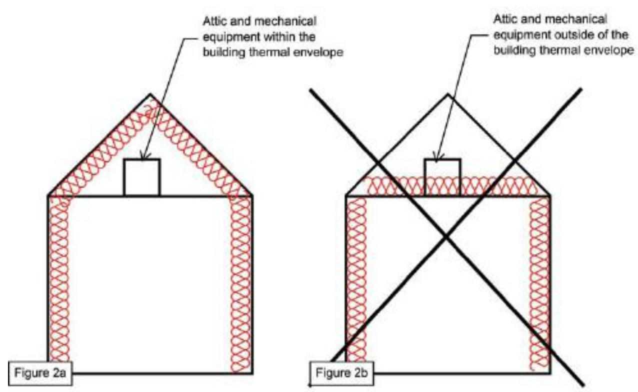
IMPROVED AIR BARRIER

An Air Barrier is a part of the building construction that reduces the flow of air through the wall and roof, primarily at the joints of materials. Uncontrolled air leakage, more commonly known as drafts, can drain a building of its conditioned air, especially when the wind blows. Air movement, building conditioning, and ventilation are a dynamic system that are ideally controlled intentionally by the mechanical system or by operable windows. What we do not want is uncontrolled air movement, and that is what an improved air barrier provides. Air leakage is measured in CFM square foot of wall area at a specified pressure, the typical pressure for commercial buildings is 75 Pascals (CFM ft2 @ 75 Pa).

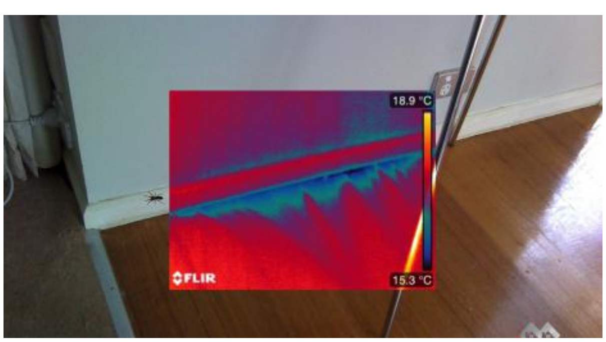
Uncontrolled air leakage is controlled in two ways, construction details and on site testing. The design drawings should have notes and details outlining how the different building assemblies tie together. Testing of air leakage is provided for by blower door test. This should occur once before the interior finishes and insulation are installed, giving the contractor time to address any issues, and once before occupancy to ensure any gaps were not created.

Target air leakage values should be;

Baseline (assumed)	0.40 CFM ft2@75Pa
Off the Shelf	0.25 CFM ft2@75Pa
Max Tech	0.15 CFM ft2@75Pa



Also, it is important that any mechanical equipment, ductwork, refrigerant lines, and domestic hot and cold water lines are within the air barrier and thermal envelope.



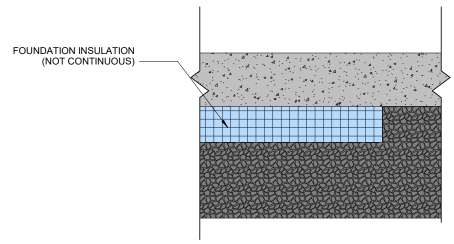
02 ENERGY CONSERVATION MEASURES

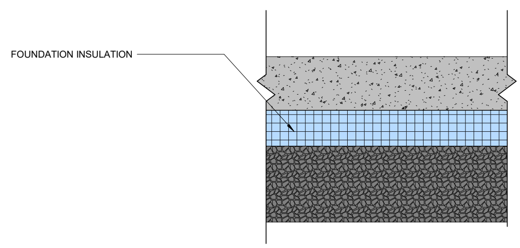
IMPROVED SLAB ON GRADE (R-VALUE)

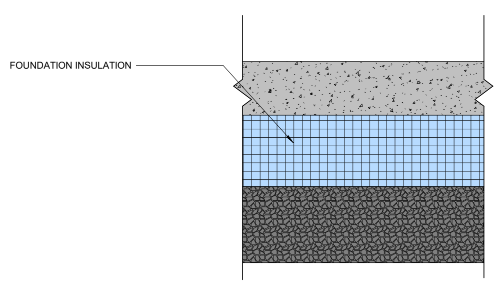
For low energy buildings, even the small losses to the ground affect performance. Foundation and slab on grade insulation is one of the least expensive and easiest types of insulation to install.

For the slabs we propose
Baseline R-10 two feet down and two feet in
Off the Shelf R-20 continuous under slab and to bottom of footing on exterior
Max Tech R-40 continuous under slab and to bottom of footing on exterior

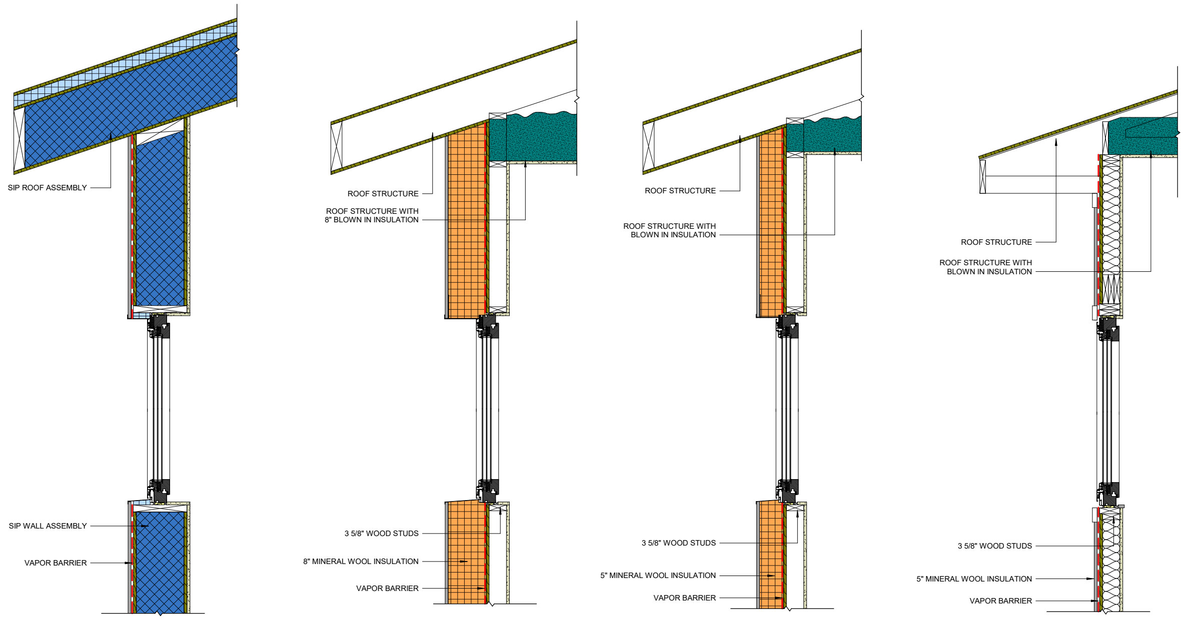
This becomes even more important when we move to a radiant slab type of mechanical system. See maintenance HVAC type.





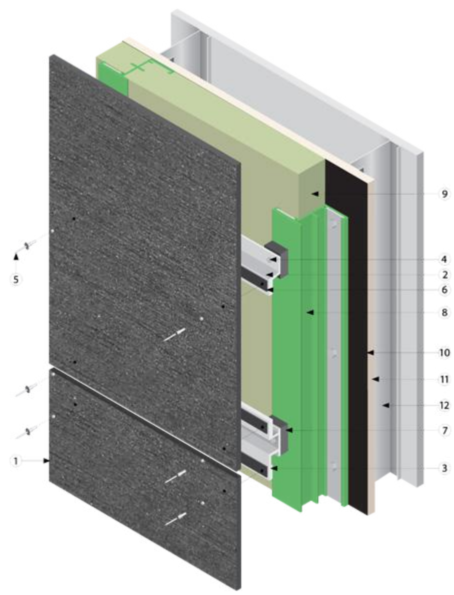


02 ENERGY CONSERVATION MEASURES



IMPROVED PERFORMANCE - WALL

Wall U-factor is a measure of the ability of a wall to resist the transfer of heat and cooling. With U-factor a lower value is a more highly insulated wall. The inverse of U-factor is R-value, where the larger the number represents a more highly insulated wall. U-factor is a more useful term for wall systems that are composed of many components and layers.



The target clear field R-values / U-factors for the walls are:

Baseline	U-0.064 = R-15.6
Off the Shelf	U-0.050 = R-20
Max Tech	U-0.025 = R-40

To build these walls we recommend that the majority of the insulation is on the exterior of the Air and Water barrier and structure and supported on thermally improved clips (fiberglass).

An alternative to stick built insulation is the use of SIPS, which have the benefit of faster site construction time and reduced wall thickness and higher performance (air leakage). For example a 2x4 wall of R-40 with exterior insulation would be about 13.5" thick vs 10.25 " thick, which in our 4,000 square foot prototype translates to about 100 square feet of conditioned floor area.
(see section on embodied carbon)

We assumed the exterior walls will be framed in wood studs and the effective U-factors incorporate the thermal bridging effects of the wood. If metal studs are used, the effective R-value of the cavity insulation should be cut in half.
(see section on thermal bridges)

02 ENERGY CONSERVATION MEASURES

IMPROVED PERFORMANCE - ROOF

Roof U-factor is a measure of the ability of a roof to resist the transfer of heat and cooling. With U-factor a lower value is a more highly insulated roof. The inverse of U-factor is R-value, where the larger the number represents a more highly insulated roof. U-factor is a more useful term for roof systems that are composed of many components and layers.

Target Roof R-values / U-factors for the roofs are:

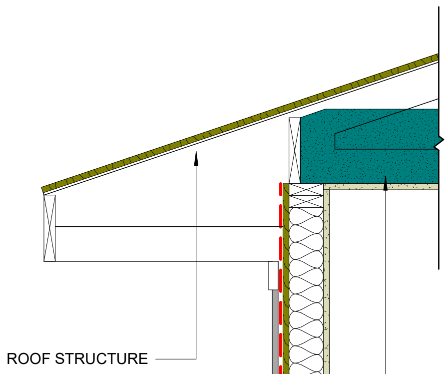
Baseline	U-0.027 = R-38
Off the Shelf	U-0.025 = R-40
Max Tech	U-0.017 = R-60

To build these roofs we recommend the insulation be located above the roof deck, thereby allowing mechanical equipment to run free within the attic (or above ceiling space) and also simplifying the continuity of the air barrier.

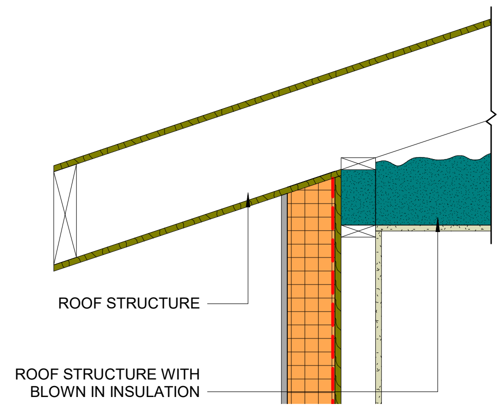
Alternatively, the design could utilize a roof constructed of SIPS.

If the project does propose blown in attic insulation because of cost, then raised heel trusses or special attention should be paid to the wall - roof intersection to allow for the full depth of the attic insulation to intersect the wall insulation.

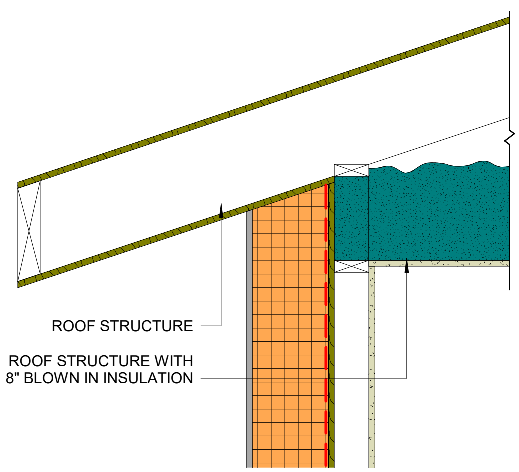
02 ENERGY CONSERVATION MEASURES



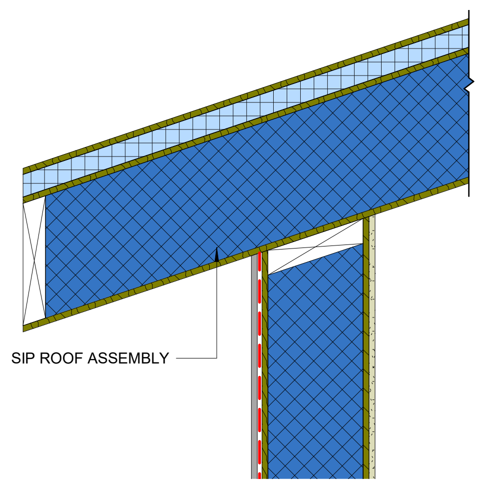
R-30 Roof
R-15 Wall



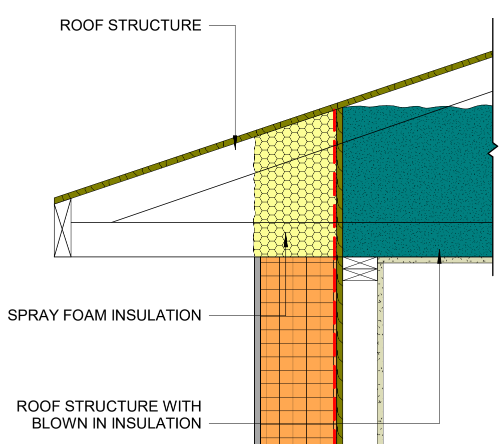
R-38 Roof
R-20 Wall



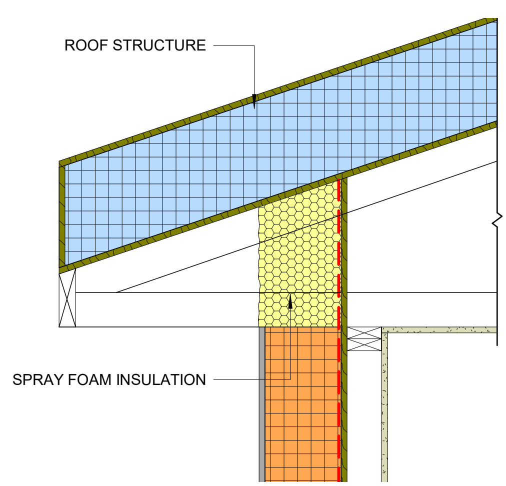
R-40 Roof
R-40 Wall



R-60 Roof
R-40 Wall



R-60 Roof
R-40 Wall



R-60 Roof
R-40 Wall

02 ENERGY CONSERVATION MEASURES

THERMAL BRIDGING

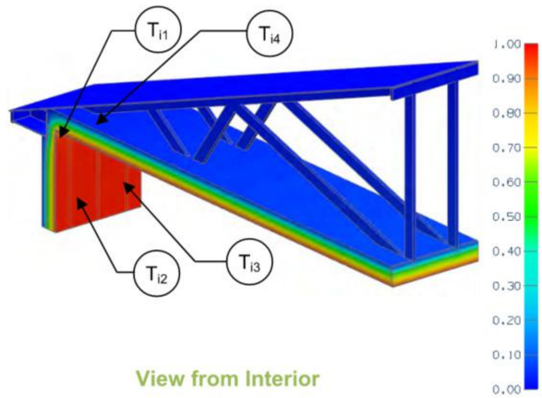
In highly insulated high performance buildings that are working to control loads breaks in the continuous insulation need to be taken into account. A thermal bridge is an area or building construction that has significantly higher conductivity than its surrounding wall. Thermal bridges can be characterized as clearfield , linear, or point.

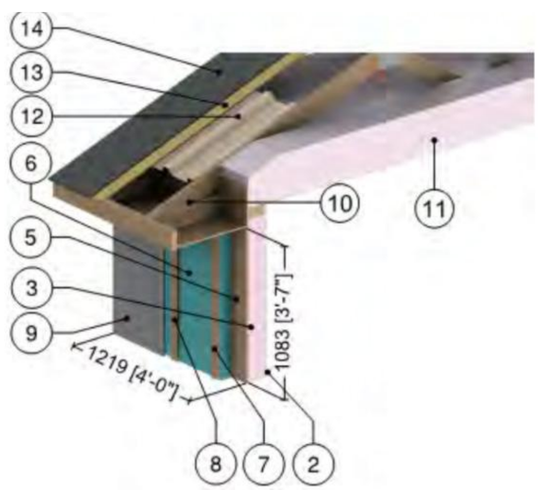
Clearfield thermal bridges are those that are repetitieve over a large wall area. The clips used to support the cladding are an example of Clearfield thermal bridges. Point thermal bridges are labeled by a Chi-factor which is measured in Btu/(h-F) and are typically larger and more unique to a particular item, such as a sun shade. Linear thermal bridges are labeled by a Psi-factor which is measured in Btu/(h-ft-F) and represent intersections between assemblies, such as the wall to roof or wall to foundation. Thermal bridges can account for as much as 10% of the envelope load of a typical building.

For ease of calculation, we include clearfield thermal bridges in the wall U-factor, the cross sectional area and conductivity of an element as a proxy for CHI factor and default constructions for PSI factors.

Recommended targets are:

	Point (Chi)	Linear(Psi)
Baseline (assumed)	None	
Off the Shelf	0.003%	0.06 Btu/(hr-ft-F)
Max Tech	0.001%	0.006 Btu/(hr-ft-F)





ASHRAE definition of thermal bridge:
An element that has higher thermal conductivity than the surrounding materials, which creates a path of least resistance for heat transfer. For the purposes of determining building envelope requirements, the classifications for thermal bridges are defined as follows

347 Btu • in/(ft2hr °F) x 0.003% • above grade area of the building envelope ≥ (k1 x A1) + (k2 x A2) + (k3 x A3)...
(5.5.5.5) I-P

Where
k1, k2, k3 ... = the thermal conductivity of material I, material 2, material 3, etc...
expressed in Btu • (W/(m•K)) for point thermal bridge material I, material 2, material 3, etc.. .(e.g. concrete, carbon steel, stainless steel, wood)

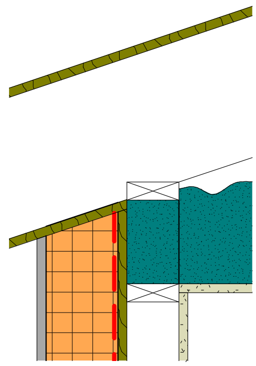
A1, A2, A3 ... = the total cross sectional area of point thermal bridges and linear thermal bridges of material I, material 2, material 3, etc... -expressed in ft2 (m2)

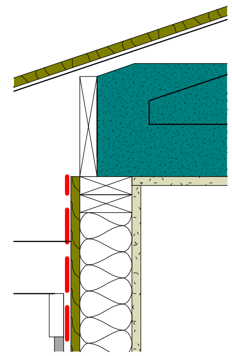
02 ENERGY CONSERVATION MEASURES

PROPOSED
(default constructions)
PSI-factor < 0.06 Btu/(hr-ft-F)

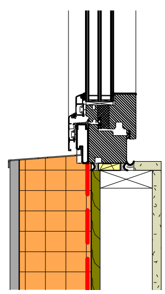
BASELINE

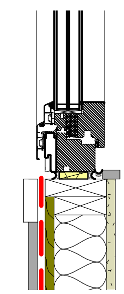
ROOF TO WALL



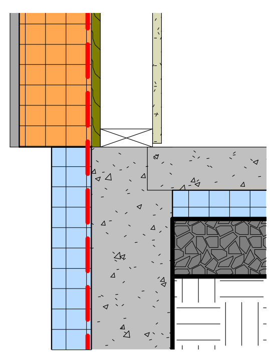


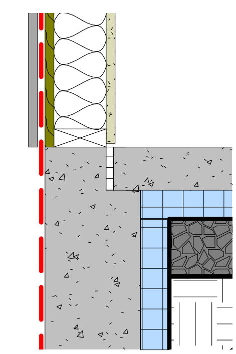
WINDOW TO WALL





WALL TO FOUNDATION

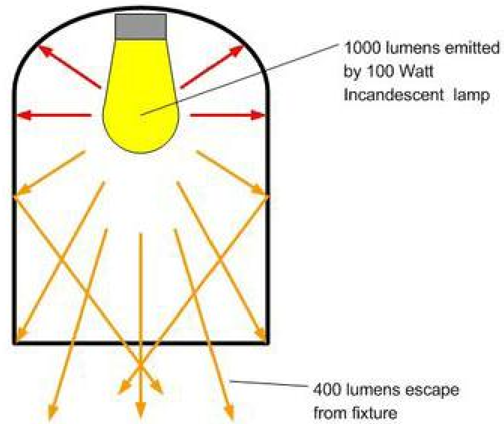


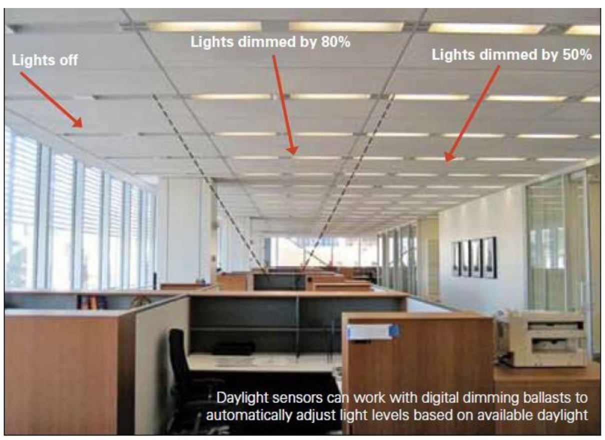


NOTE:

Exterior Insulation should overlap window frame. Not all windows can accommodate this type of overcladding. For flanged windows, wood bucks will need to be built to allow secure fastening of the window thru the insulation.

02 ENERGY CONSERVATION MEASURES





Efficiency
Fixture lumens/ Lamp lumens = Fixture Efficiency
400 Fixture lumens/1000 Lamp lumens = 40% Fixture Efficiency

Efficacy
Fixture Lumens / Fixture wattage = Fixture Efficacy
400 lumens / 100 Watts = 4 Lm/W Efficacy

LIGHTING POWER DENSITY

Reduced lighting power density and controls
LED lighting affords a significant opportunity to reduce the installed wattage of the lighting. An efficient lighting design will prioritize total fixture lumen output per watt, space fixtures to optimize even lighting level at the lowest possible wattage. Important strategies to enhance even lower installed wattage are more reflective material and color selection within the finished rooms.

Recommended Surface Reflectances

Ceilings	85%
Walls	60%
Floors	25%

An important portion of reduced lighting power density is also fixture Efficacy, which is a measure of usable light for a given amount of power in. A target fixture efficacy would be 100 - 150 lumens / watt input power.

Target Lighting Power Densities are:

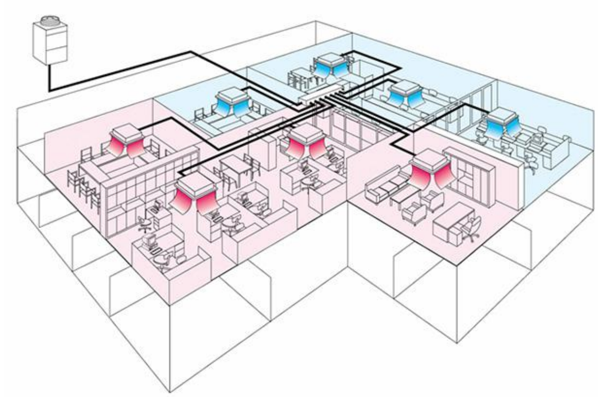
Baseline (code)	0.76 W/sf
Off the Shelf	0.60 W/sf
Max Tech	0.40 W/sf

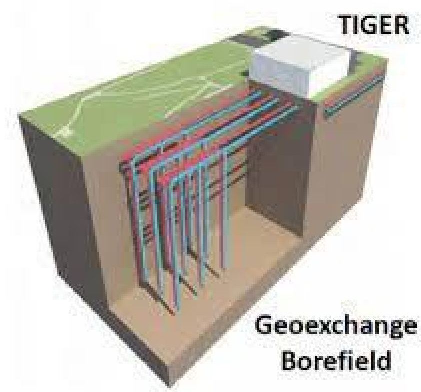
Efficacy Target

Average	70 lm/W
Top Performer	150 lm/W

On the control side (this does not affect installed wattage) daylight harvesting and occupancy controls can be used to further reduce lighting energy use.

02 ENERGY CONSERVATION MEASURES





HVAC TYPE - OFFICE

The current office HVAC system incorporates two heat pump units. For ventilation, an outdoor air duct is connected to the return duct. This air is then mixed with system air and heated or cooled before being delivered to the space. This allows for an all electric HVAC approach with reasonable levels of efficiency.

The Off the Shelf approach would centralize the system to a single air-cooled variable refrigerant flow (VRF) system - VRF systems provide space level heating/cooling to each room. The system uses a cassette within each room and refrigerant piping to move energy between indoors and outdoors and between rooms when one room requires cooling and another requires heating. These systems have very efficient variable speed compressors and fans. It is important to note that they can still heat when outdoor temperatures are as low as -15F. The VRF system will be connected to the maintenance area to allow energy transfer between the office occupancy and the shop occupancy.

The MaxTech scenario would switch the single air-cooled VRF system to a water cooled VRF system that is tempered with a geothermal field. A geothermal system uses a wellfield to exchange energy between the building and the ground. This is a closed loop water-based system that rejects heat into the ground during the summer and extracts heat from the ground in the winter. This provides a more efficient means to energy transfer than and air cooled system. As with the Off the Shelf system, the Max Tech system will be coupled with the maintenance facility to allow for energy exchange with that zone as well.

Note both of the proposed systems separate space conditioning from ventilation. Ventilation is discussed below.

02 ENERGY CONSERVATION MEASURES

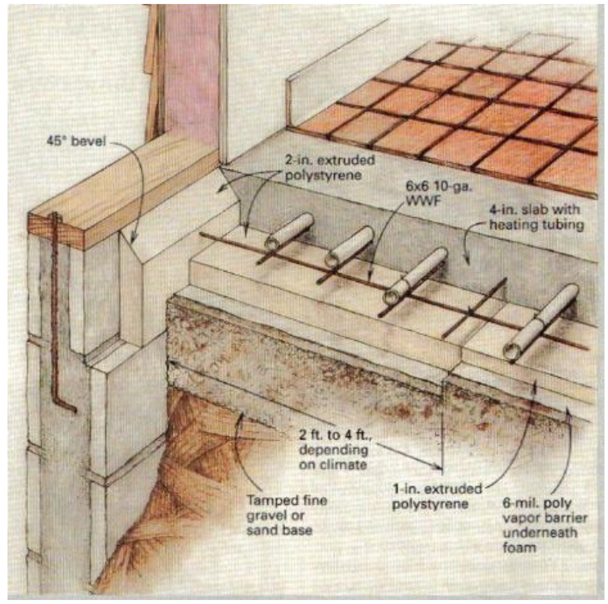
HVAC TYPE - MAINTENANCE SHOP

The maintenance shop is currently only heated in the winter; there is no cooling in the summer months due to the typical use for the space type. The heating system consists of two electric unit heaters that provide heat to the space. This does a good job of tempering the space for its needed function but is not a very efficient solution from a cost in energy perspective.

The Off the Shelf approach would put this space in the same VRF system as the offices. In this way the shop can be heated more efficiently using the same compressors that are being utilized for the office area. This would also allow heat transfer into the shop when some spaces in the offices are in cooling mode. An additional benefit to this approach would include the VRF's ability to provide some amount of cooling as needed to temper that space in the summer and improve comfort needs. This approach adds energy use to the facility as the baseline design has no cooling for the maintenance area.

The MaxTech approach would have the VRF system tied to the geothermal field as described in the office HVAC section above. It also proposes an in floor radiant heating system that would be fed from a small water to water heat pump. That water water heat pump would exchange energy with the geothermal field. This is a low temperature water system that is a very efficient way to heat the space and maximizes comfort in the winter time. The thermal mass of the floor can maintain heat better than air, making it less sensitive to opening/closing of the overhead garage door. In this scenario the floor would provide the base load of heating to the space and then the VRF units could be used to ramp temperature up and down for small adjustments to space needs.

As with the office ventilation, both of the proposed systems separate space conditioning from ventilation. Ventilation is discussed below.



02 ENERGY CONSERVATION MEASURES

HVAC TYPE - SCADA ROOM

The current design for the Scade room includes a cooling only unit to cool the server rack and process loads.
The Off the Shelf design incorporates this room into the VRF system so that this year round source of heat could be transferred to other rooms that require heating in the winter months. This approach ties spaces together to save energy and eliminates a dedicated piece of equipment for a single room.

This same arrangement would be maintained with the MaxTech system that incorporates geothermal

02 ENERGY CONSERVATION MEASURES

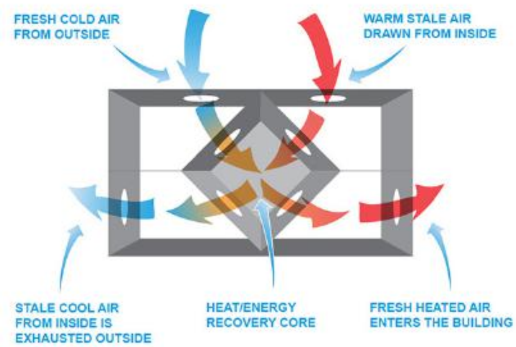
HVAC TYPE - VENTILATION /ENERGY RECOVERY

The building has a small exhaust requirement for the restrooms and large requirement for the maintenance shop. As stated in the Office HVAC System section above, ventilation is connected directly to each heat pump unit and does not include energy recovery.

Energy Recovery Systems, exchange hot (or very cold) outdoor air with tempered exhaust air. Instead of just exhausting that tempered air outdoors, energy recovery systems transfer energy between incoming and outgoing ventilation air streams. In the winter, heat that would otherwise leave the building is recovered to the incoming cold ventilation air. The opposite occurs in the summer months. This reduces both heating and cooling energy.

For the Off the Shelf concept, we propose to provide outside air for ventilation and exhaust within two separate dedicated outdoor air units. The first would provide outside air and ventilation for the exhaust needs of the shop. This unit will include an energy recovery plate for heat transfer between incoming and outgoing air streams. It will also include a variable frequency drive to ramp outside air up and down as needed for the maintenance facility. No heating or cooling is provided with this unit. Tempered air is delivered via the energy recovery plate. For the office space, a separate dedicated unit with an energy recovery plate will be provided. This unit would be a VRF air handling unit and connected to the same VRF refrigerant loop used for conditioning the office and shop spaces. Exhaust air from the restrooms would route through this unit and outdoor air would be provided directly to the office space.

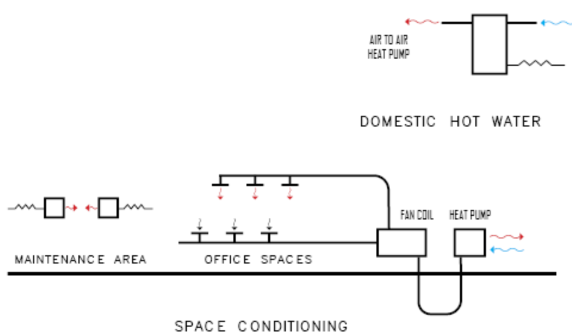
The Max Tech concept would utilize the same equipment as in the Off the Shelf concept.



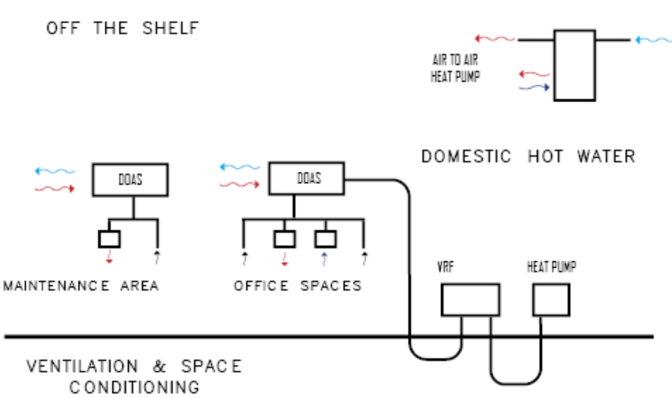
SYSTEM EFFICIENCY

For this analysis, the equipment efficiency is not really a comparison of various efficiencies of similar types of equipment but a general comparison of the three technologies and their resulting effective 'system' efficiencies. Improved DX efficiency is inherent in the upgraded HVAC options listed above.

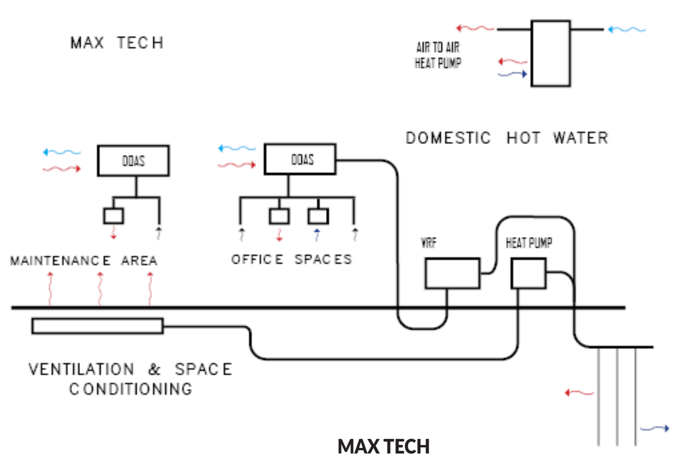
DX efficiency	current	11 EER cooling, 2.5 COP heating, 0F ambient heating minimum
DX efficiency	upgraded	13 EER cooling, 3.5 COP heating, -15F ambient heating minimum
DX efficiency	optimized	18 EER cooling, 5.5 COP heating, ground coupled



BASELINE



OFF THE SHELF



MAX TECH

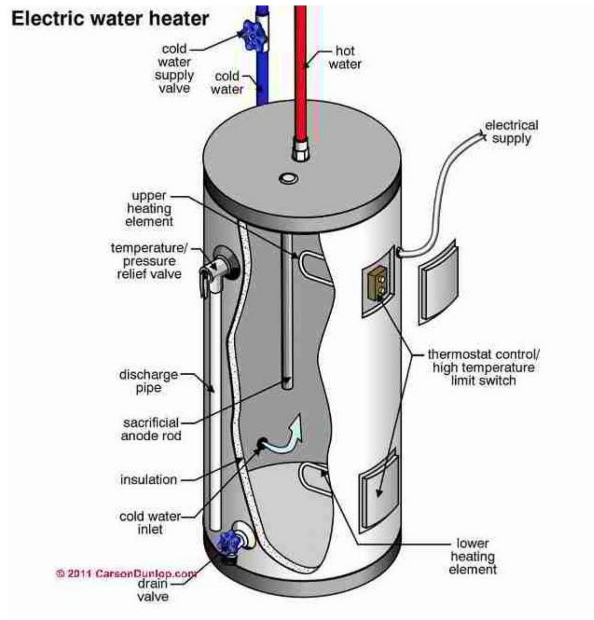
02 ENERGY CONSERVATION MEASURES

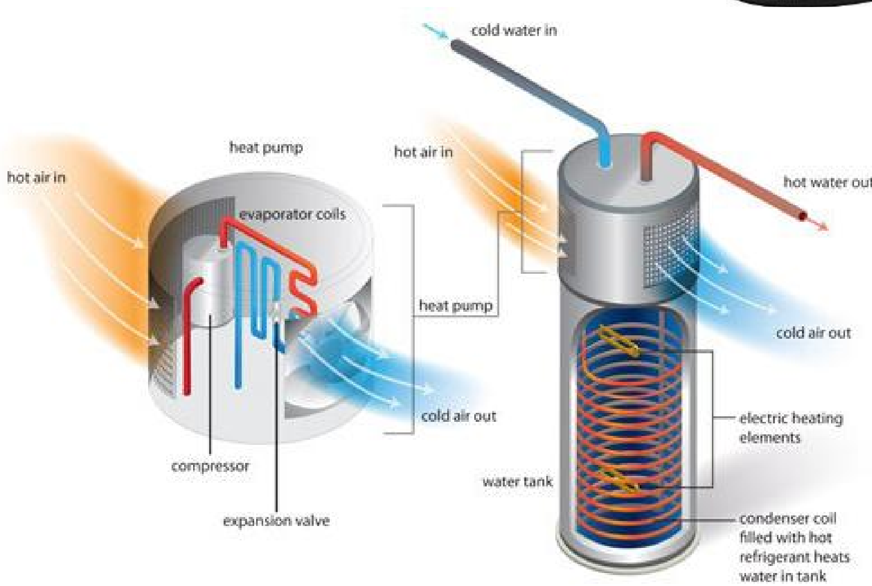
DOMESTIC HOT WATER HEATING

The current design uses an electric tank water heater to store and distribute hot water to the facility. The overall load is low for this building, primarily serving kitchen sinks and lavatories, so overall impact is less than some of the other building measures but still important for net zero consideration.

The Off the Shelf approach is to improve the efficiency of this system and would incorporate an electric instantaneous water heater. The system would only supply energy when there is a demand for hot water. In this way, it avoids the standby heat loss from the tank to the room. Eliminating this loss would reduce energy use by 30-50%. These heaters could be a centralized system or be located by underneath each of the sinks separately.

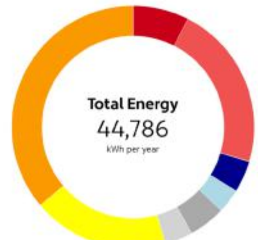
The MaxTech option would consider a heat pump hot water heater. A heat pump hot water heater uses electricity and a compressor to heat this water more efficiently. This unit will extract heat from the mechanical room through the refrigerant circuit and use the compressor to heat the desired temperature. This process would save 50-75% of the energy compared to the current electric tank heating system.





02 ENERGY CONSERVATION MEASURES

PLUG & PROCESS LOADS



Segment	kWh per year	% of total use
Heating	**13,261**	**30 %**
AHU	3,347	7 %
Zones	9,892	22 %
Humidification	22	0 %
Cooling	**3,335**	**7 %**
AHU	1,888	4 %
Heat Rejection	0	0 %
Zones	1,447	3 %
Fans	**3,881**	**9 %**
AHU	2,203	5 %
Zones	1,678	4 %
Interior	**24,309**	**54 %**
Lighting	8,121	18 %
Equipment	16,188	36 %
Pumps	**0**	**0 %**

Plug and process loads have a significant impact on building energy use. While these may only makeup 20-25% of the energy for a typical performing building, for a net zero building, they can make up to over 50% of the building energy use if not optimized. The table below outlines an inventory of the plug/process loads in the facility. Many of these come down to equipment choice. Choosing energystar equipment is a primary priority. Choosing laptops over desktops and switch phones to VOIP (or eliminating phones) are also primary measures. We did not analyze options for the Scada room. Our approach does include utilizing the waste heat from that equipment for heating needs in other rooms via the VRF system. We also did not analyze the energy use from shop equipment. Those are considered necessary to perform primary function in that space. In general, our analysis did not uncover significant opportunities to reduce plug/process loads.

One other item discussed was electric vehicle charging. In general, EV charging (EVCS) is not included in the net zero building scope using current definitions. It is often viewed as energy used off-site, so not part of the building energy use. This would, however, have a significant impact to the building energy use and should be evaluated if installing EV charging on-site.

It is recommended that the EVCS is metered separately, so its contribution to the annual load can be pulled out.

For this analysis we assumed the same plug and process loads for all scenarios.

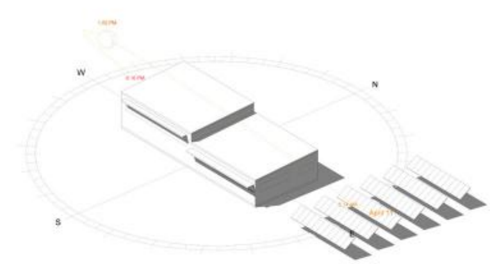
DESCRIPTION	Mnfr	MFG #	QTY	kWh/yr	ea use	per day	per person	days/yr
CONVECTION MICROWAVE OVEN	KITCHENAID	KMCC5015GSS	1	62.64	0.12	1	2	261
SIDE BY SIDE REFRIGERATOR	WHIRLPOOL	WRS315SNHM	1	574				
ADA UNDERCOUNTER DISHWASHER	WHIRLPOOL	WDF550SAHS	1	234				
BOTTLED WATER COOLER	TBD VERIFY WITH OWNER		1	0				
PACKAGED EYEWASH STATION	SAS SAFETY CORP SHOP	5135-00 W/ MOUNTING BRACKET	1	0				
Coffee Maker			1	417.6	0.4	4	1	261
Ice Maker			1	262.305	10.05	0.1	1	261
Item – SCADA room								
APC Smart-UPS Li-ion Short Depth 1500VA 240Wh UPS with SmartConnect		SMTL1500RM3UC	1	6500				
APC UPS Network Management Card with Environmental Monitoring		AP9643	1					
APC Switched Rack PDU AP7900B - power distribution unit		AP7900B	1					
Cisco Catalyst 9200 - Essential Edition - switch - 48 ports - smart - rack		C9200-48P-E	2					
Cisco Catalyst 9200 Series Network Module - expansion module		C9200-NM-4G	2					
Cisco - network stacking module		C9200-STACK-KIT=	2					
Cisco Digital Network Architecture Essentials - Term License (3 years) - 48		C9200-DNA-E-48-3Y	2					
Proline Cisco GLC-LX-SM-RGD Compatible SFP TAA Compliant Transceiver - SFP		GLC-LX-SM-RGD-PR	4					
Black Box 3M SC/LC Duplex Single-mode 9-micron Fiber Patch Cable, Yellow		FOSM-003M-SCLC	4					
HPE Aruba Instant IAP-315 (US) - wireless access point		JW813A	2					
HPE Aruba Central - subscription license (3 years) - 1 access point		Q9Y59AAE	2					
APC NetShelter 2 Post Rack 45U - 752 lbs.		AR201	1					
Other Office Equipment								
BrightSign XT244 - digital signage player		XT244	1					
Polycom RealPresence Trio 8800 - conference VoIP phone - Bluetooth interfac		2200-66070-001	1					
Polycom Trio RealPrsenece Visual+ Accessory		2200-21540-001	1					
HP 830 G7 I7-10610U 256/16	laptop	226R2US#ABA	3	250.56	0.04	8	1	261
HP SB USB-C Dock G5 - U.S.		5TW10UT#ABA	3					
Dell Latitude 5420 Rugged - 14" - Core i5 8350U - vPro - 16 GB RAM - 512 GB	laptop	0P0HG	2	167.04	0.04	8	1	261
HP EliteDisplay E273 - LED monitor - Full HD	monitor	1FH50A8#ABA	3	250.56	0.04	8	1	261
Logitech Wireless Combo MK520		920-002553	5					
HP ProDesk 400 G6 - mini desktop - Core i5 10500T 2.3 GHz - 8 GB - SSD 256	laptop	211A6UT#ABA	2	167.04	0.04	8	1	261
HP EliteDisplay E223 - LED monitor - Full HD (1080p) - 21.5" - Smart Buy	monitor	1FH45A8#ABA	2	167.04	0.04	8	1	261
Apple iPad mini 5 Wi-Fi - 5th generation	laptop	MUQW2LL/A	2	167.04	0.04	8	1	261
Jabra Evolve2 40 MS Stereo		24089-999-999	3					
TVs - Common Area, SCADA, Weather – 43"	LED/4k UHD		3	444.744	0.071	8	1	261
TV – Conference Room 75"	LED/4k UHD		1	140.94	0.18	3	1	261
HP Clr LaserJetMgdFlw MFP E783z Base		8GR98A#BGJ	1	60				
Maintenance			1	783	3	1	1	261
TOTAL				**10,649**				

03 PV AND NET ZERO

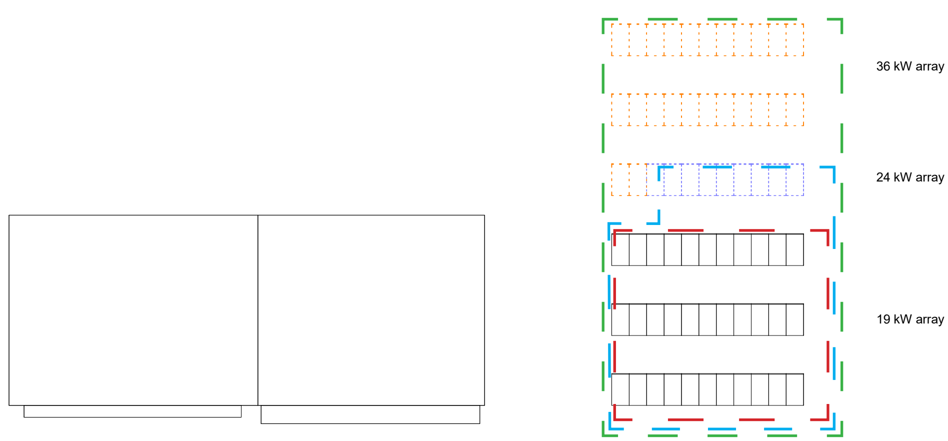
PV OFFSET

We calculated the size of the PV array required to balance out the energy on an annual basis (net zero). Based on a ground mounted, south facing array with a 36 deg tilt, and limited self shading, we would have the capacities outlined below.

We compared the footprint with the building footprint and diagramed that below. Since the PV area required is less than the building area, if the building footprint were determined to be the Net Zero boundary, the project could be defined as Net Positive.



	Baseline	Off the Shelf	Max Tech
EUI	37	26	24
kWh	44,996	31,291	28,586
Solar PV size (kW)	38	24	19
Solar PV generation (kWh)	51,300	32,400	25,650
Solar PV area required (sf@65 sf/kW)	2470	1560	1235



04 EMBODIED CARBON

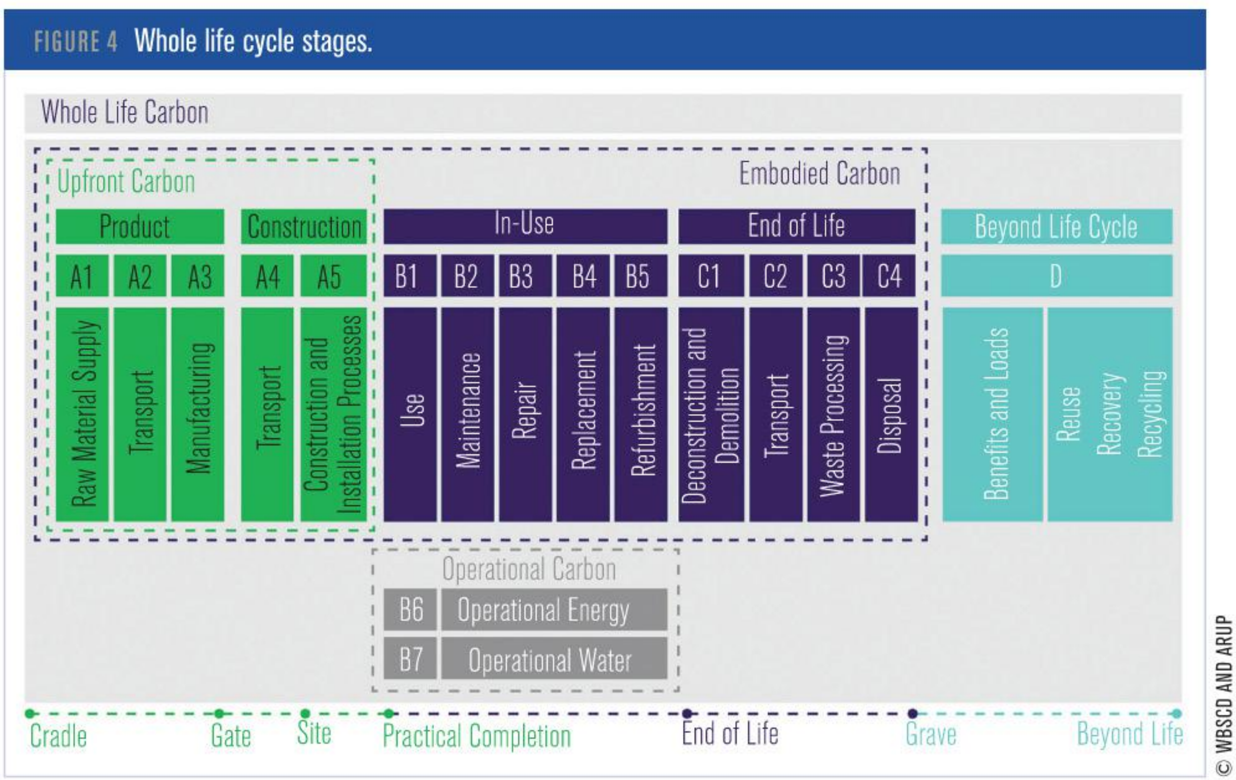
03 EMBODIED CARBON

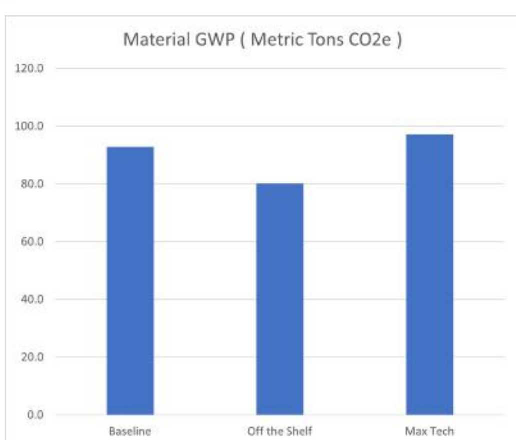
EMOBODIED CARBON

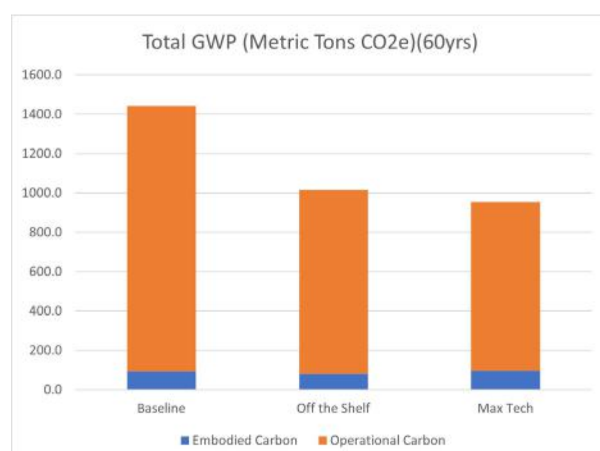
Embodied Carbon is a calculation of all the energy (in metric tons of CO2) to extract, fabricate, and transport the building materials to the site. In the chart below you can see the comparison between the baseline design, the Off the Shelf concept, and the Max Tech concept.

Embodied carbon is typically broken down into 3 stages, manufacturing, use, and end of life. These are known as A, B and C stages and is measured in CO2equivelant (metric tonnes). We tend not to calculate the C stage at this time as the uncertainty with recycling or re-use are very hard to predict in the future.

The graph below looks at the A1 through A5 stages of the materials in the project. Notice the baseline actually has a lower embodied carbon equivalent tonnage. This is because the building has less insulation, mass in the form of less building







03 EMBODIED CARBON

Insulation Material	R-value R/inch	Density lb/ft^3	Emb. E MJ/kg	Emb. Carbon $kgCO_2/kg$	Emb. Carbon $kgCO_2/ft^2 \cdot R$	Blowing Agent (GWP)	Bl. Agent kg/kg foam	Blowing Agent GWP/ bd-ft	Lifetime GWP/ $ft^2 \cdot R$
Cellulose (dense-pack)	3.7	3.0	2.1	0.106	0.0033	None	0	N/A	0.0033
Fiberglass batt	3.3	1.0	28	1.44	0.0165	None	0	N/A	0.0165
Rigid mineral wool	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polyisocyanurate	6.0	1.5	72	3.0	0.0284	Pentane (GWP=7)	0.05	0.02	0.0317
Spray polyurethane foam (SPF) – closed-cell (HFC-blown)	6.0	2.0	72	3.0	0.0379	HFC-245fa (GWP=1,030)	0.11	8.68	1.48
SPF – closed-cell (water-blown)	5.0	2.0	72	3.0	0.0455	Water (CO_2) (GWP=1)	0	0	0.0455
SPF – open-cell (water-blown)	3.7	0.5	72	3.0	0.0154	Water (CO_2) (GWP=1)	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	2.5	0.0307	Pentane (GWP=7)	0.06	0.02	0.036
Extruded polystyrene (XPS)	5.0	2.0	89	2.5	0.0379	HFC-134a[1] (GWP=1,430)	0.08	8.67	1.77

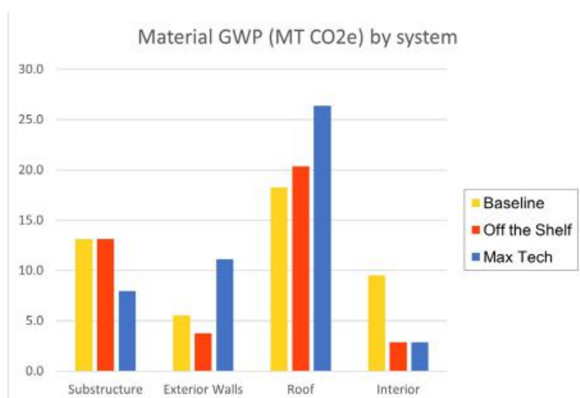
1. XPS manufacturers have not divulged their post-HCFC blowing agent, and MSDS data have not been updated. The blowing agent is assumed here to be HFC-134a.

insulation. When you add in the B stage, the operational stage, you can see the Max Tech design has the lowest embodied carbon over an assumed 60 year life.

(Utilizing 1.418 lbs CO2/ kWh)

Material Specific and Systems Analysis
To further optimize the design, it is important to understand the relative impacts of individual materials that perform the same function. Looking at insulation for example, the chart below looks at the GWP of various insulations and compares them to their R value (insulating capacity) per inch and suggests we should use mineral wool as the preferred insulation, however, we need to look at this material in context of the other materials in the project, to determine the optimum insulation for the entire project. The major other factor that drives total CO2e, is usually quantity.

We can also look at building systems. The chart below compares our three buildings by the 4 major construction systems, substructure, superstructure, roofs, and



03 EMBODIED CARBON

Interiors. This analysis does not compare mechanical, electrical, or plumbing systems as the industry has not produced a large enough dataset to draw any meaningful conclusions.

Once we define the Building system, we can then look at the individual materials and their relative impact. Again, this is primarily a combination of CO2e per unit and total quantity used. You can see for the substructure, the material with the largest contribution is the concrete. Removing that so we can re-adjust the scale we see the various insulation packages.

The following charts show the impacts of the various major building elements by the 4 systems described above, substructure, superstructure, roof, and interiors. While we cannot reduce the Embodied Carbon to Zero (that would be no building), we can draw some conclusions for this project that can inform our specifications to create a "lower" embodied carbon building on an absolute level.

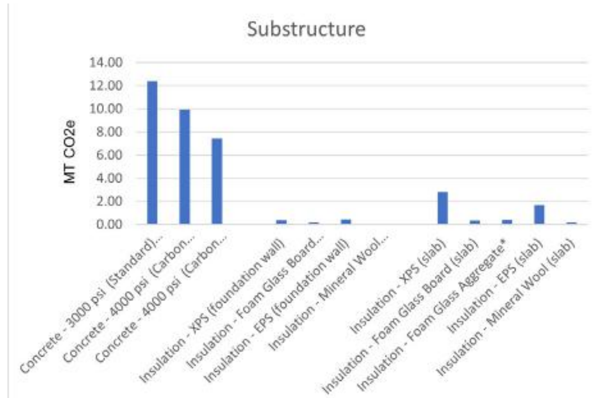
The recommendations are:

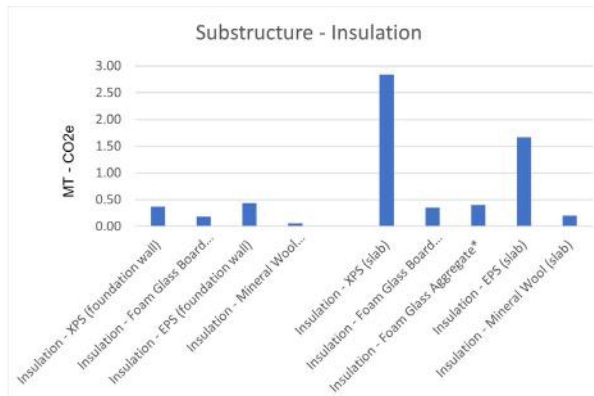
Substructure

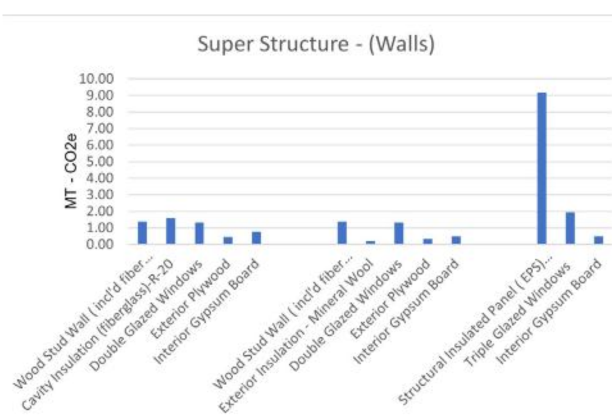
Concrete

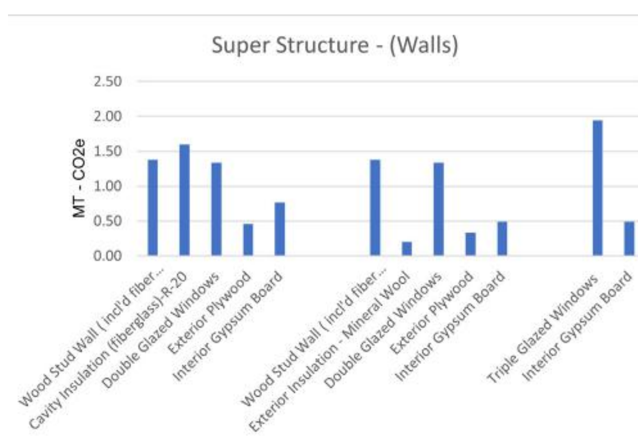
Provide concrete that has a Global Warming Potential (GWP) that is 40% less than the NRMCA Great Lake Midwest Regional Average for the specific compressive strength.

NMRCA averages can be found here:
https://www.nrmca.org/wp-content/uploads/2020/10/NRMCA_REGIONAL_BENCHMARK_April2020.pdf









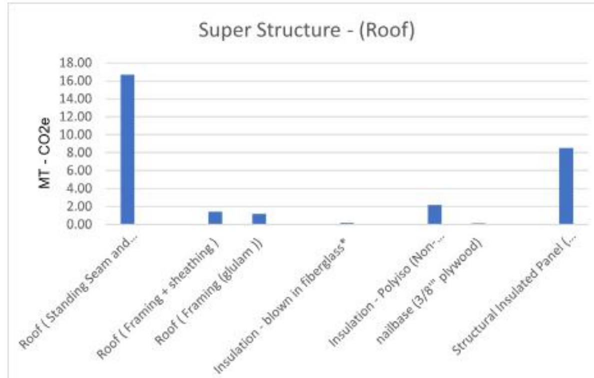
03 EMBODIED CARBON

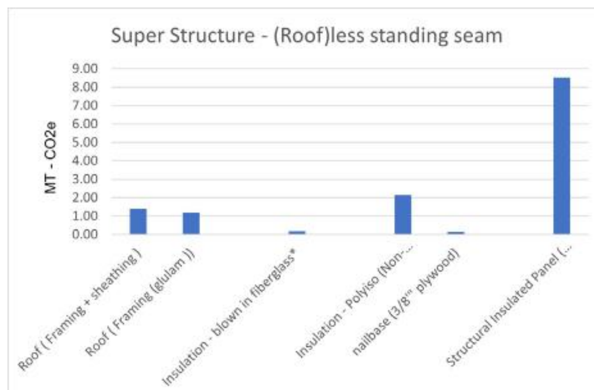
Foundation insulation (vertical)
Mineral Wool board -
Underslab Insulation - EPS

Superstructure
Wood studs - same
Exterior Sheathing (plywood) -Roseburg / softwood plywood various thicknesses
Interior Gypsum Board - USG / EcoSmart
Wall insulation

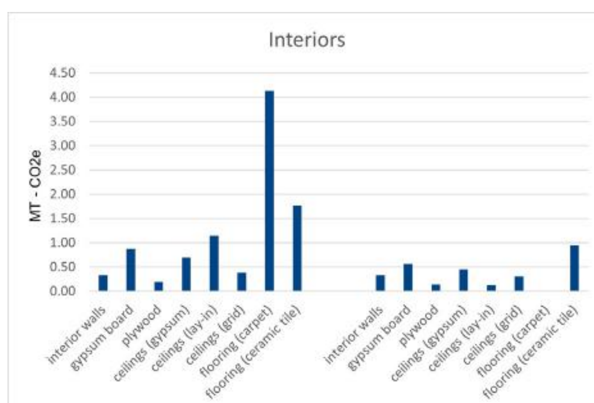
Roof
Framing - trusses or Laminated timber
Plywood - Roseburg / softwood plywood various thicknesses
Roof insulation - Polyisocyanurate

Interiors
Gypsum Board - USG / EcoSmart
Carpet tile - Interface / Embodied Beauty
Ceramic tile - Marazzi Tile / Sunnyvale, TX plant
Acoustical Tile (Panels) - Rockfon / Artic
Acoustical Tile (Grid) - USG / DONN-Fineline DXF-DXFL
Plywood - Roseburg / softwood plywood various thicknesses





Comparison of a low carbon square foot of ceiling tile to the Industry average



05 COSTS

04 COSTS

COSTS

Below is a table with Rough Order of Magnitude costs associated with the Energy Conservation Measures studied. In order to evaluate a Return on Investment, a study of the actual square footage of the measure or equipment size would need to be compared to the utility rate paid at the site, including demand charges.

Cost are compared to the Baseline

		Impact on...			
		EUI*	**COST**	**EMBODIED CARBON**	**COMPLEXITY**
STRATEGY					
Orientation	Baseline	37	$0	-	LOW
Orientation	Off the Shelf				
Orienation	Max Tech	24	$0	-	LOW
Massing	Baseline	37	$0	-	LOW
Massing	Off the Shelf				
Massing	Max Tech	24	$0	-	LOW
Glazing Performance (SHGC)	Baseline	37	$0	-	LOW
Glazing Performance (SHGC)	Off the Shelf	26	$0	-	LOW
Glazing Performance (SHGC)	Max Tech	24	$0	-	LOW
Glazing Performance (U-factor)	Baseline	37	$0	-	LOW
Glazing Performance (U-factor)	Off the Shelf	26	$700	-	LOW
Glazing Performance (U-factor)	Max Tech	24	$5,200	-	LOW
Window to wall ratio	Baseline	37	$0	-	LOW
Window to wall ratio	Off the Shelf	26	$0	-	LOW
Window to wall ratio	Max Tech	24	$0	-	LOW
Daylighting approach	Baseline	37	$0	-	LOW
Daylighting approach	Off the Shelf	26	$500	-	MED
Daylighting approach	Max Tech	24	$2,000	-	MED
External shading	Baseline	37	$0	-	LOW
External shading	Off the Shelf	26	$10,000	S	MED
External shading	Max Tech	24	$10,000	S	MED
Air Leakage	Baseline	37	$0	-	MED
Air Leakage	Off the Shelf	26	$3,000	-	MED
Air Leakage	Max Tech	24	$3,000	-	MED
Wall (R-value)	Baseline	37	$0		LOW
Wall (R-value)	Off the Shelf	26	$4,387	M	MED
Wall (R-value)	Max Tech	24	$15,300	H	MED

04 COSTS

Roof (R-value)	Baseline	37	$0.00	-	LOW
Roof (R-value)	Off the Shelf	26	$8,220	M	MED
Roof (R-value)	Max Tech	24	$16,440	H	MED
Thermal Bridging	Baseline	37	$0	-	LOW
Thermal Bridging	Off the Shelf	26	$2,000	-	MED
Thermal Bridging	Max Tech	24	$4,000	-	HIGH
Lighting power density	Baseline	37	$0	-	LOW
Lighting power density	Off the Shelf	26	$0	-	LOW
Lighting power density	Max Tech	24	$0	-	LOW
Office HVAC type	Baseline	37	varies	M	LOW
Office HVAC type	Off the Shelf	26	varies	H	MED
Office HVAC type	Max Tech	24	varies	H	MED-HIGH
Maintenance shop HVAC type	Baseline	37	varies	L	LOW
Maintenance shop HVAC type	Off the Shelf	26	varies	M	MED
Maintenance shop HVAC type	Max Tech	24	varies	M	MED-HIGH
Scada room	Baseline	37	varies	M	LOW
Scada room	Off the Shelf	26	varies	H	MED
Scada room	Max Tech	24	varies	H	MED-HIGH
Add energy recovery to DOAS	Baseline	37	varies	L	NA
Add energy recovery to DOAS	Off the Shelf	26	varies	M	LOW
Add energy recovery to DOAS	Max Tech	24	varies	M	LOW
DX efficiency	Baseline	37	$0	-	LOW
DX efficiency	Off the Shelf	26	$51,000	-	MED
DX efficiency	Max Tech	24	$83,000	-	MED
DHW	Baseline	37	$0	L	LOW
DHW	Off the Shelf	26	$3,000	L	LOW
DHW	Max Tech	24	$3,000	M	MED
Plug/process load	Baseline	37	-	-	-
Plug/process load	Off the Shelf	37	-	-	-
Plug/process load	Max Tech	37	-	-	-
		* EUI is representative of the combined strategies			

06 CONCLUSION

05 CONCLUSION

CONCLUSION

Based on high performance envelope and mechanical system strategies, the study demonstrated the following project benefits between the current design and the Max Tech concept:

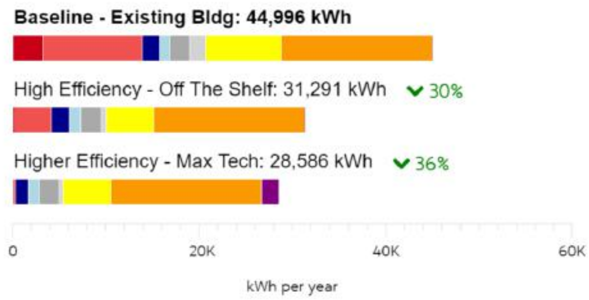
- 35% reduction in EUI (37 to 24)
- 5% reduction in peak cooling equipment sizing (0.5 tons) and we are cooling more area*
- 46% reduction in peak heating equipment size (50 Mbh)

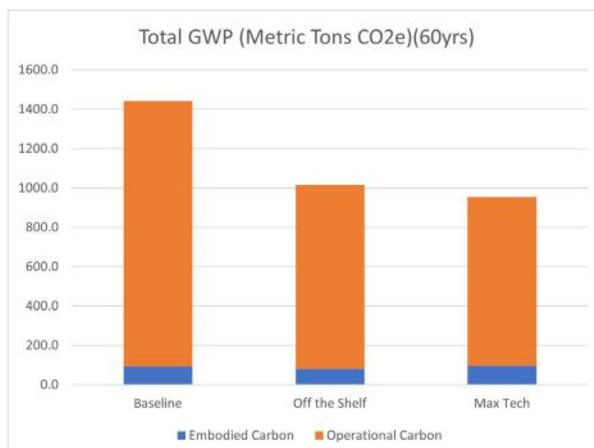
While the study itemized measures that can help when implemented individually, the consolidated approach allows a reduction in installed equipment size to save first cost that can be re-invested into the more premium improvement options. These improvements also bring the occupants a higher level of thermal and visual comfort. High performance buildings are generally more desired by occupants. Ownership will also benefit financially through reduced utility and maintenance cost each year of operation.

While the baseline concept could achieve Net Zero with an equivalent PV area to the building footprint, the Max Tech option would allow for either a Net Positive project if the building footprint were considered the boundary, or Net Zero utilizing just the office area footprint.

To reduce the impact of the project further, and utilizing the Greenhouse Gas Global Warming Potential (GWP) as a metric, we see we can reduce the GWP of the project by 37% over a 60 year life compared to the baseline. It is important to note that the annual GWP reductions due to Energy Savings outweigh the embodied carbon savings, but that the Energy Savings require the investment in additional physically installed material (Insulation).

* we are cooling the maintenance area.





07 APPENDIX

06 APPENDIX

CLIMATE ZONE

Many of these strategies will work in all climate zones, however some will need to be adjusted.

In general, the colder the climate the more important heat loss is, and in warmer climates, reducing heat gain is important.

For mechanical systems, radiant cooling can be challenging in hot humid climates and VRF systems may have capacity issues, so, unless the air tight, high performance envelope (wall, roof, & window) the VRF may not have the capacity.

These are outlined below.

	Climate Zone...					
	2	3	4	5	6	NOTES
STRATEGY						
Massing (optimized)	Y	Y	Y	Y	Y	
Glazing Performance (SHGC)	M	M	Y	Y	Y	Lower SHGC in warmer climates
Glazing Performance (U-factor)	M	M	M	Y	M	Higher U-factor in warmer climates, Lower U-factor in CZ6
Window to wall ratio	M	M	Y	Y	Y	
Daylighting approach	Y	Y	Y	Y	Y	
External shading	Y	Y	Y	Y	Y	
Air Leakage	Y	Y	Y	Y	Y	
Wall (R-value)	M	M	M	Y	M	Higher U-factor in warmer climates, Lower U-factor in CZ6
Roof (R-value)	M	M	Y	Y	M	Higher U-factor in warmer climates, Lower U-factor in CZ6
Lighting power density	Y	Y	Y	Y	Y	
Office HVAC type	Y	Y	Y	Y	M	verify VRF minimum operating temp v. winter design day in CZ 6 and heating capacity with expected envelope losses
Maintenance shop HVAC type	N	N	M	Y	Y	radiant floor and geothermal not suited for CZ 2/3
Scada room	Y	Y	Y	Y	Y	
Add energy recovery to DOAS	Y	Y	Y	Y	Y	
DX efficiency	Y	Y	Y	Y	Y	without geothermal, VRF efficiency will be reduced in CZ 2/3
DHW	Y	Y	Y	Y	Y	
Plug/process load	Y	Y	Y	Y	Y	
						Y=strategy works in all climate zones
						M=strategy should be evaluated