U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

SOLAR TEXAS

Texas A&M University

Solar Texas

Durability and Resilience Contest Narrative

March 28, 2023

Durability and Resilience Jury

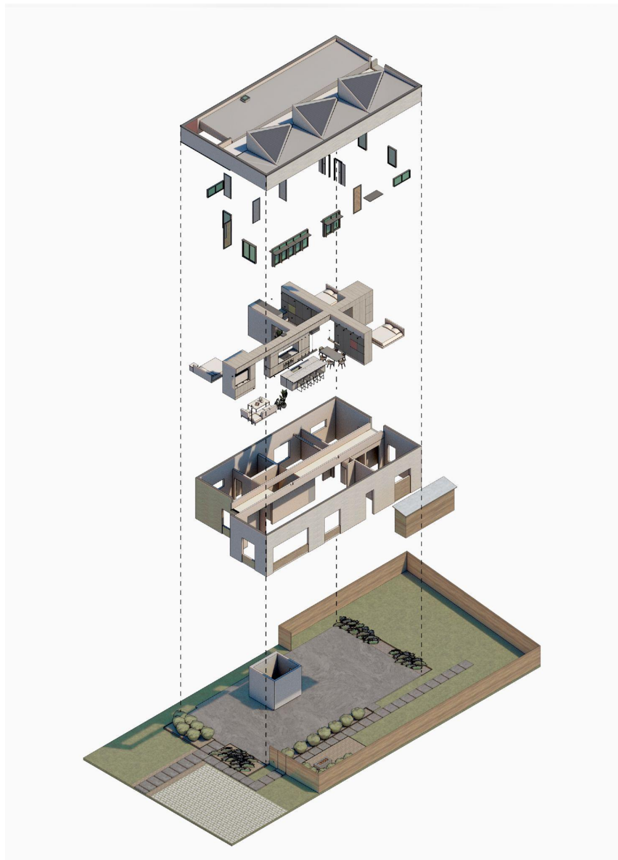

Figure 1: Exploded Axonometric of Building Components with FEMA Safe Room

As climate change cannot separate from maintaining the continuity of our communities or the quality of human experience, Solar Texas uses an integrated design approach that delivers long-term, resilient urban responses. Solar Texas focuses on a wide range of efficient strategies as a central design consideration. The structural system of the Solar Texas house will use a pre-tensioned slab set on helical piers. This approach develops primarily due to the site's expansive clays but also enables a metaphorical "level playing field" for the target market from which to build. The primary structural elements will include a FEMA-compliant safe room that serves as a centrally-located bathroom (Figure 1). The remaining structural elements will consist of standard wood framing and brick exterior. The combination of concrete, wood, and brick will enable file-to-factory and file-to-site fabrication and on-site construction methods. Solar Texas incorporates high-quality and durable materials for all surfaces and systems. The TAMU team selected materials for environmental stewardship, recyclability, reuse, repurposing, and remanufacturing capabilities. In addition, if Bryan Utilities (BU) reduces electricity consumption by switching off the power supply to groups of customers because the entire system is at risk of a grid outage, the *Solar Texas* project will enable the power transfer to battery backups during an emergency. The team examines proportional responses to providing enough storage for blackouts for one night and temporal outages for up to five days. As an integral component of the team's resiliency-based approach, the *Solar Texas* house promotes intelligent smart home devices that communicate to the grid, enable grid interaction to sense power fluctuations and outages, and tap into smart solutions for the house, including smart appliances operation for shedding peak loads.

Integrated Performance: The *Solar Texas* house orientation adheres to the selected site constraints, which do not align with True North. However, the house is organized with its long side stretching primarily east-east to take advantage of the rising sun (bedrooms) and setting sun (living areas). The *Solar Texas* house will rely on natural resources to provide necessary energy and comfort to the occupants. Adopting varied passive design strategies, including appropriate building form, orientation, material selection, airtightness of the building, efficient envelope, and solar panels in conjunction with smart building systems makes it possible to achieve Net-Zero energy performance and align to AIA's 2030 Challenge for carbon-neutral designs. These strategies will considerably assist in minimizing the heating and cooling loads while adapting to the interior and exterior environment utilizing smart building systems. The *Solar Texas* project will include high-efficiency appliances, controllable LED lighting systems, energy-efficient heat pumps and thermal storage tanks, hydronic radiant systems, and an intelligent control system that optimizes indoor thermal comfort. The *Solar Texas* team plans on integrating a smart electrical panel that controls and monitors every circuit in the house using a smartphone. Incorporating this system will enable a comprehensive understanding of how the *Solar Texas* house sources, stores, and uses energy in real-time.

Building Assemblies

Building orientation: Although the site constrains the building's axial orientation, our photovoltaics will orient toward the sun. Functionally the living room, kitchen, and dining room will be set on the southwest side, enabling the winter sun to enter while buffering the sun from entering these spaces during the summer cooling months (Figure 2)..

Floor slab: Whereas the typical best-case scenario is to build a slab-on-grade foundation, given the expansive clay soils in the region, the *Solar Texas* team is validating cost-to-benefit analyses of two design solutions - one for a stiffened slab on grade with grade beams that require 3'-0" of cut soil to be replaced with select structural fill and another with helical piers installed at engineered intervals along with the footing forms and tied into the steel gridwork before pouring concrete footings. The helical pier design solution will incorporate a prestressed concrete slab. The floor R-value will be R15.00.

Site drainage: The lot will be properly graded - 5% grade slope - to drain away from the structural foundation. The site will use Low-Impact Development (LID) strategies such as biophilic "ecoregional" green vegetated swales (goal: to manage, retain and delay stormwater runoff, mitigate ecological imbalances caused by urbanization, conserve energy in the building, further reduce urban heat islands, provide biophilic benefits) and pervious pavers to minimize runoff and lessen impacts on municipal sewer systems.

Roof: A combination of a cool, reflective roof (goal: to reduce the roof surface temperature by more than 50-degrees F, reduce air conditioning load, solar heat gain, and negative heat island effect, improve interior comfort level), reduce building life-cycle costs, and provide restorative well-being for the homeowners, and adequately ventilated, radiant barrier, and well-insulated roof to equalize interior and exterior temperatures. The roof will use a fully adhered roofing membrane at eaves and gable ends, butyl-based adhesive back flashing strips on roof sheathing joints, and hurricane-rated BIPV tiles/shingles. This will include installation of hurricane strapping, rods, and bolts per code. The roof R-value is 42.00.

Wall construction: Wood frame Wall R-value R27.04 (goal: to create a tight thermal envelope, install a positive pressure ventilation system, in a well-insulated, bridge-free construction that eliminates all thermal bridging, integrative use of vapor barrier on the exterior side of the exterior insulation, properly sealed). The team is looking at cost-to-benefit options for various products, from structural insulated panels (SIPs) to autoclaved, high-performance insulated concrete panels to standard 2” x 6” nominal wood framing with 2” of continuous XPS insulation. The exterior skin of the building will be brick that uses a king brick with a more linear profile than common.

Exterior envelopes: The *Solar Texas* house will use high-performance, low-emissivity windows with low solar heat gain coefficient, with windows located to maximize views and take advantage of breezes. The installed windows will use sill wrap, corner shields, and adhesive flashing tape to protect against water intrusion. The *Solar Texas* house uses a combination of overhangs, covered porches, light shelf awnings, and strategically placed shade trees to minimize solar heat gain and maximize the use of natural daylight light.

Envelope, Windows, & Doors: As an integral part of the proposed development for the Essential Aggies, *Solar Texas* will utilize predominantly south-facing for higher solar panel exposure to the sun. Given the site location in Climate Zone 2 (Figure1), windows must have at least the following performance factors: Window U-factor ≤0.40, Window SHGC ≤0.25, Skylight U-factor ≤0.65, and Skylight SHGC <0.25. Door U-Value: Door SHGC: 0.40 in CZ 2 0.25 in CZ 2; Opaque: 0.17 Opaque: Any ≤1/2 lite: 0.25 ≤1/2 lite: 0.2 >1/2 lite: 0.25 in CZ 2, Infiltration rates: 4 ACH50 in CZ 2; ENERGY STAR windows and doors. The team will continue to examine tilting the windows relative to the sun's angle, maximizing reflection in the summer and minimizing reflection in the winter months. The energy simulations used a window U-value of 0.13 and a Solar Heat Gain Coefficient (SHGC) of 0.28, which exceeds the AIA 2030 Challenge goals. The design infiltration rate is 0.220 cfm/ft^2.

Interiors: The *Solar Texas* building design does not have an attic space, therefore, the roof and the ceiling have the same R-value: 42.00. The design specifies an installation of non-paper-faced, mold-resistant, fiberglass-mesh-covered drywall products.

Systems: As the *Solar Texas* house will elevate above the ground due to the expansive soils of the Bryan-College Station area, the team will examine the costs and performance of a combinatory system of geo-exchange ground source heat pumps and earth tube with an earth-to-air heat exchanger. The balanced wholehouse ventilation system will use either an Energy Recovery Ventilation (ERV)/Heat Recovery Ventilation (HRV) unit that vents through the roof. The *Solar Texas* team will examine duct-free, mini-split systems with individual HVAC units in each space, each with its own indoor and outdoor component to eliminate ductwork. The design will compare the mini-split system to a packaged system that combines heating and cooling capabilities in one unit. In each scenario, the system will incorporate a thermostat with humidity controls, a dehumidifier to control seasonal humidity, and ceiling fans for comfort.

Cooling Equipment: Cooling equipment will be modeled at the applicable efficiency levels at 20 SEER / 12 EER AC.

Heating Equipment: For the energy performance simulations, the design uses heating equipment modeled at the applicable efficiency levels and is dependent on fuel and system type, 8.2 HSPF / 20 SEER / 12 EER air-source heat pump with electric or dual-fuel backup.

Water Heater, Thermostat, & Ductwork: The design integrates programmable thermostats, with all ducts and air handlers within a conditioned space.

Lighting & Appliances: ENERGY STAR light bulbs modeled in 90% of ANSI / RESNET / ICC Standard 301-defined Qualifying Light Fixture Locations. The *Solar Texas* house will maximize available natural lighting, thus reducing electrical lighting during daylight hours. The *Solar Texas* team will examine the use of window coverings on the inside and outside of the building to control lighting levels and maximize privacy. Lighting throughout the house will incorporate light-emitting diode (LED) solid-state lighting for ambient, general, and task lighting. All lights will have dimmable controls at a CRI color temperature of 2900K. Controls include timers, automatic daylight shut-off, motion sensors, and photocells that automatically turn lights on or off when not in use. Appliances will include ENERGY STAR refrigerators, dishwashers, induction cooktops, and ceiling fans.

The *Solar Texas* project is a 2018 IECC International Code Council code-compliant building developed and an energy-compliant residential project that incorporates passive solar design features situated on a site in Bryan/College Station. The project goal is to be carbon-neutral and net-zero. The project uses a combination of site orientation (east-west orientation), properly sized and shaded windows and doors optimized to reduce solar gain and cooling demands in relation to baseline building types to achieve this goal. The team intends to measure and reduce emissions through integrative building design strategies and energy efficiency measures such as incorporating carbon-free on-site renewable energy systems to meet its energy needs. The team goal is to reduce emissions from the baseline building by 90%.

Daylight Design and Analysis: Passive Survivability

Climate, Shading and Materials

This house is designed to function for at least one week after a potential grid failure. The building is rotated ∠34-degrees from the True North (north-south) axis. In this design, the solar panels are oriented toward the south. The roof design maximizes the number of PV panels while enabling the inflow of soft, northerly light into the house's primary public spaces (living room, kitchen, and dining room). Therefore, the design has a scheme that generates enough power to achieve net-zero energy while enabling controlled light to enter the house. The family room and kitchen are facing southwest so they can utilize the warmth of the southern sun. Since the bedrooms face southeast, the size of their window openings has been optimized to protect the building from the eastern sun (Figure 2). The building is accessible from the northern part of the site. A shed is also provided beside the building since it is required for all Habitat for Humanity Houses. Details from material reflectance / transmittance were investigated, and lighting simulations were run on the house. Results are shown and briefly described in Figures 3-10. Circadian rhythms were also included to improve occupant health.

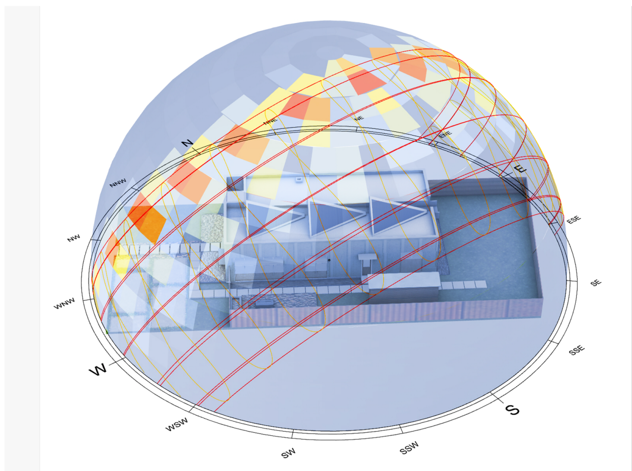

Figure 2: Solar Responsive Design(software: HoneyBee v1.3.0)

Shading is required from 8:00 AM to 6:00 PM from May to September.

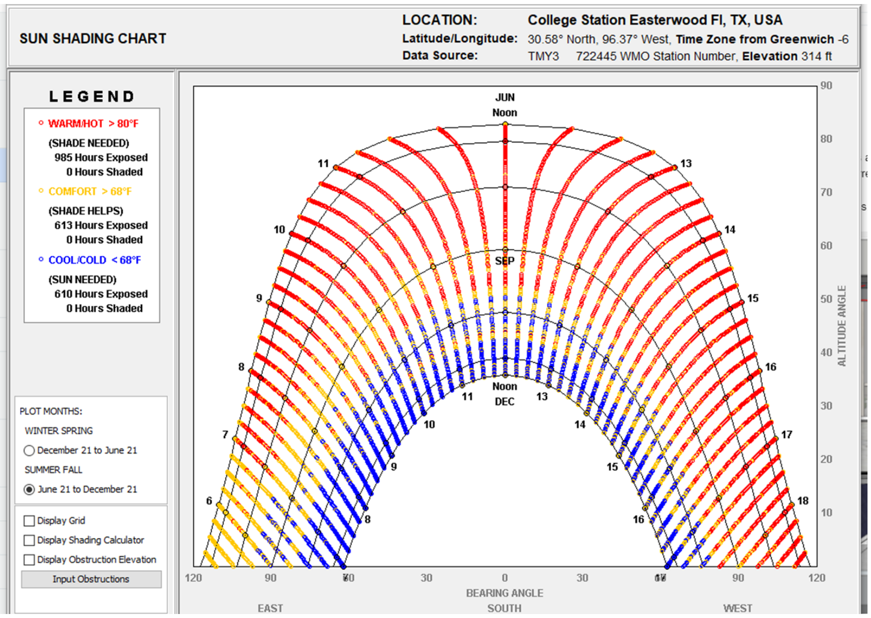

Figure 3: College Station Shading Chart (software: Climate Consultant 6.0)

MR: Melanopic Reflectance, PR: Photopic Reflectance
MT: Melanopic Transmittance, PT: Photopic Transmittance

Figure 4: Material Optical Properties (Source: ClimateStudio 1.57955 and ALFA 6.0)

Daylight Availability: UDI, LEED V4 (SDA & ASE)

Percentage of the year between 8:00 AM and 6:00 PM when the illuminance levels are above 300 lux throughout the house.

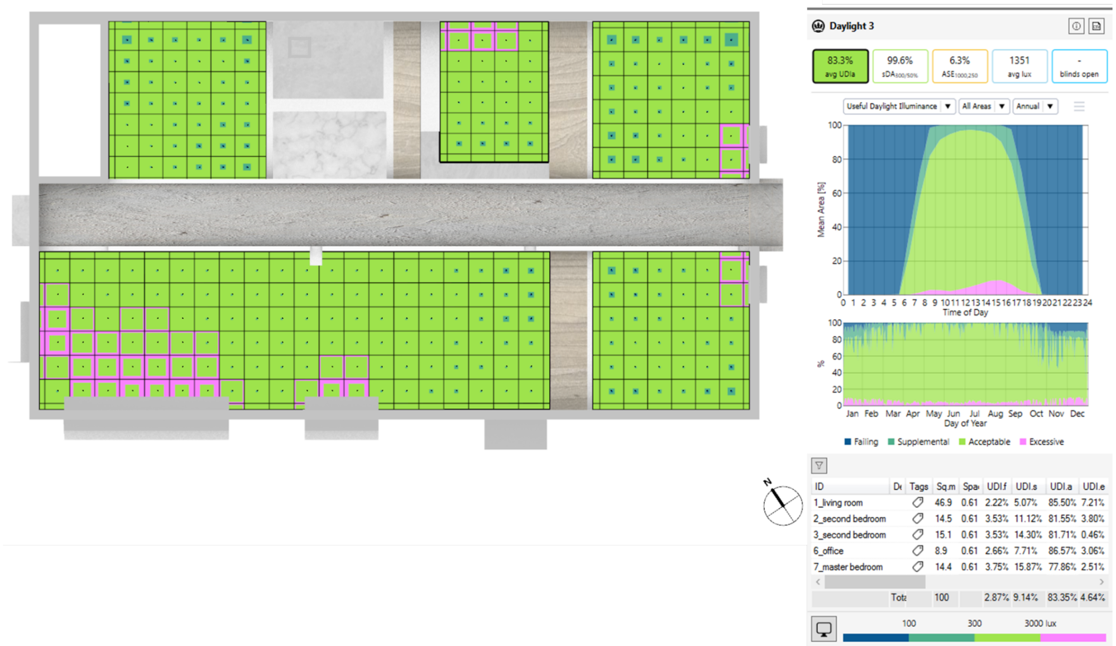

Figure 5: Useful Daylight Illuminance (UDI): 83.3%

Almost 100% of the house receives more than 300 lux during 50% of the daytime regularly occupied hours (8:00 AM to 6:00 PM).

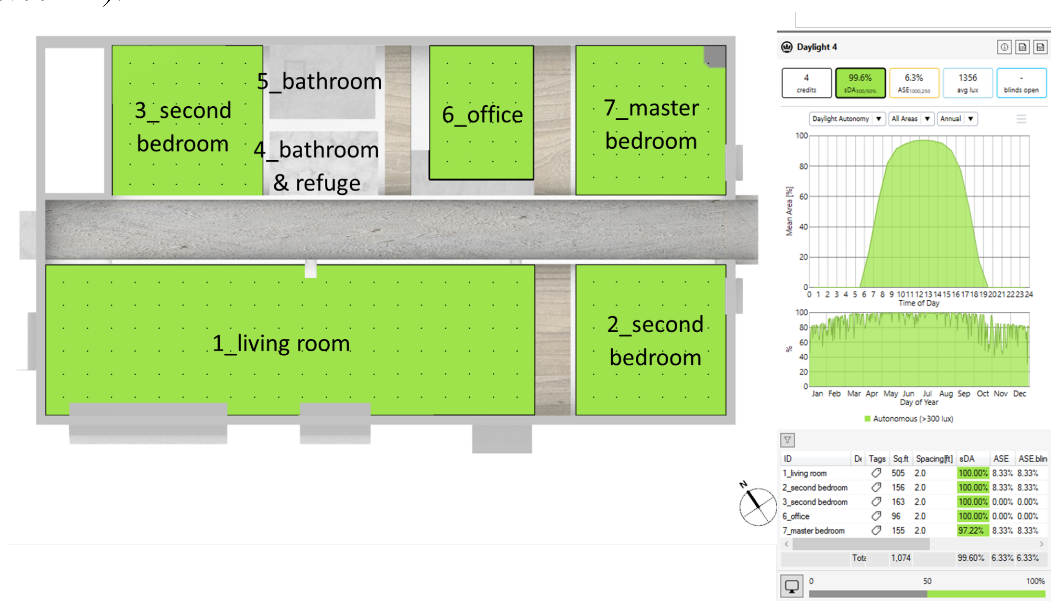

Figure 6: Spatial Daylight Autonomy (sDA): 99.6%

The house envelope has been designed to control the entrance of sunlight, provide high lighting levels, and provide healthy circadian light throughout the year.

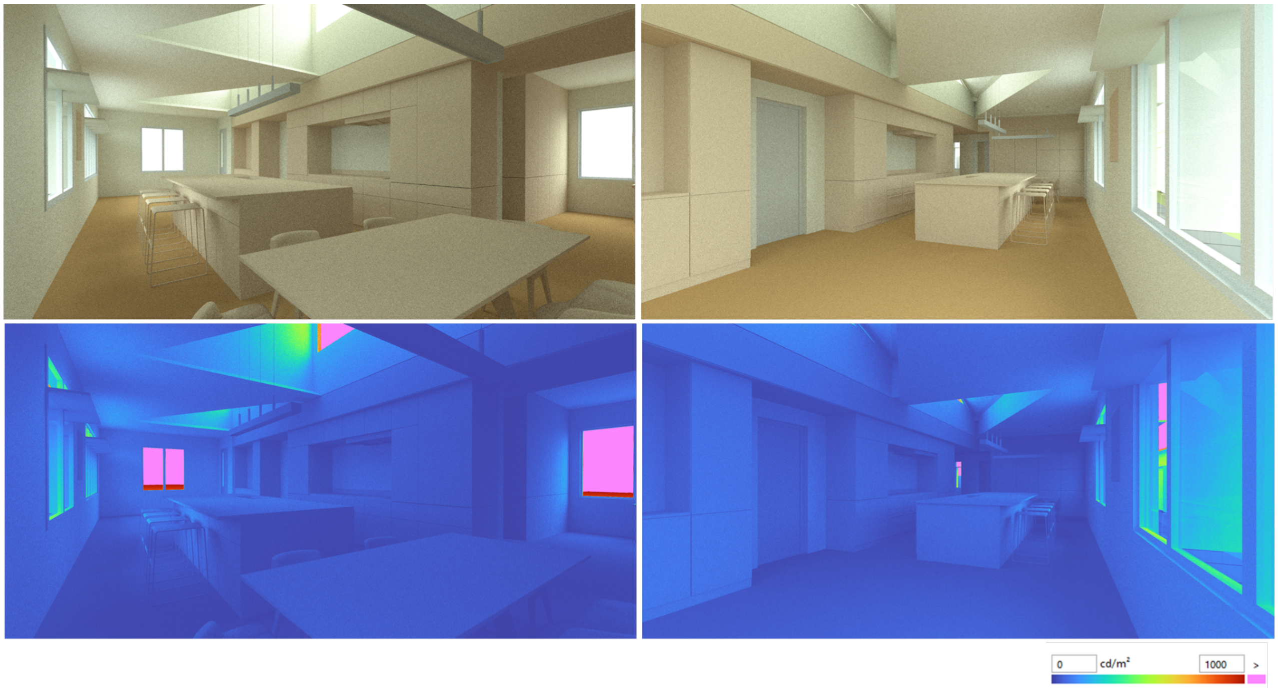

Figure 7: High Dynamic Range Images of Living Room and False Color Luminance Distribution

Throughout the year only a small area of the house receives direct sunlight for less than 250 hours.

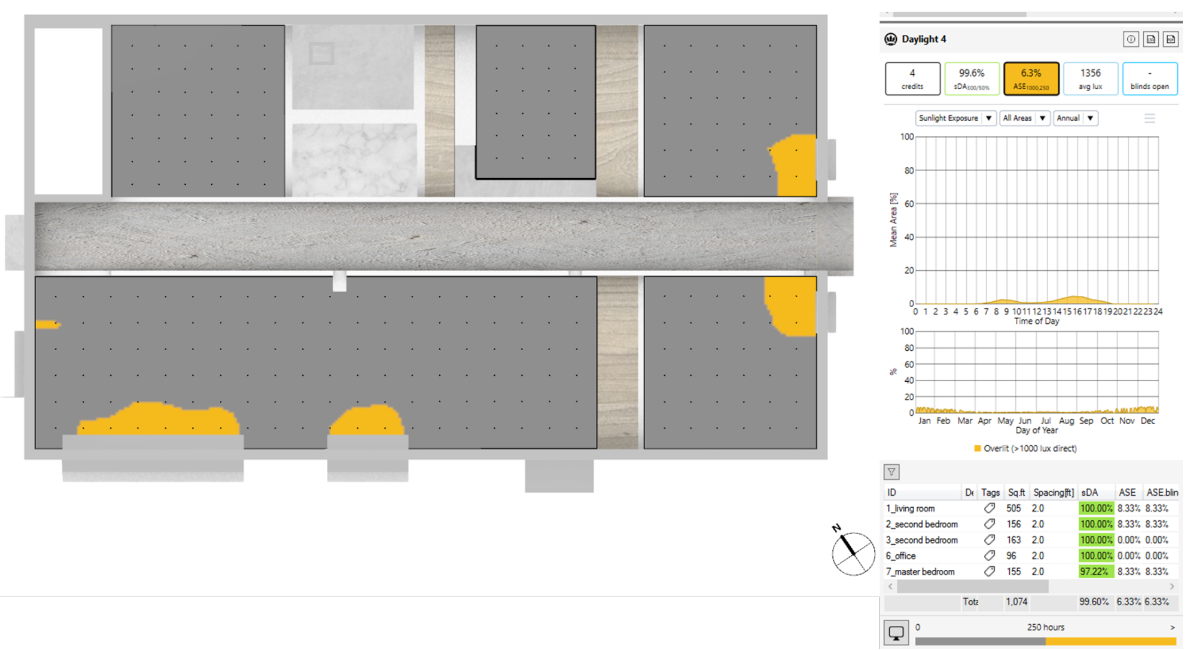

Figure 8: Annual Sunlight Exposure (ASE): 6.3%

Circadian Lighting Design - Equivalent Melanopic Lux (EML) Healthy circadian light (EML>250) is achieved for at least four hours (9:00 AM – 1:00 PM) between the Vernal Equinox and Summer Solstice in more than 99% of the house. The M/P (Melanopic/Photopic) Ratio >1 indicates how daylighting, with its blue light energy, will promote alertness in house occupants.

Figure 9: Circadian Lighting Design (June)

Healthy circadian light (EML>250) is achieved for at least four hours (9:00 AM – 1:00 PM) between the Autumnal Equinox and Winter Solstice in more than 84% of the house. The M/P (Melanopic/Photopic) Ratio >1 indicates how daylighting, with its blue light energy, will promote alertness in house occupants.

Figure 10: Circadian Lighting Design (December)