ENGINEERING

DESIGN APPROACH

The Alley House incorporates many different engineering strategies that are different from typical homes, from the foundation system to the solar array on the roof. The house uses an innovative insulated floating slab on grade as its foundation system. This method eliminates the need for spread footings and stem walls, minimizes site disturbance during construction, and decreases the amount of heat lost by directly connecting the slab's rigid insulation to the insulation within the exterior walls via a specially designed foam slab edge piece. The net zero energy west unit (the competition unit) employs an energy recovery ventilator (ERV) and a split, short-ducted heat pump system with two soffit-mounted air handlers, one on each floor. The ERV reduces HVAC energy loss through energy recovery and increases fresh air supply to all spaces of the home. Since the east unit (non-competition unit) also employs a similar heating/cooling system but without an ERV. Instead, fresh air is ducted into one of the air handlers to provide breathing air, but the system does not have energy recovery. In addition to these mechanical systems, the west unit (competition unit) has a heat pump water heater that uses ambient air in the home as part of the heat pump process of waring the domestic hot water and lowers energy consumption. The duplex utilizes a 2x6 advanced wood framing system which uses less wood, decreases thermal bridging at studs, and reduces construction costs when compared to a traditional stick-built frame. Floors/ceilings are framed with 11-7/8" wood truss joists (TJIs), which allow longer clear spans with less joist depth. The asymmetrical gabled cold roof is composed of engineered, prefabricated wood trusses. A layer of ZIP sheathing is used on the bottom chord of the trusses as part of the continuous air barrier and blown in cellulose is use on the floor of the attic space. This design reduces the volume of conditioned space within the home. A 22-panel solar array sits on top of the asphalt shingle roof, producing power to the west unit (competition unit) mechanical room to help power the home. Two small Ecoflow home batteries can be charged for use during power outages and for load shedding. Henceforth, the narrative describes only features in the west (competition) unit.

CONTEST

OVERVIEW

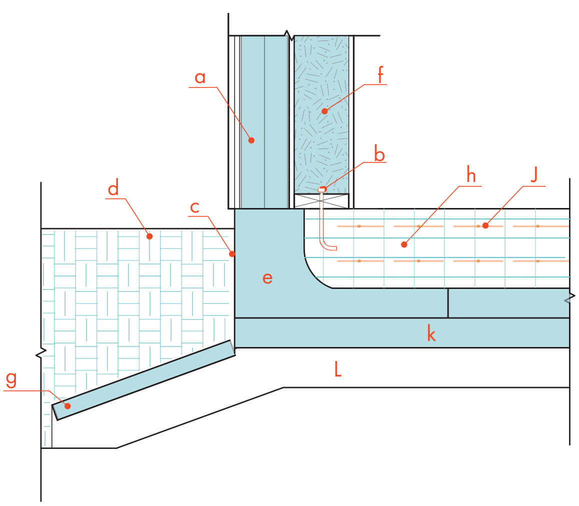
FOUNDATION

Insulated Floating Slab

The Alley House sits on a frost protected shallow foundation (FPSF) system, which is sometimes referred to as a "raft slab." This Legalett Geo-slab uses 8" of reinforced concrete over a rigid foam insulation base and is unheated. FPSFs do not use traditional concrete footers and stem walls saving energy, time, and construction costs by reducing materials quantities, site preparation time, and slab construction time (one concrete pour instead of three). The 6" of EPS foam beneath the slab sits on a compacted gravel base and provides R-21.6 of insulation, which results in less heat loss to the ground and warmer floors for the occupants in Indiana's cold winter climate. The slab system also uses a unique, proprietary foam slab edge piece that remains in place once the concrete is cured and allows continuity of the thermal control layer where it connects with the continuous insulation on the façade. Cardinal Studio

a] Exterior Mineral Wool Insulation
b] "J" Bolt Anchor
c] 1/2" EPS Insulation
d] Earth Infill
e] Legalett Slab Edge
f] Blown-in Insulation

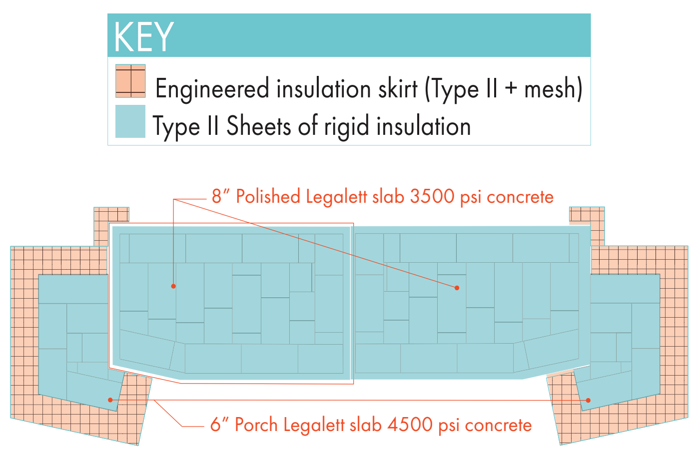
Rigid Insulation Skirt [g
8" Concrete Slab (3500 psi) [h
#4 Rebar [J
Min. 6" EPS Rigid Insulation [k
Compacted Gravel [L



selected the Legalett system because of the prefabricated and engineered components, which aided in the city permitting process. This system includes:

- EPS slab edge formwork that stays in place after the concrete pour for thermal control
- EPS insulation below the slab
- All EPS is precut and labeled for installation
- Detailed slab pour instructions including chair placement,reinforcing bar details, concrete specs, etc.
- A 10mil Stego, polyethylene Class A vapor barrier.

The section detail and plan view below shows a typical exterior wall and foundation detail in the west unit (competition unit) where the slab edge ties into the continuous wall insulation. The foundation plan below also shows the poured slabs for the unheated, exterior porches, the edge pieces specific to the wall thickness of each unit, and the foam board insulation skirt around the edge of the porch slabs. The slab system design ensures that the ground below the slab remains unfrozen to prevent frost heaving, which eliminates the need for concrete footers below the frost line.

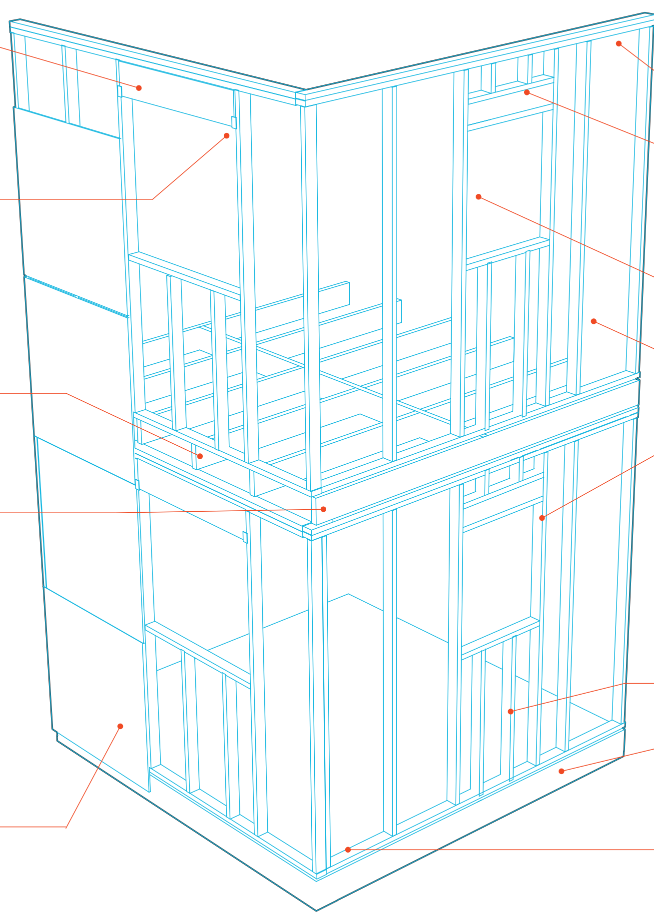


Section and plan view of the Engineered Frost-protected shallow foundation

STRUCTURAL SYSTEM

ADVANCED FRAMING

Advanced framing, also known as optimum value engineering (OVE), is a light wood framing method designed to optimize material usage and increase energy efficiency in exterior envelopes. The Alley House uses 2x6 wood studs spaced at 24" on-center, which reduces lumber use and thermal bridging; overall construction costs; and operational energy costs over the life of the home. Advanced framing creates more space for the blown-in dense-packed cellulose insulation by allowing a greater area of the wall to be insulation instead of wood. In traditional light wood frame construction, headers above windows and doors are often a large thermal bridge. In the Alley House, advanced framing techniques align window/door openings with the structure module, which allows for less wood at window and door openings. "C" shaped box headers allow for insulation and fewer king, jack, and cripple studs are necessary. Also, advanced framing allows, in most cases, for single bottom and top plates. Overall, the system dramatically reduces the quantity of wood in the exterior walls, reduces thermal bridging and provides more insulation while maintaining optimal structural capabilities.



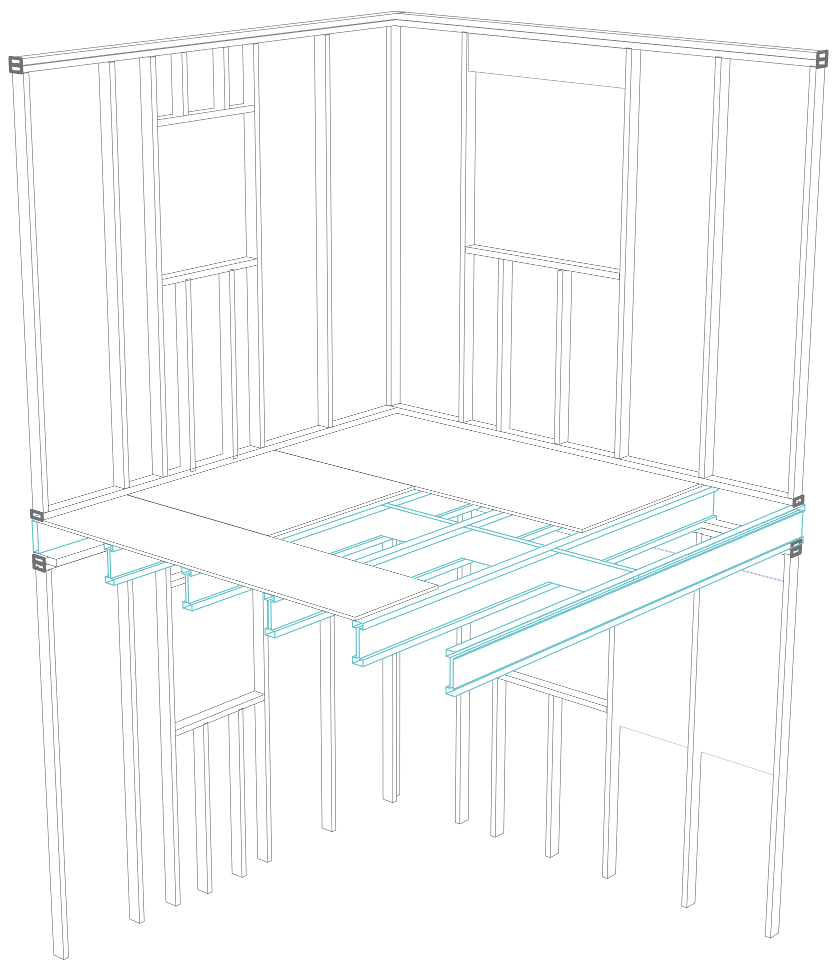
Advanced Framing (OVE) Diagram

FLOOR SYSTEM

The Alley House's second floor and stair tower roof are constructed with wooden truss joists called TJIs, which are spaced 24" on-center. TJIs are pre-manufactured members similar to trusses. These joists directly align with the advanced framing studs below, and in some instances the TJIs are doubled to carry the load of a wall on the second floor. Highlighted in blue in the detail at right, TJIs consist of a top and bottom flange of solid lumber held together with an oriented strand board (OSB) web and resembles a traditional wide-flange steel member. TJIs use approximately 50% less wood than traditional joists and are pre-manufactured, resulting in high accuracy, consistency, and quality. Made of engineered wood, they shrink less than traditional lumber and have greater resistance to twisting and warping. Cardinal Studio selected TJIs to reduce material usage and overall carbon footprint, which are major goals of the Alley House project.

Optimal Value Engineering + TJI | Benefits

- Studs are generally spaced 24" on center instead of 16" saving lumber
- Framing method uses less wood in headers, sills, and jambs of windows and doors
- Framing method + 24" O.C. TJI selection allows for minimal wood in overall framing
- Less lumber to install = less labor cost + faster framing time
- Less lumber also decreases the heat loss from thermal bridging + more insulation



TJI Floor Construction

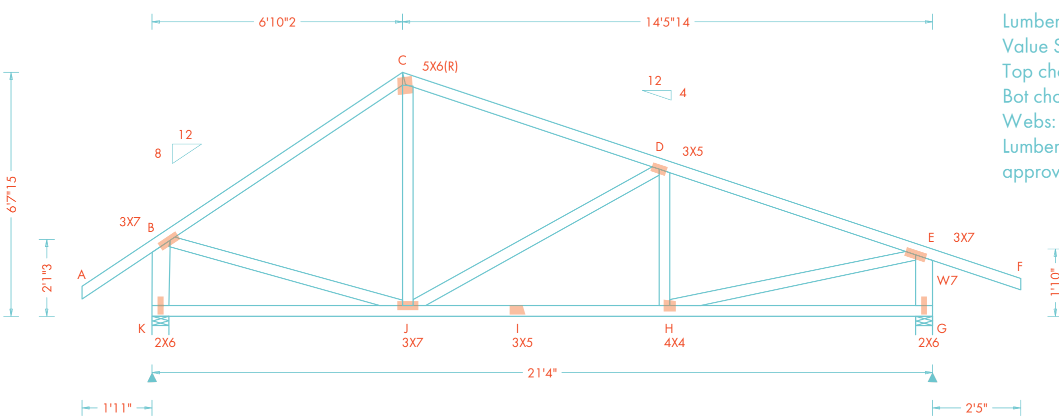
ROOF TRUSSES

The roof trusses were engineered by OKAW Truss Inc. for the Alley House. The south roof slope is 4:12 pitch, and the north slope is 8:12 pitch. The trusses are spaced 24" on-center to align with the advanced wood stud framing below. The roof slopes facilitate rainwater and snow melt runoff where gutters, downspouts, and rain barrels will collect it for irrigation use. Cardinal Studio's asymmetrical gabled roof design also allows for the small mono-pitch section of the roof over the stair towers to work structurally and aesthetically as well as maintain our desired roof height to fit within existing context of the neighborhood. The most important contribution of this irregular gable form is that it provides creation more roof square footage on the south orientation to accommodate a larger solar PV array, which allow the home to achieve net-positive energy. The mono-pitch section of the roof allows for a taller stair tower to facilitate stack ventilation without requiring the entire roof cavity to be oversized.

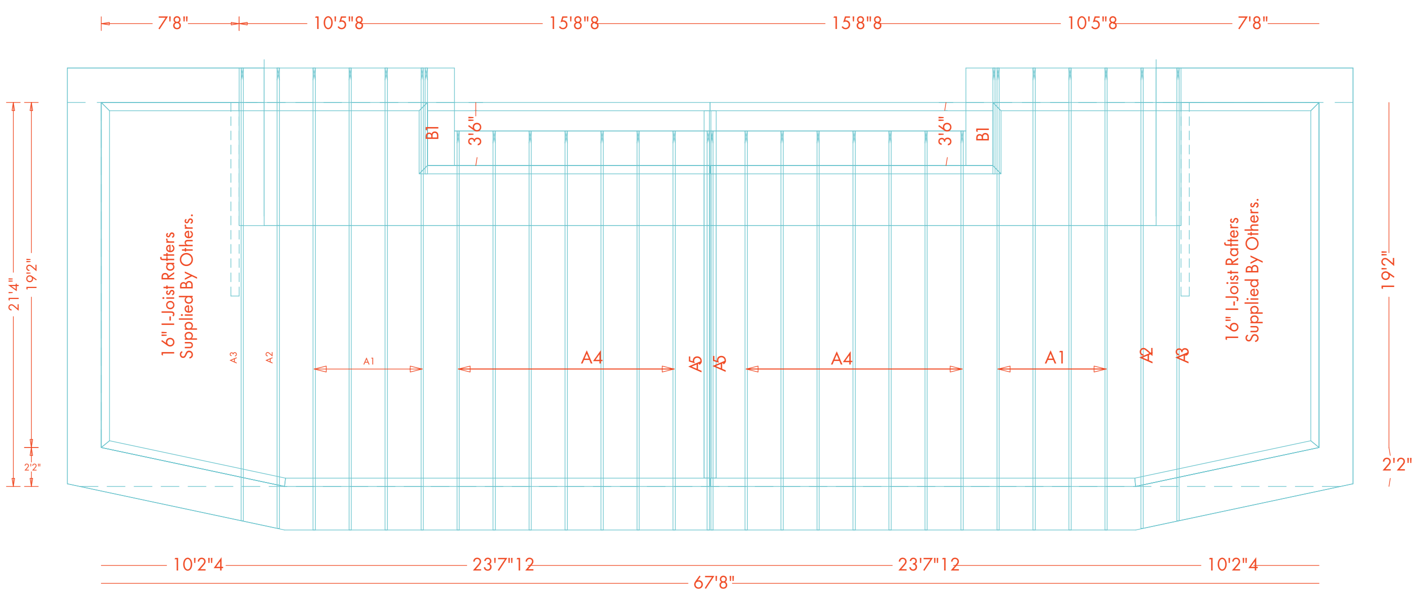
An innovative aspect of the Alley House's cold roof system (non-conditioned attic space) is the design of its control layers. The asphalt shingle roof and underlayment serve as the water barrier. On the underside of the trusses, a layer of ZIP sheathing attached to the bottom chord of the truss acts as the air barrier. The floor of the attic is then filled with approximately 26" of loose-fill cellulose to achieve a thermal performance of R-92. Taped gypsum board below the ZIP layer acts as the Class III vapor barrier. Pictured below is a roofing truss layout and a section view of a typical asymmetrical truss.

Loading:
Truss designed for unbalanced snow loads.
Wind loads based on MWFRS with additional C&C
Truss designed for unbalanced snow loads.
End verticals not exposed to wind pressure.

Lumber:
Value Set: 13B (Effective 6/1/2013)
Top chord: 2x4 SP #1;
Bot chord: 2x4 SP #1;
Webs: 2x4 SP #3; W1,W7 2x6 SP #1;
Lumber value set "13B" uses design values approved 1/30/2013 by ALSC



Roof Truss (A4)



Roof Truss Layout

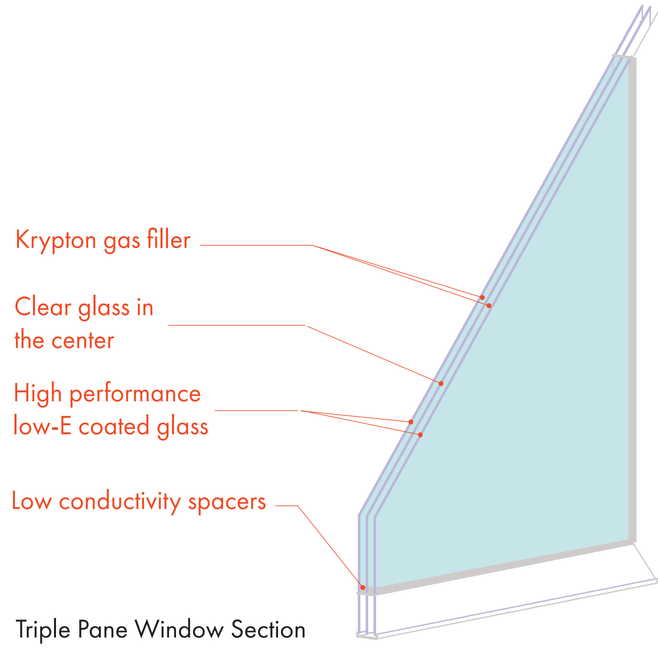
WINDOW OPENINGS/GLAZING

The window openings in the Alley House are strategically located as part of the 24" advanced framing module, which results in a consistent stud layout with minimal wood needed at window headers and jambs. The Alley House uses Pella triple-pane insulated glazing units (IGUs) in fiberglass frames. The IGUs have are filled with Krypton gas between glass panes and have low-e coating as shown on the graphic at right. These Energy Star-certified windows are 50% better than energy code compliant windows in Indiana, meet the PHIUS Core Prescriptive standards, and achieve the following energy performance ratings:

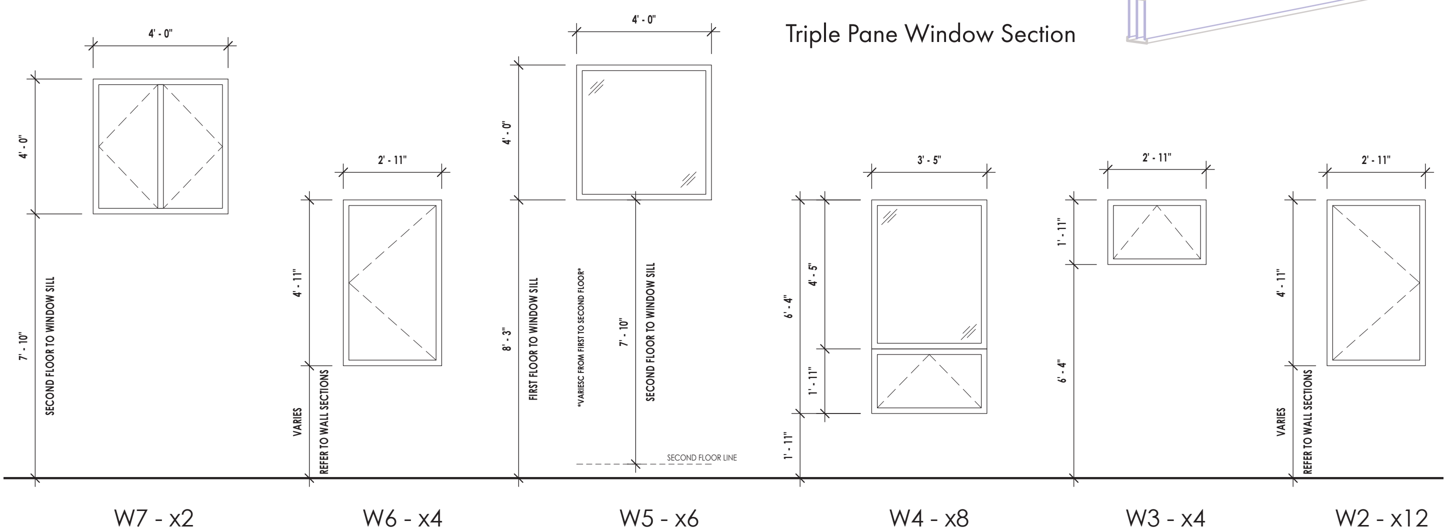
- U-factor 0.16-18
- Solar Heat Gain Coefficient (SHGC) 0.24 - 0.27
- Visible Transmittance (Tvis) 0.43 - 0.50

The sixteen 18 windows are a combination of fixed, operable casements, and operable awnings. The operability of the windows, while reducing airtightness, allow the design to take advantage of natural cross and stack ventilation for cooling in the shoulder seasons.

Fiberglass was chosen for its strength, durability, and lower carbon footprint compared with vinyl frames and were lower cost and required less maintenance over time compared with metal clad wood frames.



Triple Pane Window Section



Window Elevations

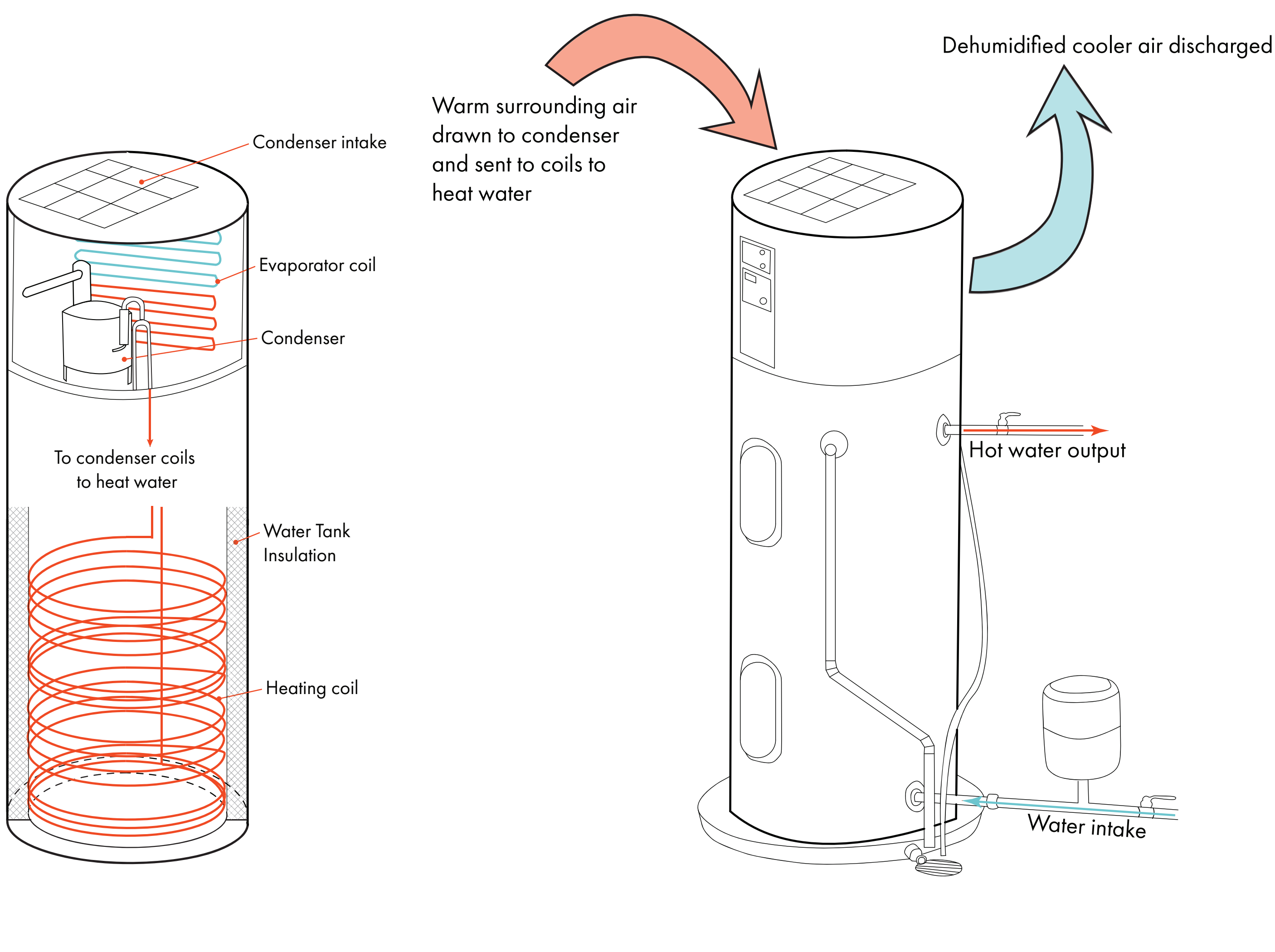
ENERGY PERFORMANCE

The Alley House has a predicted EUI (kBtus/sf/yr) of 21.64. This translates to 29,214 kBtus/yr or 8,449 kWh/yr. Energy modeling used Cove.Tool software, and significant EUI reductions were achieved through the selection of energy efficient and high-performance systems, components, and assemblies. The Architecture 2030 baseline for typical residential buildings in Indianapolis is EUI 49.77, which means that the Alley House has a 57% lower annual energy use intensity compared with the baseline. A significant factor in this efficiency is the measured/tested airtightness of 0.037 CFM50/SF of enclosure area, which was used as an input in the energy simulation. Interestingly, diminishing returns on the attic insulation means that the difference in predicted EUI for R-68 (the requirement for the PHIUS Core Prescriptive certification) and the R-92 installed is EUI 0.12 or 47.5 kWh per year (or less than 2 days of typical power usage for home). Coupled with the 8.8 kW solar PV array, the Alley House achieves an EUI -9.15 or net-positive energy.

PLUMBING
SYSTEM

HEAT PUMP HOT WATER HEATER

Cardinal Studio chose a heat-pump hot water heater for the Alley House. Heat pump water heaters are 2-3 times more efficient than conventional electric resistance hot water heaters, which result in lower annual energy use and cost for occupants. The A.O. Smith water heater includes a user interface module (UIM) that allows real-time monitoring and control features such as vacation setbacks. This heat pump water heater will extract ambient heat from the interior air in the home as part of the efficient vapor compression refrigeration cycle, and that heat will then be exchanged with the water in the tank. The tank also has 4" of insulation to prevent heat loss from the tank to the interior. The tank is located in the ground floor mechanical room, which was specifically located to allow short hot water pipe runs to bathroom and kitchen faucets and fixtures.



Water Heater Diagram

VENTILATION
SYSTEM

HVAC SYSTEMS

Heating and cooling for the Alley House is provided by a Mitsubishi multi-zone, short-ducted heat pump system. This system uses two, small soffit-mounted air-handling units (AHU) connected to a single multi-zone exterior condensing unit on the north side of the house. Low heating and cooling loads in this super insulated unit meant a less expensive mini-split system would not provide enough interior cassettes/heads to provide consistent temperature control in all spaces (especially bedrooms). A conventional ducted heat pump system was not possible given our TJI floor joist framing. The team decided to use a separate AHUs downstairs and upstairs to provide zone control. Compact soffit mounted units were chosen to reduce the size of the mechanical room in this compact unit. Soffits in the kitchen and upstairs flex space accommodate these hidden units and provide architectural interest. Short flex ducts run from each AHU supply hot/cold air to spaces on each floor and there is a single return grille in the side of the soffit to bring the air back into the unit. The units are controlled by a thermostat on each level. The performance characteristics of the system are as follows:

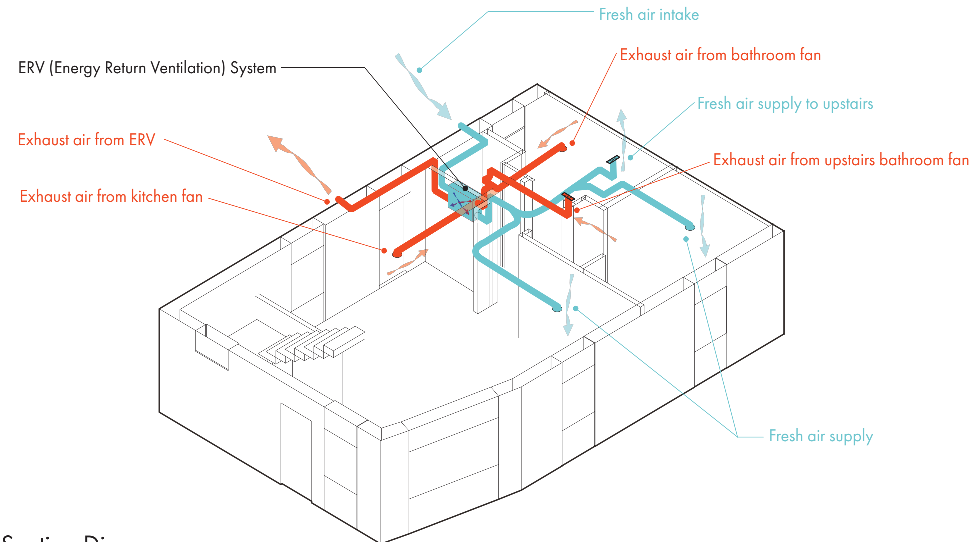
• SEER	17.3
• EER	13
• HSPF	9.8
• COP Heating (47F)	3.10
• COP Cooling	4.82
• Indoor Acoustics	23-30 dB (A)

Hvac System Floor Plan Diagrams

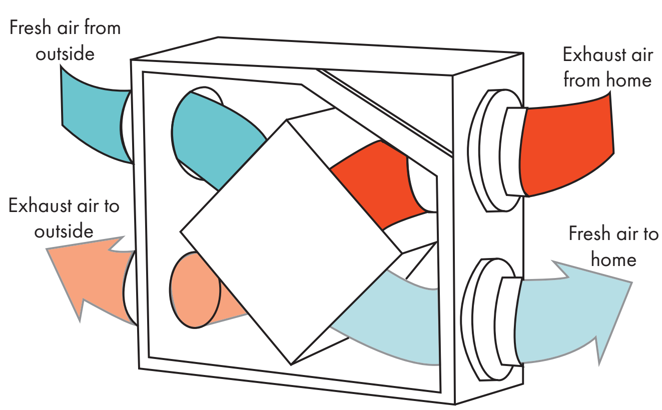
ENERGY RECOVERY VENTILATOR

To meet indoor environmental quality (IAQ) standards such as ASHRAE 62.2, modern airtight homes must provide a source of fresh, outside breathing air to occupants. The Alley House provides for optimal IAQ with a balanced ventilation system equipped with energy recovery. This system provides the calculated 74 CFM of air to the home through a Greenheck Sync 180 energy recovery ventilator (ERV). The ERV, fitted with a MERV-13 filter, supplies air to "clean" spaces such the living area, bedrooms, and flex space via 6" hard ductwork. Contaminated air is pulled from the kitchen and bathrooms continuously. Bathrooms are fitted with a boost mode switch to temporarily increase the air flow rate (supply and exhaust) after a high-moisture event like a shower. Fresh, dehumidified air supplied via the ERV is then used by the multi-zone heating/cooling system, which does not supply any fresh outside air. The ERV has a sensible recovery efficiency of 84%. Exhaust and supply air streams do not cross but run through a heat and moisture exchanger for energy recovery. The system is fitted with a CO_2 and a particulate matter sensor that will boost air flow rates if concentration thresholds are exceeded.

By utilizing an ERV system, the IAQ of the unit is improved to provide a healthy, comfortable environment for occupants. As shown in the graphic below, inside the filter box of the ERV air flows in four channels: two channels are for unconditioned outside fresh air and two channels are for exhaust air. They are separated by a thin plastic membrane or core. This configuration allows for the transfer of heat and moisture from the exhaust air to fresh air in winter and from the supply air to the exhaust air in the summer. Combined with filters, this clean transfer of heat allows clean and fresh air into the home year-round, regardless of the outside temperature with minimal energy loss and operational cost.



Erv Axonometric And Section Diagram



Erv Axonometric And Section Diagram

ERV Benefits

- Saves utility costs
- Modify humidity levels for optimal comfort
- Prevent moisture issues for cleaner room air
- Remove potential contaminants with air filtration
- Save energy by exhausting conditioned air without recycling heat
- LEED, PHIUS, and ASHRAE 62.2 compliant
- Provides fresh air

ELECTRICAL

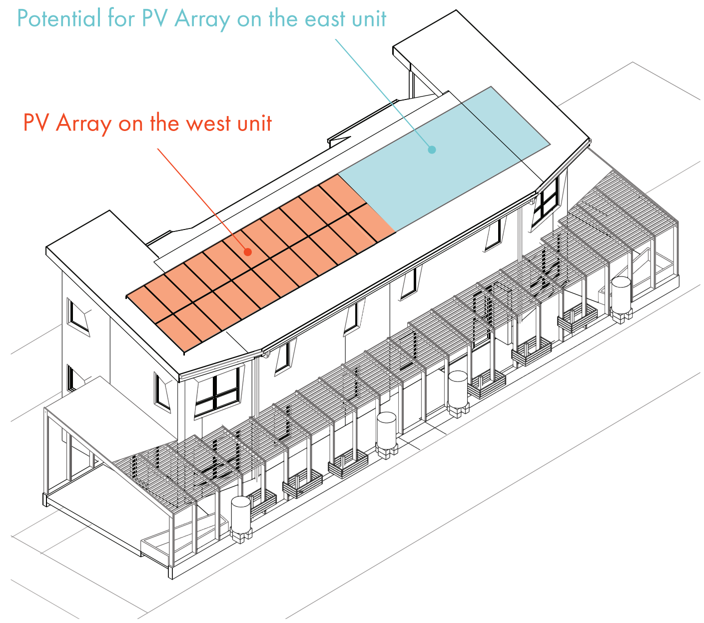
SYSTEM

SOLAR PANEL ARRAY

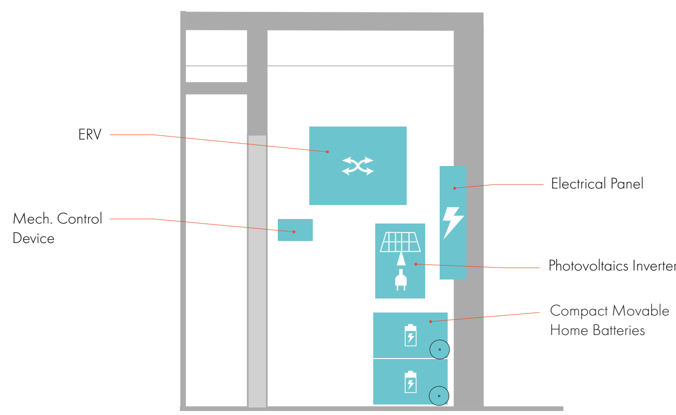
The Alley House provides onsite renewable energy generation via an 8.8kW solar photovoltaic (PV) system composed to 22 Panasonic Evervolt 400w PV modules mounted on a rack to the south facing roof. Solar analysis using Helioscope software suggest that the array can provide 12,181 kWh of renewable energy per year. The Panasonic Evervolt modules were chosen because of their 25-year warranty and their expected module yield at the end of the warranty period of 92%. The mono-crystalline cells in the modules are 21.6% efficient, which results in fewer rooftop modules needed to achieve net-zero energy. Energy analysis using Cove.Tool software suggest that annual energy use is 8,559 kWh per year. Thus, the PV array will provide, on an annual basis, all the energy needed by the occupants with approximately 3,622 kWh of surplus power each year, which results in a net-positive energy unit. The array also uses Solar Edge power optimizers and a Solar Edge inverter, which individual panels to generate power even when others are in shade and are a less expensive solution than micro-inverters on each module.

INVERSION AND STORAGE

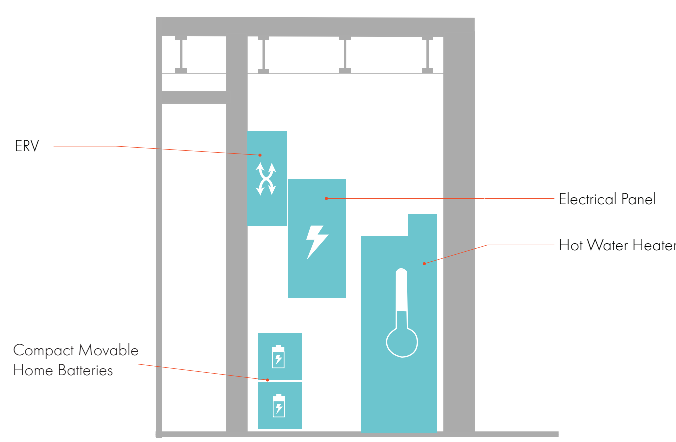
The PV array collects energy in the form of direct current (DC). The energy then is moved through an inverter in the mechanical room to become the alternating current (AC) used by the appliances, outlets, and other equipment in the home. The inverter and disconnects are located in the mechanical room to improve performance and durability over exterior locations. Two Ecofl ow modular, portable batteries can be charged during the daytime when occupants are using less solar energy and used in the event of a power failure or for loadshedding. The electrical system connects to an outdoor electric vehicle (EV) charging station for use by occupants with an electric vehicle. The portable batteries allow occupants to connect stored power directly to breaker panel or simply to move the units to a device in the home. This smaller battery storage system requires two units to support our home's basic energy loads, but they are more versatile than other battery storage systems as well as being scalable by simply connecting another battery pack to the others. Also, the cost of the two 3.6 kWh Ecofl ow battery modules was far less than other premium battery storage options such as a Tesla Powerwall, which was a primary consideration for this limited budget, affordable housing project. Cardinal Studio designed this innovative storage solution to make the Alley House adaptable to occupants' needs overtime while limiting fi rst cost. The graphic at right shows the layout of the mechanical room's battery systems.



Pv Panel Array



Pv Panel Array And Storage Diagrams - Mech Room West Wall



Pv Panel Array And Storage Diagrams - Mech Room North Wall

Updated Alley House West Unit

Energy Analysis

Mar. 28 2023

ANALYSIS SUMMARY

Location

201 N Temple Ave, Indianapolis, IN 46201, USA

Climate Zone

ASHRAE Climate Zone 5

50

Walk Score®

Car-Dependent

40

Transit Score®

Some Transit

66

Bike Score®

Bikeable

Building Type

Single Family Home

22

Overall Energy

The current model is done using ASHRAE Residential 2018 energy code assumptions. The current design is better than the national average and can be significantly improved by higher performance of envelope, HVAC and more. The building load is driven by Hot Water and Equipment.

BENCHMARKS

WHERE DO WE NEED TO BE?

Energy

50
National Average

10
2030 Target

EUI is expressed as energy per square foot per year. It is calculated by dividing the total energy consumed by the building in one year (measured in kBtu) by the total floor area of the building. The most common unit for EUI is kBtu/ft²/year.

55 %
Daylight

Spatial Daylight Autonomy (sDA) describes the percentage of floor area that receives at least 300 lux for at least 50% of the annual occupied hours.

10 %
Glare

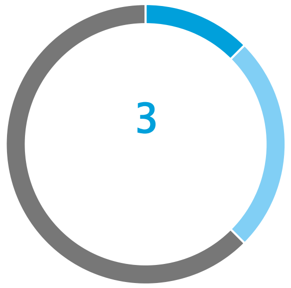
Annual Solar Exposure (ASE) refers to the percentage of space that receives too much direct sunlight (1000 Lux or more for at least 250 occupied hours per year), which can cause glare or increased cooling loads.

Water Use

Total Water Use (gal/yr)

Single Family Home	171729 gal/yr
Cooling Tower	0 gal/yr
Outdoor WU	0 gal/yr

LEED Points - WEc1-c2 Credit

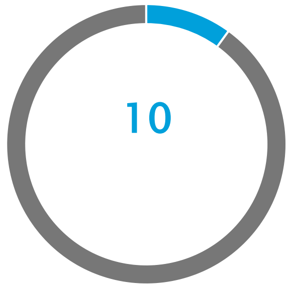


Indoor Reduction	30 %
Outdoor Reduction	0 %

Indoor WUI (gal/ft²/yr)

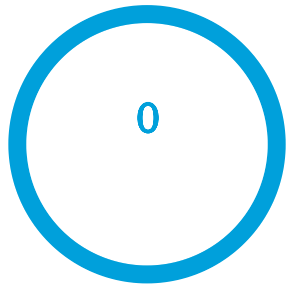
Single Family Home	130.03 gal/ft²/yr

Stormwater Managed Onsite %



Total Runoff	872 gal/yr

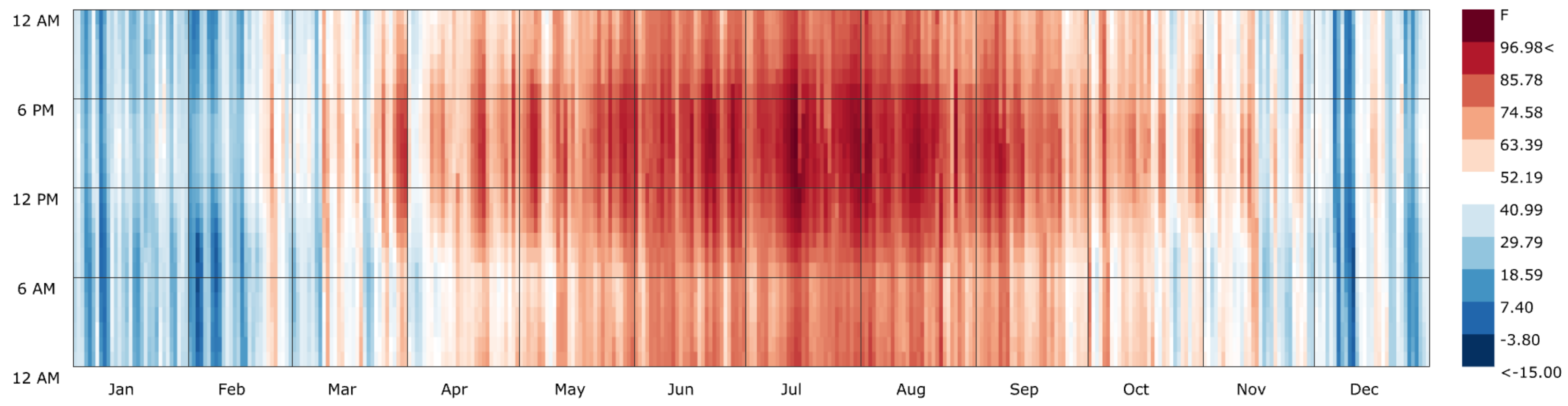
Irrigation WUI (gal/ft²/yr)



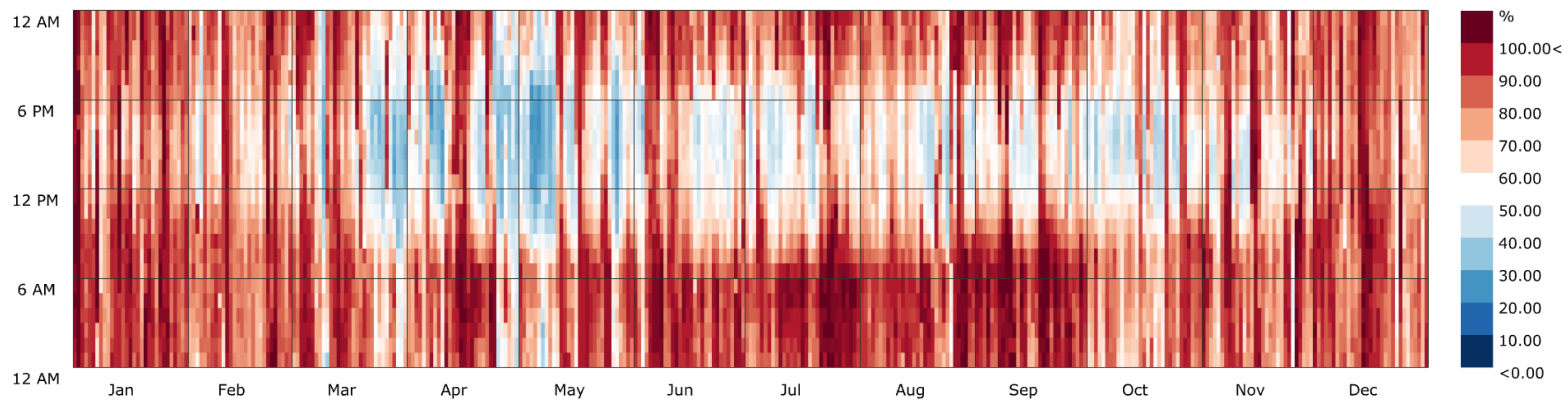
Total Irrigation Water Use	0 gal/yr

CLIMATE ANALYSIS

RELATIVE TEMPERATURE & HUMIDITY

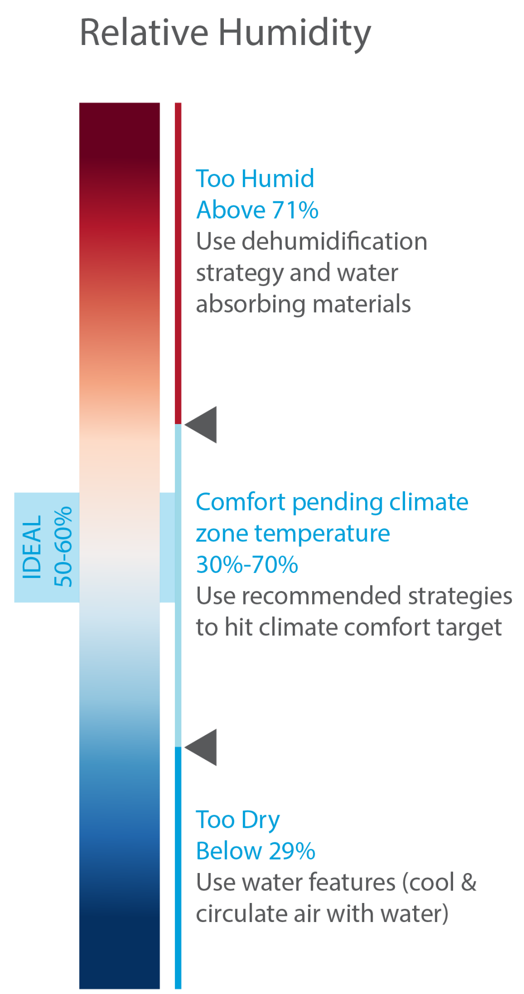


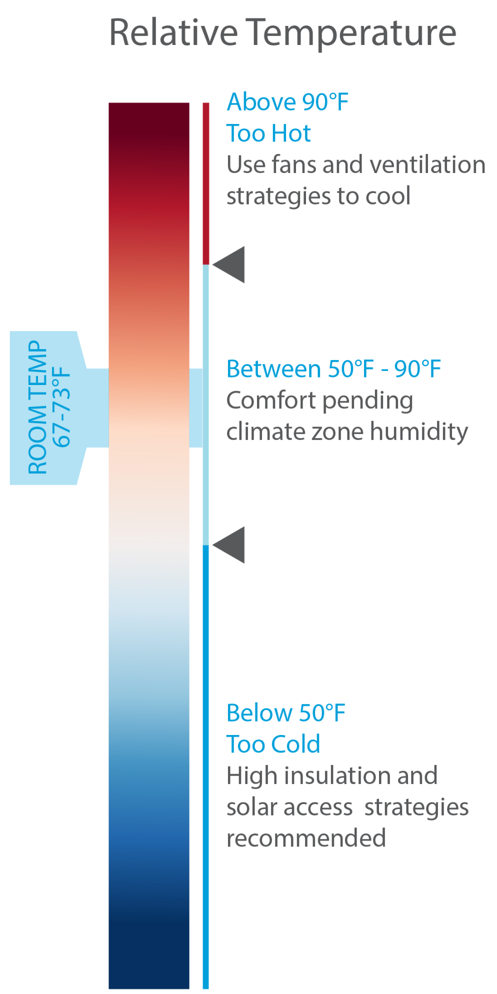
Dry Bulb Temperature (F) - Hourly
Indianapolis Intl Ap_IN_USA
1 JAN 1:00 - 31 DEC 24:00



Relative Humidity (%) - Hourly
Indianapolis Intl Ap_IN_USA
1 JAN 1:00 - 31 DEC 24:00

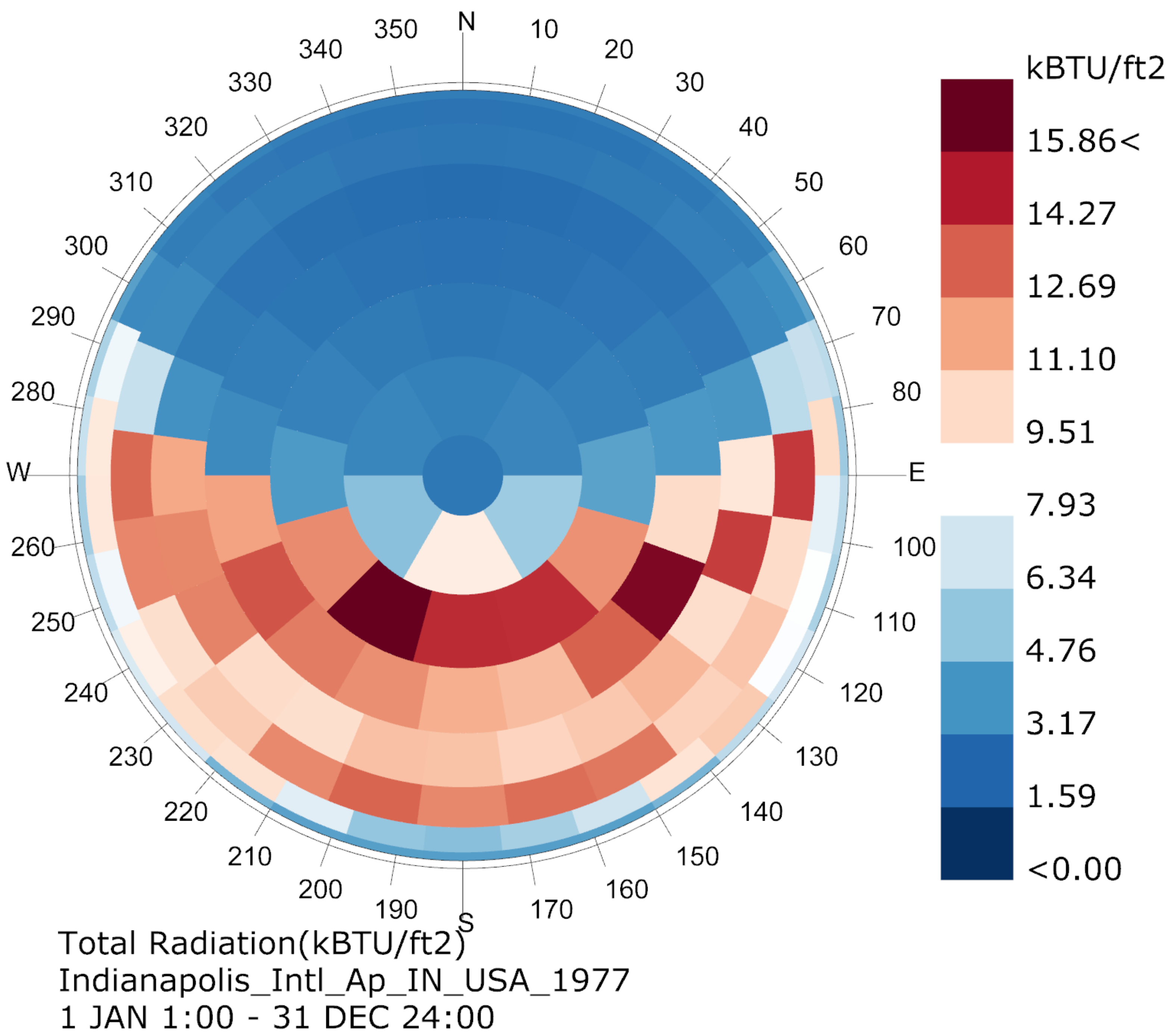
This graph shows the outdoor comfort in Indianapolis using the yearly range of temperatures and humidities.



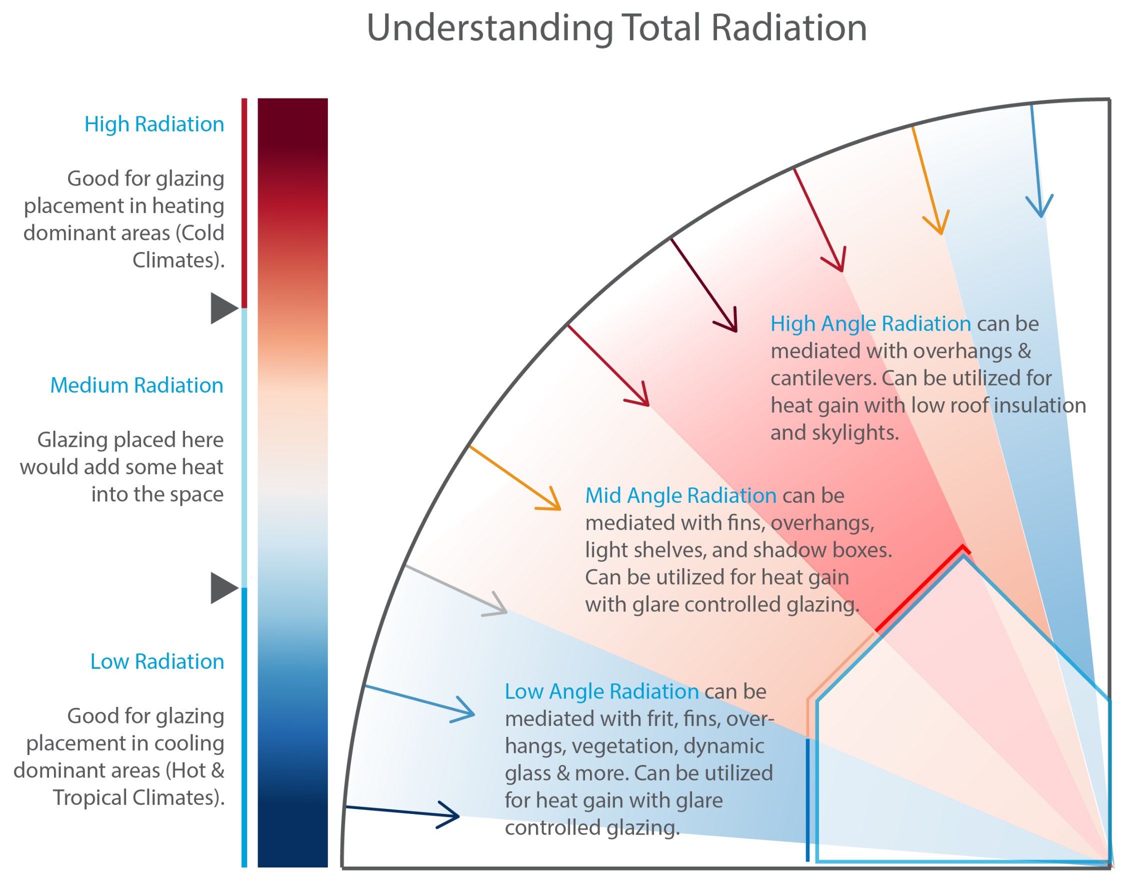


CLIMATE ANALYSIS

RADIATION BY SKY SEGMENT



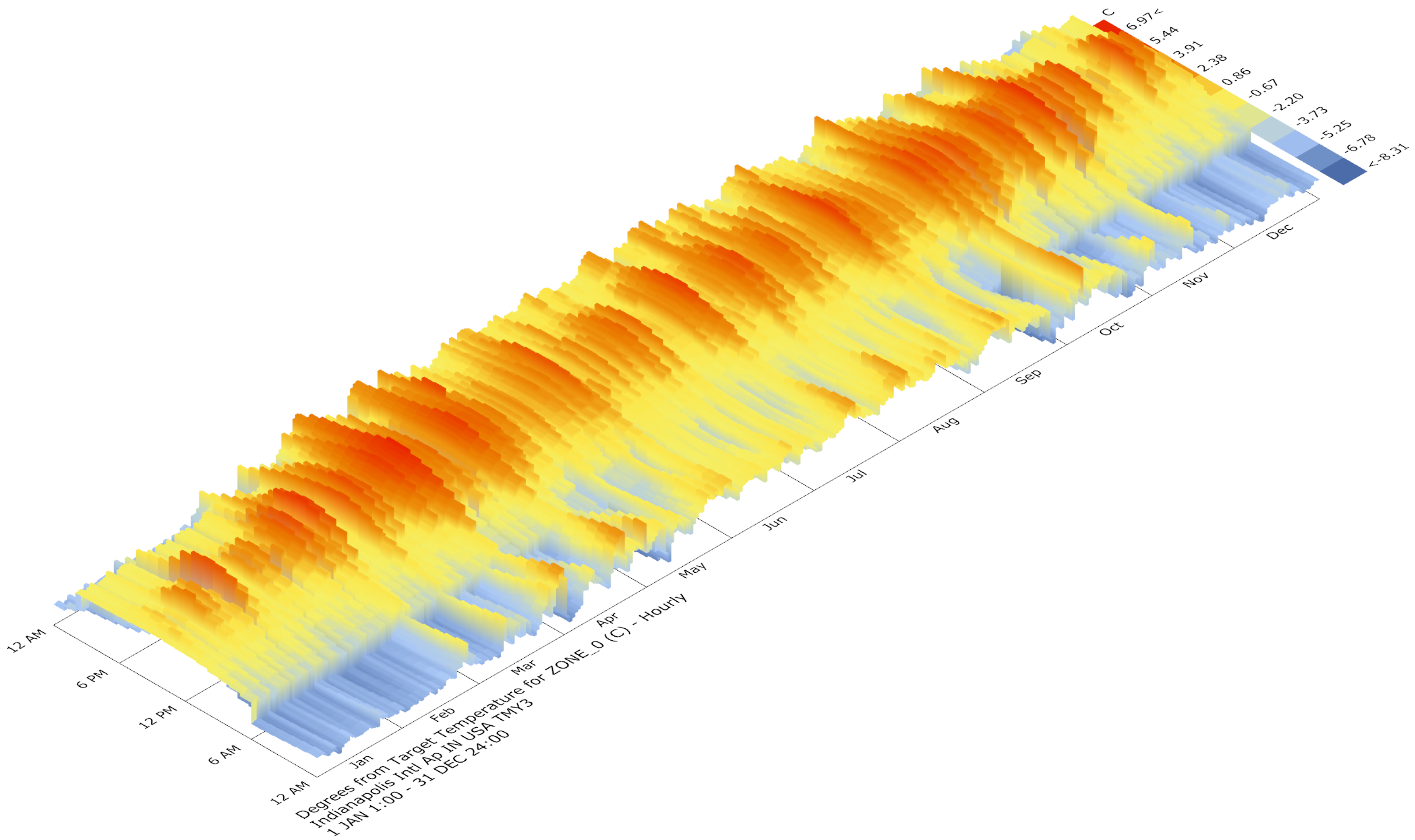
This graph maps the radiation onto a sky dome to show the intensity of the direction and intensity of solar radiation on a yearly basis around the cardinal points for Indianapolis.



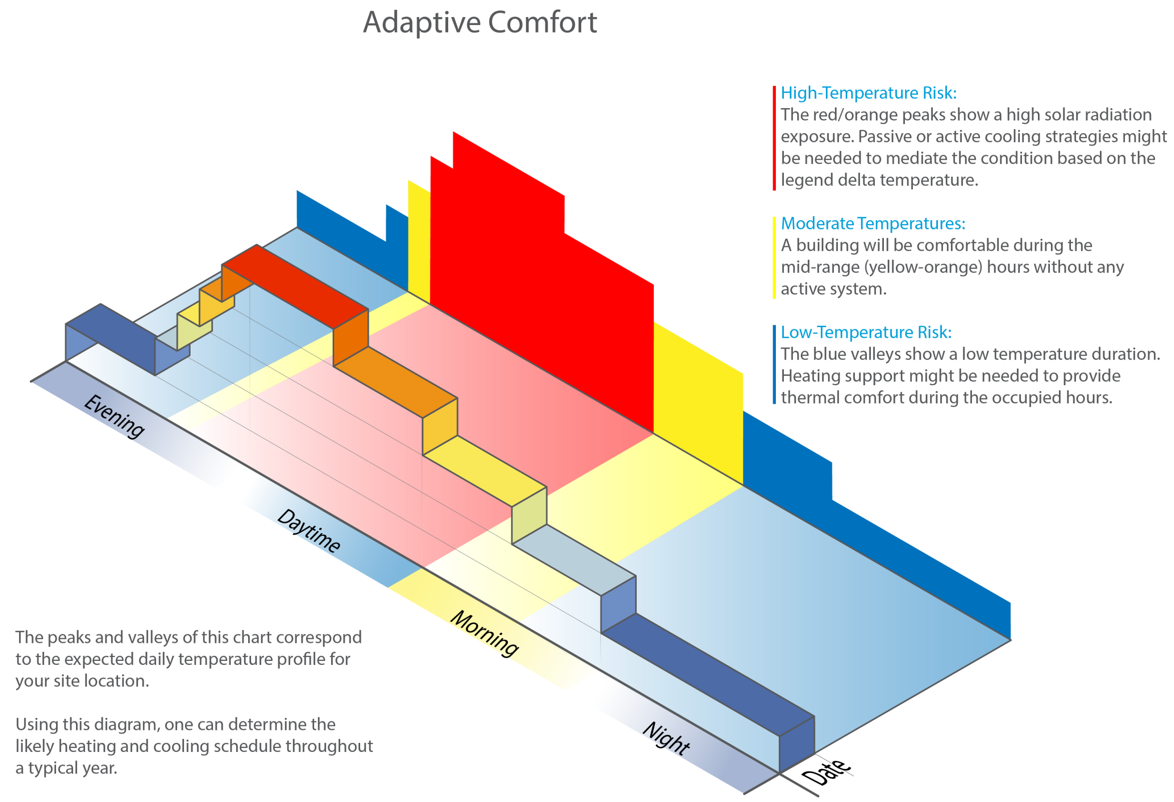
This diagram shows a radiation map projected onto a dome which is used to determine the best placement for glazing and possible radiation mediation strategies. Use the color, angle, and direction of radiation to identify what strategy you can use to optimize thermal comfort and ideal placement.

CLIMATE ANALYSIS

ADAPTIVE COMFORT

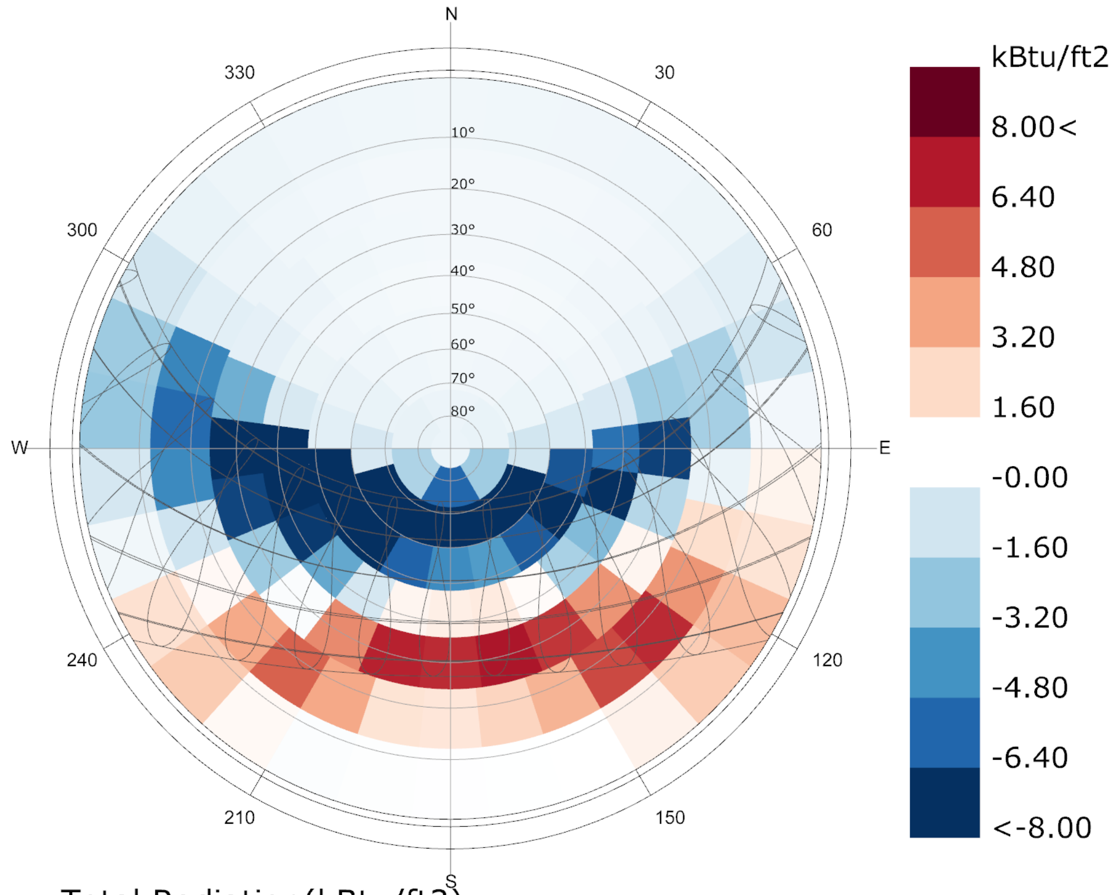


Adaptive Comfort chart showing the time of day and time of year with the greatest human comfort for your location.

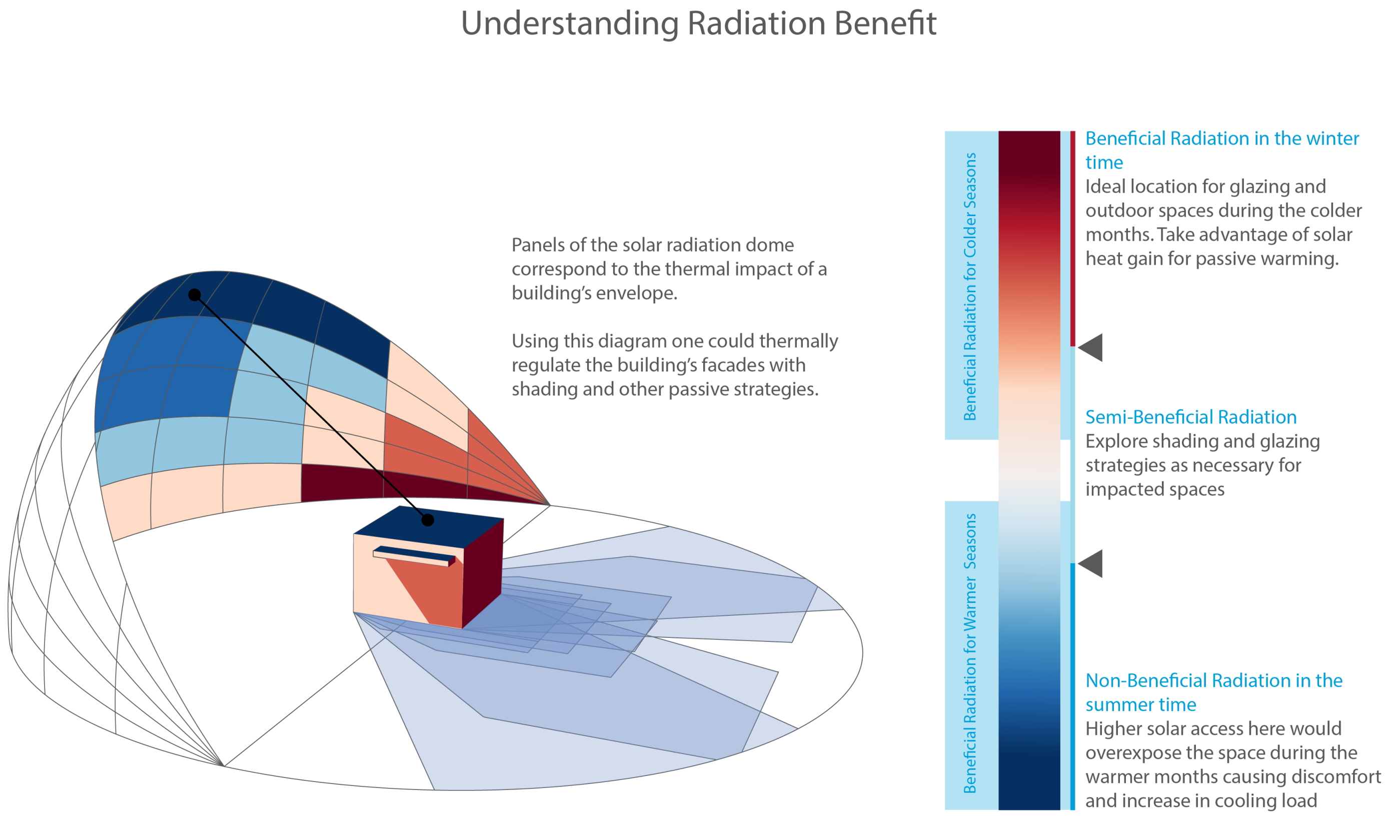


CLIMATE ANALYSIS

RADIATION BENEFIT

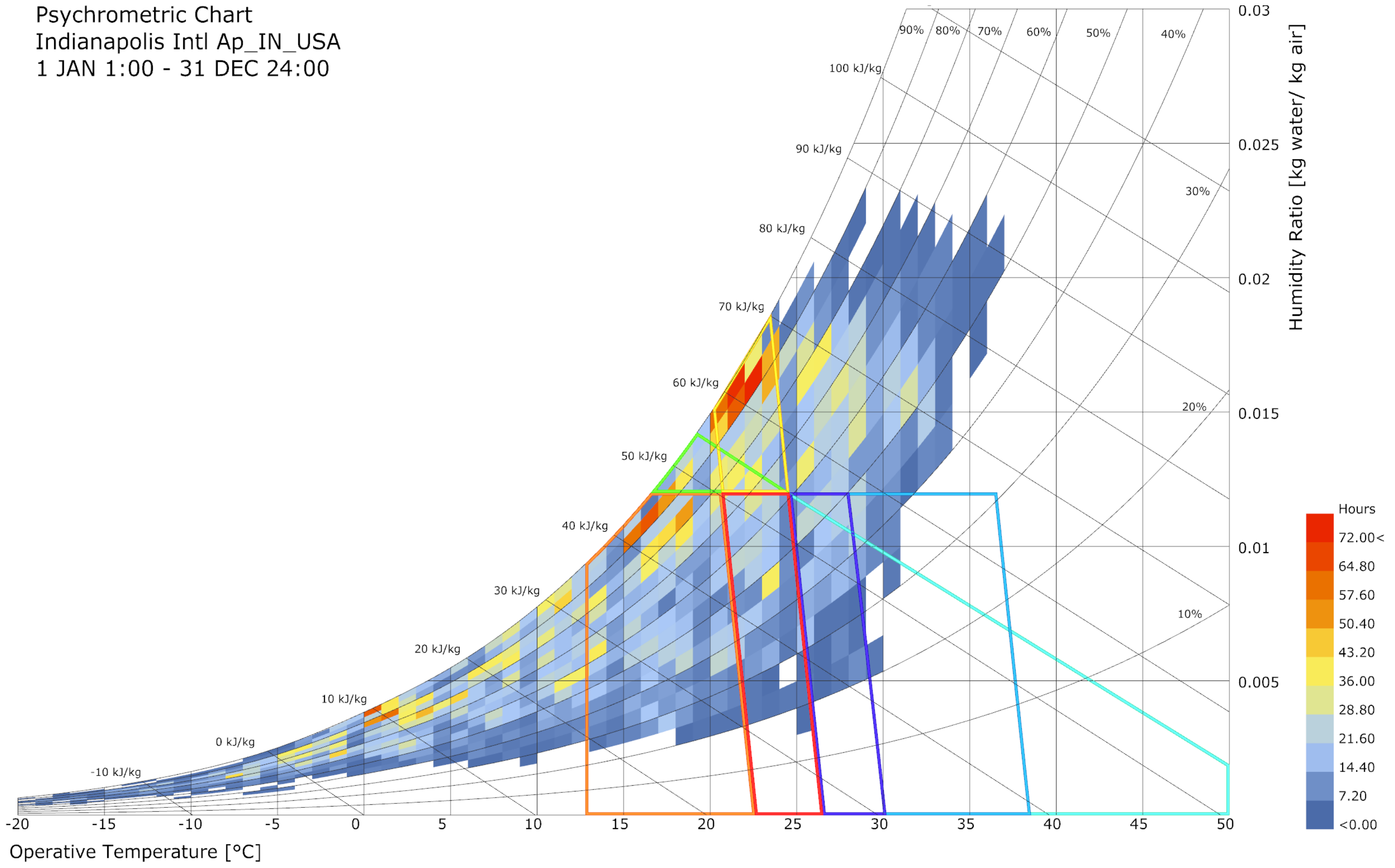


Total Radiation(kBtu/ft2)
Indianapolis_Intl_Ap_IN_USA_1977
1 JAN 0:00 - 31 DEC 23:00



CLIMATE ANALYSIS

PSYCHROMETRIC CHART



4.62 % COMFORT - NO PASSIVE STRATEGIES

Impact of Design Strategies

% of additional comfort - higher is better

2.17 % EVAPORATIVE COOLING

2.16 % THERMAL MASS + NIGHT VENTILATION

2.36 % OCCUPANT USE OF FANS

21.82 % INTERNAL HEAT GAIN

3.39 % DESICCANT DEHUMIDIFICATION

7.67 % DEHUMIDIFICATION

This chart shows the relationship between dry bulb, humidity ratio, and enthalpy. The polygons overlaid on the chart represent different strategies to increase comfort. Based on ASHRAE 55-2013 under standard conditions.

Understanding the Psychrometric Chart

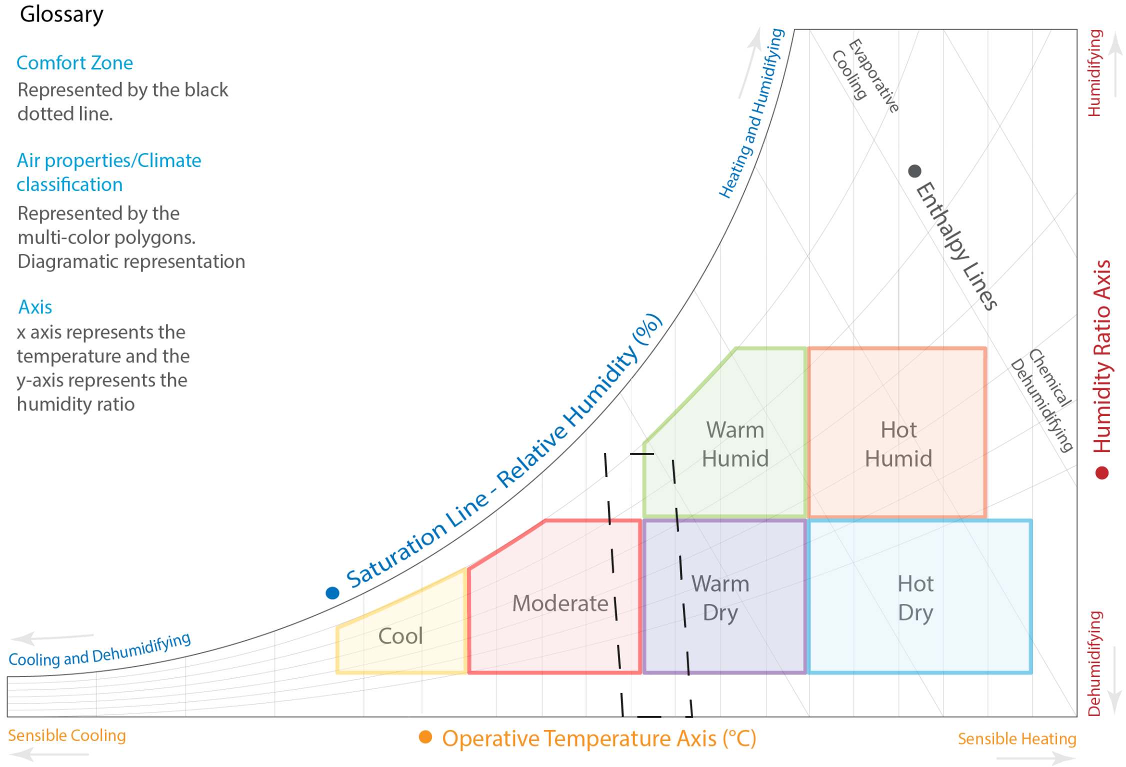
(For more details refer to ASHRAE 55)

Glossary

Comfort Zone
Represented by the black dotted line.

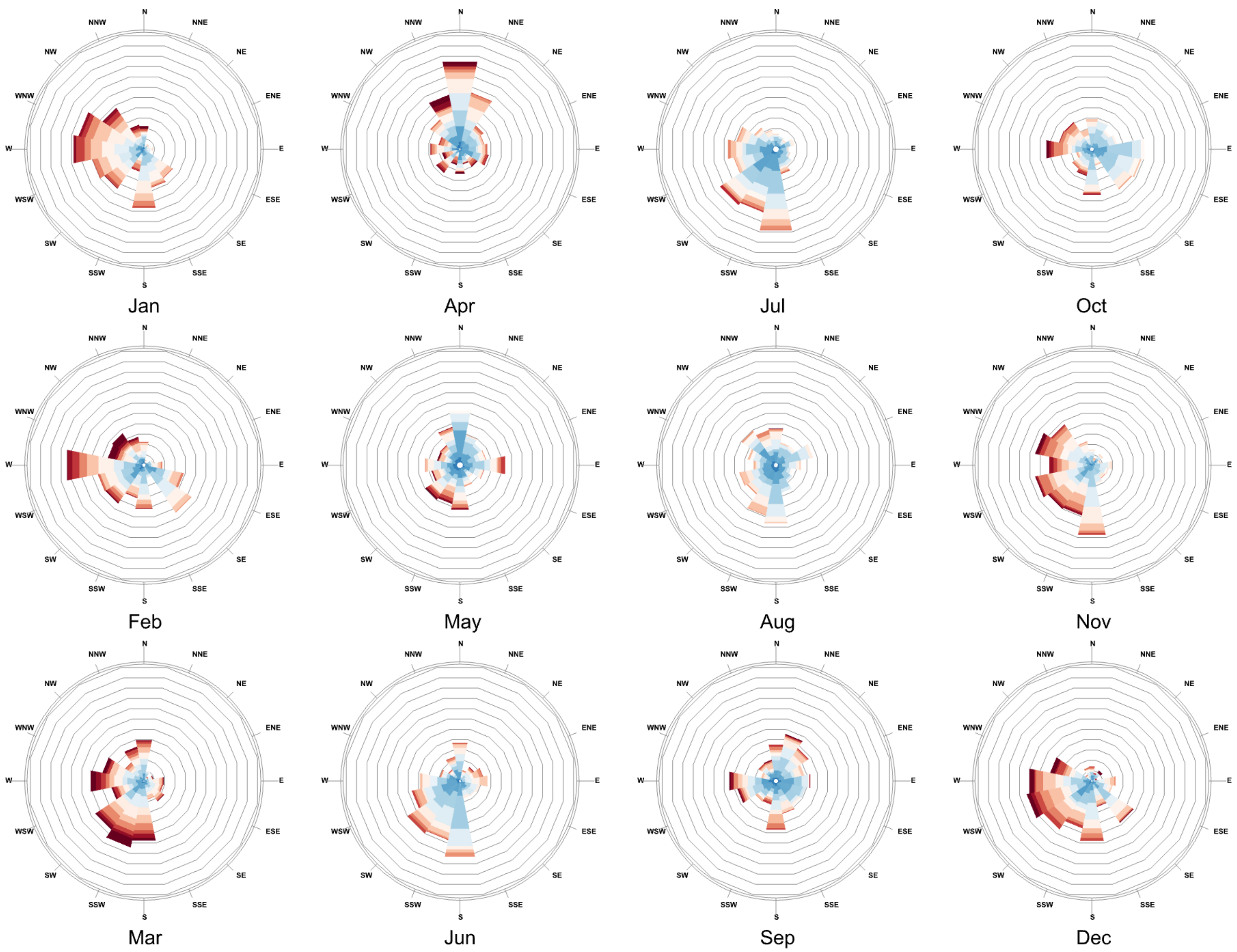
Air properties/Climate classification
Represented by the multi-color polygons. Diagramatic representation

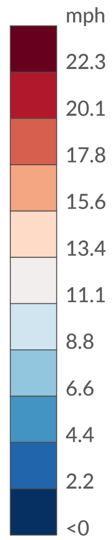
Axis
x axis represents the temperature and the y-axis represents the humidity ratio



CLIMATE ANALYSIS

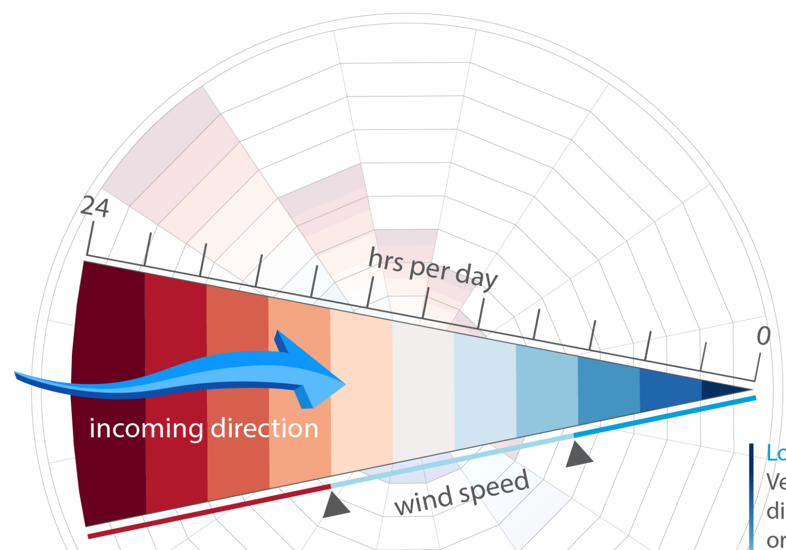
WIND





The diagrams show the wind direction and intensity coming to the site. The number of hours are reflected by the size of the rose, and the intensity is expressed in colors as shown in the legend.

Understanding the Wind Diagram



Using this graph one can identify a climate zone's prevailing winds. Knowing ones prevailing winds can help identify best building facades to use for passive ventilation strategies such as operable window placement.

Low Wind Speeds
Ventilation placed along the directions of 'low wind speeds' or 'winds of minor reach' will not be effective in cooling dominant areas (Hot/ Tropical Climates)

Mild Wind Speeds

High Wind Speeds
High wind with the furthest reach is the prevailing wind for that climate area. This is the best area/ direction for ventilation strategy.

Envelope | Usage and Schedules | Building System | Energy Generation | General

Roof R-Value (h ft² F / BTU)	92
Wall R-Value (h ft² F / BTU)	40
Spandrel U-Value (BTU/h ft² F)	0
Glazing U-Value (BTU/h ft² F)	0.2
Glazing SHGC	0.23
Skylight U-Value (BTU/h ft² F)	0
Skylight SHGC	0
Envelope Heat Capacity	Light: 110,000
Blinds/Curtains/Shades	(Interior) Blinds
Wall Emissivity	0.6
Roof Emissivity	0.86
Ground Floor Area (ft²)	645.8
Ground Floor U-Value (BTU/h ft² F)	0.05
Below Grade Area (ft²)	0
Below Grade Depth (ft)	0
Below Grade U-Value (BTU/h ft² F)	0

Envelope | Usage and Schedules | Building System | Energy Generation | General

Inputs

Daylight Sensors (%)	No Sensors: 0%
Occupancy Sensors (%)	No Sensors: 0%
Lighting (W/ft^2)	0.1
Exterior Lighting Power (Watts)	0
Appliance Use (W/ft^2)	0.25
Metabolic Rate (MET Value)	Sitting: 60
Heating Set-Point (F)	68
Heating Set back (F)	59
Cooling Set-Point (F)	78
Cooling Set back (F)	84
Total Occupants	14

Envelope | Usage and Schedules | **Building System** | Energy Generation | General

System Type	DOAS w/ FCU, with ASHP and Air Co	
Integrated Part Load Value	Variable Speed Drive Centrifugal Chill	
Heating System COP	3.1	green
Cooling System COP	4.82	green
Heat Recovery System	Sensible Or Enthalpy Wheels	green
Fan Flow Control Factor	Inlet Blade Adjunct	
Specific Fan Power	Other Local Units (Fan Coil Units)	
Ventilation Type	Combined	
People Outdoor Air Rate (CFM/Person)	15	
Area Outdoor Air Rate (CFM/ft²)	0.05	
Ventilation Calculation Type	Ventilation Rate Procedure	
Infiltration (CFM/ft²)	0.04	
Building Energy Management System	Simple	yellow
Ventilation Control	Always On	
Exhaust Recirc. %	None	red
DHW Gen.	Heat Pump	green
Hot Water Distribution System	Taps Further Than 3 Meters Of Heat G	yellow
Domestic Hot Water Demand (gal/yr)	20000	
Pump Control for Cooling	All Other Cases	
Pump Control for Heating	All Other Cases	