SU+RE HOUSE | JURY NARRATIVES

THE FUTURE OF COASTAL HOUSING.
DESIGNED + BUILT BY STEVENS STUDENTS.

Stevens Institute of Technology
U.S. Department of Energy Solar Decathlon 2015

SU+RE HOUSE

THE FUTURE OF COASTAL HOUSING.
DESIGNED + BUILT BY STEVENS STUDENTS.

Contents

ARCHITECTURE

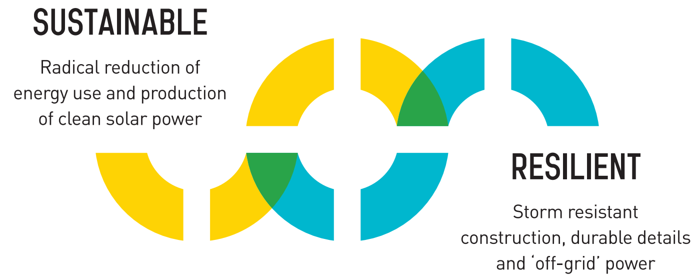
Coastal towns and cities across the Northeastern US, with their high population density, aged utility infrastructure, and unique geography, are increasingly vulnerable to climate change related storm events. In October 2012 superstorm Sandy highlighted the fragility of our current coastal building types and made clear the need for a new model of design and construction which works to understand and mitigate these weaknesses.

Dramatic changes in public policy, championed by both The Federal Emergency Management Agency (FEMA) and the National Flood Insurance Program (NFIP) are driving the rebuilding of these shore communities, often resulting in costly renovations, un-sustainable neighborhood configurations and in direct conflict with concurrent government policies such as The American with Disabilities Act (ADA). The SURE HOUSE demonstrates a series of new design solutions to these conflicting public policies and environmental imperatives.

At Stevens Institute of Technology, the 2015 Solar Decathlon started with the challenge:

Can we design a home for coastal New Jersey that dramatically reduces its energy use while protecting itself from the realities of a changing, more extreme climate?

The SURE HOUSE is our response.



The SURE HOUSE merges the iconic 20th century shore home with 21st century building science. Utilizing innovative renewable energy technologies, a 'Passive House' level building envelope, and rugged glass-fiber-composite materials to flood-proof the home, the SURE HOUSE is a high-performance, net-zero-energy home, armored against extreme weather, designed for the contemporary lifestyle of the Jersey Shore and other vulnerable coastal communities.

SUSTAINABLE

At Stevens, we recognize that energy use in the home and workplace is directly connected to the growing problem of climate change. Reducing our energy consumption by designing higher performing, compact homes that are both functional, comfortable and desirable is the first critical step towards a modern, sustainable architecture for New Jersey and beyond.

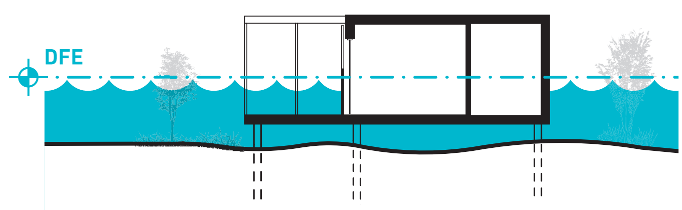
This is what informed the architectural design of the house. Configured about a compact form, thickly insulated and air-sealed walls eliminate thermal bridging and minimize energy losses while advanced glazing brings in free solar heat during the winter months. As a result of these passive design strategies, the SURE HOUSE has a greatly reduced carbon footprint requiring 91% less energy than a typical New Jersey home. Photovoltaic (PV) arrays on both the rooftop and operable shutters easily provide energy in excess of the home's modest demands.

The Stevens team considers a truly sustainable home in the era of climate change, one that prioritizes low energy use, and integrates right-sized renewable generation to supply the home's needs. Low consumption, low production.

RESILIENT

In October of 2012, Hurricane Sandy wreaked havoc along the east coast of the US. In New Jersey alone there was an estimated 29.4 billion dollars in damages, 346,000 homes affected, and almost two and a half million people left without power, in some cases for over 10 days. Recovery from this storm and associated flooding is ongoing to this day, as many New Jersey homeowners grapple with the large costs of rebuilding and struggle to adapt to complicated new home building regulations. Damage from this storm to Hoboken, the home of the Stevens Institute of Technology's campus, and to the New Jersey shore was extensive and many students on the SURE HOUSE team were directly affected by this historic event.

The Stevens design team recognizes that in a world of more frequent and stronger storms, the ability to absorb and adapt to change is more important than ever. Successfully weathering the next storm and its aftermath is one of the primary goals in the design of the SURE HOUSE prototype.



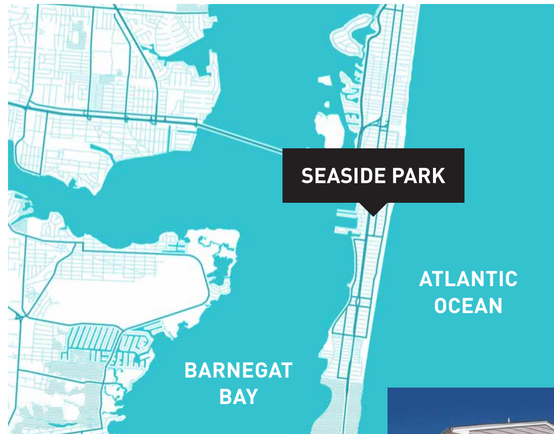
The SURE HOUSE introduces unique 'dry flood-proofing' methods to residential construction. Innovative wall and floor flood-proofing, utilizing durable composite sheathing materials adapted from the boating industry, were developed by the student team to render the SURE House's building envelope flood proof up to the FEMA AE 6/7 Zone (+ 6/7 feet of water above sea-level).

Designed and fabricated utilizing glass-fiber composite materials, the custom storm shutter system serves to protect the large glazed openings of the home from both air-borne debris impact and water infiltration during a storm event while also providing deterrence from the vandalism that often occurs in the aftermath of a calamitous event. During extended power outages, a 'resilient' solar array is capable of supplying critical amounts of energy and hot water to the home, without the use of battery storage or grid infrastructure.

CONTEXT | LOCATION | TARGET MARKET

The New Jersey and the New York City coastline boasts a rich history as a home to diverse middle-class communities. While most well known as summer-time recreation areas (Atlantic City, Asbury Park, Coney Island, Rockaway Beach), these shore communities are also home to multiple generations of tight-knit, full-time residents, who represent the target market of the SURE HOUSE. The architecture of these neighborhoods has evolved over the years; from the historic homes of the 1920's, to mid-century modernism to the current encroachment of a suburban aesthetic. The SURE HOUSE draws from this rich overlap of design cultures as it seeks to address the most pressing issue facing these communities today: protection from rising sea levels and recurring severe coastal storms.

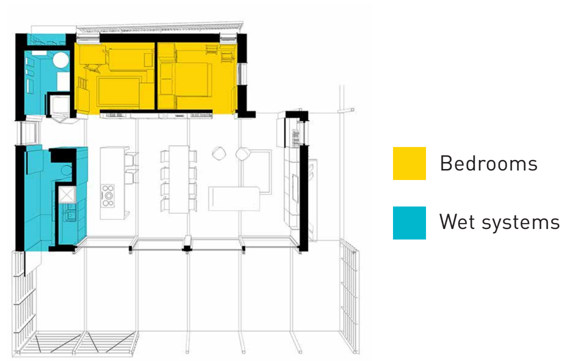
A storm-proof, durable and low-energy home design, situated at elevations appropriate to the street level activity of existing neighborhoods and accessible to people of all ages and abilities, will help to revitalize and strengthen the vibrant communities of the Jersey Shore and surrounding New York coastline.



The Jersey Shore barrier islands are a narrow strip of land pinched between two bodies of water. As a result, FEMA mandates extreme elevation methods for homes in these vulnerable areas.

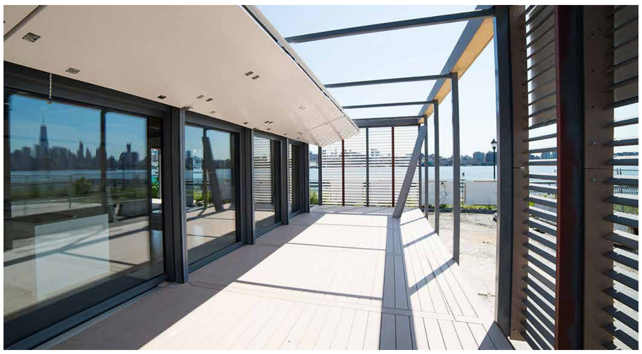
ORGANIZATION AND CONCEPT

The architecture of the SURE HOUSE is organized around three principles: a **clear expression of closed (solid) vs. open (terrace) massing**, **a seamless relationship between indoor and outdoor spaces** (oriented to directional views), and a **delicate balance between nostalgic (vernacular) and technologically progressive (durable) material choices.**



1. MASSING

The compact form of the modest 1,000 sf. home is organized around the private and public programmatic requirements. Along the home's northern exposure, two bedrooms provide private sleeping spaces. Along the west, all of the home's 'wet' systems of bathroom, mechanical room and kitchen are tightly compacted minimizing the cost and complexity of the construction. The east side provides a thickened media and storage wall to accommodate a family's accumulated accessories. These three "closed" zones surround and partially enclose an expansive living, dining and kitchen space, visually open to the home's south deck.



2. INDOOR vs. OUTDOOR

Operable glazed openings along the southern side allow the comfortable living zones of the home's interior to seamlessly extend onto a large southern terrace. With an equal amount of interior and exterior space, the home embraces the social culture of shore living. During warm weather, a family can take advantage of an expanded home of 2,000 sf of usable interior and exterior spaces. During the colder winter months, a family can compress into an efficient and functional 1,000 sf of comfortable interior space.

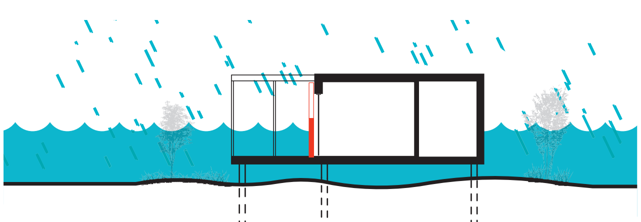
The bathroom, too, is inspired by this shore lifestyle. A private entrance from the southern terrace allows for direct access to the bathroom. This atypical configuration allows the bathroom to serve as a 'mudroom' when returning from the beach, eliminating the unwanted tracking of sand throughout the home.

The large overhang of the home's shutters provide ample solar shading during the moderate seasons while optimizing solar gain during the colder winter months, when the sun is lower in the southern sky. During a storm or crisis event, the shutters are deployed into a closed position providing critical protection from water, debris and vandalism.

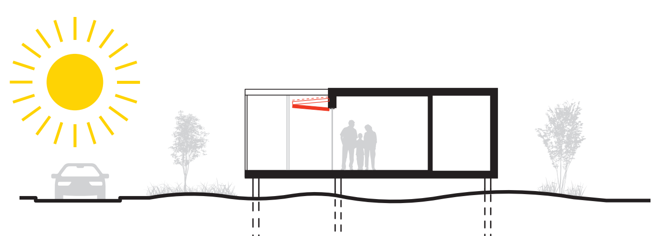
3. MATERIALITY

Decisions about the SURE HOUSE's materiality started by revisiting the history of the region. Historically, the shore neighborhoods had a great deal of architectural integrity. The homes were mostly hand built by their owners based on tried-and-true techniques learned from generations spent adapting building practices to the seaside environment. From the traditional cedar shake beach bungalows of the 1920's, to the aluminum-sided industrialized homes of the post-war era, each period provides a lesson in material and detailing for this unique place.

The challenge for a contemporary shore home is to achieve a delicate balance between the vernacular materials long accepted throughout the region with the more modern, durable materials now being developed by contemporary manufacturers in the home building industry. In striving to achieve this balance, weather resistance is integrated into every decision in the design of the SURE HOUSE, down to each and every detail.



RESILIENT | closed



SUSTAINABLE | open

The North, West and East facades of the home are clad in a durable cedar-shake rain screen facade over horizontal wood battens. This time-honored method of installation creates an air space between the siding and the weather barrier to allow for drainage and evaporation, increasing the lifespan of the siding and finishes significantly.

The interior of the SURE HOUSE has a relaxed aesthetic, with built-in cabinetry walls and ceilings clad in Baltic Birch plywood, and a bright, clean kitchen. This warm, textured wood box with its white accents and exposed edges is juxtaposed against the glass, steel and fiber-composite southern porch. Composed primarily of high-durability fiber composite materials for the decking, louvers and siding, this outdoor living room will easily weather the extremes of a shore climate.

INTERIOR COMFORT

By incorporating German 'Passive House' standards into every aspect of the SURE HOUSE, we are able to create a healthy, comfortable, and durable home with very low levels of energy use. Thickly insulated walls and airtight construction combine to provide SURE HOUSE with unmatched interior thermal comfort thanks to very low levels of temperature stratification or temperature asymmetry. The continuous mechanical ventilation (with heat recovery) of fresh, filtered air provides a healthy conditioned space even in the winter months when opening a window for fresh air is less desirable.

The southern glass wall affords expansive views of sea and sky. A generous ceiling height and strategic placement of west, north, and east glazing allows daylight to penetrate deeply into the open floor plan. Luminous interior finishes with medium to high surface reflectances were selected to maximize daylight diffusion and minimize glare. Simple, operable visual comfort shades provide additional glare control and privacy screening.

When required, layers of electric lighting provide each room with unique task and ambient illumination. The south porch, main living space, and east porch are connected by vertical and horizontal washes of warm white light, delivered from dramatic track, pendant, and in-grade LED sources of high color quality. Bathroom, kitchen, and bedroom electric lighting adjusts to the subtle daily variations in the color temperature of sunlight. Morning showers are high color temperature and invigorating; midnight trips to the refrigerator are lit with a warm, low-intensity glow. These subtle and intuitive shifts in electric lighting are in harmony with our circadian cycles of wake and sleep.

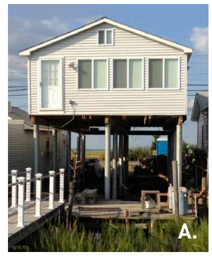
CONCLUSION

The SURE HOUSE is designed as a comfortable, low energy home which resists flood and storm damage through an innovative 'dry-flood-proofing' approach. This sustainable and resilient home is a model of how coastal communities can affordably build in a world of rising temperatures, regular power disruptions, and increasingly severe storms.

MARKET APPEAL

The SURE HOUSE provides a new model of design and construction for the post-Hurricane Sandy Jersey Shore. It delivers the active lifestyle of a typical shore home while also satisfying the desire for energy efficiency, practicality, affordability, and protection from increasingly severe storm events.

A. Home elevation methods mandated by FEMA guidelines. **B.** SURE HOUSE design allows it to remain at street level.



THE JERSEY SHORE IN AN ERA OF CLIMATE CHANGE

In October of 2012 Hurricane Sandy wreaked havoc along the east coast of the US. In New Jersey alone there were more than 29 billion dollars in damages, 346,000 homes affected, and almost two and a half million people left without power. Recovery from this storm and associated flooding is ongoing to this day as many New Jersey homeowners grapple with the large costs of rebuilding and struggle to adapt to complicated new home building regulations.

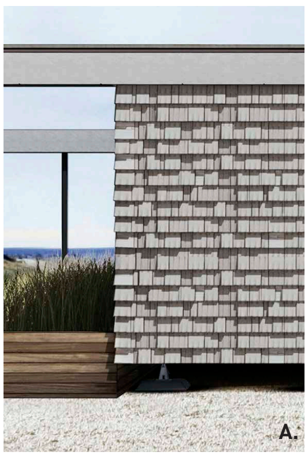
Despite the rallying cry of "Jersey Strong" in response to the devastation of Superstorm Sandy, members of these communities have faced disappointment with their attempts at rebuilding. At the end of 2014, just 330 homes in the State of New Jersey had completed their reconstruction through the Federal RREM Program (Reconstruction, Rehabilitation, Elevation and Mitigation). The program had initially received more than 15,000 applicants. The SURE HOUSE targets this unique problem:

How do you rebuild, restore, and maintain these longstanding and beloved shore communities with the assurance of affordability and protection from the very thing that destroyed them?

While the FEMA guidelines for post-Sandy reconstruction are well intentioned, their mandate of elevating homes well above street level has had serious unintended consequences on the streetscapes and finances of shore communities located within flood zones. The SURE HOUSE offers an alternative that can keep buildings at street level, enabling homeowners to maintain the scale of the traditional shore neighborhood while still having the peace of mind that their homes will withstand the next storm.

INNOVATION IN A FAMILIAR PACKAGE

Though the SURE HOUSE is technologically innovative, it utilizes conventional framing and finish systems, smartly re-engineered to improve energy performance and storm resilience. In this way, it has been carefully designed with the typical building contractor in mind. For example, though the exterior finishes of the SURE HOUSE were chosen for their durability and resilience to the harsh salt-air environment, their essential appeal is in their familiarity and reference to the iconic shore vernacular of wood boardwalks, shingled homes, covered porches, and sun-bleached finishes, all of which will be familiar to the local shore contractor. In addition, state of the art energy performance is supplied by careful construction detailing utilizing proven methodologies and equipment therefore allowing the conscientious contractor to innovate and build better with his or her existing tool set and expertise. Even major innovations, such as the large, operable storm shutters and 'flood-sheathing', were realized using materials and methods adapted from boat building, a long-standing and thriving industry in the shore region. The result is powerful innovation in a practical, repeatable, and hence competitively affordable package.



East, west and north-facing facades of the SURE HOUSE are covered with traditionally-inspired cedar shakes **(A)** while the south side of the home is comprised of extra large high-performance windows secured with a state-of-the-art innovative fiber composite storm shutter system **(B)**.

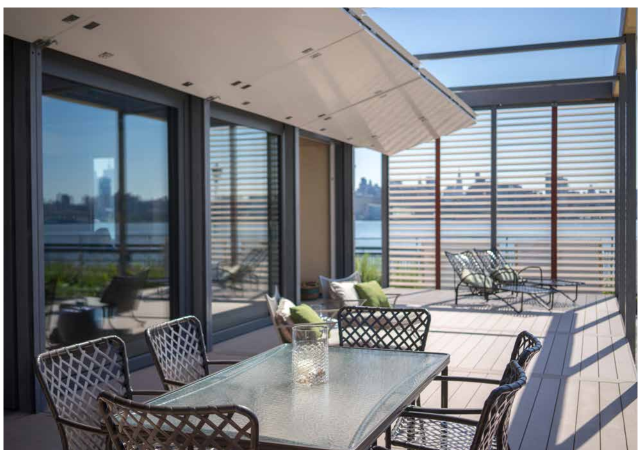
DELIVERING A RESILIENT SHORE LIFESTYLE AFFORDABLY

The core appeal of a shore home stems from its direct relationship to the outdoors; the smell of the salt air, cool evening breezes coming off of the ocean, awakening to the sound of seagulls. During warmer months, the homeowner in this market embraces this setting by transitioning to a highly social set of expanded outdoor activities. Coffee is shared with neighbors on the porch. Meals are prepared and eaten outdoors. Tasks such as showering and laundry have migrated to private terraces. The luxury of napping in a hammock is rediscovered. This all changes during

the winter when shore communities become quieter and semi-dormant. Residents then take on a form of hibernation where comfort and warmth matter most.

The SURE HOUSE celebrates and enables this lifestyle by adapting with the seasons. During most of the year, indoor/outdoor living is a natural with interior and exterior rooms of similar square footage seamlessly connected through an operable floor to ceiling wall of glass. In the winter, a retreat inside is enabled that maximizes comfort economically while maintaining the outdoor connection pivotal to shore living. A technologically advanced design delivers warm wood interiors and living spaces sunlit by the same floor to ceiling southern glass while maintaining exacting climate control and draft-free comfort... all at a fraction of the monthly energy use of a typical home. What's more, all of this is accomplished in a compact and functional 1,000sf package that balances efficiency and pleasure.

Efficiency is maximized through careful organization of the space. The kitchen, bathroom, and mechanical rooms are clustered along a "wet wall" on the west side of the house. Plumbing and mechanical runs are thereby minimized, cutting heat loss through ducting and plumbing while reducing construction costs and giving centralized access to basic necessities. The two bedrooms are set to the north, taking advantage of indirect daylight, and adjacent to the kitchen and bath for convenience which minimizes hallway length. These compact yet functional areas surround and partially enclose the expansive living, dining and kitchen space which opens up to the home's southern deck. Floor to ceiling sliding glass doors create a seamless connection to this outdoor room, essentially doubling the house's living space and embracing the indoor/outdoor culture of shore living.



The rest of the house follows suit. For example, a private entrance from the southern deck allows the bathroom to serve as a 'mudroom' when returning from the beach, eliminating the unwanted tracking of sand throughout the home. The large 5' overhang of the southern shutters provide ample solar shading during the moderate seasons while optimizing solar gain during the colder winter months when the sun is lower in the southern sky. The spacious northern entry porch provides a social gathering place at the juncture between public and private, indoors and out.

MERGING THE ICONIC 20TH CENTURY SHORE HOME WITH 21ST CENTURY BUILDING SCIENCE

By rigorously incorporating German 'Passive House' standards into the design, the SURE HOUSE provides a healthy, comfortable, and durable living environment while reducing energy consumption by up to 91% compared to a typical New Jersey home. Thickly insulated walls, elimination of 'thermal bridging', airtight construction, triple pane glazing, and an intelligent HVAC system all combine to provide SURE HOUSE with unmatched interior thermal comfort. An ERV (Energy Recovery Ventilator) supplies continuous mechanical ventilation of fresh, filtered air providing a healthy conditioned space even during the winter months when opening a window for fresh air is less desirable.

The expansive southern exposure allows natural daylight to penetrate deeply into the open floor plan, with light-toned interior wood finishes carefully chosen to ensure a minimum level of glare. Simple interior roller shades provide additional solar control when needed. To supplement the natural daylight, adjustable track lighting is used in the main living space, allowing variable area illumination as well as exacting task lighting to accommodate everyday activities.

Additional layers of electric lighting provide each room with unique task and ambient illumination. The south porch, main living space, and east porch are connected by vertical and horizontal washes of warm white light, delivered from track, pendant, and in-grade LED sources of high color quality. Bathroom, kitchen, and bedroom electric lighting adjusts color subtly throughout the day based on presets. These subtle and intuitive shifts in electric lighting color are in harmony with our circadian cycles of wake and sleep.

Atypical for a home of this size, the SURE HOUSE, the SUREHOUSE offers a multi-zoned and efficient forced-air heating and cooling system. This enables the homeowner to control temperatures separately in each of the various rooms through wireless thermostats thereby increasing interior comfort while also reducing energy use. The ERV also has easy to use controls. Preset 'away', 'standard' or 'party' modes allow for effective yet intuitive adjustment of this system.

The SURE HOUSE introduces unique **'dry flood-proofing'** methods to residential construction. Innovative wall and floor flood-proofing, utilizing durable composite sheathing materials adapted from the boating industry, were developed to render the SURE HOUSE's building envelope flood-proof up to the FEMA AE 6/7 Zone (+ 6/7 feet of water above sea-level). To protect the expansive glass windows and doors, a custom storm shutter system was designed and fabricated utilizing glass-fiber composite materials. During a storm or crisis event, the shutters are closed and locked from the outside, providing critical protection from rising water, air-borne debris and vandalism.
The house is fully solar powered, with production capacity projected to fully meet consumption needs even in worst case weather scenarios. SURE HOUSE is grid-tied for convenience and safety, but during extended power outages a 'resilient' solar

array is capable of supplying limited amounts of energy and hot water to the home and can even serve as a small power hub for the neighborhood. This system engineered by the design team includes what may be the first hybrid heat pump + direct solar electric water heater in the US.

Taken together, these innovations offer a bold alternative to existing types of shore home construction. The SURE HOUSE approach allows residents to stay at street level while still being protected, an absolute necessity if the indoor/outdoor lifestyle and social culture of shore communities is to be maintained.

A SHORE HOME FOR THE EXTENDED FAMILY

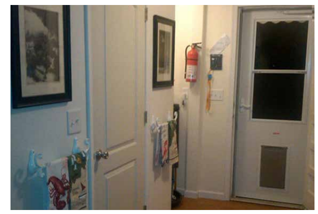
The towns of the Jersey Shore stretch south from Manhattan more than 150 miles to the southern tip at Cape May. While much of New Jersey's population flocks to the shore on summer weekends, year round living is not uncommon for active residents who seek a connection with the beautiful shore environment during its quieter months as well. **The SURE HOUSE Target Market, then, is a young, active, professional couple with an extended family who visit regularly. With an annual income of $80,000 –125,000** these are the members of the shore community who sustain the local economy year-round and anchor the population during the non-summer months.

To accommodate this market, the SURE HOUSE's compact, single floor living and centralized floor plan simplifies the tasks of daily living and maintenance for busy couples. At the same time, a dedicated second bedroom and ample covered outdoor space accommodate extended family easily, particularly over long holidays and during the summer months that bring the lure of the beach. The home's intuitive climate control system guarantees exacting comfort to meet specific and changing needs. The styling is elegant and simple, harkening back to the shore houses of 50 years ago while delivering contemporary amenities and state of the art performance.

Other features are more generally appealing, expanding market flexibility and increasing resale and investment potential. Core to project marketability is the fact that build cost for the house is comparable to existing homes in the market, most of which are mid-century aging bungalows that are either teardowns or in need of significant renovation. This means that non-existent power bills (the house creates a surplus of power on site) and the peace of mind and financial benefits of a storm resilient power system and innovative storm shutters come with little to no upfront premium. In fact, these features continue to save money for owners throughout the life of the building, generating long-term net savings in addition to improved comfort and security. Finally, the house is a state-of-the-art response to the realities of climate change and a transforming energy market. Burning no fossil fuels while creating a consistently comfortable, healthy indoor environment, it is a distinctive showpiece of self-sufficiency and storm resilience. Leading by example, the SURE HOUSE is a way for an owner to really make a difference. For the right client, the clarity of conscience that comes along with that fact is priceless.

57 DECATUR AVENUE
Seaside Park, NJ

Purchase Price: $400,000
Year Built: 1940
Est. Renovation Cost: $250,000
TOTAL COST: $650,000*

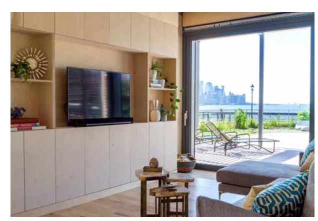


110 G STREET
Seaside Park, NJ

Purchase Price: $600,000
Year Built: 1924
Est. Renovation Cost: $200,000
TOTAL COST: $800,000*

43 BRIGHTON AVENUE
Seaside Park, NJ

Purchase Price: $665,000
Year Built: 1950
Est. Renovation Cost: $250,000
TOTAL COST: $915,000*



SURE HOUSE
Seaside Park, NJ

Purchase Price (land): $400,000
Year Built: 2015
Est. Construction Cost: $340,000
TOTAL COST: $740,000**

* Total Cost includes both Purchase Price plus estimated renovation cost to meet contemporary market rate finishes. Renovation costs do not include additional FEMA Requirements or provisions for sustainable engineering systems.

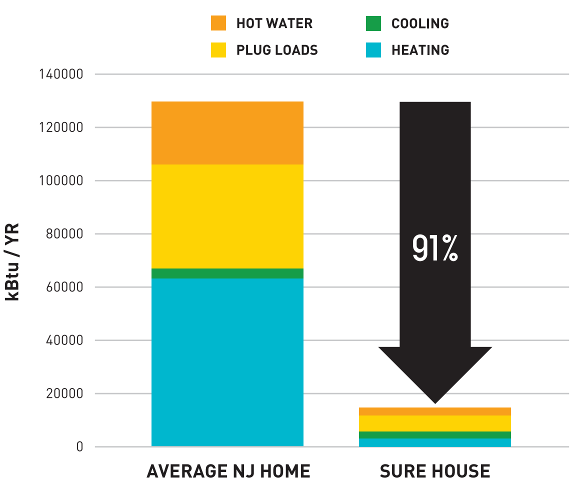
** Total Cost includes land purchase plus construction cost. Total Move-In Cost includes solar array, waterproofing sheathing system and composite storm shutter system.

ENGINEERING

PART 1: INTRODUCTION TO SURE HOUSE

Sustainable in its everyday operation and resilient to an increasingly severe climate, the SURE HOUSE is a prototype for a New Jersey shore home which is carefully engineered to create a healthy, durable and comfortable building. The northeast US coastline is uniquely vulnerable to climate-change related storm events because of the density of its towns and cities, the age of its utility infrastructure, and the unique geography and weather patterns of the north Atlantic. In October 2012, superstorm Sandy accentuated these weaknesses and reminded us of the vital need for innovative design and intensional engineering to address these vulnerabilities.

YEARLY SITE ENERGY CONSUMPTION COMPARISON



The SURE HOUSE is engineered to use 91% less energy than a typical New Jersey home through simple Passive House measures. Along with an innovative 'resilient' solar energy system capable of offsetting electricity consumption over a year, the SURE HOUSE integrates resilience to flood and storm damage through custom engineered 'dry-flood proofing' measures. These innovations combine to create a model for how coastal communities can, and must, be built in a world of rising temperatures, regular power disruptions, and increasingly severe storms.

SUSTAINABILITY

THE NEED FOR SUSTAINABILITY

The way energy is used in homes and workplaces is directly connected to the growing problem of climate change. New Jersey homes consume more energy per-building and are typically 20 percent larger than the average US home. Reducing energy consumption by designing compact, energy efficient homes that are comfortable and functional is the first critical step to creating more sustainable architecture in New Jersey.

The SURE HOUSE's sustainability focus is centered on energy conservation and utilizing Passive House design methods to reduce energy needs. This focus means the SURE HOUSE can have a much smaller solar photovoltaic (PV) array than a typical home of its size and can still produce more energy over a year than it consumes. As a result, the house has a very small carbon footprint, which is the only way to build a truly sustainable home in an era of climate change.

PASSIVE HOUSE & THE BUILDING ENVELOPE

The SURE HOUSE is designed and built to achieve the German Passive House standard, which mandates strict caps on energy consumption as a route towards global climate change mitigation. This standard requires that both heating and cooling energy be held to an ambitious 4.75 kBtu/sf·yr or less, and total 'Primary' (Source) Energy to less than 38 kBtu/sf·yr. In addition, whole-building air-tightness must be tested at less than 0.6 air changes per hour (ACH) when measured at 50 Pascals above atmospheric pressure.

While the Passive House standard is met by reaching a very low level of energy consumption and a high level of air tightness, these target values are primarily derived by focusing on increasing interior thermal comfort and the long-term durability of the building. A building that is designed to control heat gains and losses as well as a Passive House does, will achieve a high level of occupant comfort due to the elimination of surface-temperature asymmetry, air temperature stratification, and cold-air drafts. The durability of the home is increased because of the control of air-transported moisture within its wall, floor, and roof assemblies. These techniques combine to create a comfortable, durable, and healthy home which uses a fraction of the energy of a typical house.

NET-ZERO ENERGY PRODUCTION

The SURE HOUSE's primary engineering goal is to create a comfortable and healthy home which produces more energy over the course of a year than it consumes. To supply the energy needs of SURE HOUSE, the home is equipped with two distinct solar-energy systems that together produce all of the AC electricity and hot water necessary for the building. The house not only produces more energy than it consumes, but is engineered with an innovative 'resilient' solar energy system capable of producing limited AC power and hot water when the utility grid is not functioning.

RESILIENCE

THE NEED FOR RESILIENCE

Superstorm Sandy made landfall just northeast of Atlantic City, NJ on October 29th, 2012, destroying over 650,000 homes and leaving 8.5 million people without power[1] across the eastern US. Recovery from this storm and associated flooding is ongoing to this day, as many New Jersey homeowners grapple with the large costs of rebuilding and struggle to adapt to complicated new home building regulations. Damage from this storm to Hoboken, home to Stevens Institute of Technology, and the New Jersey shore was extensive and many students on the SURE HOUSE team were directly affected by this historic event.

Flooding after Hurricane Sandy

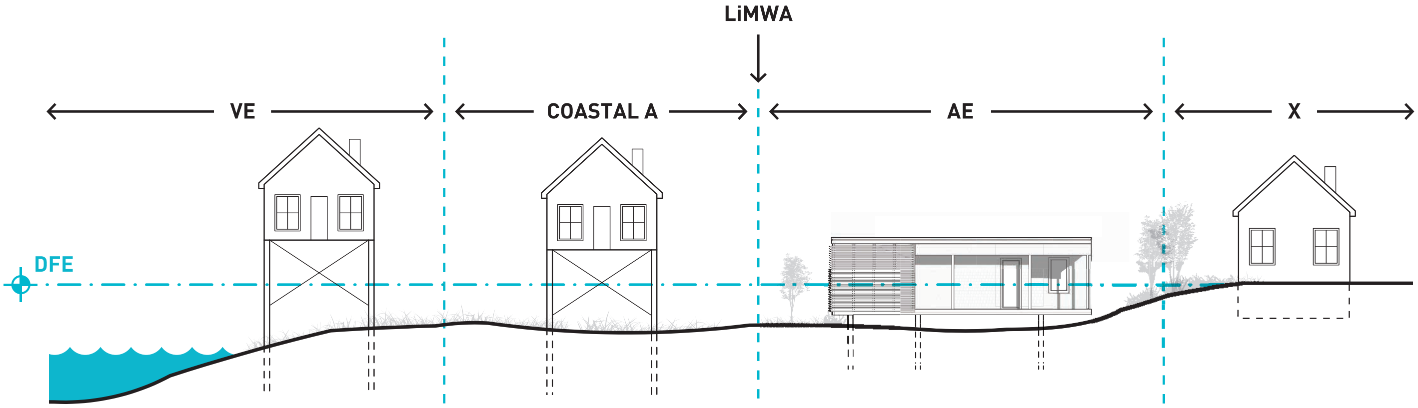
The Stevens design team recognizes that in a world of more frequent and stronger storms the ability to absorb and adapt to change is more important than ever. Successfully weathering the next storm and its aftermath is one of the primary goals in the design of the SURE HOUSE prototype.

RESILIENT COASTAL CONSTRUCTION AND FEMA

While there are many potential engineering solutions to the problem of flooding, current FEMA (Federal Emergency Management Agency) and NFIP (National Flood Insurance Program) regulations for residential buildings in coastal flood areas only allow for homes to be raised above potential flood elevations [Flood Insurance Reform Act, 2004]. Recent updates to regional flood maps designate much higher design flood elevations (DFEs) than previous versions, forcing homeowners to build or renovate their homes to unprecedented standards. This rigidly prescriptive approach to coastal engineering and design is not only raising construction costs for homeowners attempting to rebuild from Superstorm Sandy, but limiting physical access to homes for elderly or handicapped residents.

In addition to the financial and physical burden, many New Jersey shore communities have unique traditions of architecture and streetscape design

1. See Appendix 9: "Hurricane/Post-Tropical Cyclone Sandy" for Citation Information



that are being destroyed by the elevated home design model. There is a compelling need for innovative solutions to the very real problem of severe coastal flooding.

FLOOD-PROOF DESIGN

In order to preserve the historic 'Jersey shore' streetscape pattern and maximize accessibility, the SURE HOUSE is not elevated on tall piles but instead remains just above ground level and has adapted dry flood-proofing measures as flood and hurricane protection. According to FEMA, dry flood-proofing is the "...ability to limit water accumulation [during a flood event] to a maximum of four inches over the span of 24 hours ... (USACE 1995)."

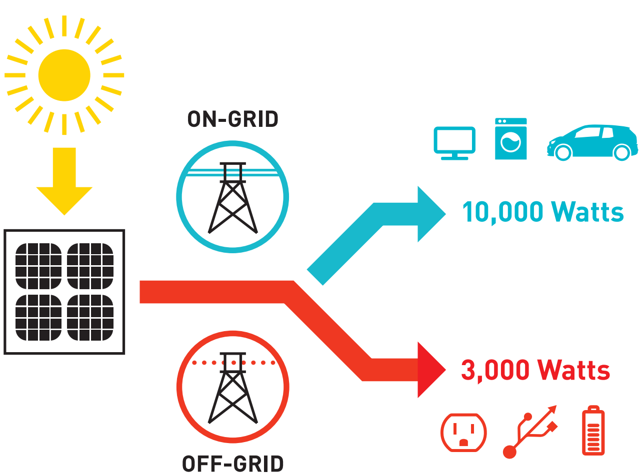
Designed for a 5 foot DFE in a non-coastal AE zone (common along the New Jersey shore), the primary flood-proofing is comprised of high-strength plastic sheathing and sealant materials adopted from the marine boat industry that seal the floor and walls of the home. For an explanation of flood zone choice see Appendix 8A-1. Additionally, custom engineered glass-fiber-composite flood shutters and plugs tightly seal all windows and doors during storm situations. These innovative wall, floor, and window-shutter designs ensure that the SURE HOUSE residential dry-flood-proofed prototype will have minimal to no leakage for at least seventy-two hours. The prototype has also been carefully designed to resist the associated flood loads including hydrostatic, hydrodynamic, buoyant, and impact forces. For a summary of parameters used in flood-proofing design see Appendix 8A-1a.

'STANDBY' POWER SYSTEM

The solar energy systems of SURE HOUSE are designed to supply more AC energy on a yearly basis than the home consumes, (see Appendix 2A and 5C). The systems have also been designed to be uniquely resilient to natural disasters and other grid disruption events. In the northeast US, storm events regularly leave communities without grid power for days and even weeks, often during periods of intense and cold weather. In order to mitigate against these risks the SURE HOUSE is designed to use a transformerless inverter solar-electric system which is able to isolate or 'island' itself from the grid during disruption events and continue to produce up to 3 kW of standby power while the sun is shining to provide critical energy to charge electronic devices and small appliances.

After Hurricane Sandy, many homes and businesses that were lucky enough to still have electricity, shared power strips with their neighbors, especially to charge their portable communication devices to stay connected to family and friends. In order to let the SURE HOUSE's neighbors access the resilient power after a storm, the design of the house includes accessible exterior, marine-grade USB receptacles.

The interior of the home has induction chargers built directly into the kitchen island for wireless charging, along with a standard electrical receptacle to allow for a broader range of devices to be powered during a blackout. This system presents a simple, safe, clean alternative to diesel-fueled backup generators or expensive battery systems and is a model for the kind of resilient, smartly designed infrastructure shore communities will need if they are to adapt to the combination of rising sea levels and increasingly severe storms.



PART 2: SURE HOUSE ENGINEERING DESIGN AND INNOVATION

YEARLY ENERGY MODEL (COASTAL NEW JERSEY)

To design the SURE HOUSE's envelope, windows, solar-shading, and mechanical systems to be energy efficient and economical, detailed local climate data for the planned post-competition site in New Jersey was used to drive yearly energy-use simulations during the design phase, see Appendix 1. Using the Passive House Planning Package (PHPP), the monthly and yearly energy consumption of the SURE HOUSE was modeled to ensure that the house meets the Passive House standard. This modeling tool was chosen for the design phase since it has the flexibility and the speed needed to inform the design team's decisions regarding massing, window configuration and orientation, envelope R-values, and mechanical systems.

The PHPP model includes data for envelope geometry and orientation, window placement, shading geometry, and thermal bridging in its final energy balance. The results of this model predict that the SURE HOUSE will use 31,046 kBtu (36,888 BTU/sf·yr) of primary energy per year with 5,972 kBtu (7.1 kBtu/sf·yr) per year for cooling and 5,298 (6.3 kBtu/sf·yr) for heating. For more information on the yearly energy model see Appendix 2A.

COMPETITION-PERIOD ENERGY MODEL

In addition to the monthly New Jersey energy use modeling, hourly energy consumption during the Solar Decathlon competition period was simulated to ensure that the home would function well in the very unique climate of southern California. For this 'contest simulation', a worst case hourly weather data scenario was created based on 15 years of recorded data. See Appendix 1 for the results of the team's climate analysis.

The home's hourly interior temperature, relative humidity, and energy use during the competition period in Irvine was simulated in order to ensure that the total grid-tied AC energy consumption will be below 175 kWh (the upper limit in the Solar Decathlon 'Energy Balance' contest). A static calculation of appliance energy consumption based on Energy Star ratings, as well as an hourly energy model of the HVAC and hot water consumption for the house were created and combined for a total simulation of energy usage which allowed to design team to make decisions regarding envelope, shading, equipment type and other energy-generation. The hourly energy models were primarily created in TRNSYS, a powerful transient systems analysis tool. These simulations drove choices on the building form, envelope, materials and equipment. To ensure competition energy models were correct, the SURE HOUSE team has currently completed and will complete another dry-run of the entire competition utilizing the final prototype. For results and explanations of the full-house test see Appendix 2C.

THE PASSIVE HOUSE BUILDING ENVELOPE

INSULATION

The envelope R-Values of the SURE HOUSE were determined by considering the constructability, performance, costs, and testing extensively through the PHPP and physical mock-ups. In general, the home has twice as much wall insulation as required by NJ local codes (2009 IECC-NJ Section 402) in order to cost-effectively achieve a comfortable, low energy home that meets Passive HouseStandards. See Appendix 3A for a detailed explanation of the envelope assemblies.

In the construction of the SURE HOUSE's walls, the wood 2x6 structural walls are filled with mineral wool batt, a durable and water resistant material. Over the exterior sheathing, 1-¼" continuous mineral wool board is installed, and the interior of these walls is also furred out with an additional 2-½" of mineral wool batt, increasing R values of the walls to 39.6 (Btu/h ft2F). Floor and roof cavities were each made 9-½" inches deep and filled with mineral wool batts. The roof has additional polyisocyanurate insulation applied to the top side, giving the floor and roof R values of 31.1 (Btu/h ft^2F) and 50.7 (Btu/h ft^2F) respectively. This unique 'triple-layer' insulation strategy is very flexible and forgiving to framing or cladding modifications required during construction, ensuring that the home achieves its modeled performance.

WINDOWS

The windows on the SURE HOUSE are high performance imported windows by Schuco. These windows are airtight, have very high R-Values, and high Solar Heat Gain Coefficients (SHGC). Oriented smartly, during the winter months these windows gain more heat energy from the sun than they lose via transmission overall, making them in effect part of the heating system of the home. High R-values also mean that surface temperatures will always stay within the comfortable range, even in the coldest part of the winter. Large sliding glass doors are used along the south which, when combined with proper shading during the summer, harvest solar heat throughout the winter months. Smaller, tilt-turn windows are used on the east, north and west sides to minimize winter-time loses. See Appendix 3B for shading analysis.

AIRTIGHT AND VAPOR BARRIER

Air-tight construction is central to the Passive House standard. The IRC 2009 (International Residential Code) requires an airtightness of less than 7.0 Air Changes per Hour (ACH) at 50 Pascals above atmospheric pressure (N1102.4.2.1). Compared to this, the Passive House standard requires less than 0.6 ACH at 50 Pascals above atmospheric pressure tested via blower-door under strict quality control conditions. This extremely high level of airtightness both reduces energy losses via infiltration, but also increases the durability of the home by ensuring that there is no risk of condensation from air-transported moisture vapor. Rigorous air sealing of the SURE HOUSE used an interior air-barrier/vapor-retarding membrane in between the main structural layer and the interior 'service chase.' This membrane, sealed with specialized airtight all-acrylic tapes, is capable of allowing moisture to move through it when humidity is high (summer), but becomes vapor closed when humidity levels drop (winter). This membrane keeps airborne moisture vapor safely away from the dew point in winter, but allows for effective drying of any trapped moisture during the summer. The effectiveness of SURE HOUSE's air barrier was tested using a blower door at several points throughout construction. Air sealing details and results of blower door testing can be seen in Appendix 3C and 3D.

THERMAL BRIDGING

To fully model the energy balance of the SURE HOUSE, all unique connection details occurring in the envelope were considered and their heat transmission quantified. Through rigorous two-dimensional heat flow simulations, the SURE HOUSE team identified key thermal bridges through the building envelope and worked hard to eliminate or reduce them. This methodology of iterative design drove decisions on framing techniques, detailing, material selection, and fastener type used in assembly.

The SURE HOUSE team utilized a two-dimensional heat-transfer modeling tool known as THERM, created and distributed by the Lawrence Berkeley National Lab (LBNL). The results of these simulations are used to create a measurement of the heat losses per linear foot of detail (a PSI value, Btu/hr·Lf·°F). Although it is labor intensive to quantify each detail in this manner, it is required in order to create a comprehensive energy model of the home's performance. Representative results for the SURE HOUSE thermal bridge modeling can be seen in Appendix 3A.

HEATING/COOLING AND VENTILATION

To correctly size the HVAC equipment, the SURE HOUSE team first simulated the peak heating and cooling loads using the PHPP (Passive House Planning Package) energy model. Once corrected with additional safety factors it was determined that 2 tons (24,000 Btu/hr) of sensible and latent cooling capacity were required.

For space heating and cooling, an electric multi-zone, forced, air-split system, Daikin SkyAir, was selected as it met the energy efficiency targets and allows the homeowner to individually control the temperature of the four zones within the SURE HOUSE, see Appendix 4A. A manifold divides the Air Handling Unit (AHU) airflow into 5 ducts, which are then routed to the home's zones, see Appendix 4B. The airflow through each duct is modulated by motorized dampers, which are controlled by wireless thermostats placed in each zone. This allows the user to personalize the heating and cooling schedule to the occupants' preferences, increasing personal comfort while also reducing energy consumption. To manage humidity, the AHU can be set to 'dry' mode when needed, which switches the focus to decreasing humidity instead of cooling.

To maximize system efficiency, care was taken to minimize and air seal all the ducting, (see Section 4C), and to minimize refrigerant branch piping by placing the exterior condensing unit on the roof directly above the AHU. Maintaining service access was considered in design, allowing the user to easily access and change filters with nothing more than a small step ladder from inside the home. The SURE HOUSE's high level of airtightness requires a mechanical fresh air ventilation system to maintain indoor air quality. This is achieved using an Energy Recovery Ventilator (ERV), which brings in continuous fresh air from outdoors while exhausting stale kitchen and bathroom air. A heat exchanger in the core of the ERV allows exhausted air to precondition incoming air, therefore reducing heating and cooling loads while maintaining air quality in the home, see Appendix 4D. The Zehnder (Paul) Novus 300[2] was chosen for its extremely high efficiency of 93% and its certification by the Passive House Institute. The unit contains self-balancing dampers, ensuring proper flow at all times. A recirculating range hood has also been installed in the kitchen to prevent a buildup of cooking contaminants.

AC GRID-TIED PV SYSTEM

The SURE HOUSE solar system consists of two distinct arrays, the grid-tied rooftop array which produces AC Powerand the shutter-mounted array which converts DC power generated by the modules directly into usable heat for the domestic hot water (DHW).

The roof-mounted AC grid-tied array is comprised of three strings, two 11 module strings connected to an SMA SB 5000TL-US-22[3] inverter and a single 10 module string equipped and an SMA SB 3000TL-US-22 central inverter. All modules for the rooftop AC array are LG MonoX 280[4] watt solar panels, chosen for their durability and efficiency. Inverter sizing and string size are optimized to the electrical characteristics of the chosen PV modules and the desired energy production, see Appendix 5B. The SURE HOUSE is projected to produce 12,353 kWh per year to meet 6,157 kWh per year of estimated consumption, see Appendix 5C. For field testing results, following system construction, see Appendix 5E.

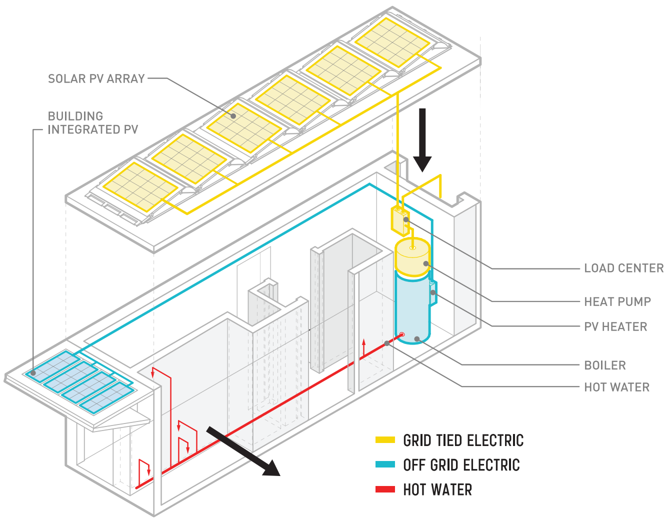
Solar modules for the two AC grid-tied sub arrays are mounted on the main roof surface of the SURE HOUSE with a 10 degree tilt angle using a partially-ballasted polyethylene roof mounting system made by Renusol, which is particularly suited to the corrosive salt air of a coastal environment. This method was chosen for its installation simplicity and to limit detrimental roof penetrations. The 10 degree tilt optimizes the energy generated per roof area at a lower price, see Appendix 5A, and ensures that there is minimal wind uplift.

DC SOLAR ELECTRIC DOMESTIC HOT WATER

The SURE HOUSE's approach to sustainable and resilient domestic hot water (DHW) consists of a unique, custom engineered DC solar electric hot water system. Employing the use of Advanced Energy's DC electric PV heater (DCPVH)[5] to heat domestic water well beyond the draw temperature, the SURE HOUSE is able to obtain a remarkably high solar fraction of 75% or more. The custom modified 80 gallon Vaughn DHW tank acts as a large solar 'battery' that stores heat energy in the form of hot water at almost 150 degrees, harvesting energy when the sun is out for use later in the day or overnight.

The system, which uses electricity rather than heated fluid, is distinct from traditional 'solar thermal' systems by eliminating the dangers and associated maintenance issues of fluid based systems. By forgoing the use of external fluid loops, overheated solar collectors and pipes are not an issue for the SURE HOUSE system which never needs any yearly or seasonal flushing. In weather

2. See Project Manual: 23 72 00 for details on ERV
3. See Project Manual: 48 19 16 for details on SMA SB Inverters
4. See Project Manual: 26 31 00 for details on LG MonoX 280 Solar Modules
5. See Project Manual: 23 56 00 for details on AE PV Heater



conditions where the integrated DCPVH unit cannot produce enough hot water via solar energy alone, the Vaughn hot water tank comes factory made with an AC powered 2.6 COP heat pump and a AC heating coil that serve as back-up heating elements.

The DCPVH is powered by a DC array consisting of 10 custom-made Solbian by PVilion 180 watt, monocrystalline, flexible solar modules[6]. The Solbian modules are directly mounted to the top half of the operable storm shutters on the south façade of the SURE HOUSE. The SURE HOUSE team worked closely with PVillion, a PV system designer specializing in flexible architectural photovoltaics, to design an adhesive system that works with the glass-fiber storm shutter surface in a reliable manner over an extended period.

Because this system operates in DC-only mode and never connects to the municipal power grid, the system can continue to create hot water safely and effectively even during grid disruption events. This hot water, and the energy stored within it, could be used for a range of activities including washing and cooking to more elaborate hydronic heating systems as desired. See Appendix 6 for system engineering, sizing and modeling.

MONITORING SYSTEM

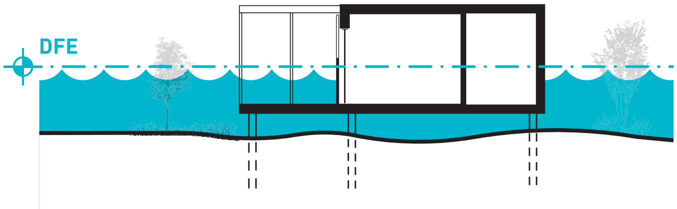
To monitor home electricity use, the SURE HOUSE utilizes an extensive array of current transformers (CTs) aggregated by two eGauges. This collected data is read and displayed on a "home dashboard," custom designed to distill the energy use data down into a display that is understandable by a typical homeowner. This allows the residents to easily see where their electricity is currently being used and inform their future energy use choices.

Using the Web Energy Logger (WEL) and a combination of temperature and relative humidity sensors, a homeowner can also monitor individual rooms of the house which can confirm the proper function of the HVAC system (air handler, condensing unit, and ERV). Through the use of both the energy and temperature/humidity monitoring systems, the SURE HOUSE can educate the homeowner on how to operate the house as efficiently and effectively as possible. See Appendix 7 for more details.

FLOOD-PROOF DESIGN

The SURE HOUSE's flood-proofing design exceeds FEMA's requirements in almost every aspect. The house has been designed to meet NFIP (National Flood Insurance Program) requirements as well as all ASCE 24 and ASCE 7-10 design manual loading conditions for the house's zone, elevation,

6. See Project Manual: 48 14 13 for details on Solbian by PVilion Solar Modules



The SURE HOUSE's innovative flood-proofing allows flood waters to rise up around the home while the interior stays dry and undamaged.

and velocity. For a summary of design loading and flooding values, please see Appendix 8A-1 Figure A. The SURE HOUSE also satisfies the concern over residents 'sheltering in place' by designing the flood-proof shutters so that they can only be enacted from the outside, ensuring that residents cannot remain in the home during a flood event. The main objective with the SURE HOUSE residential prototype is to showcase how dry flood-proofing can be safe, economical, and simple in design and construction for individual residences, allowing for storm safety without utilizing FEMA's harsh and unappealing design prescriptions.

The flood proofing of the SURE HOUSE's main structure is comprised of an acrylonitrile butadiene styrene (ABS) sheathing, Prime ABS 50,[7] attached to all exterior wall faces and underneath the floor with gasketed roofing screws and marine-grade 3M 5200 caulk adhesive.[8] ABS is readily available in standard 4'x8' construction sheets, adaptable to standard construction techniques, and rated to span along with ZIP sheathing across studs to resist flood loads. ZIP system (for walls) and Advantech OSB (for floors) sheathings are stronger than standard plywood and provide a water and mold resistant layer; they will not be damaged or destroyed, ensuring the envelope is protected from flood water. For a wall section calling out flood-proofing layers see Appendix 8A-1 Figure B. Loads were defined in the structural calculations and have been verified via coastal-modeling software at Stevens Davidson Laboratory, for results see Appendix 8A-2.

During the design phase, physical prototype testing was completed by the team to simulate flooding conditions expected for a 100-year storm on the New Jersey coast, see Appendix 8A-3. This testing proved the ABS sheathing remained waterproof for the duration of an 80-hour test period, above the required 72 hours, in the as-built prototype condition. It is important to note that during this test, only 3M 5200 Marine Adhesive was used at the joints, whereas in the final house prototype Grace Vycor waterproof tape was installed over this sealant to provide a redundant waterproof layer. The ABS sheathing is resistant to hurricane debris and will still remain effective after deflection due to heat.

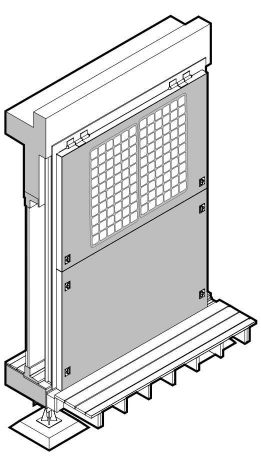
A high strength ABS layer is laminated to typical OSB floor sheathing. Once the seams are bonded, this creates a strong, waterproof shell underneath the home.

STORM SHUTTERS AND PLUGS

Working with Gurit, a world renowned composites engineering company, the SURE HOUSE team designed and manufactured innovative storm shutters[9]—a series of glass-fiber composite bi-folding doors that are able to close down and protect the home during flood and high wind events. The shutters sit over the large southern glazing to provide passive shading (Appendix 3B) during

7. See Project Manual 07 13 54 for details about the ABS sheathing.
8. See Project Manual 07 19 19 for details about the 3M 5300 Structural caulk adhesive.
9. See Project Manual Section 3 for manufacturing techniques

normal daily use as well as active solar energy collection via Building Integrated Photovoltaic (BIPV) electric panels. See Appendix 6 for details on our DC solar electric domestic hot water analysis. When closed down during a storm, these shutters are capable of protecting the home from water infiltration and debris impact loads. This system saves the homeowner in everyday energy costs as well as repair expenses after a storm. Their durable materials[10] are proven to have extended performance through years of marine industry implementation.[11] Panels are individually removable and repairable in the event of incurred damage. Extensive research and development of this system has yielded a customizable, durable and innovative product for homeowners that contributes both to daily comfort and to extreme weather resilience. See Appendix 8B for detailed analysis and research of the design.



CONCLUSION

As climate change creates more extreme weather-driven challenges, a sustainable home will need to be resilient as well. The SURE HOUSE demonstrates how a truly SUstainable and REsilient building can be constructed in a safe, durable, healthy, and cost effective manner. This prototype for low energy, flood-proof coastal construction exhibits innovations which can be implemented to decrease energy footprints and help protect the unique lifestyle of vulnerable coastal communities. This combination of everyday sustainability and powerful resilience is key to the success of the SURE HOUSE as a prototype for coastal communities in an era of climate change.

10. See Project Manual: 06 00 00, 06 83 13 for details on material selection
11. See Project Manual: 05 13 00, 05 45 00 for details on hardware selection

COMMUNICATIONS

The SURE HOUSE communications mission is to educate and inform the public on how state-of-the-art technology can integrate with smart design to produce beautiful, energy-efficient homes which are also resilient to extreme weather such as flooding. The SURE HOUSE team's communications objective is to reach the public locally, regionally, nationally and globally through the use of integrated marketing communications including: social media, traditional media, conferences, presentations, tours, and educational events.

SU+RE

SUSTAINABLE RESILIENT

Our strategy to reach these objectives includes:

THE SURE HOUSE BRAND
A brand identity is much bigger than just a logo mark – it is experienced in everything you say and how you say it. It is your project's unique personality and spirit, communicated visually, through every interaction you have with your audience. Keeping this personality consistent and tangible in everything we do has been integral to the success of the SURE HOUSE to-date.

PRODUCING ENGAGING PLATFORMS
To inform, educate and inspire technologically and demographically diverse audiences, both online and off.

GENERATING AND DEPLOYING CONTENT
That is information-rich and visually-dominant, across all communications outlets.

THE SURE HOUSE BRAND

At the same time that the quest for a sustainable status quo continues, many of our homes and ways of living continue to be put into jeopardy by severe storm events. This reality reflects the dual needs addressed by the **SU**stainability plus **RE**siliency aspects of our engineering and design project, and are the inspiration for our visual identity – from the logo, to our use of color, typography, and all supporting elements of every communications item we have, and are producing.

KEY MESSAGES

1. SUSTAINABILITY BEGINS WITH RADICALLY REDUCING OUR HOME'S ENERGY USE

2. RESILIENCY TO COASTAL FLOODING DOESN'T REQUIRE HOUSES TO BE UP ON STILTS

3. IN AN ERA OF CLIMATE CHANGE, A HOME MUST BE BOTH SUSTAINABLE AND RESILIENT

PRODUCING ENGAGING PLATFORMS

Using a play on words for 'shore house', the SURE HOUSE aims to engage an audience of people who live in proximity to potential flood waters, especially those who have been, or may still be, affected by storms such as Hurricane Sandy. In addition to demographics, our audience profile also includes varying levels of technological knowledge and electronic media proficiency as well as being geographically dispersed.

Given these audience profile requirements our execution is centered first on electronic media and the integration of links to other types of communications platforms, but also focused on in-person message delivery. The website serves as our information and communication hub; it is the primary information source for our project audience with constant and routine updates of original information as well as being a distribution point for other 'publishing' channel's content including traditional media, social media and student blogging. **With over 10,250 unique users accessing our site between January 1st and August 15th of 2015**, with an average session duration of approximately 3 minutes, this continues to be our primary platform for engagement.

Coordinated with the website, the team uses social media to provide regular project updates, fresh photos of the house and team, and educational content to reinforce the innovation of the home. Our goal is to be the most followed team on Facebook, Instagram and Twitter in the 2015 Solar Decathlon, using electronic media as an advantage despite Stevens Institute competing as the smallest student-bodied team in the competition.

In partnership with the Center for Innovation in Science and Engineering (CIESE) here at Stevens, the team has hosted continuing STEM education programs for over 50 grade- and middle-school teachers, many of whom will host curricular field trips to the SURE HOUSE upon it's return to New Jersey after the competition. The SURE HOUSE team also had the opportunity to share the project in over 30 formal presentations and 3 trade conferences to professional, civic and academic research groups. The presentation format ranged from one-on-one tours of the house for high level executives from project sponsors, to going offsite to local high-schools to present to general education as well as STEM classes. In addition, the team regularly hosted public open houses in the community at the work site every Friday throughout construction, with dozens of tours given to local residents curious about the home they have witnessed growing near a well trafficked pedestrian walkway along the Hudson river bank with custom project information signage.

GENERATING AND DEPLOYING CONTENT

Media features have been wide ranging for the SURE HOUSE. Given the damage to our campus, city, state and region, as well having students whose homes were directly affected by Hurricane Sandy, the team's story has high editorial interest value and was picked up by local, regional and national news. Over 30 features have come out about the SURE HOUSE to date, including CBS-NY, WCBS Radio, FOX-NY, NJTV and soon-to-air nationally on FOX. In addition to traditional media there has been an exceptionally strong viewership record on our Popular Science blog with close to **30,000 views on 25 blogs posts**. The social media following has also been very strong, with over **2000 'Likes' on Facebook** and around **550 followers on both Instagram and Twitter**. These diverse outlets have given us the opportunity to get the word out about the SURE HOUSE and build a strong interest in the project, leading up to the Solar Decathlon.

The house itself is also envisioned as a venue where our key messaging and content can be conveyed. The house's vast array of renewable and efficient technologies in combination with it's marine-inspired storm protection methodologies, necessitates very clear explanations. In order to aid in understanding these complex concepts, and to tell our story while onsite in Irvine, our core team has taken coursework in building science and data visualizations to facilitate the creation of useful information graphics that are used internally, on our website and in our competition public exhibition signage.

These information graphics and educational displays are designed around the elements of the house for the exhibition and the individual tour visitor. Using summary overviews, object accompanied signage and color-coded labelling, this distributed contextual information approach enhances the ability of visitors, when crowd flows permit, to engage with the house in a self-instructed manner.

ENGINEERING APPENDIX

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

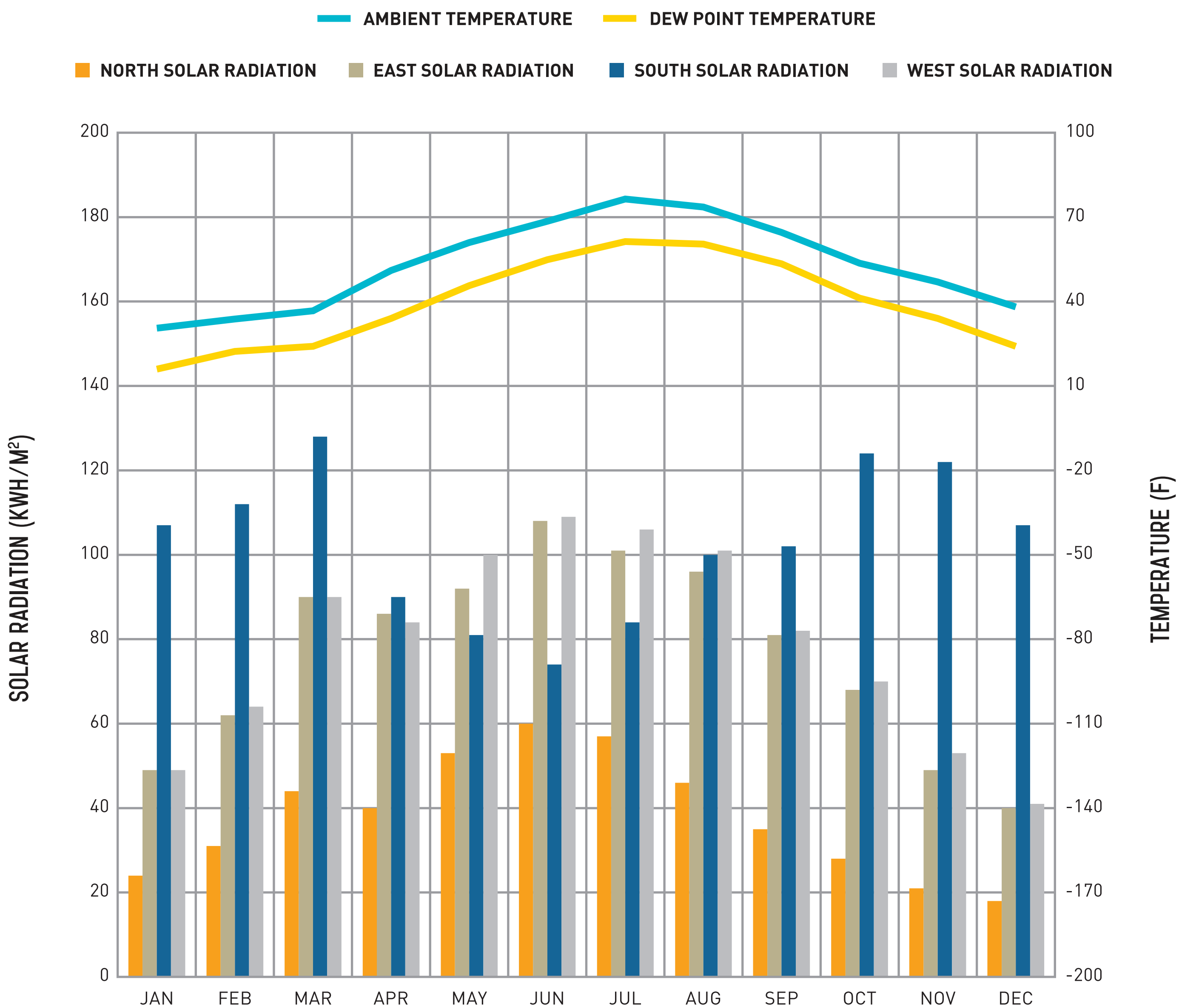
TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

SECTION 1: CLIMATE ANALYSIS

FIGURE 1A: MONTHLY CLIMATE DATA - BELMAR, NJ



The SURE HOUSE design responds to the unique climate conditions of the Jersey Shore, namely Belmar, NJ. Highest solar gains occur from the South during the shoulder seasons when the ambient temperature remains high and typical overhead shading may no longer be effective due to low solar angles. In addition, relatively high dew point temperatures require attention to humidity issues.

SECTION 2: ENERGY MODELING

SECTION 2A: YEARLY ENERGY MODEL

FIGURE 2A-1: BUILDING DATA

ENVELOPE SPEC.	IECC 2009 CODE(NJ)	IECC 2012 CODE(CA)	SURE HOUSE	UNITS
WINDOW U-VALUE	0.35	0.35	0.12 - 0.21	Btu/(h ft^2 F)
WINDOW GLASS SHGC	0.30	0.40	0.62	-
FLOOR R-VALUE	19.00	19.00	31.09	(h ft^2F)/Btu
WALLS R-VALUE	13.00	20.00	39.58	(h ft^2F)/Btu
ROOF R-VALUE	38.00	49.00	50.70	(h ft^2F)/Btu
AIR TIGHTNESS	7.00	3.00	0.8	ACH50

PERFORMANCE CRITERIA	PASSIVE HOUSE INST.	SURE HOUSE	UNITS
HEATING DEMAND	3998.27	3880.42	kBtu/yr
SPECIFIC HEATING DEM.	4.75	4.61	kBtu/(ft^2 yr)
COOLING DEMAND	4402.30	4267.62	kBtu/yr
SPECIFIC COOLING DEM.	5.23	5.07	kBtu/(ft^2 yr)
PRIMARY ENERGY DEM.	31986.12	31046.69	kBtu/yr
SPECIFIC PE DEMAND	38.00	36.78	kBtu/(ft^2 yr)
AIR TIGHTNESS	0.60	0.80	ACH50

BUILDING GEOMETRY	SURE HOUSE	UNITS
WINDOW DIST. N/E/S/W	7.6% / 11.9% /7 3.2% / 7.3%	% OF TOTAL GLAZING AREA
FORM FACTOR (SA/TFA)	4.26	-
A/V RATIO	.30	ft^2/ft^3
TREATED FLOOR AREA (TFA)	841.74	ft^2
TREATED AIR VOLUME (Vn50)	7388.44	ft^3

WEATHER DATA	SURE HOUSE	UNITS
WEATHER STATION ALTITUDE	85.30	ft
BUILDING ALTITUDE	0.00	ft
LATITUDE	40.20	-
LONGITUDE	-74.10	-
NORTH	457.00	kWh(m^2)
EAST	922.00	kWh(m^2)
SOUTH	1231.00	kWh(m^2)
WEST	949.00	kWh(m^2)
GLOBAL	1508.00	kWh(m^2)
HEATING DEGREE DAYS	5325.00	degree-F-day

In order to achieve Passive House Qualification, envelope specifications often eclipse typical code requirements.

SECTION 2: ENERGY MODELING

SECTION 2A: YEARLY ENERGY MODEL

FIGURE 2A-2: TOTAL YEARLY SITE ENERGY CONSUMPTION

ENERGY DRAWS (kBtu)	AVERAGE NJ HOME	SURE HOUSE
HEATING	63311	2038
COOLING	3731	2297
PLUG LOADS	37655	5979
HOT WATER	23554	1628
TOTAL ENERGY	127400	11942

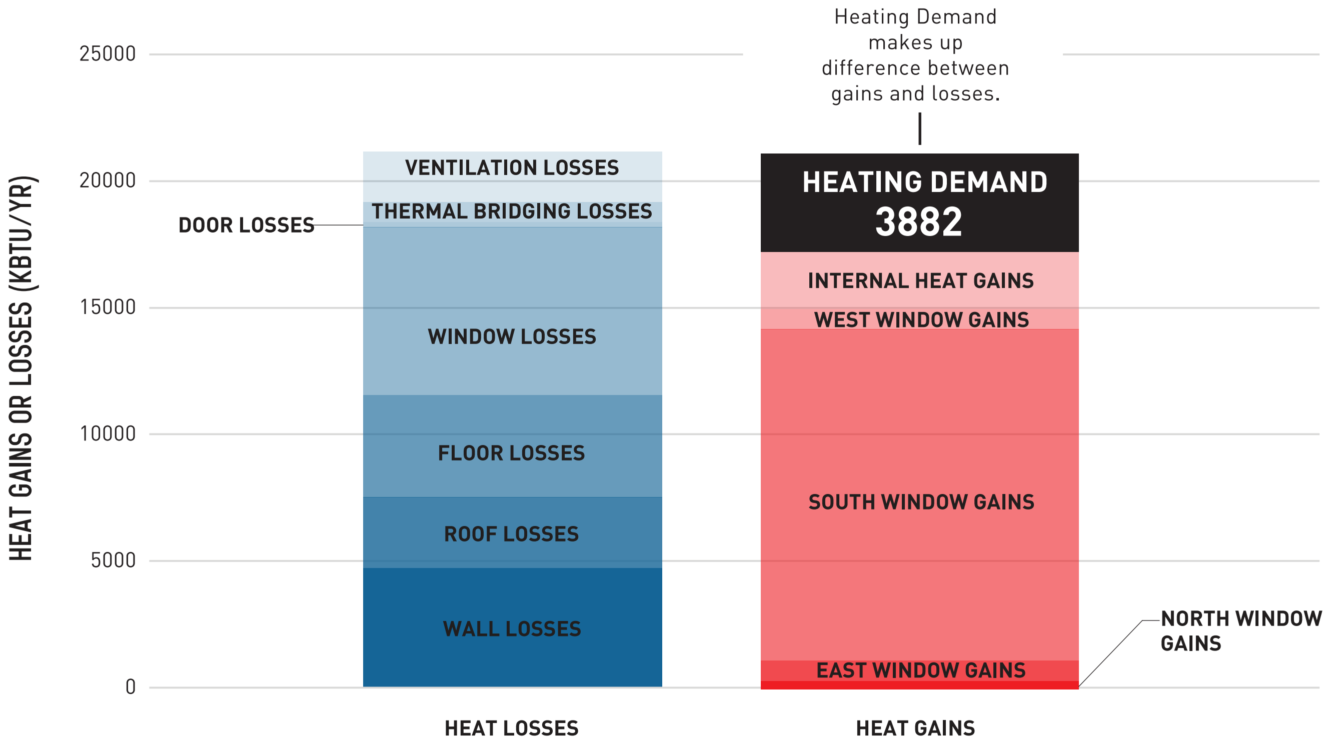
The values used for the average NJ home were taken from the 2009 Residential Energy Consumption Survey conducted by the EIA. SURE HOUSE consumption values represent yearly consumption for a family of four in Belmar, NJ as calculated by the Passive House Planning Package.

To model yearly energy consumption, two main tools were used:
1. Passive House Planning Package - created by the Passive House Institute to verify compliance with the Passive House Standard.
2. TRNSYS - modular transient systems simulation tool.

SECTION 2: ENERGY MODELING

SECTION 2A: YEARLY ENERGY MODEL

FIGURE 2A-3: HEATING PERIOD ENERGY BALANCE

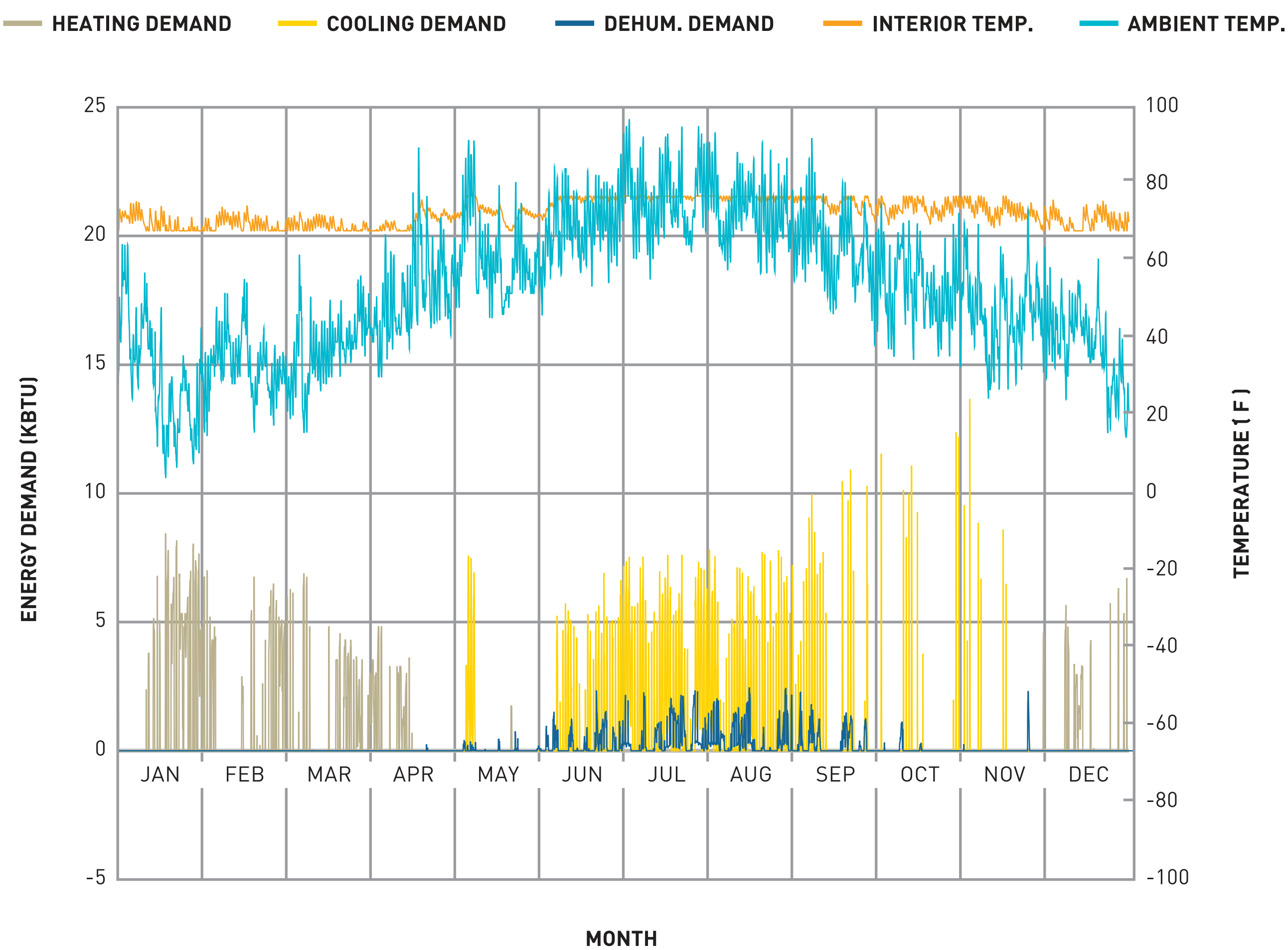


The Passive House Planning Package (PHPP) computes the yearly heating and cooling demands by quantifying heat gains and losses inside the building for the specific climate. During the heating period (winter) the heating demand is the heat gain required to balance the gains and losses in the building. Heating demand is defined as the energy required to condition the space regardless of the efficiency of the heating system. This is different from the actual site energy consumed for heating the home which accounts for the losses in the system.

SECTION 2: ENERGY MODELING

SECTION 2A: YEARLY ENERGY MODEL

FIGURE 2A-4: YEARLY HEATING, COOLING, AND DEHUMIDIFICATION DEMAND

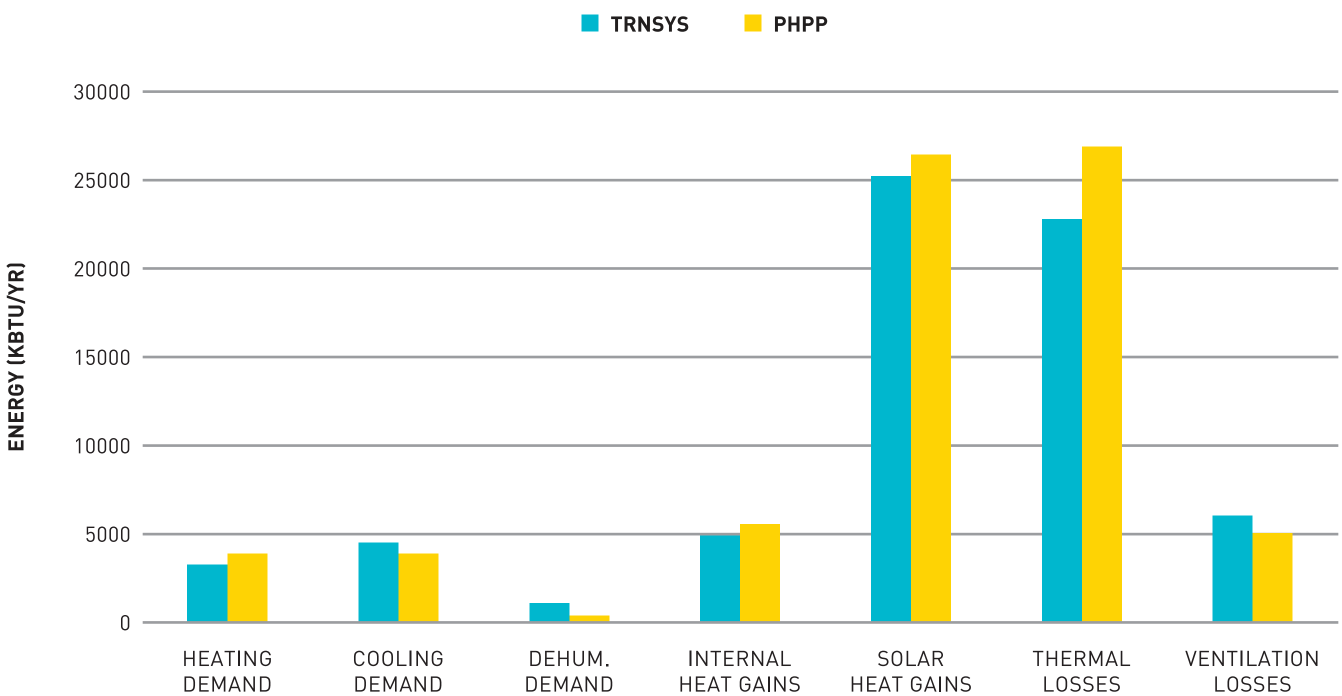


An hourly energy model of the entire year was created using TRNSYS to compare to the monthly approximations derived in the Passive House Planning Package. For this TRNSYS model, solar radiation was computed taking into account detailed shading geometries using an analysis grid of less than 1 square inch to achieve the granularity needed to account for the effect of each louver (5/8" thick). The Solar Radiation Analysis definition in Honeybee for Grasshopper was used for the solar analysis. For more information on shading modeling see Appendix Section 3B.

SECTION 2: ENERGY MODELING

SECTION 2A: YEARLY ENERGY MODEL

FIGURE 2A-5: TRNSYS vs. PHPP YEARLY COMPARISON



A comparison of the gains and losses calculated by the hourly TRNSYS model and the monthly PHPP model reveals where discrepancies occur in the total heating and cooling demand values. Lower thermal losses calculated in TRNSYS make up the largest difference, possibly accounting for a lower heating demand (3,267 kBtu/yr) compared to the PHPP (3,882 kBtu/yr). While the monthly PHPP estimation accounts for higher solar gains overall, the effect of these on a small time scale may account for the higher cooling demand produced in TRNSYS (4,507 kBtu/yr) compared to the PHPP (3,898 kBtu/yr).

SECTION 2: ENERGY MODELING

SECTION 2B: DRY RUN TESTING AND ANALYSIS

In order to simulate the performance of the house under competition conditions, the team organized a mock competition that adhered to the schedule outlined in the Solar Decathlon Rules. The following data demonstrates the conclusions the team obtained.

FIGURE 2B-1: APPLIANCE ENERGY CONSUMPTION COMPARISON

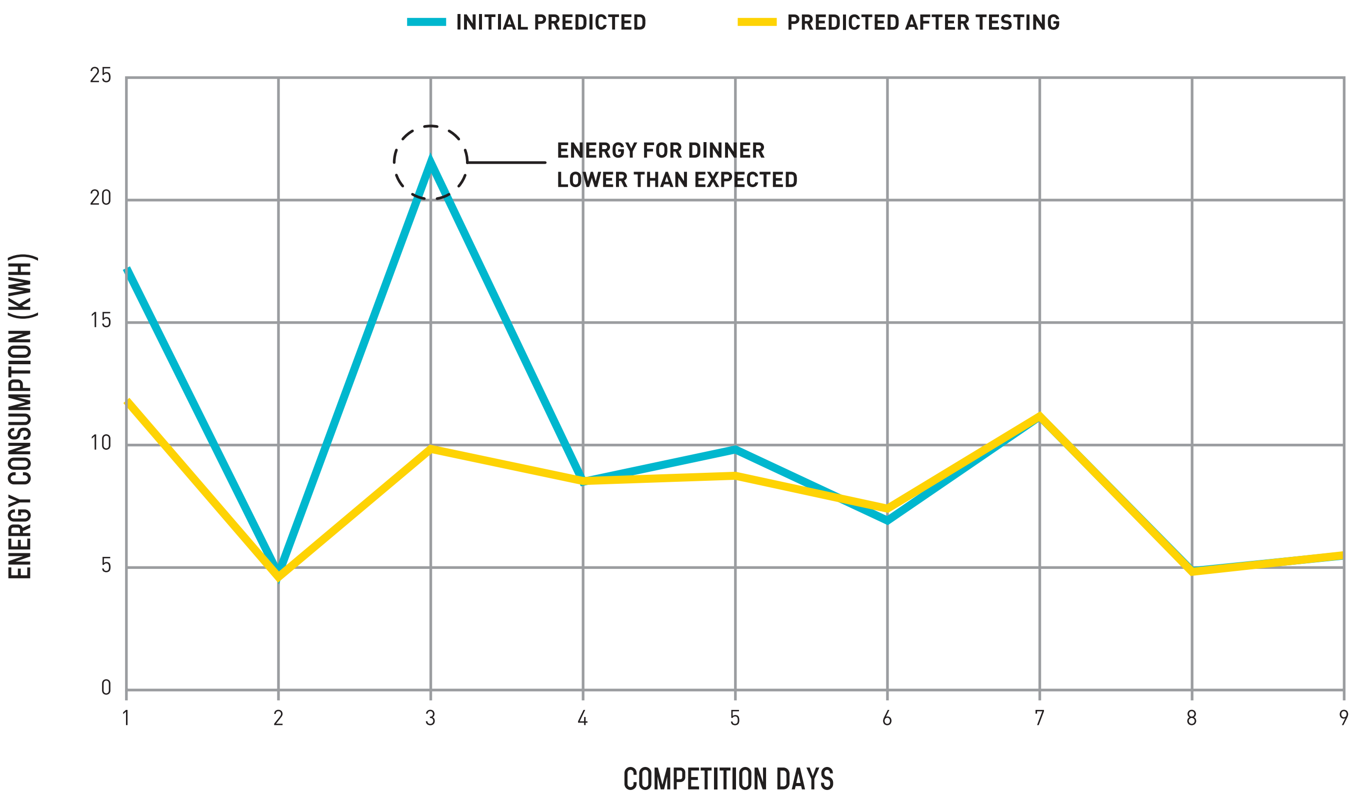
	ENERGY IN KWH	TOTAL ENERGY CONSUMPTION		HOURLY CONSUMPTION RATES	
	TOTAL HOURS	INITIAL APPROX.	APPROX. AFTER TESTING	INITIAL APPROX.	APPROX. AFTER TESTING
REFRIGERATOR	202.5	9.131	5.376	0.0451	0.0266
LIGHTING	25.0	20.000	20.000	0.8000	0.8000[e]
WASHER	24.0	2.347	5.761[a]	0.0978	0.2401
DRYER	24.0	15.717	8.331	0.6549	0.3471
ELECTRONICS ON	32.0	1.556	1.556	0.0486	0.0486[f]
ELECTRONICS STANDBY	184.0	0.048	3.190[b]	0.0003	0.0200
DISHWASHER	13.5	6.505	6.505	0.4819	0.4819[g]
WATER BOIL	12.0	8.292	11.652[c]	0.6910	0.9710
DINNER 1 FOOD	2.0	13.416	8.000	6.7080	4.0000
DINNER 2 FOOD	2.0	13.416	1.700	6.7080	0.8500
MOVIE SNACK	1.0	0.000	0.420[d]	0.0000	0.4200
PUMPS	38.0	0.287	0.250	0.0075	0.0066
SUMP PUMP	1.0	0.250	0.007	0.2500	0.0066
CAR CHARGING	1.0	49.000	42.000	49.0000	42.0000
	TOTAL	**139.965**	**114.749**		

The above table shows a comparison between the first approximation of appliance energy consumption and a refined model based on actual consumptions during the dryrun. The red numbers in the Second Approx. Energy Consumption column indicate the areas which the estimated energy consumption for the competition increased in the dryrun. The summation of energy consumption increases was less than the summation of decreases due to the conservative first estimates. The three yellow numbers in the Second Approx. Consumption Rates column indicate unchanged values. The team was unable to install lighting and the dishwasher during the first dryrun due to time constraints and were therefore unable to refine those initial approximations. Finish work was still occurring in the house during the dryrun, therefore plug load monitoring was diluted by the unregulated use of power tools. Even though the first dryrun was a bit rudimentary, energy estimations were refined significantly and were decreased by 25 kWh. The team is currently preparing for a second less rudimentary dryrun now that construction is largely complete, allowing the team to bring these estimates even closer to predicting competition values.

SECTION 2: ENERGY MODELING

SECTION 2B: DRY RUN TESTING AND ANALYSIS

FIGURE 2B-2: APPLIANCE ENERGY CONSUMPTION



A graphical representation of the appliance energy consumption over the mock competition is shown above. The largest differences in predicted and real energy consumption values are due to the dinner parties.

SECTION 2: ENERGY MODELING

SECTION 2B: DRY RUN TESTING AND ANALYSIS

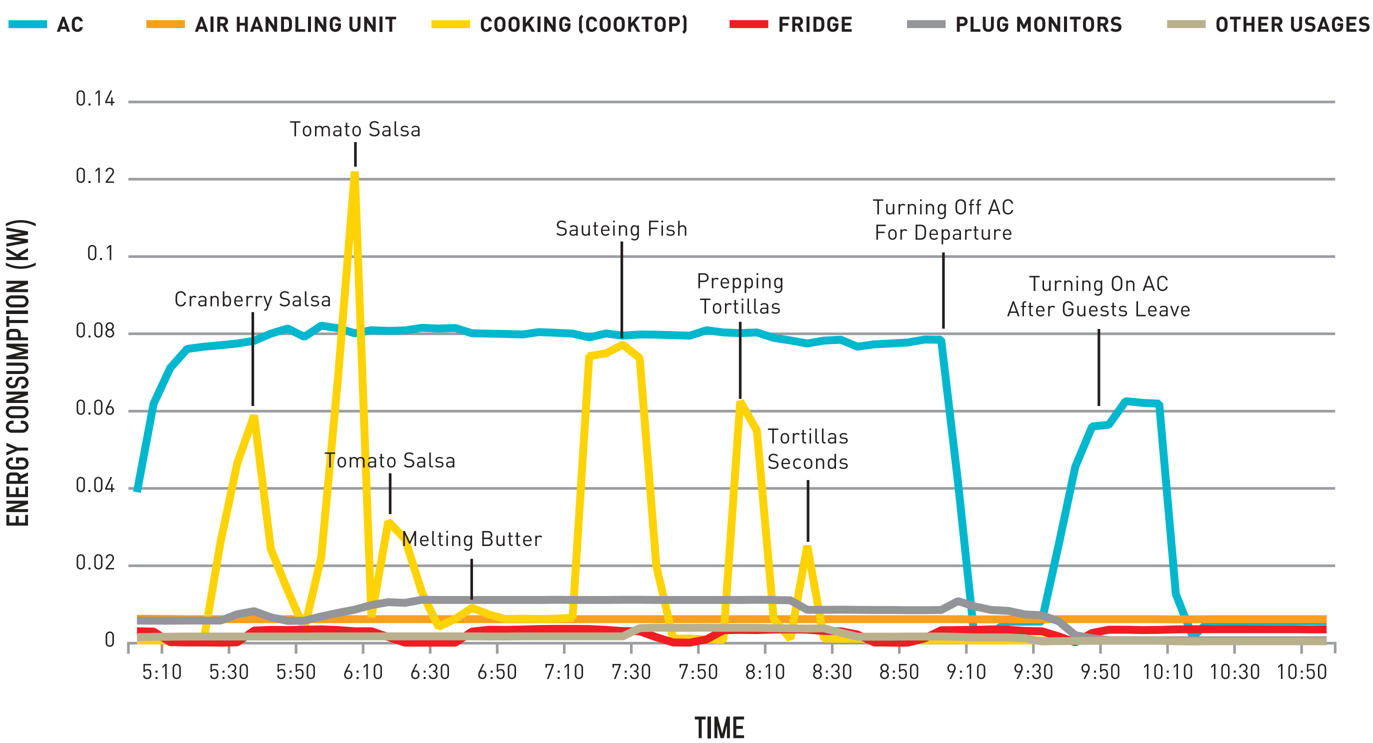
FIGURE 2B-3: TOTAL ENERGY CONSUMPTION COMPARISON

	ENERGY IN KWH	TOTAL ENERGY CONSUMPTION	
	SYSTEM	INITIAL APPROX. (KWH)	APPROX. AFTER TESTING (KWH)
DOMESTIC HOT WATER	PV+HP	5.98	10.00
SPACE CONDITIONING	Heating	0.26	0.26
SPACE CONDITIONING	Cooling	24.32	41.98
APPLIANCES		139.965	114.749
	FULL TOTAL	**170.52**	**166.99**

The table above combines the energy consumption for the appliances with the consumption of the domestic hot water system and the space conditioning systems. The team learned over the first dry run that more energy would be used than initially predicted in both heating water and conditioning the space. Those increases cancel some of the appliance energy savings and result in a prediction less than the previous 170, at 167 kWh.

SECTION 2B: DRY RUN TESTING AND ANALYSIS

FIGURE 2B-4: NUEVA JERSEY DINNER PARTY HOME ENERGY CONSUMPTION

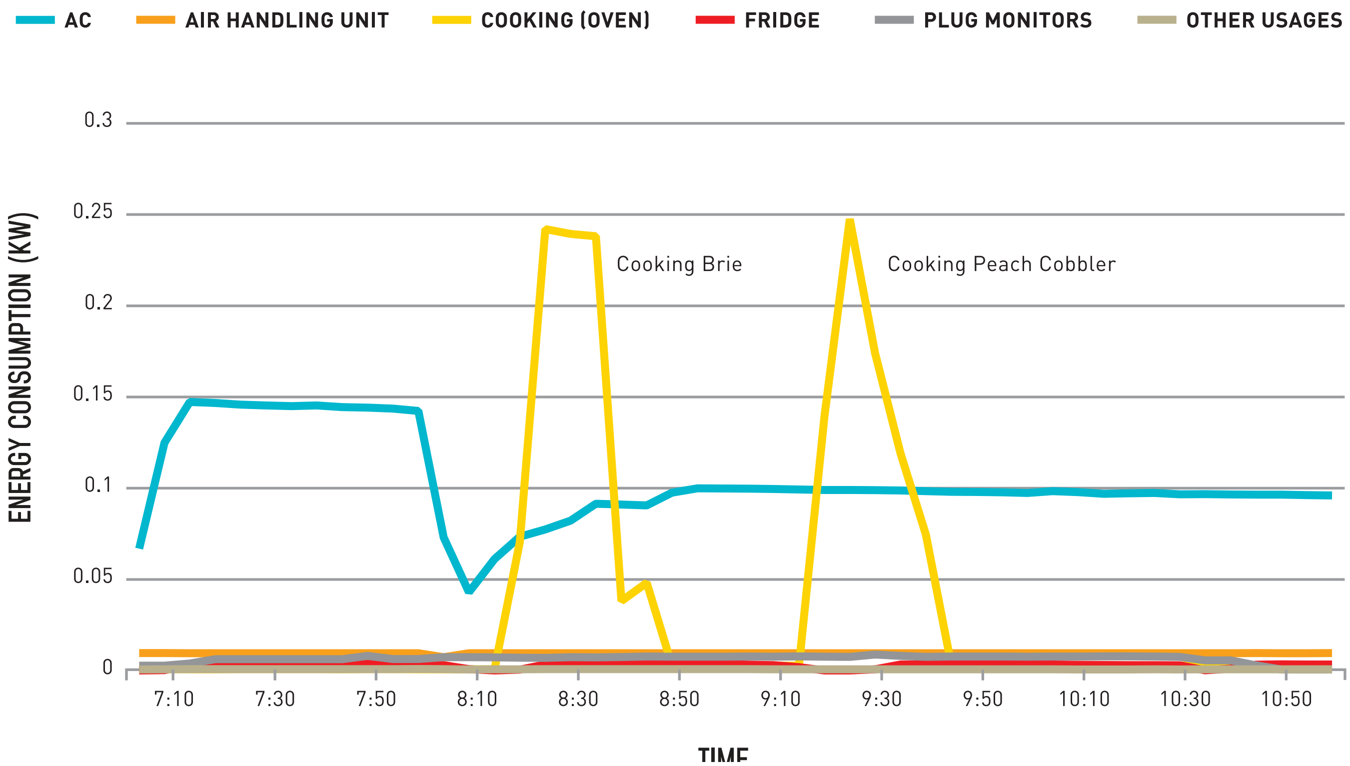


The largest decrease between the first approximation and the postdryrun estimation occurred over both dinner parties. The dinner party calculations were based on maximum power consumption of the oven, cooktop, and range hood simultaneously for one hour. A clear overestimation, this created a margin of safety for the other appliances in addition to covering the energy expenditure of the Movie Night snack. In the graph above, the peaks are labeled to show the different cooking tasks during meal preparation. The largest amount of energy was used by cooking the fish and the smallest amount melting the butter.

SECTION 2: ENERGY MODELING

SECTION 2B: DRY RUN TESTING AND ANALYSIS

FIGURE 2B-5: STORMY SUPPER DINNER PARTY HOME ENERGY CONSUMPTION

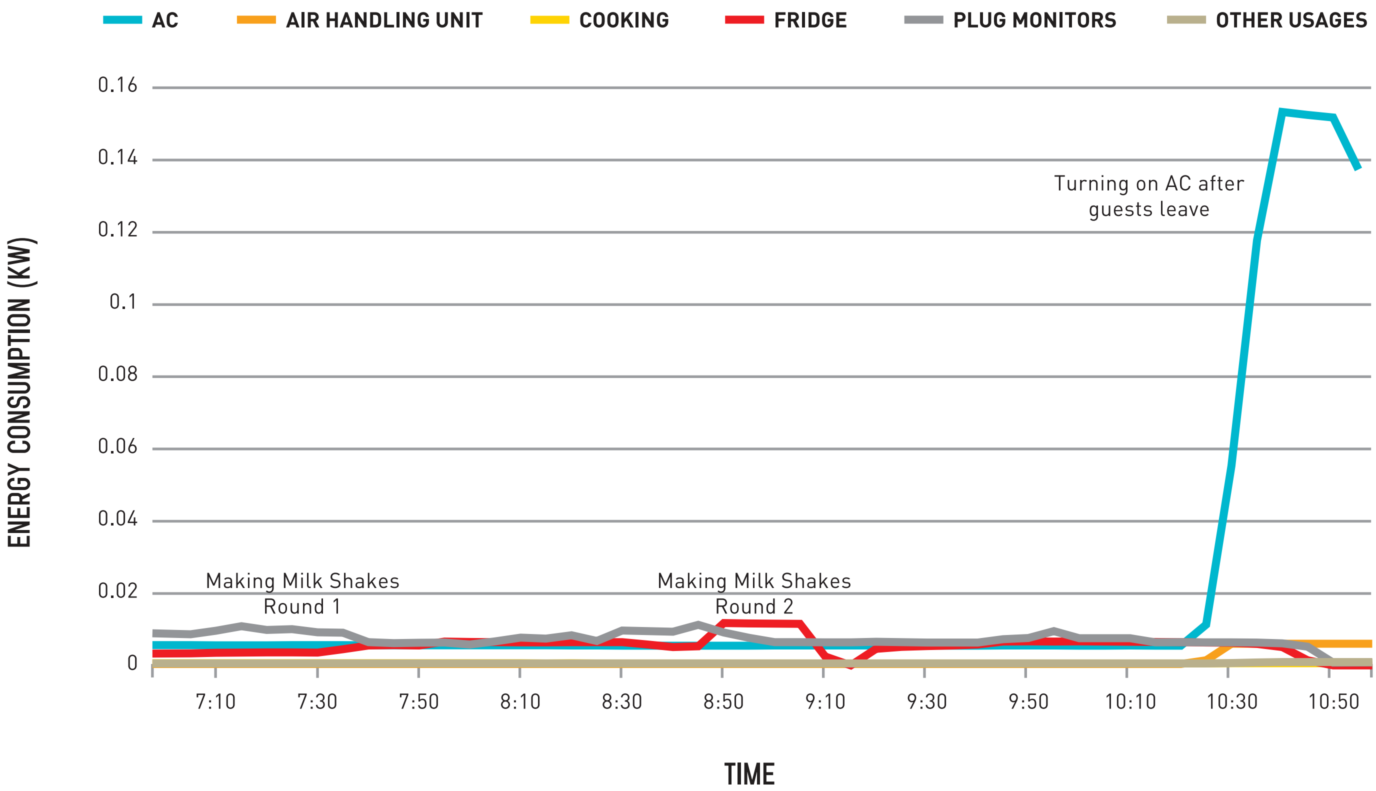


The Stormy Supper had two main spikes caused by baking the brie and the peach cobbler. This will be reduced in the second dryrun and competition by cooking the brie and peaches together.

SECTION 2: ENERGY MODELING

SECTION 2B: DRY RUN TESTING AND ANALYSIS

FIGURE 2B-6: BOARDWALK TREATS MOVIE NIGHT HOME ENERGY CONSUMPTION

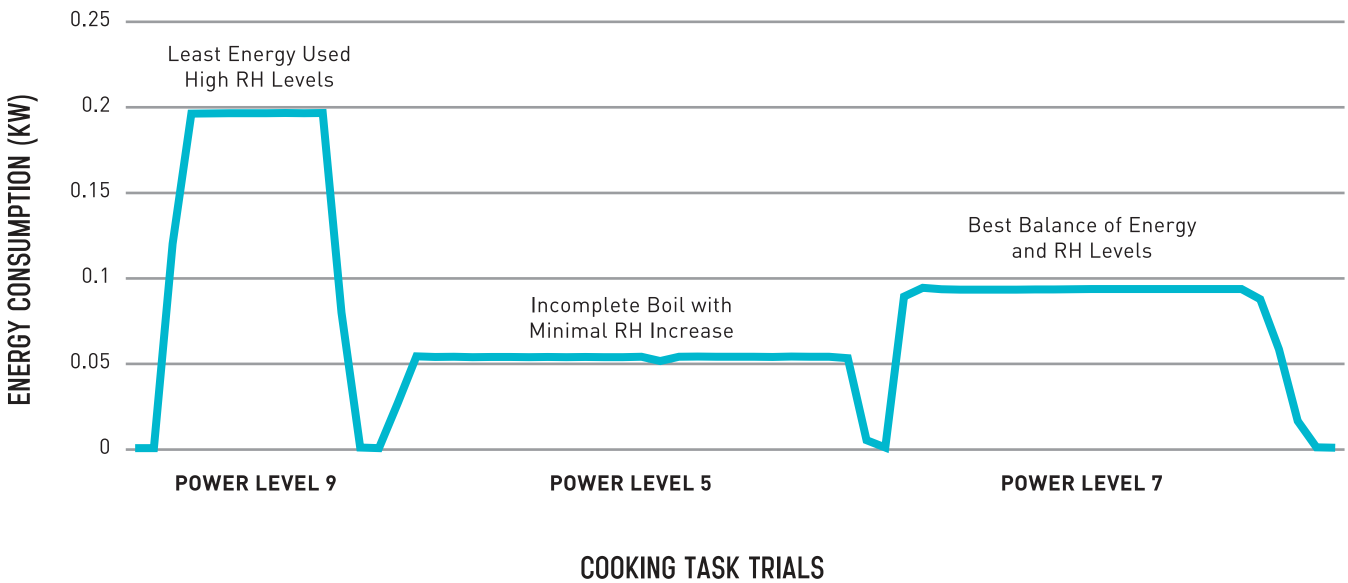


The data collected during the Movie Night shows the need to be more intentional with the opening of the refrigerator. Opening the refrigerator and freezer will cause an obvious loss of cold air, forcing the system to work harder to maintain the appropriate temperature. For the second dryrun the team will create a schematic of the inside of the refrigerator and illustrate food locations. Ideally, the cooks will be able to refer to this document and determine exactly where everything is to reduce idle periods with the refrigerator doors open.

SECTION 2: ENERGY MODELING

SECTION 2B: DRY RUN TESTING AND ANALYSIS

FIGURE 2B-7: COOKING TASK POWER LEVEL TRIALS ENERGY CONSUMPTION



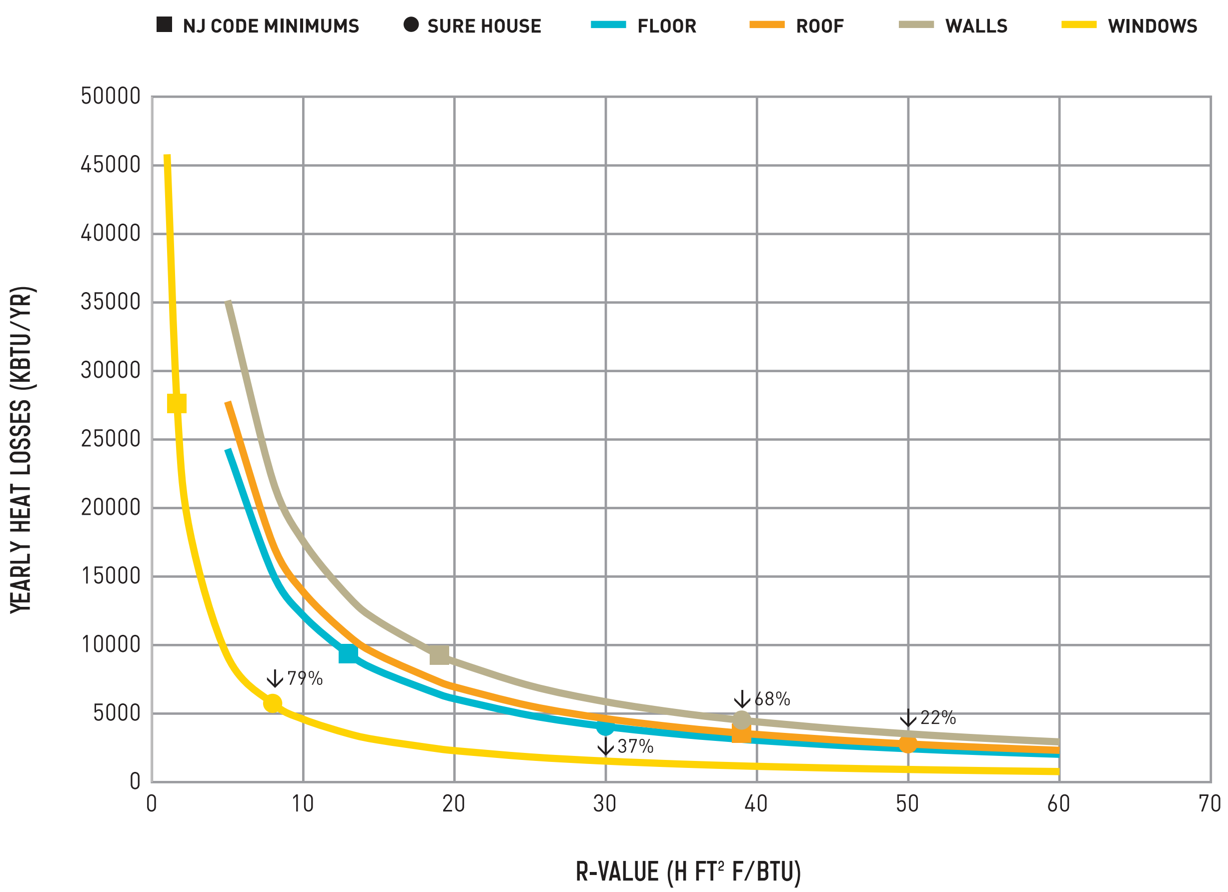
Beyond practicing for the competition, the dryrun is helping the team create strategies for completing tasks. The above graph shows a few trials of the cooking task water boil. The stove was set at three separate power levels and the task was timed. Results show that the higher power levels use incrementally less energy than lower power levels, therefore it will be best to use the highest power level while maintaining the 60% relative humidity limit. Practicing for the task and modifying energy models (and by extension operation of the house) due to real data obtained in the house has proven priceless in informing the team for competition. Over the second dry run the team will refine this strategy and apply similar logic to other tasks of the competition.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

Material choices made while designing the envelope of the SURE HOUSE had to take into account both their energy reduction value as well as performance during a storm or flooding event. For this reason, a mineral wool (Roxul) was used in conjunction with a smart vapor permeable membrane to help protect against the dangers of having a vapor closed flood-proof layer covering an airtight, highlyinsulated wall cavity. Mold damage is of great concern in NJ due to high humidity; using insulation that will not trap moisture is essential for the buildings durability as well as occupant health.

FIGURE 3A-1: EFFECT OF R-VALUE ON HEAT LOSS



One of the first steps in designing a Passive House envelope is to determine the constraints and goals for the assembly RValues. RValues can vary significantly depending on building geometry, cost, efficiency, local product requirements, and many more. Based on these effects and a decreasing return on efficiency of increasing RValues, SURE HOUSE was designed to have a R50 roof, R40 walls, R30 floor, and R8 windows. Compared to code, these values represent a reduction in heat losses ranging from 22% to 79%.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

FIGURE 3A-2: MATERIAL CONDUCTIVITIES

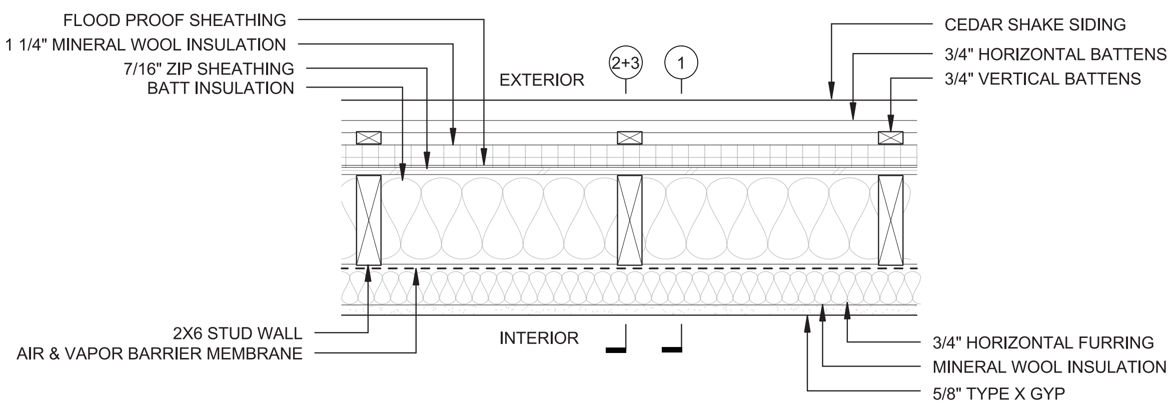
MATERIAL	CONDUCTIVITY (BTU-in/hr-ft²-F)	R-in (hr-ft²-F/BTU-in)	MANUFACTURER	CONDUCTIVITY REF.
CEDAR SHAKES	1.15	0.87	MSI	2013 ASHRAE
MINERAL WOOL	0.24	4.20	ROXUL	MANUFACTURER
ABS PLASTIC SHEATHING	1.18	0.85	PRIMEX	MANUFACTURER
ORIENTED STRAND BOARD	0.71	1.42	HUBER	2013 ASHRAE
WOOD STUDS (SPF)	0.80	1.25	LUMBER YARD	2013 ASHRAE
GYPSUM BOARD	1.10	0.91	USG	2013 ASHRAE
FIBER-CEMENT BOARD	1.75	0.59	EQUITONE	2013 ASHRAE
TILE BACKER	0.21	4.80	SCHLUTER	2013 ASHRAE
PLYWOOD	0.69	1.44	LUMBER YARD	2013 ASHRAE
M. DENSITY FIBERBOARD	0.46	2.18	LUMBER YARD	2013 ASHRAE
POLYISOCYANURATE	0.16	6.25	ROOFING INSTALLER	2013 ASHRAE
VINYL ROOF MEMBRANE	1.30	0.58	SIKA	2013 ASHRAE
EXTRUDED POLYSTYRENE	0.20	5.00	DOW-CORNING	2013 ASHRAE
H. DENSITY XPS	0.32	3.10	475 BLDG. SUPPLY	MANUFACTURER
CEMENT BACKERBOARD	1.70	0.59	JAMES HARDIE	2013 ASHRAE
MAPLE FLOORING	1.10	0.91	LUMBER LIQUIDATORS	2013 ASHRAE
TILE	10.40	0.10	DALTILE	2013 ASHRAE

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

R-Values were evaluated in the PHPP for all the home's exterior envelope assemblies. Both Parallel-Path and Isothermal-Plane method R-Value calculations are done, and combined to create an average R-Value for the assemblies shown below. This method is accurate enough for variations in material thermal conductivity up to a factor of 4 to 5. The PHPP contains an accuracy analysis, which automatically recommends a two-dimensional heat flow calculation (thermal bridge calculation), if the two methods differ by more than 10%.

FIGURE 3A-3: WALL ASSEMBLY



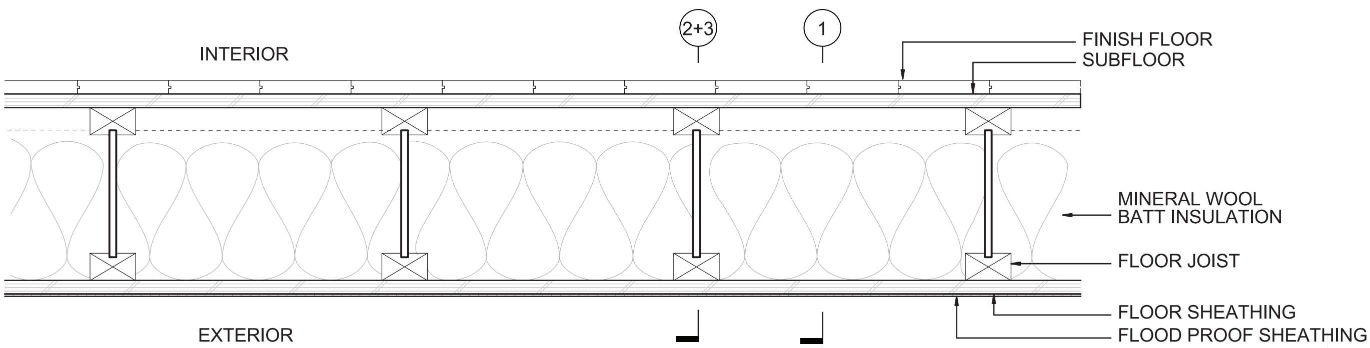
SECTION 1	R/IN.	SECTION 2 (9.4%)	R/IN.	SECTION 3 (9.4%)	R/IN.	THICKNESS (IN)
Gypsum Board	0.91	-		-		5/8"
Mineral Wool	4.24	Studs	1.25	-		2-1/2"
Mineral Wool	4.24	-		Studs	1.25	5-1/2"
OSB	1.44	-		-		7/16"
Mineral Wool	4.24	-		-		1-1/4"
ABS Sheathing	0.85	-		-		1/8"
WD. Vertical Battens	1.22	-		-		3/4"
WD. Horiztonal Battens	1.25	-		-		3/4"
Cedar Shakes	0.87	-		-		1"
					TOTAL THICKNESS (IN.)	**12 15/16"**
					TOTAL R-VALUE (BTU/H FT²F)	**39.58**

The typical wall section is a testament to the SURE HOUSE vision. While resembling a typical stud frame wall, a 16" o.c. 2x6 construction layered on both sides with additional insulation and flood proof sheathing gives us a R39 assembly which is just under our original goal of R40.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

FIGURE 3A-4: FLOOR ASSEMBLY



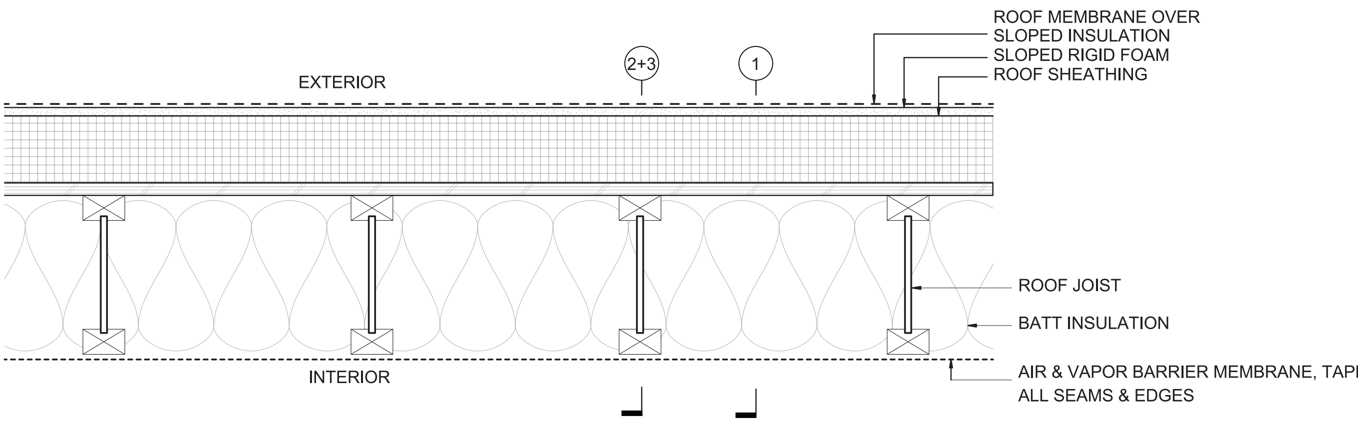
SECTION 1	R/IN.	SECTION 2 (16%)	R/IN.	SECTION 3 (16%)	R/IN.	THICKNESS (IN)
Maple Flooring	0.91	-	-	-	-	3/4"
OSB	1.36	-	-	-	-	3/4"
Air	0.60	Wood I-Joist	1.25	-	-	2"
Mineral Wool	4.24	-	-	Wood I-Joist + Mineral Wool	1.60	7-1/2"
OSB	1.36	-	-	-	-	3/4"
ABS Sheathing	0.85	-	-	-	-	1/8"
					TOTAL THICKNESS (IN.)	**11-7/8"**
					TOTAL R-VALUE (BTU/H FT²F)	**31.09**

The goal of R30 was achieved with 7 ½" of Roxul Comfortbatt in a Wood I-Joist floor cavity. The change from the air cavity above the insulation and thermal bridging of the Wood I-Joist was accounted for in this calculation and checked with a THERM analysis.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

FIGURE 3A-5: ROOF ASSEMBLY



SECTION 1	R/IN.	SECTION 2 (16%)	R/IN.	SECTION 3 (16%)	R/IN.	THICKNESS (IN)
Air	1.11	Wood I-Joist	1.25	-	-	1/2"
Mineral Wool	4.24	-	-	Wood I-Joist + Mineral Wool	1.49	9"
OSB	1.36	-	-	-	-	3/4"
Polyisocyanurate	6.27	-	-	-	-	2-3/4"
Cement Backerboard	0.91	-	-	-	-	1-1/2"
Vinyl Roof Membrane	0.58	-	-	-	-	1/8"
					TOTAL THICKNESS (IN.)	13-5/8"
					TOTAL R-VALUE (BTU/H FT²F)	50.7

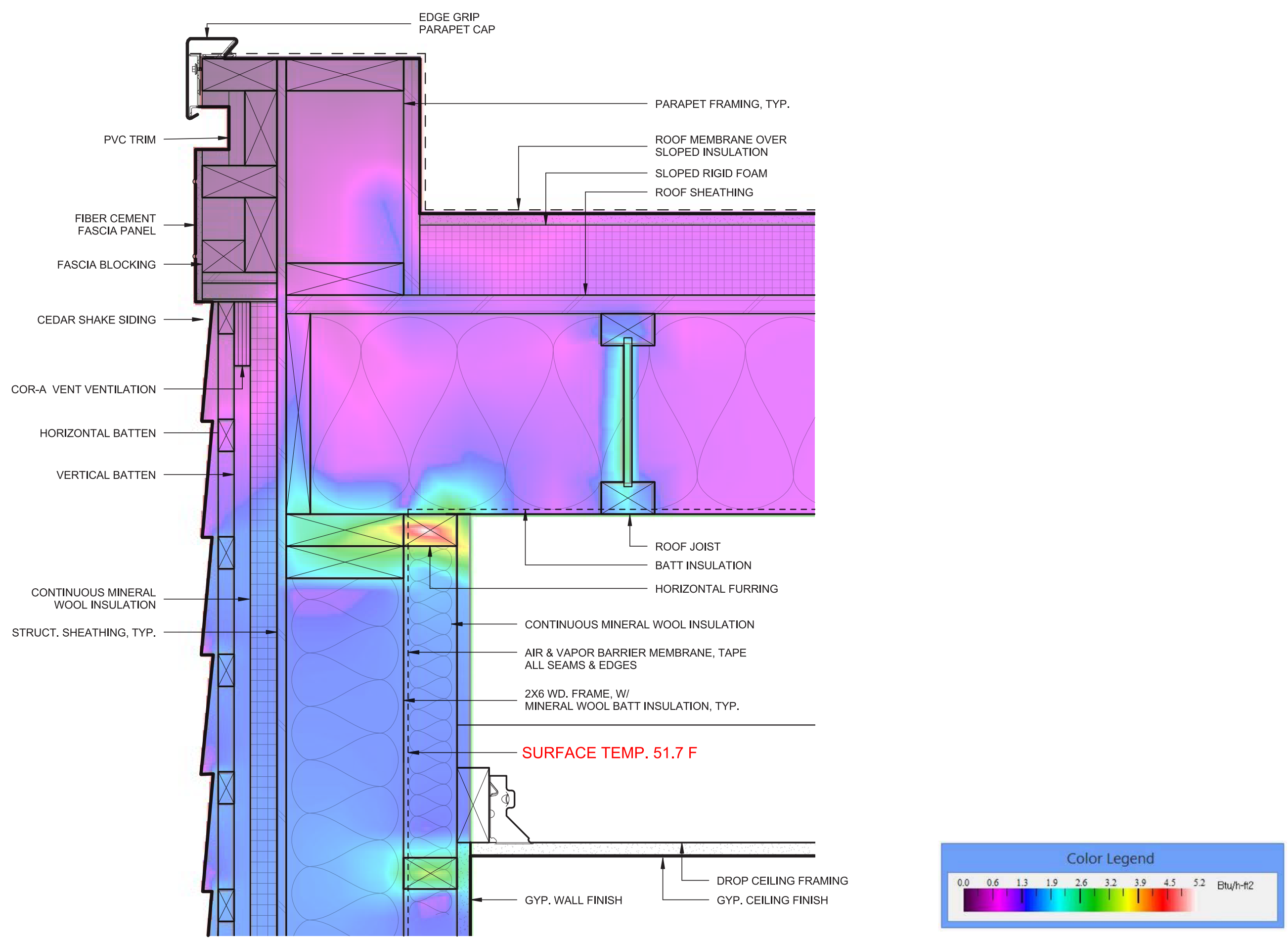
An average roof RValue greater than R50 was achieved by using 9" of Roxul Comfortbatt in a Wood I-Joist roof construction capped with sloped Polyisocyanurate. The slope of Polyisocyanurate is smallest above the East porch where it does not affect the energy demands of the home and is greatest over the mechanical room where retaining heat is most important.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

Graphical 2 dimensional thermal heat flow analysis was executed for all critical construction details. The final results of some typical details (presented here) represent the final state after removing/reducing thermal bridging as much as possible. The 2-D analysis is used both to visualize the heat transfer of the assemblies, but also to calculate a PSI value (Btu/hr·LF·°F) which is then included as part of the total Transmission heat losses for the comprehensive yearly energy model. Additional, surface temperatures at all critical details are evaluated to ensure there is no risk of condensation at the air-barrier plane.

FIGURE 3A-6: ROOF/WALL HEAT FLOW

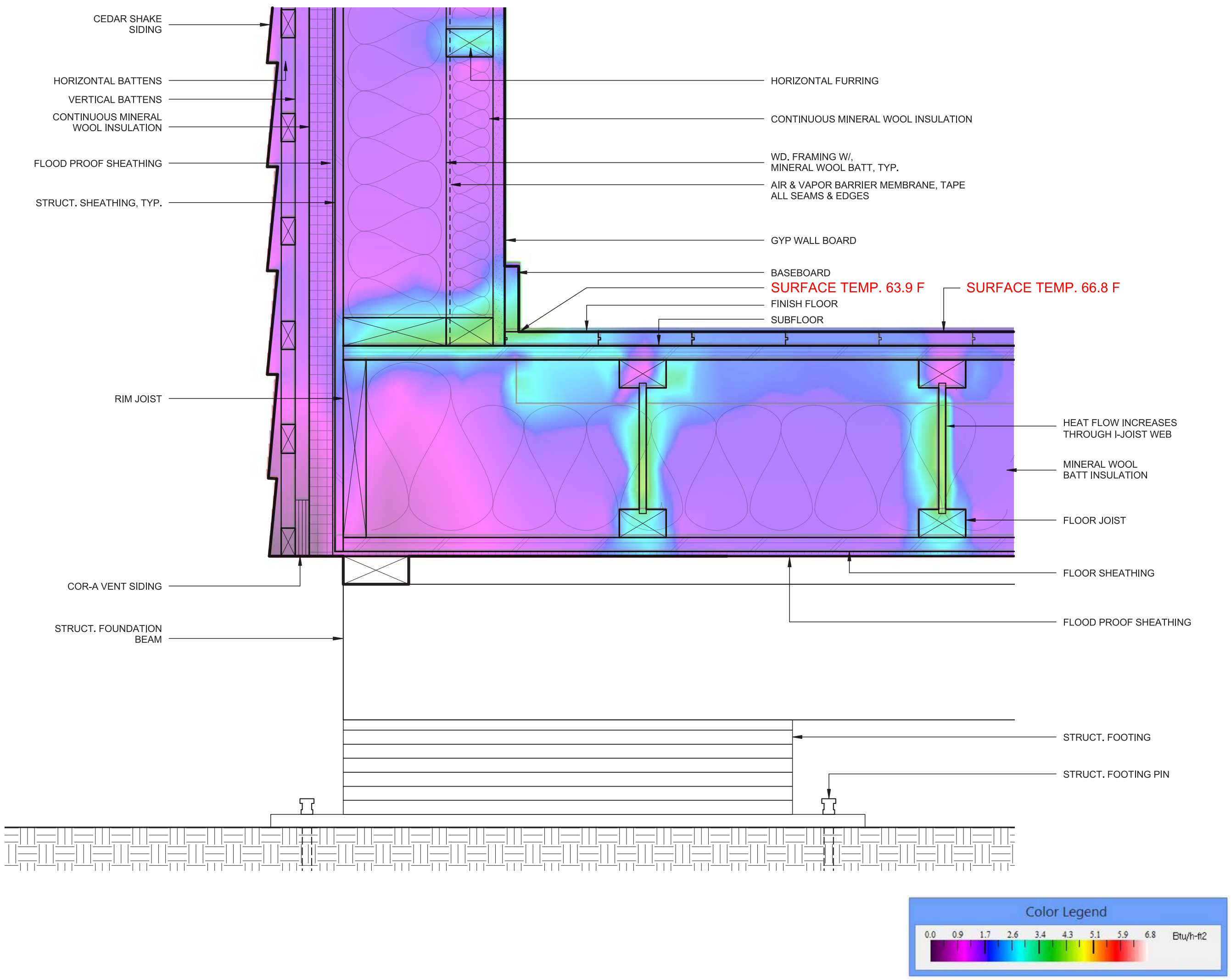


The typical top-plate detail of the wall where it joins to the roof is a site of possible thermal bridging, particularly at the top plate of the wall. Interior insulation does not help trememndously at this joint due to the requirement for a batten at the top, in plane with the wall's top-plate. The continuous exterior insulation, however, wraps completely over this detail ensuring a thermal-bridge free assembly.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

FIGURE 3A-7: FLOOR/WALL HEAT FLOW

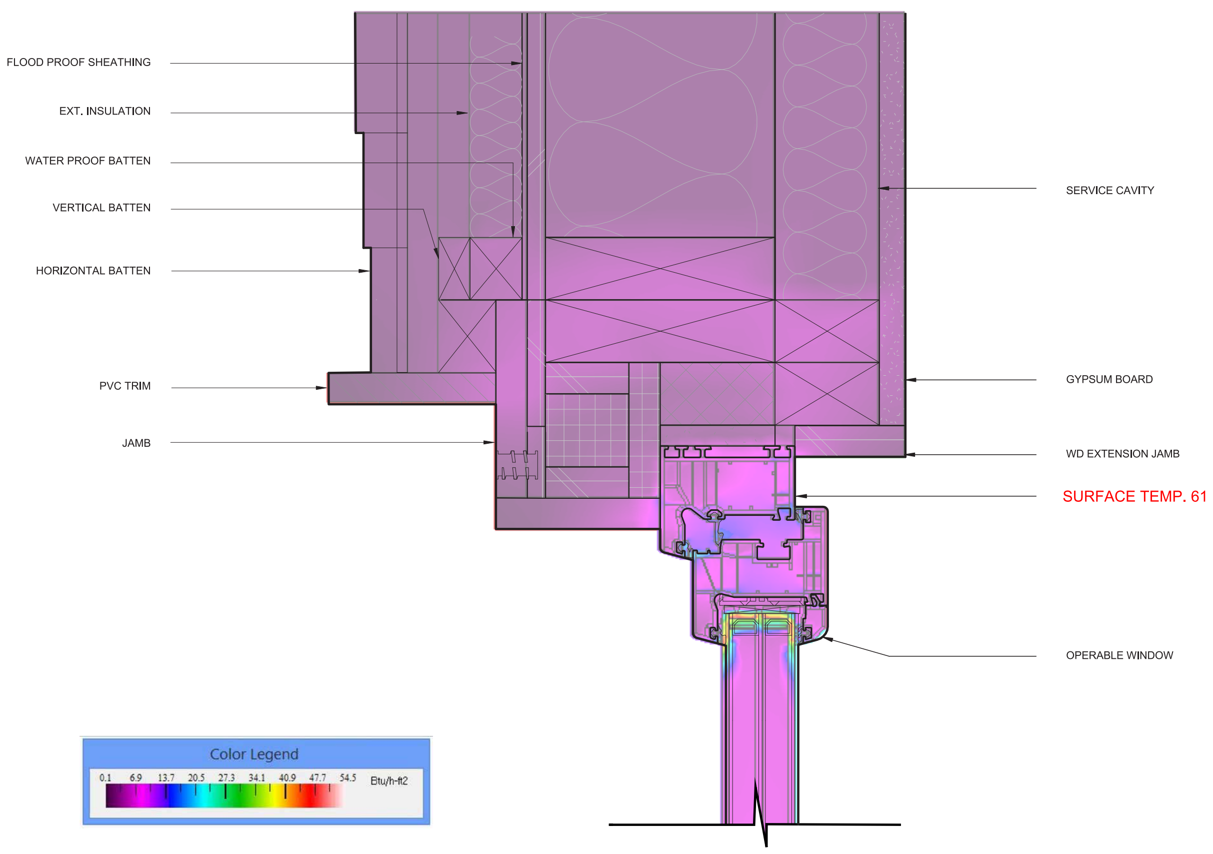


Heat flow through the bottom plates in a wall construction can often lead to considerable thermal bridging. Condensation at the junction between the sub-floor and a wall is often a great concern. Packing out the floor cavity insulation to connect up to the bottom of the walls is essential to reduce thermal bridging and condensation potential.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

FIGURE 3A-8: WINDOW JAMB HEAT FLOW



A typical THERM calculation performed for the window frames. Heat flow can be seen primarily through the window spacer.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3A: R-VALUE ANALYSIS

FIGURE 3A-9: TYPICAL DETAIL PSI VALUES

	2D MODEL				
	U	L	DT	ULDT	ERROR
	(BTU/H FT^{2}F)	(IN)	(F)	(BTU IN/H FT^2)	(%)
OPERABLE WINDOW JAMB	0.09	15.52	55	77.86	6.4
WALL TO FLOOR	0.04	38.63	55	77.96	7.59
WALL TO ROOF	0.03	15.52	55	59.81	7.76

	1D MODEL A				
	U	L	DT	ULDT	ERROR
	(BTU/H FT^{2}F)	(IN)	(F)	(BTU IN/H FT^2)	(%)
OPERABLE WINDOW JAMB	0.13	5.8	55	39.87	6.4
WALL TO FLOOR	0.03	16	55	27.19	7.59
WALL TO ROOF	0.03	16	55	23.14	7.76

	1D MODEL B				
	U	L	DT	ULDT	ERROR
	(BTU/H FT^{2}F)	(IN)	(F)	(BTU IN/H FT^2)	(%)
OPERABLE WINDOW JAMB	0.03	16	55	23.57	6.4
WALL TO FLOOR	0.03	16	55	32.50	7.59
WALL TO ROOF	0.02	16	55	15.31	7.76

	PSI		
	PSIDT	DT	PSI
	(BTU IN/H FT^2)	(F)	(BTU IN/H FT^{2}F)
OPERABLE WINDOW JAMB	14.52	55	0.26
WALL TO FLOOR	27.28	55	0.50
WALL TO ROOF	21.35	55	0.39

In order to calculate the final Psi-value of each detail, the results of the 2D model had to be subtracted from the 1D model results. This way, all thermal bridges can be accounted for in the PHPP analysis.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3B: WINDOW AND SHADING ANALYSIS

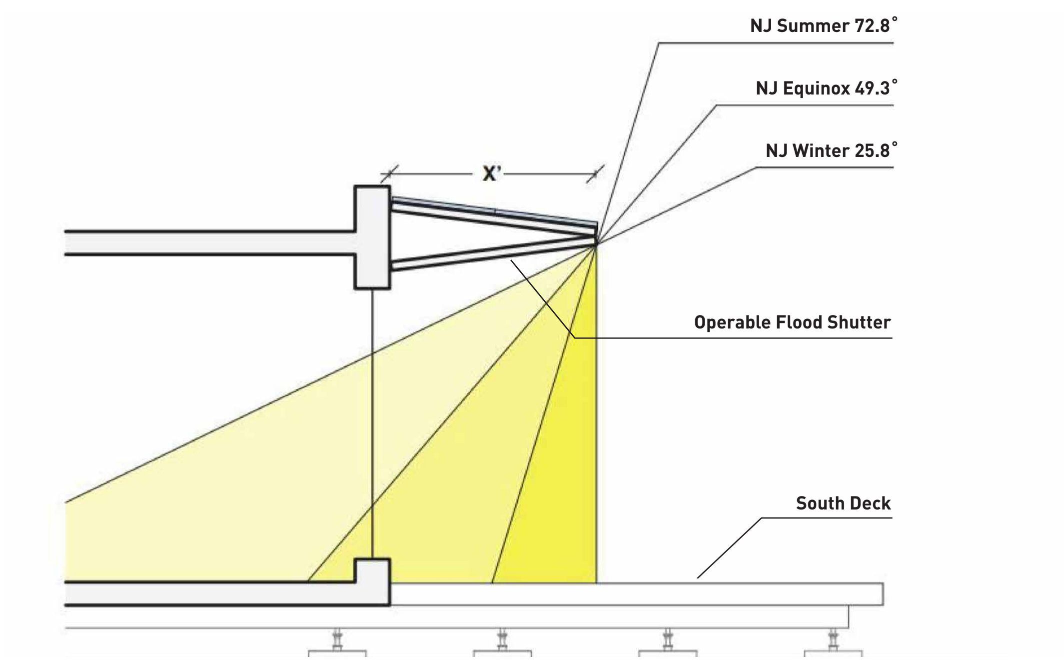
In order to reduce heating and cooling demand, particular attention must be given to the design of the windows of a Passive House. The SURE HOUSE strategy took into account several variables in order to utilize gains from sun intelligently. These include:

1. Window Orientation and Distribution
2. Window SHGC
3. Shading Strategy

Several tools were used to analyze these variables. They include:

1. Passive House Planning Package (PHPP)
2. DIVA for Grasshopper
3. Honeybee for Grasshopper

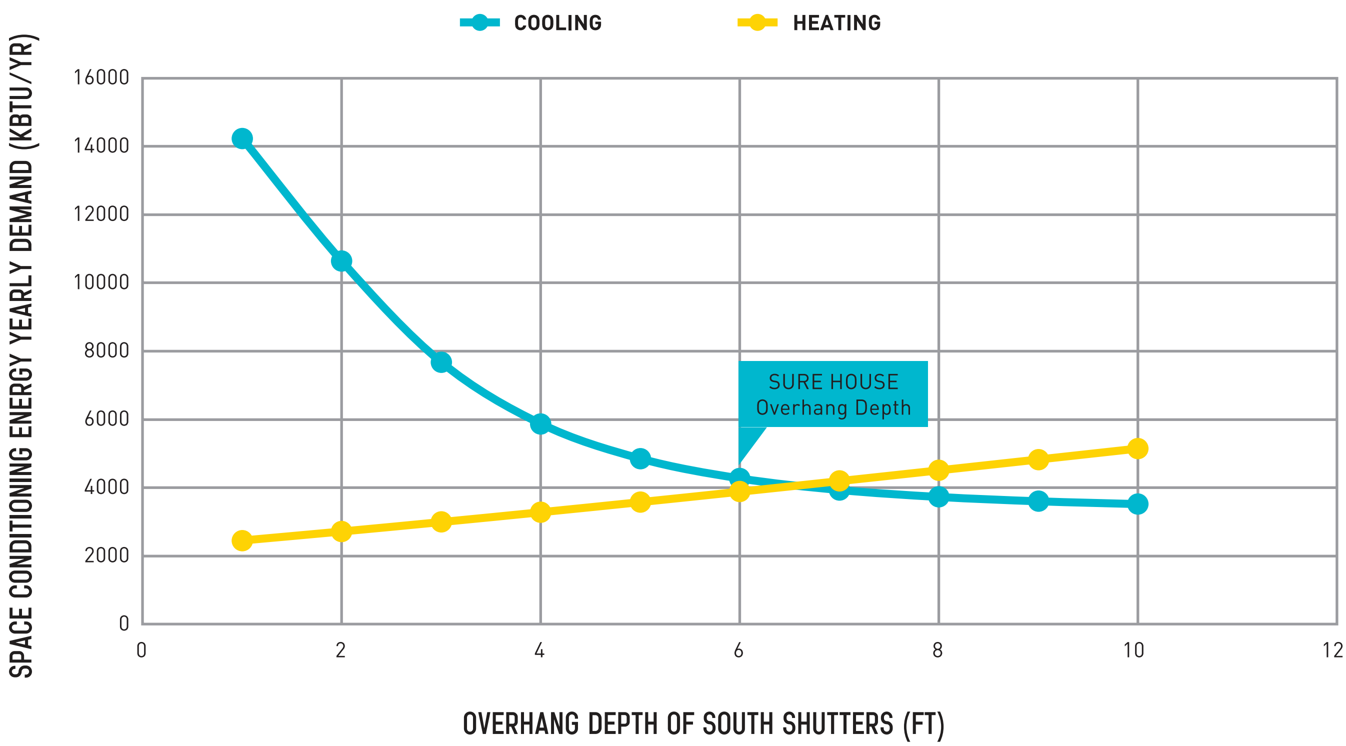
FIGURE 3B-1: SEASONAL SHUTTER SHADING DIAGRAM



To design effective shading, solar angles at different times of the year were analyzed. The most important question of the shading strategy was very simple: how deep should the overhang of othe storm shutters be (X) to minimize both heating and cooling demands for the SURE HOUSE? See Appendix Section 8 for details concerning the storm shutters.

SECTION 3B: WINDOW AND SHADING ANALYSIS

FIGURE 3B-2: EFFECT OF SHUTTER OVERHANG DEPTH ON HEATING AND COOLING DEMAND



A simple test to check the efficiency of the Shutter Overhang depth was run in the Passive House Planning Package (PHPP). A decrease in cooling demand coincides with an increase in heating demand as Overhang Depth is increased resulting in an intersection where both values are minimized. Due to geometrical constraints of the Shutter design, the overhang depth of remains at 6' although the optimal depth is slightly greater.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3B: WINDOW AND SHADING ANALYSIS

DIVA FOR GRASSHOPPER

One of the most sophisticated radiation analysis tools available today is known as DIVA, which is available as a plug-in for both Rhinoceros and Grasshopper. This tool was used to calculate a more precise measurement of the shading effectiveness of the shutters and louvers for inclusion in the PHPP. While this method would need to be officially verified by the Passive House Institute to be used for certification, the calculation was completed using the same conditions and weather data as are found in the PHPP.

In order to reach the Passive House standard, designing more efficient shading for both seasons (winter and summer) was essential. This was measured in shading percentage for calculated during the heating period (winter) or cooling period (summer) determined by the PHPP. The conditions were as follows:

PERIODS EXAMINED:

- Heating Period: October - May
- Cooling Period: May - October

SHADING PERCENTAGE GOALS TO REACH PASSIVE HOUSE:

- Heating Period Shading Goal: < 50%
- Cooling Period Shading Goal: > 70%

VARIABLES ANALYZED:

- Louver Spacing
- Length of Louvers
- Top Louver Removal (by foot of open space)

CONDITIONS:

- Only vertical louvers were considered.
- SHGC of all Windows: 0.62
- Weather Data: Belmar, NJ
- Height of South Windows: 9'
- Louver Angle: 49.5 degrees (noon at solar equinox)

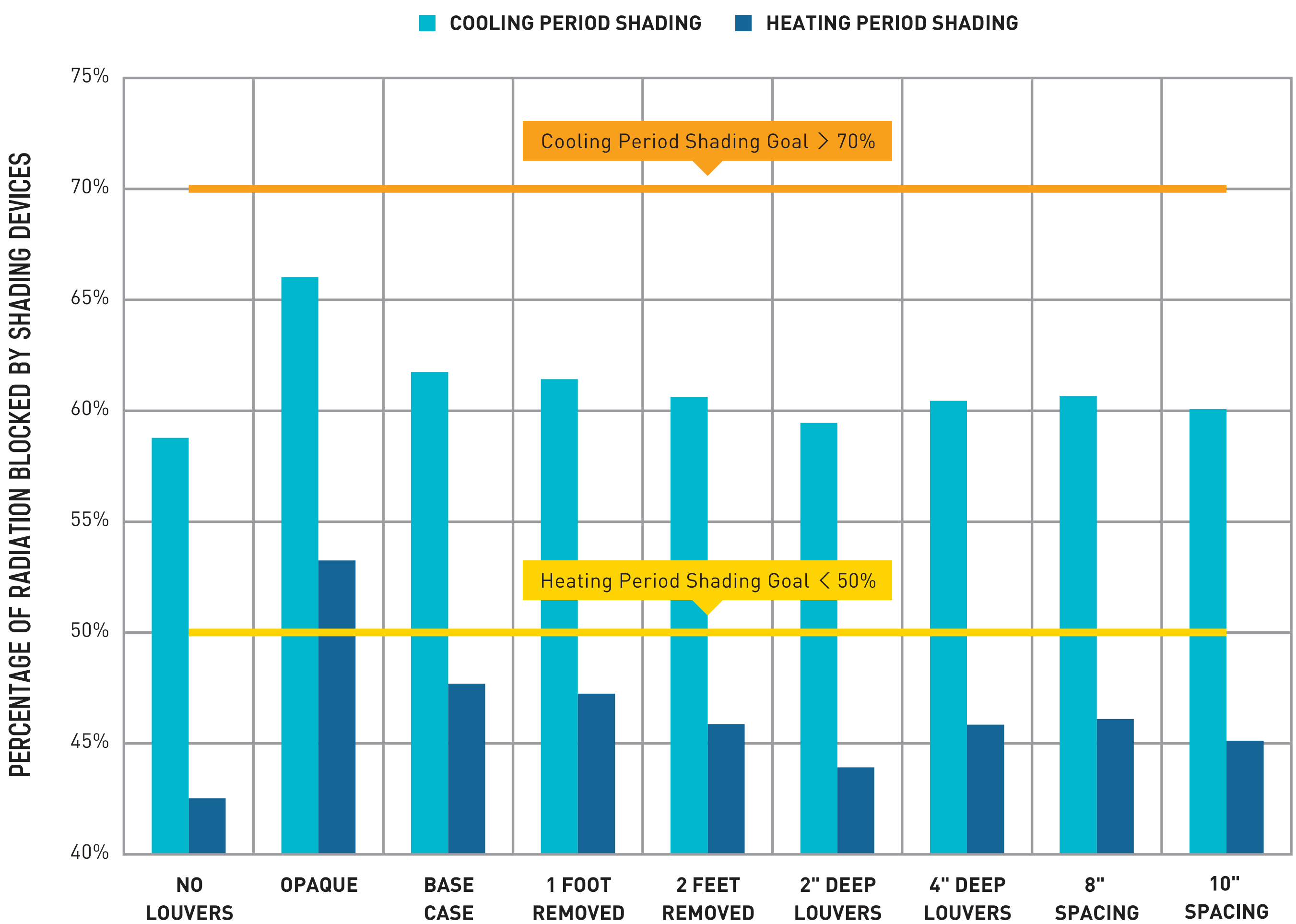
RESULTS:

No condition analysed was effective enough to provide enough shading in the summer without over-shading in the winter. As a result, the height of the South Glazing was reduced from 9' to 8' and the SHGC of the punch windows was reduced to 0.5.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3B: WINDOW AND SHADING ANALYSIS

FIGURE 3B-3: DIVA SHADING ANALYSIS OF LOUVER CONDITIONS



Based on this test, none of the options considered were effective enough to block more than 70% of radiation in the summer blocking less than 50% of the radiation during the winter.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3B: WINDOW AND SHADING ANALYSIS

CONCLUSION

The SURE HOUSE shading is least effective during the fall months (Sept. Nov.) when solar angles are low and the ambient temperature is still high enough that high solar gains greatly increase cooling demand.

POSSIBLE SOLUTIONS

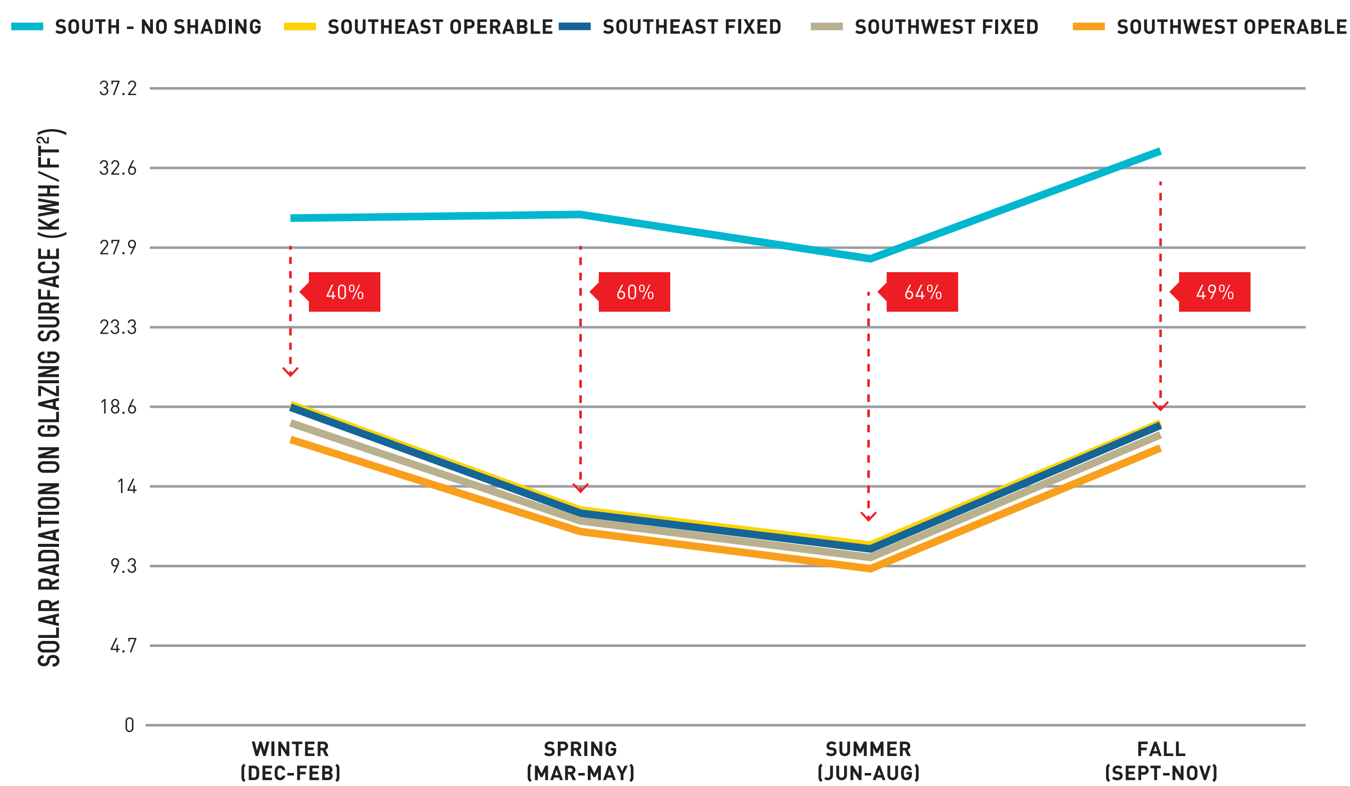
One way to deal with high solar gains during the shoulder seasons would be to add natural ventilation the energy model. This was not included in the SURE HOUSE energy model because the calculation is difficult and potentially inaccurate. The large sliding doors and operable bedroom windows provide significant opportunities for natural ventilation. In order to consider this an effective solution, field testing must be completed.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3B: WINDOW AND SHADING ANALYSIS

A final calculation of the shading % on the Southern glazing was calculated based on the as-built configuration of the louvers and shutters. This model was run for each season in Belmar, NJ.

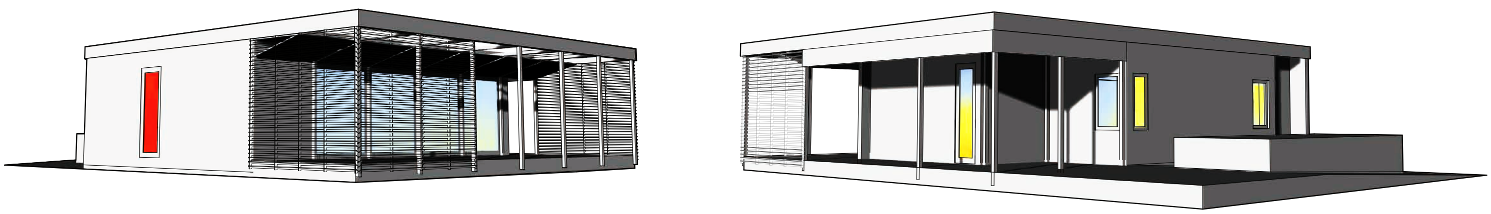
FIGURE 3B-4: EFFECT OF SHADING ON SOUTH WINDOWS BY SEASON



Shading percentages were calculated as the ratio of incident radiation (kWh/ft^2) between the unshaded condition and the shaded condition. A ground plane with the same reflectivity (0.35) was included for the base case. All exterior materials were set to a reflectivity of 0.35 for simplicity. The greatest reduction in radiation is realized during the summer with 64% and the least in the winter with 40%.

SECTION 3B: WINDOW AND SHADING ANALYSIS

FIGURE 3B-5: SUMMER SHADING ANALYSIS



During the months of June, July, and August, exterior shading devices block 64% of incident radiation.

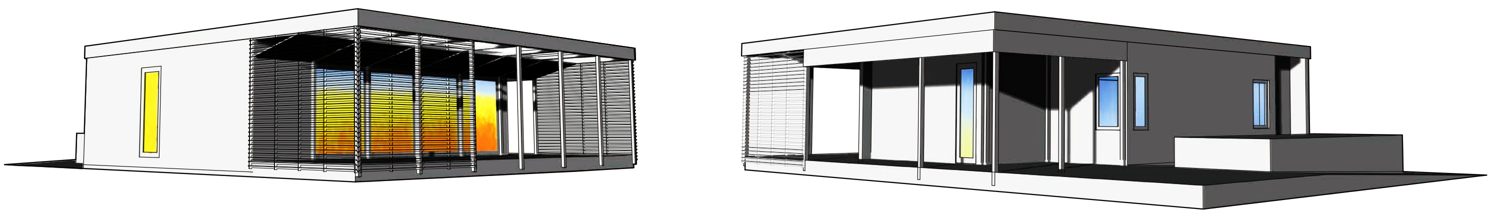
FIGURE 3B-6: WINTER SHADING ANALYSIS

During the months of December, January, and February, exterior shading devices block 40% of incident radiation.

SECTION 3: ENVELOPE ANALYSIS

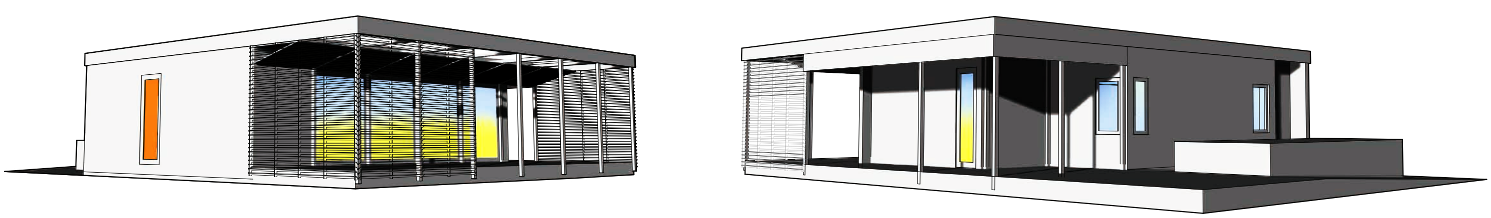
SECTION 3B: WINDOW AND SHADING ANALYSIS

FIGURE 3B-7: FALL SHADING ANALYSIS



During the months of September, October, and November, exterior shading devices block 49% of incident radiation.

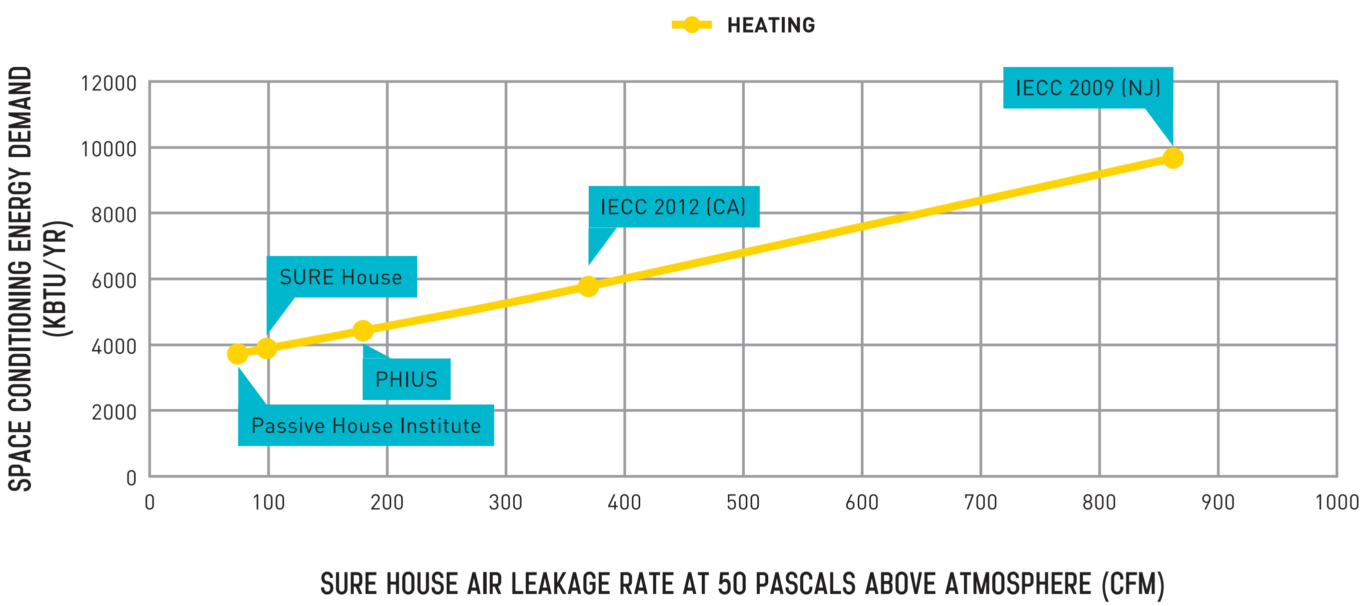
FIGURE 3B-8: SPRING SHADING ANALYSIS



During the months of March, April, and May, exterior shading devices block 60% of incident radiation.

SECTION 3C: AIR SEALING DETAILS

FIGURE 3C-1: EFFECT OF AIR TIGHTNESS ON YEARLY HEATING AND COOLING DEMAND



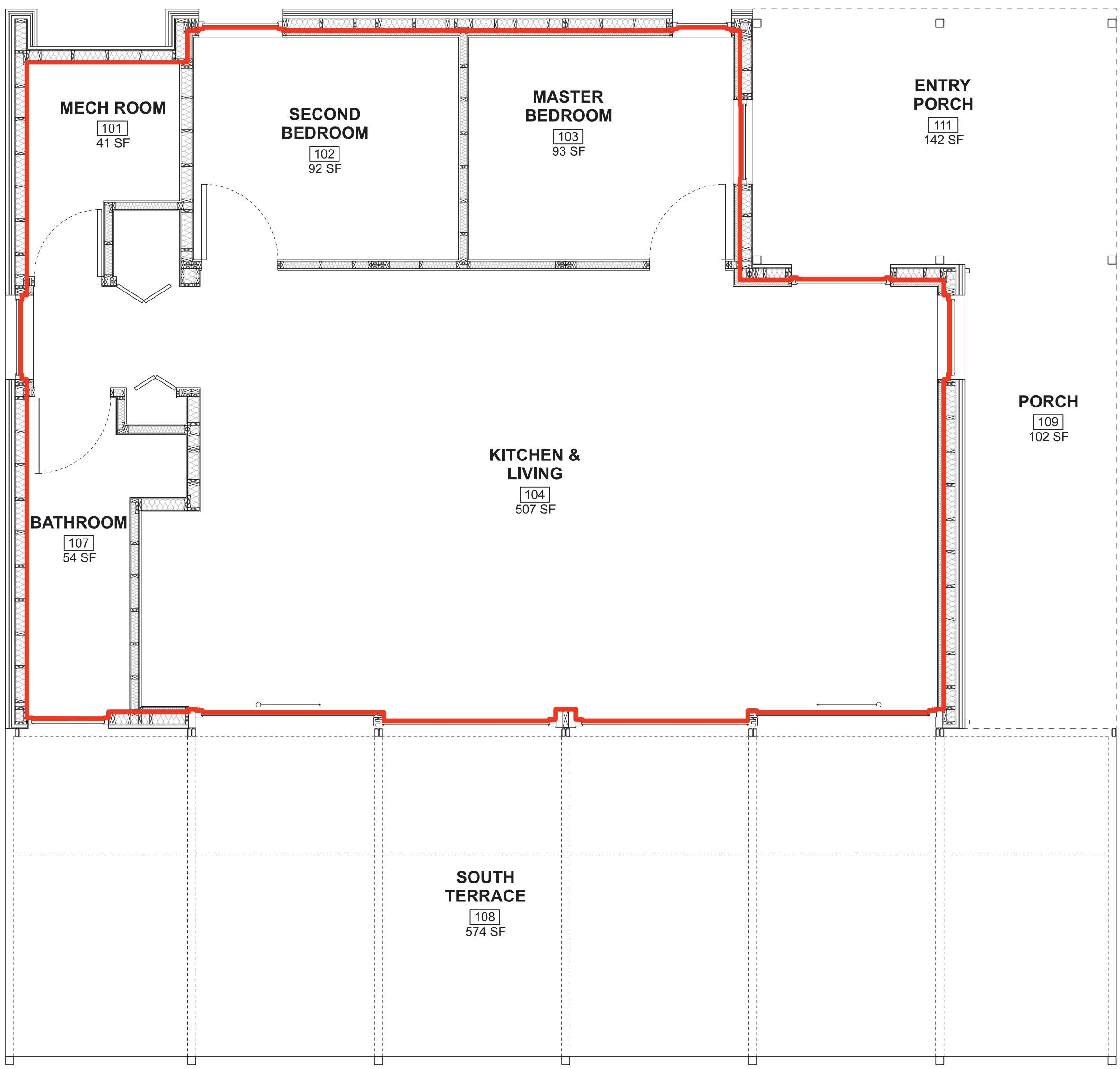
In New Jersey, the largest effects of increasing airtightness are on reducing the annual heating demand, as well as reducing condensation risk during the cold winter months. According to IECC 2009 (followed in NJ), an airtightness of 7 ACH50 is required (861 CFM for the SURE HOUSE). This is ten times greater than what is required by the Passive House Institute (0.6 ACH50 or 74 CFM). This represents a difference of 6,000 kBtu/yr of heating demand in Belmar, NJ or a 260% increase for the SURE HOUSE.

While the PHI certification requires an airtightness level of <0.6ACH@50 (n50) for certification, the Passive House Institute of the US (PHIUS) has recently adopted an alternate standard which is based on a CFM-per-sf-Envelope (w50). This standard is more focused on reducing condensation risk and is equally challenging for buildings of any size to achieve (larger buildings have a much easier time achieving the n50 target than smaller buildings) For the SURE HOUSE, the PHIUS standard of 0.05CFM/sf of envelope at 50Pa would equal 179.4 CFM, more than 1.8 times greater than the level achieved by the SURE HOUSE.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3C: AIR SEALING DETAILS

FIGURE 3C-2: RED PENCIL TEST

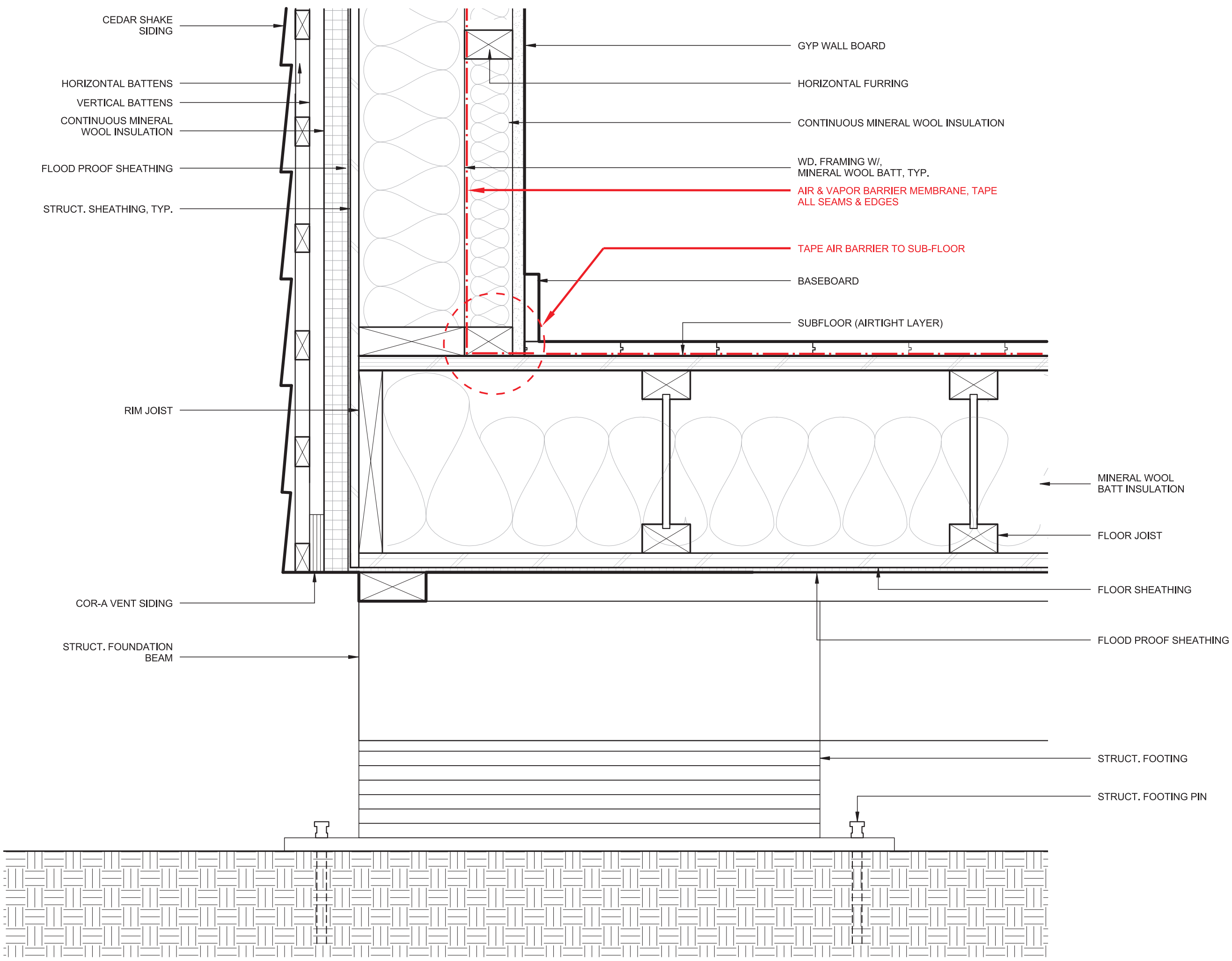


Performing a “Red Pencil Test” is essential to ensuring that the air barrier is completely unbroken. This requires tracing the air barrier around the home without picking your “red pencil.”

SECTION 3: ENVELOPE ANALYSIS

SECTION 3C: AIR SEALING DETAILS

FIGURE 3C-3: WALL TO FLOOR AIR SEALING

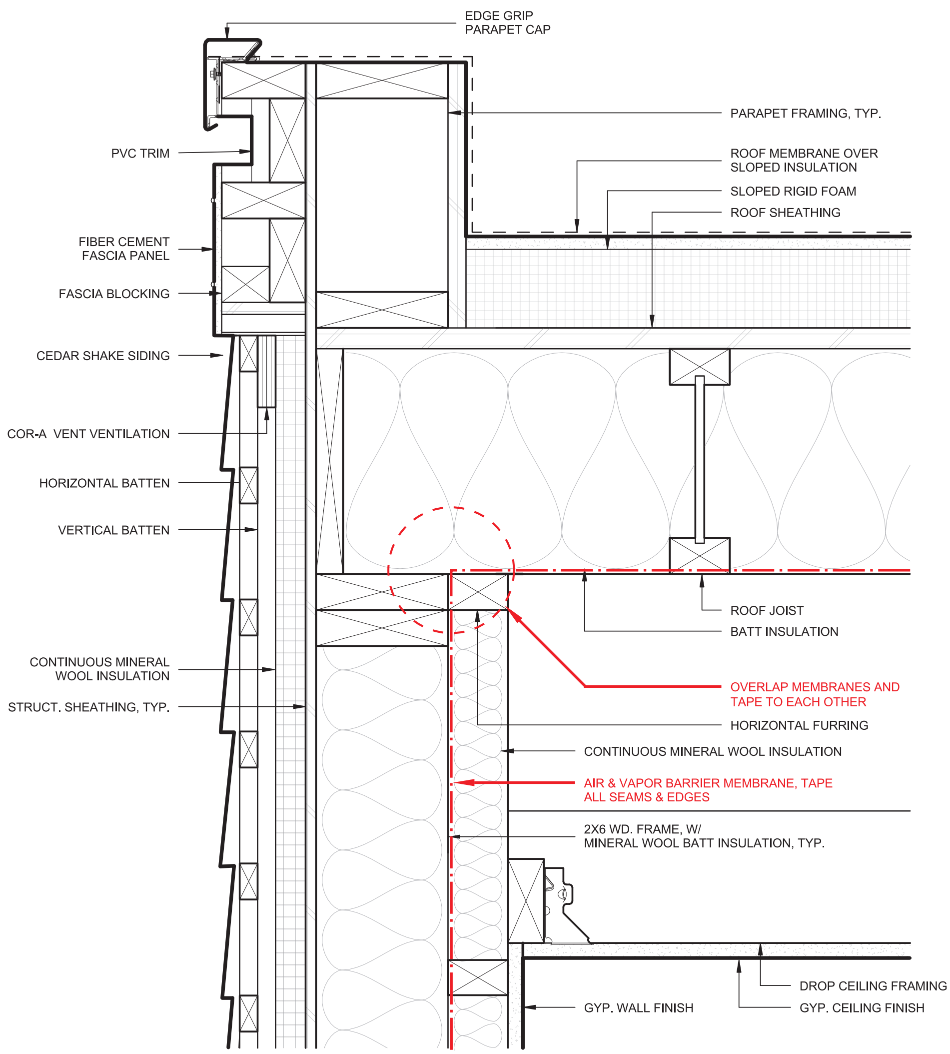


Intello connects to the subfloor with Tescon Profil high performance airsealing tape. Corners received added reinforcement.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3C: AIR SEALING DETAILS

FIGURE 3C-4: WALL TO CEILING AIR SEALING

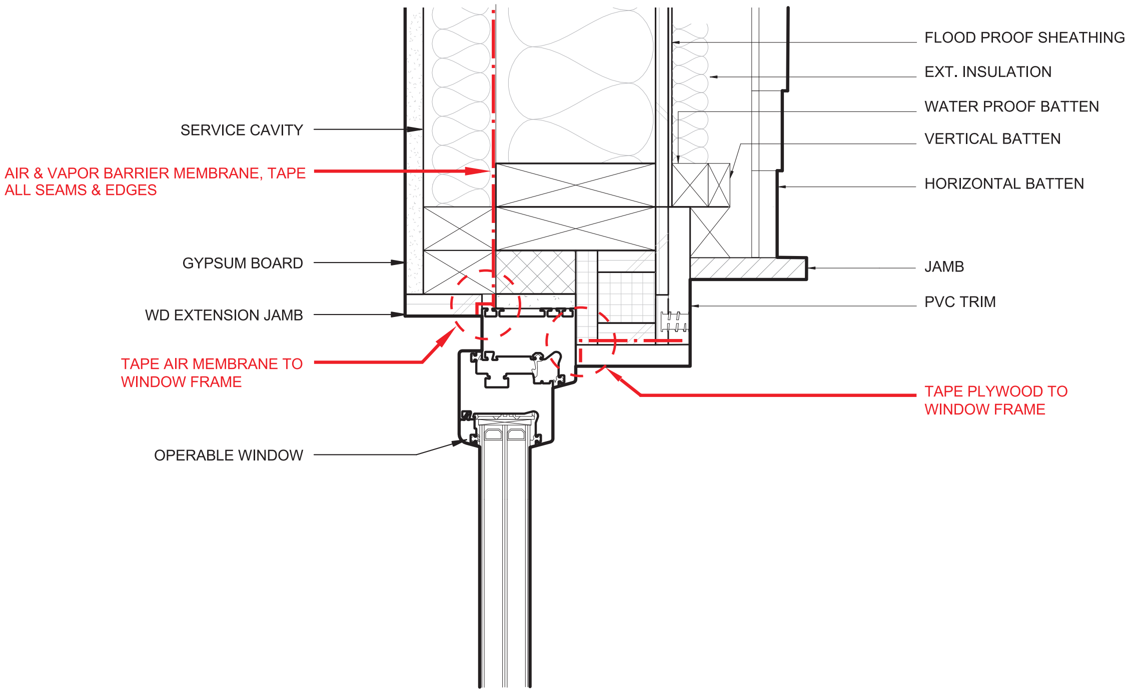


The layer of Intello on the ceiling overlapped the header of the walls with sufficient area for taping. Tescon Vana was used to connect these layers.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3C: AIR SEALING DETAILS

FIGURE 3C-5: WINDOW FRAME AIR SEALING



Windows frames were connected to the Intello air barrier with Tescon Profil and Tescon Vana tape. Additionally, the outside surface of the frames were taped to the exterior weather barrier for increased airtightness and moisture control.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

The Passive House Institute in Germany requires an airtightness measurement of 0.6 ACH50 (Air Changes per Hour at 50 pascals above and below atmospheric pressure). The importance of airtightness and its effect on energy consumption can not be overstated. The SURE HOUSE recorded leakage of 100 CFM or ACH 0.8. Although this does not meet the standard set by the Passive House Institute (PHI), it does meet the PHIUS standard of 179 CFM for the SURE HOUSE. During testing, several issues were identified as areas of leakage which should be addressed in the future:

1. Adjust hinges on bathroom door for better seal
2. Place gaskets between beams during reassembly
3. Reseal compressor refrigerant tubing to sealing Intello
4. Adjust hinges of operable windows for better seal

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-1: SUBFLOOR AIR BARRIER TAPING DETAIL

Tescon Vana airsealing tape was used to seal the seams of the subfloor air barrier. A plastic pressfix was used to apply pressure to activate the permanent seal.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

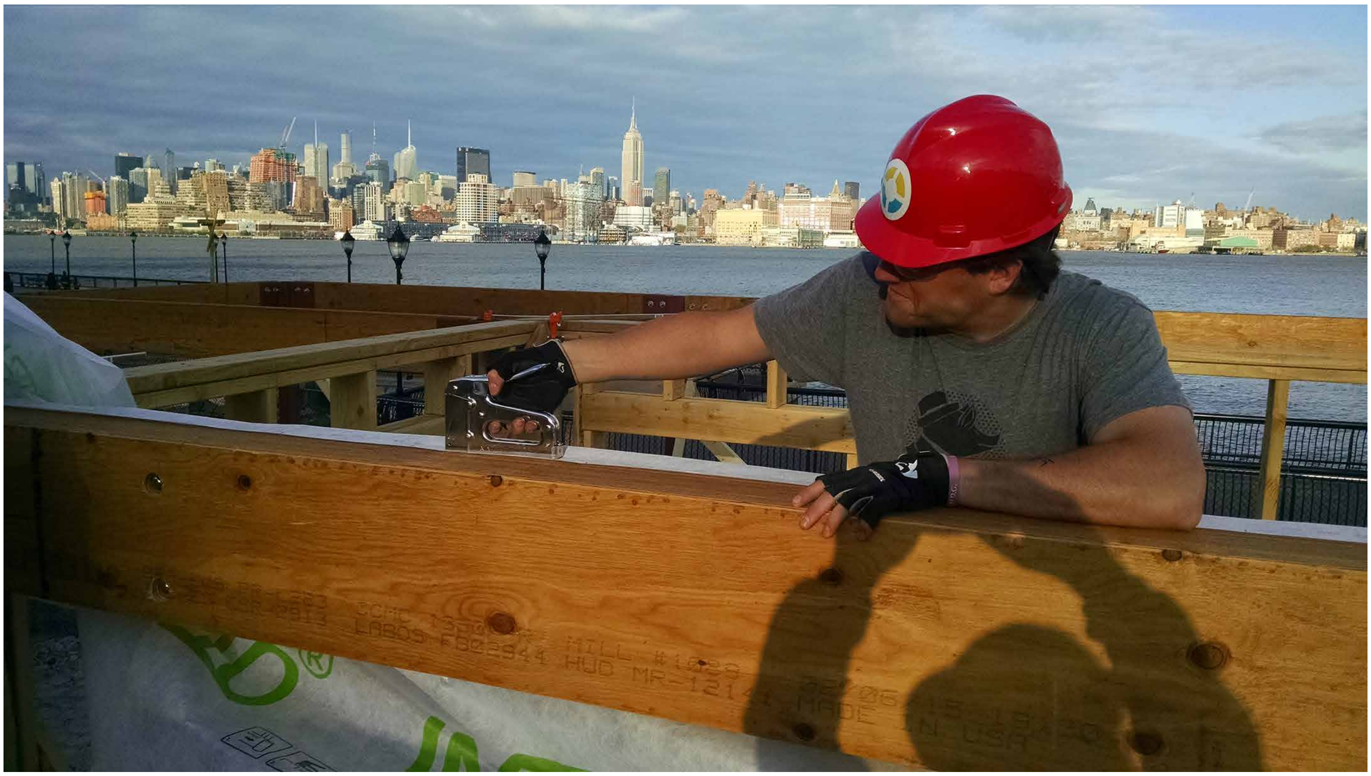
FIGURE 3D-2: COMPLETED SUBFLOOR AIR SEALING DETAIL

Once sealed, the OSB sub-floor becomes the first part of the air-barrier.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-3: BEAM AIR SEALING

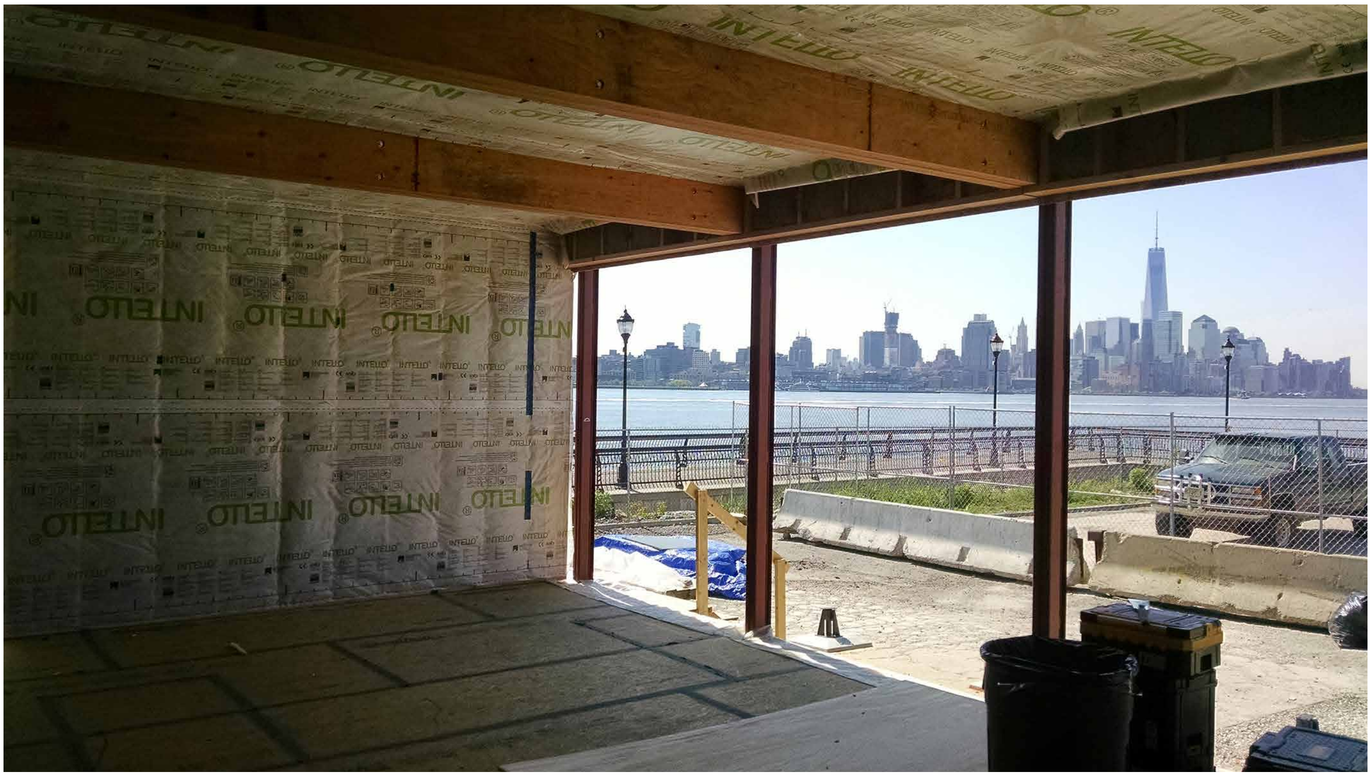


Prep strips of Intello were applied on top of beams and behind partition walls to act as a marriage strip for after the roof and exterior walls were installed.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-4: LIVINGROOM AIR SEALING



Once complete, the subfloor, wall Intello, and ceiling Intello create a continuous barrier.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-5: WINDOW AIR SEALING

Intello was run up to the frame of all windows and doors and taped using Tescon Vana or Tescon Profil.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-6: ELECTRICAL AIR SEALING

All electrical penetrations were sealed with Roflex gaskets and ProClima tapes. This floor outlet required its own fully sealed, recessed box.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-7: PLUMBING AIR SEALING

All plumbing penetrations were sealed with Roflex gaskets and sealed to the airbarrier.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

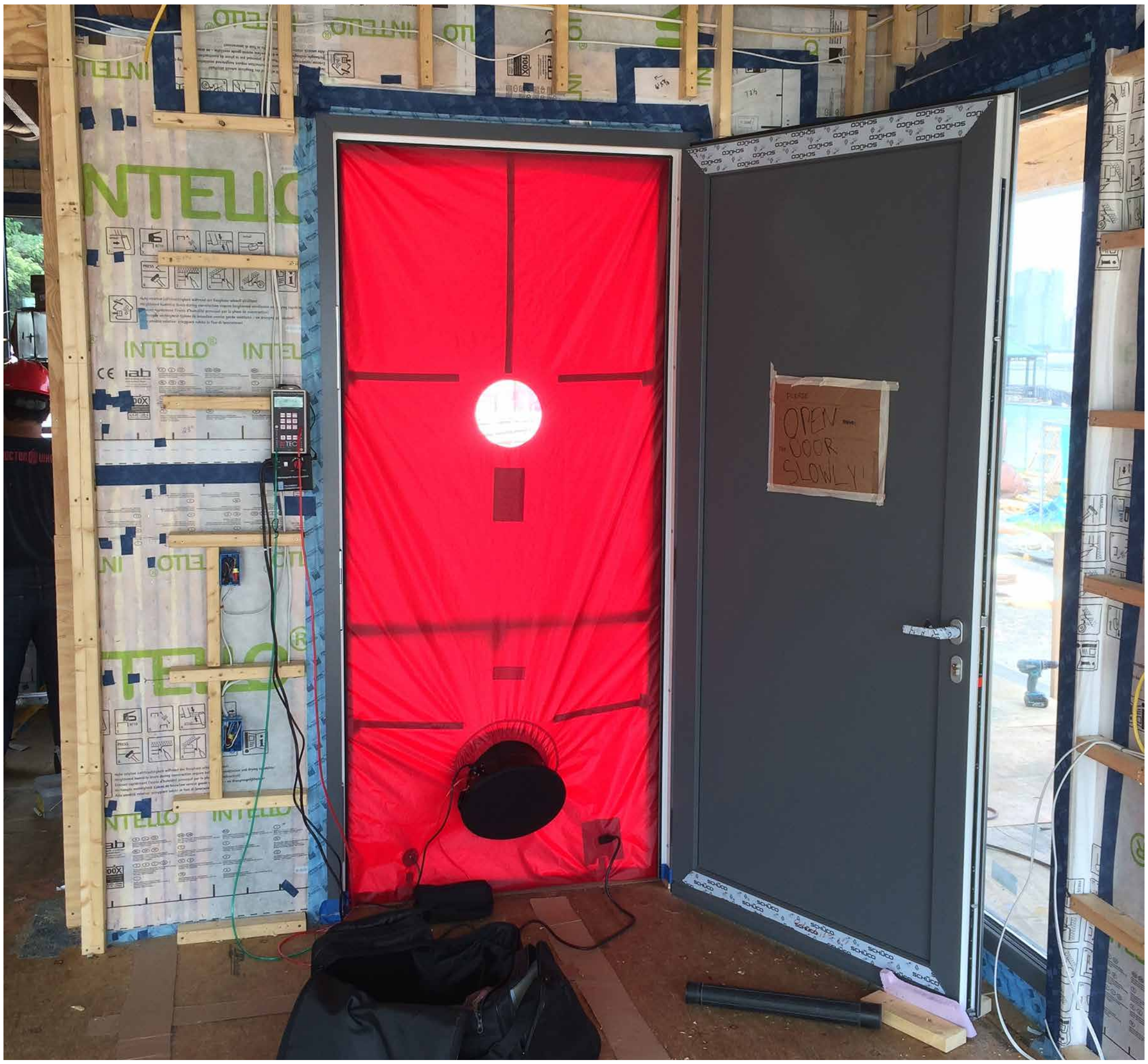
FIGURE 3D-8: SHOWER PAN AIR SEALING

The shower pan presented a large hole in the subfloor. A strip of Intello was taped to the drain and the subfloor to keep the space continuous.

SECTION 3: ENVELOPE ANALYSIS

SECTION 3D: AIR SEALING PHOTOS

FIGURE 3D-9: BLOWER DOOR TESTING

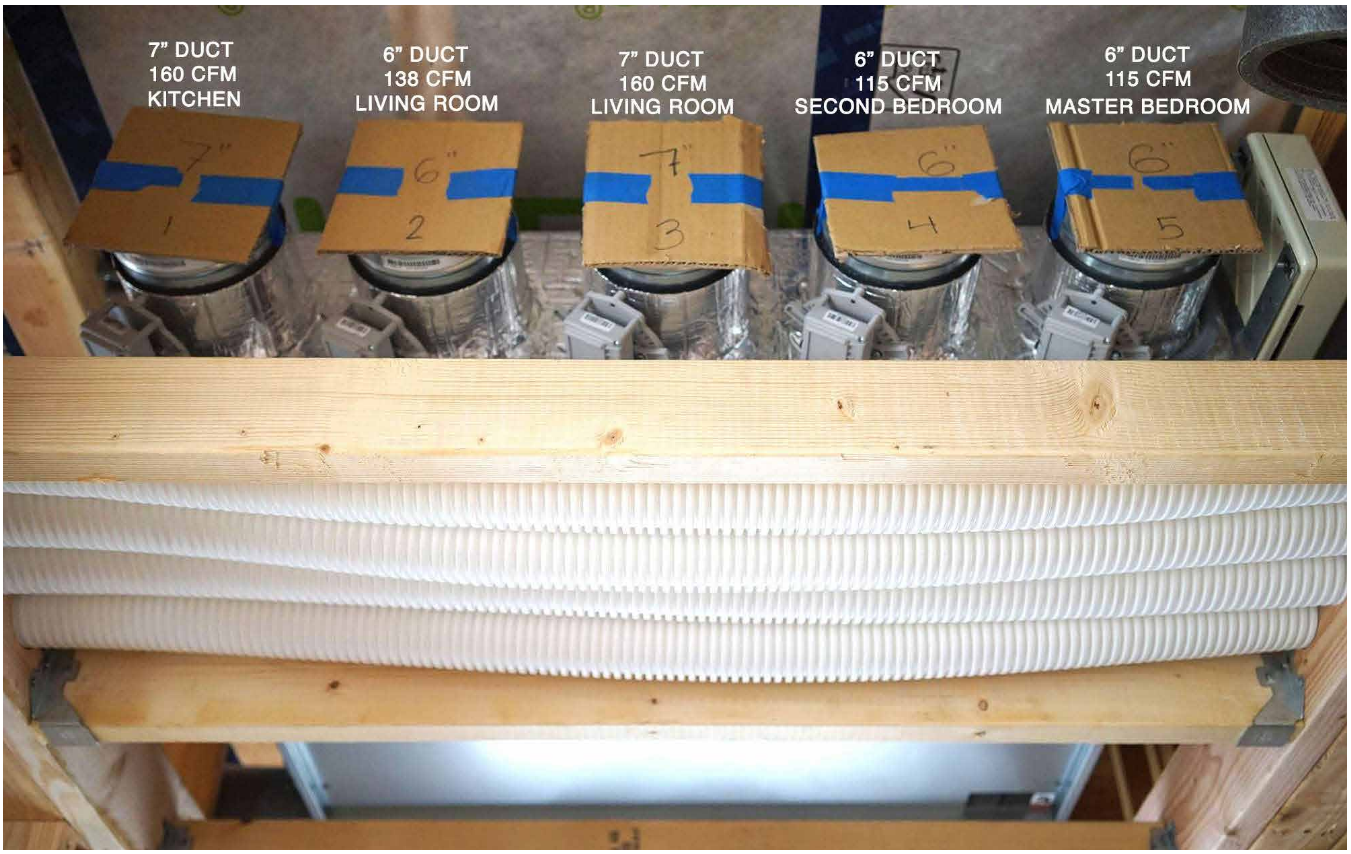


Blower door testing was conducted over the course of two weeks. The goal of 74 CFM was not reached; 82 CFM is the best measurement on record. The final CFM recorded was 100 CFM or ACH 0.8. The standard set by the Passive House Institute of the U.S. would require 179.4 for certification, putting the SURE HOUSE well below their standard.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4A: AHU AND ZONING

FIGURE 4A-1: DAIKIN ZONING KIT

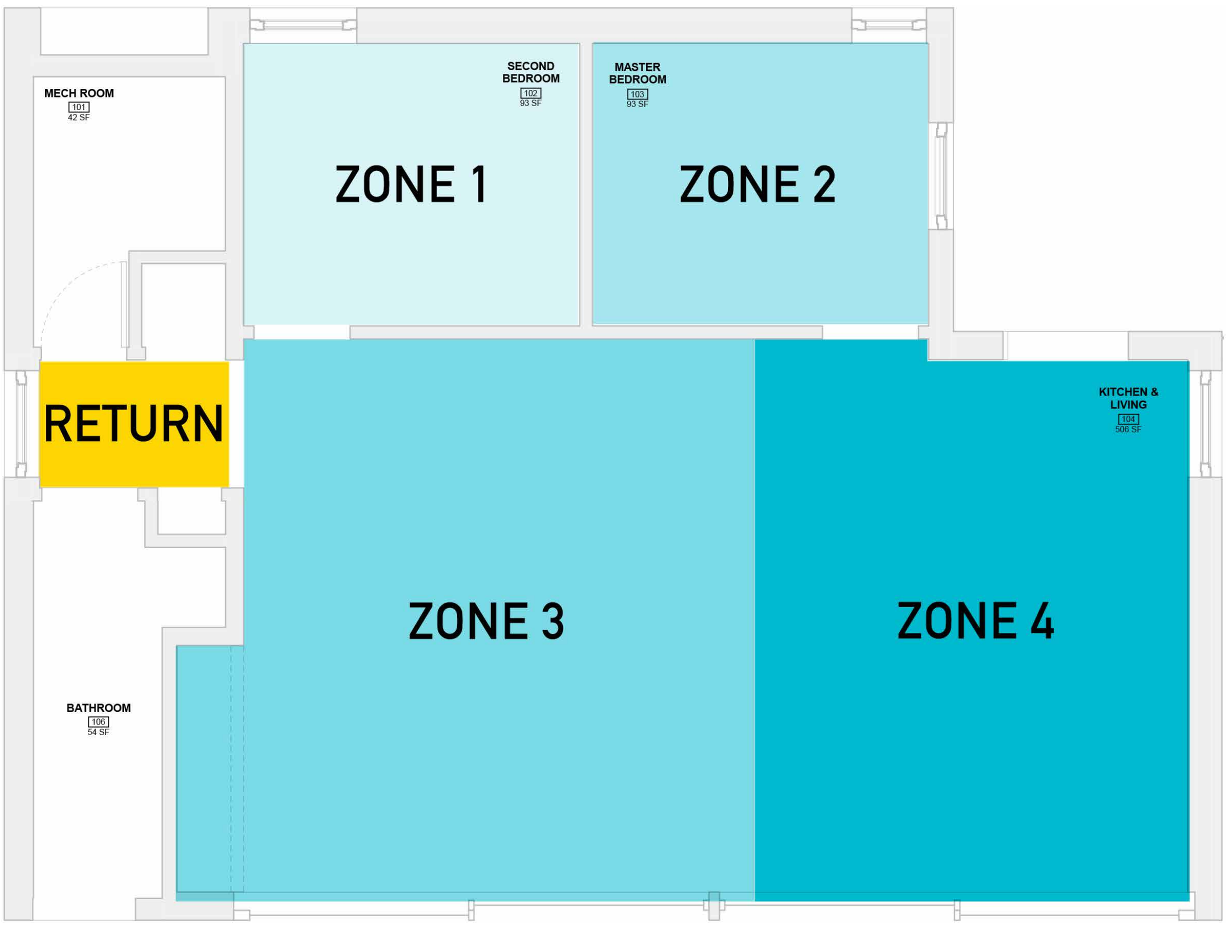


This proprietary manifold mounts directly onto the air handling unit. Also called a zoning kit, this manifold comes with five outputs which split the air leaving the AHU. The airflow for each output is controlled through automatic dampers, which limit or increase the airflow to each zone. Initial flow to each zone was set in proportion to the square footage of the zone. For example, because the bedrooms are smaller, they receive less airflow than the larger living room zone. Care was taken to make sure that higher velocity air flow would not exceed 600–700 feet per minute.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4A: AHU AND ZONING

FIGURE 4A-2: HVAC ZONES OF SURE HOUSE

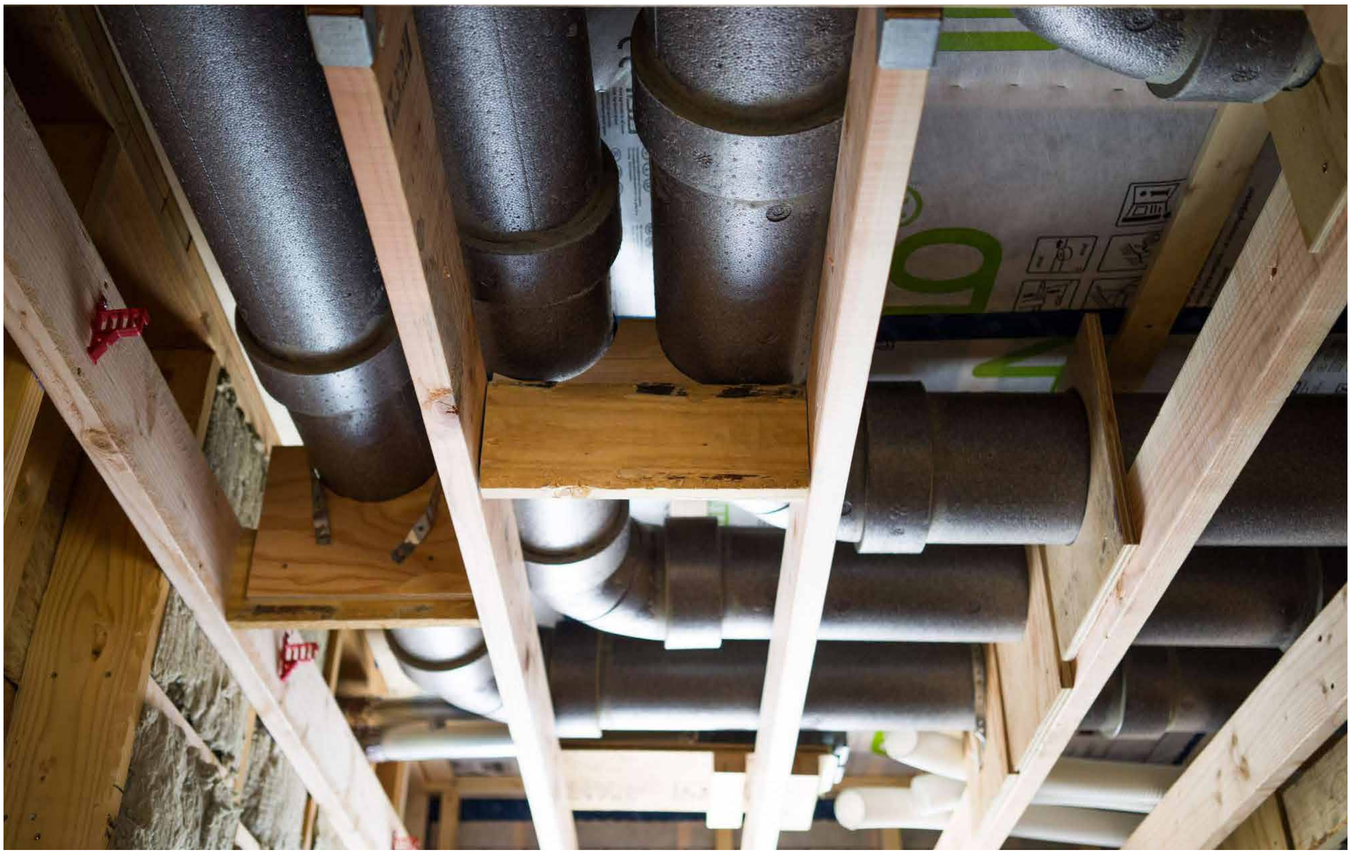


The indoor living areas of SURE HOUSE have been divided into four heating and cooling zones. The temperature in the master bedroom, second bedroom, kitchen/dining space, and living/entertainment area can be independently controlled by the user. This allows them to match the heating and cooling profile of SURE HOUSE to their living patterns, which is a simple, effective way to save energy.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4B: DUCT INSTALLATION

FIGURE 4B-1: ZEHNDER COMFOPIPE DUCTING



Foamed polypropylene ducts from Zehnder were used for the AHU ducting. The foam acts as thermal insulation minimizing thermal bridging within the house to an even higher degree. Ducts were attached to each other using round collars, saving on installation time. Once the ducts were attached and routed, they were secured in the ceiling space using gussets and mastic to prevent them from moving around during shipping. All joints are seamed with a water-based mastic and foil-faced tape as needed.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4B: DUCT INSTALLATION

FIGURE 4B-2: MODULE SEAM DUCTING

At the module seam, the ducts were secured using air barrier tape instead of permanent Mastic. This allows ducts that bridge the module seam to be easily taken out and installed again at competition.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4B: DUCT INSTALLATION

FIGURE 4B-3: CUSTOM PLENUM BOXES

To satisfy the architectural integrity of SURE HOUSE, ducts were not run to ceiling diffusers in the living room in order to conserve high ceiling height. In order to maintain effective ventilation without these diffusers, the team fabricated custom plenum boxes which could be integrated into the living room cabinetry. These plenum boxes are tapped from the top by both AHU and the ERV ducting. They have been installed in the living room cabinetry, hidden behind the face of the cabinet, with the exception of a 3" gap extending across the entire length of the cabinetry. Linear diffusers are mounted on the protruding flange of the plenum boxes, filling the gap and throwing air as needed throughout the living room and kitchen areas.

SECTION 4B: DUCT INSTALLATION

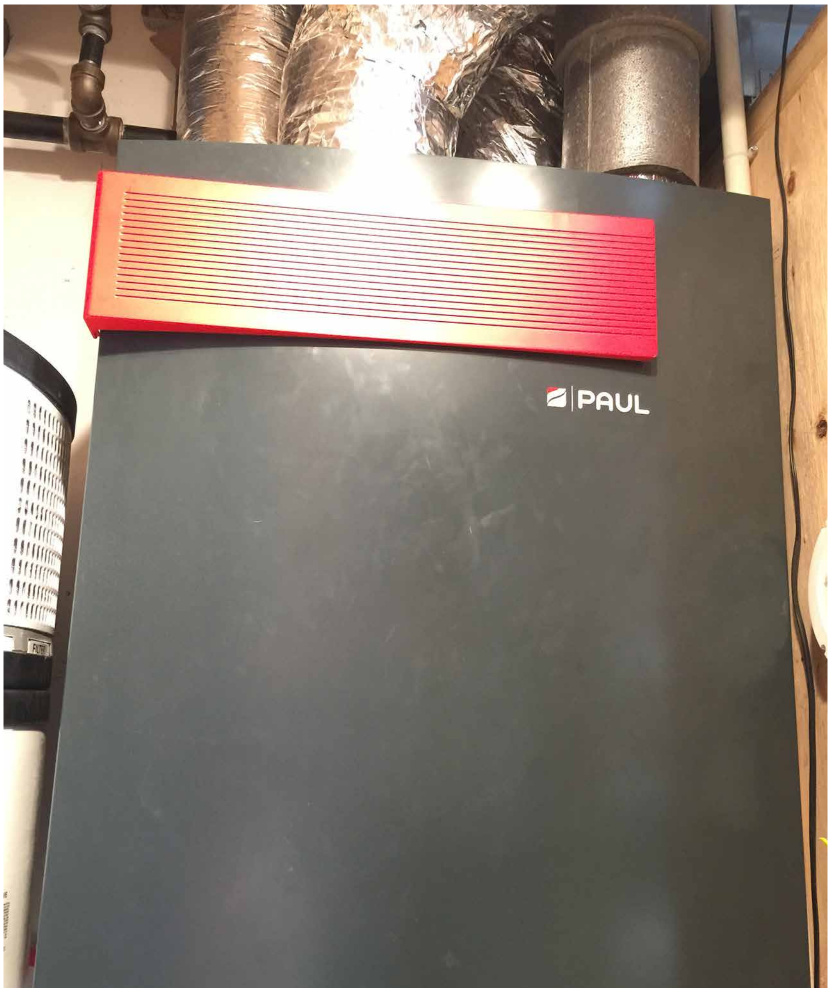
FIGURE 4B-4: LIVING ROOM CABINETRY INTEGRATION

Plenum box cabinetry details can be seen above. The linear diffusers mount into the flange of the plenum boxes to cover the gap. Plenum boxes have been installed so that the linear diffusers will line up with the bedroom doorways in order to create a clean architectural line.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4C: ERV

FIGURE 4C-1: ZEHNDER NOVUS 300



The Zehnder Novus 300 was not only chosen for its' high efficiency, but for its' form factor. Since all of its' inlets and outlets are located at the top, installation was much easier and cleaner; this also allowed the team to avoid running ducting below DFE. The ERV is also equipped with an automatic 'summerbypass' mode that allows outside air to bypass the exchanger if it is cooler outdoors than inside, as is a common occurrence on summer evenings.

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4C: ERV

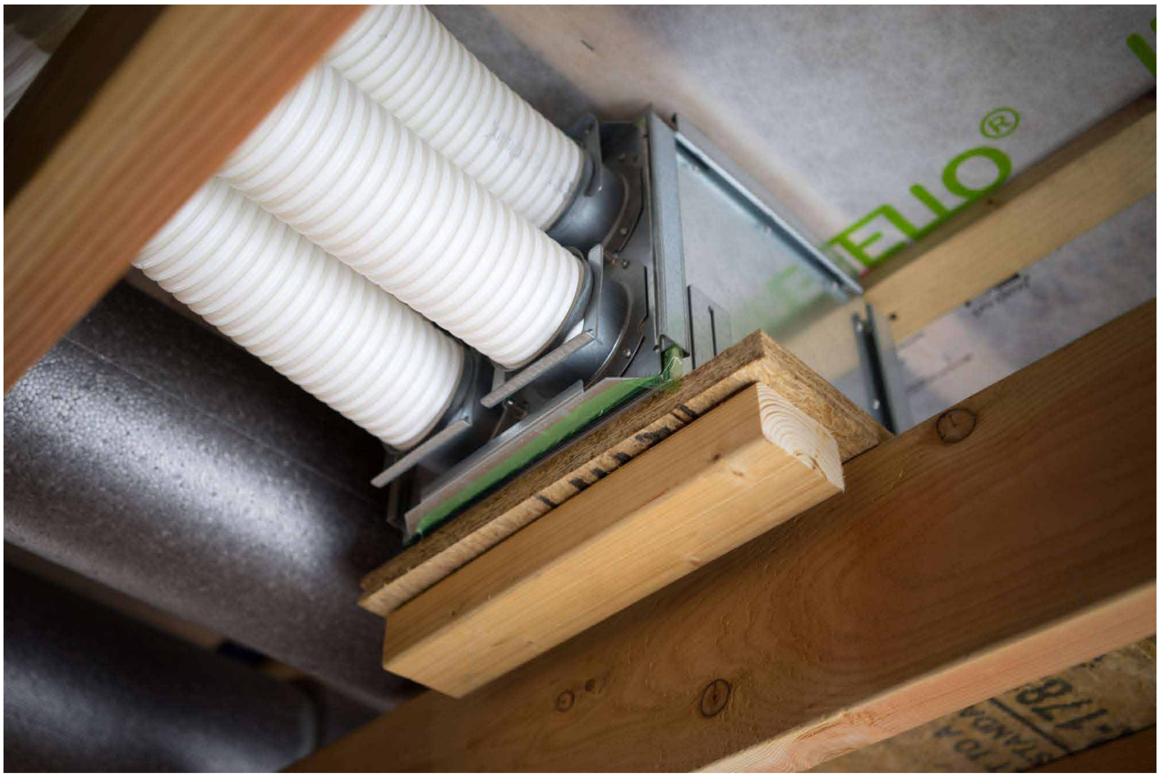
FIGURE 4C-2: ERV FLOW RATES

The ERV is set to run at 70 cfm continuously, with the amount of fresh air delivered to each zone of the house dependent on building code (See Drawing Set M001).

SECTION 4: HEATING/COOLING AND VENTILATION SIZING

SECTION 4C: ERV

FIGURE 4C-3: ZEHNDER MANIFOLD AND DUCTING



A Zehnder manifold distributes the flow from a single ComfoPipe into smaller, flexible ducts, called ComfoTube. This manifold allows air coming through the ERV supply duct to split four ways to provide fresh air to the zones of the house. Another manifold is used to combine the four ducts extracting air from the kitchen and bathroom into a single duct to be exhausted after passing through the ERV.

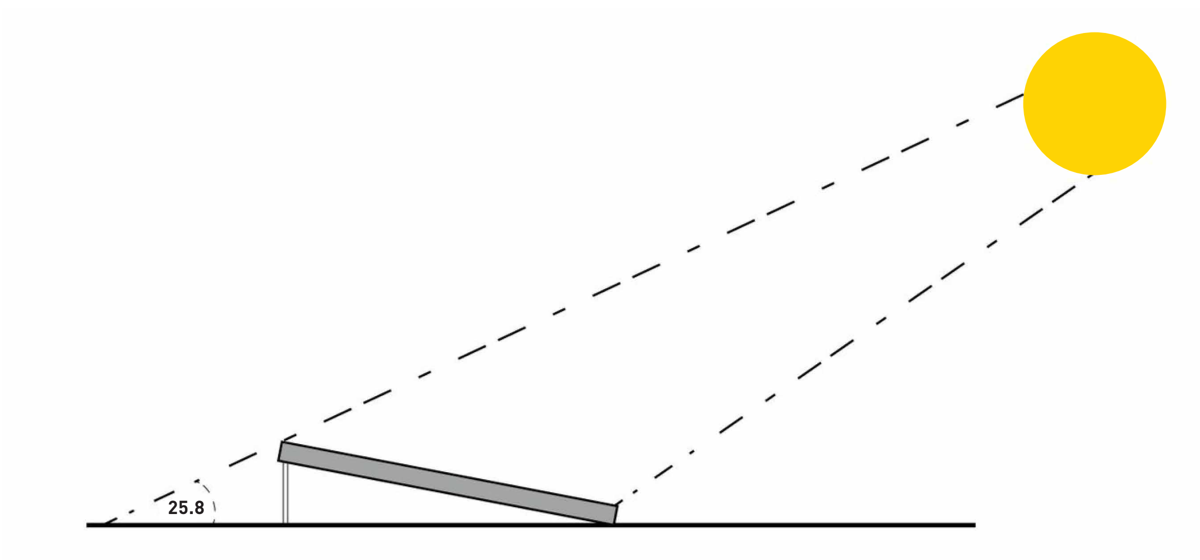
SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SURE HOUSE's energy production is sized to exceed consumption estimates in New Jersey and California in typical and reduced irradiance scenarios; an analysis of energy generation under subject climate, temperature, and shading conditions was conducted for both scenarios to ensure necessary production was met. DC optimizers and microinverters were evaluated for cost and performance for SURE HOUSE.

SECTION 5A: TILT VS AREA ANALYSIS

SURE HOUSE's 10 degree solar module tilt, although unusual, was the preferable mounting angle for maximizing power production while minimizing costs on a small residential rooftop. The SURE HOUSE team created an excel tool to calculate the required roof area taken up by a constant DC peak array with modules mounted at different angles. The tool uses trigonometry and the solar extreme angle values (Summer and Winter solstices) to calculate shadow length and necessary intermodule spacing.

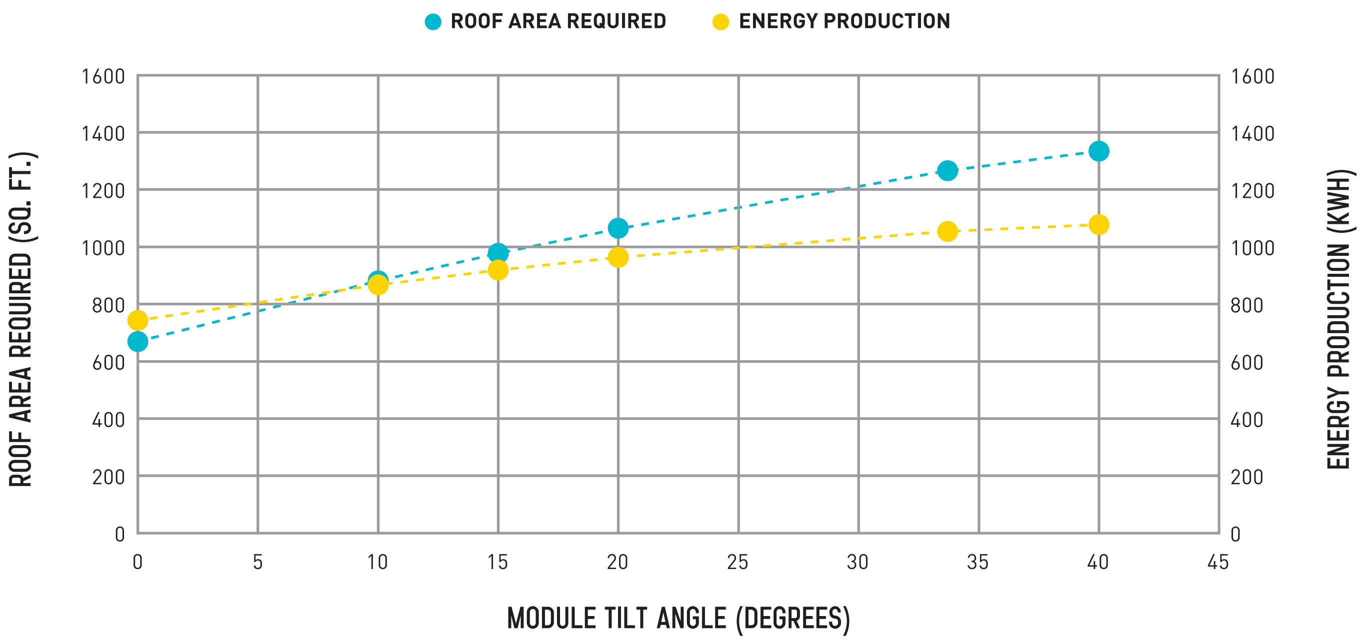
FIGURE 5A-1: SHADE FOOTPRINT



SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5A: TILT VS AREA ANALYSIS

FIGURE 5A-2: MODULE TILT ANGLE ANALYSIS



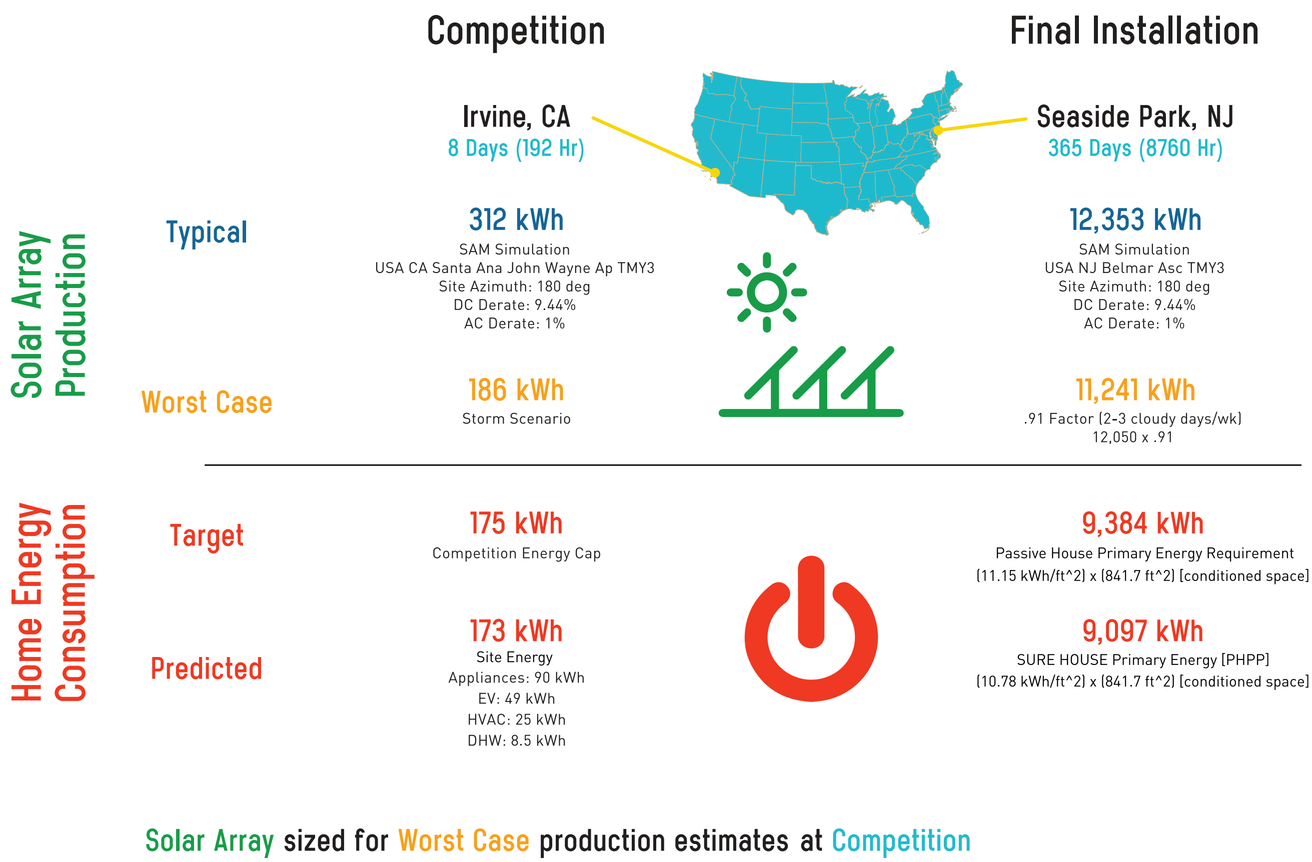
As indicated by the graph, the solar production increases much more slowly than the area required on the rooftop to fit the array. Therefore, to minimize mounting surface area required, SURE HOUSE designers favored a shallow slope for the solar modules. However, there is a very sharp increase in production from 0 degrees to 10 degrees tilt, which informed the final solar module slope choice of 10 degrees.

The calculation shows that adding additional solar panels is more efficient per available space than increasing tilt angle. For example, 36 modules at 10 degrees use approximately the same roof space as 32 modules mounted at 15 degrees; the only difference is that the lower sloped option produces an additional 56 kwh for the same roof coverage. Additional solar modules do correlate with additional cost, but this cost is supplemented with additional energy that will be sold back to the grid and provide more power for the homeowner. In applications where roof space is limited, low sloped solar panels are ideal.

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5B: ARRAY SIZING

FIGURE 5B-1: INITIAL ARRAY SIZING



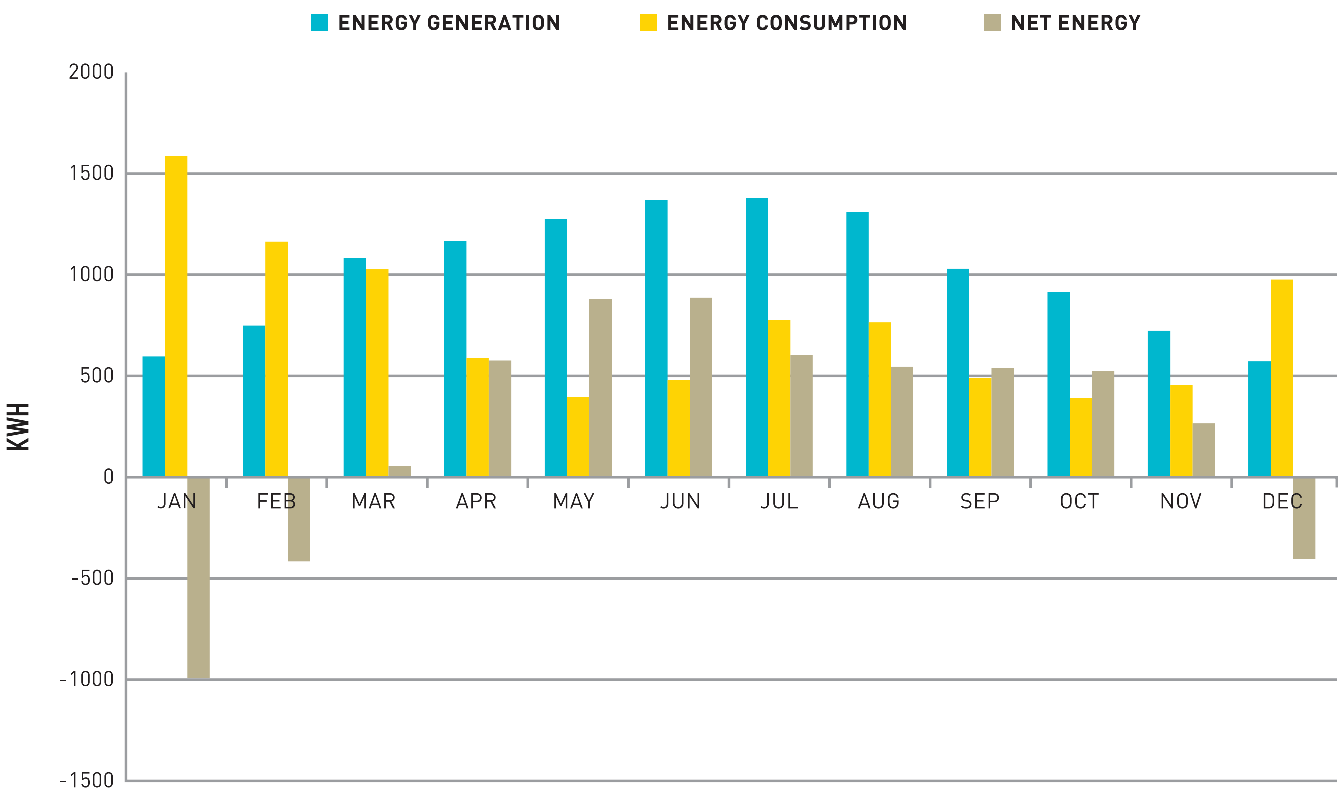
SURE HOUSE's PV sizing is derived from site consumption estimates for the competition and annual site consumption estimates in Seaside Park, NJ. SURE HOUSE needs to produce at least 175 kWh (Competition Consumption Target) during the competition, even in worst case weather conditions. It also must exceed the allotted consumption target for the house under the Passive House standard, assuming a certification standard PE of 2.6. Not only does SURE HOUSE's on site energy production provide for all primary energy consumption for the house, it also provides an excess of 3,256 kWh annually - the primary energy necessary to drive a BMW i3 about 100 miles per week.

Note: Predicted values come from preliminary estimations during the sizing process; specification and manufacturer changes have since changed some values.

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5B: ARRAY SIZING

FIGURE 5B-2: ENERGY GENERATION VS HOUSE PRIMARY ENERGY CONSUMPTION - MONTHLY



	HOUSE PRODUCTION (KWH)	HOUSE PRIMARY CONSUMPTION (KWH)	HOUSE NET ENERGY (KWH)
ANNUAL	12,175	9,102	3,073

Modeled energy production and primary energy consumption in Seaside Park, NJ – Final Model Estimates (default PE factor for Passive House certification).

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5C: SAM PRODUCTION MODELS

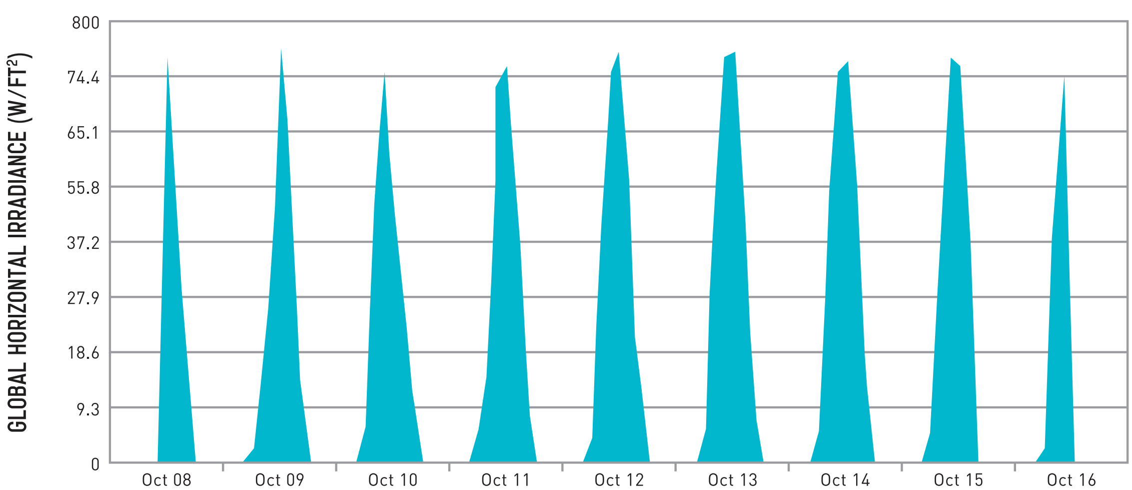
The System Advisor Model (SAM) is a performance and financial model created by the National Renewable Energy Laboratory to aid in solar energy decisionmaking. SURE HOUSE utilized SAM extensively to model solar production conditions in Belmar, NJ and in Irvine, California to optimize system sizing and performance.

Typical Meteorological Year (TMY) and Actual Meteorological Year (AMY) files were used extensively as inputs to SAM and TRNSYS models. TMY3 files and AMY files for the past 15 years were analyzed selected for both Irvine, CA and for Belmar, NJ.

Elements is a open-source software tool for creating and editing custom weather files for building energy modeling, including climate control and solar production. Using Elements, the SURE HOUSE team created synthetic weather files (modifying existing TMY3 and AMY files) to emulate the worst irradiance conditions in the last 15 years per respective location. These weather files were imported into SAM and the PV system was tested to ensure sufficient solar production in worstcase scenarios.

FIGURE 5C-2: AC COMPETITION PRODUCTION (IRVINE)

COMPETITION AC PRODUCTION (TYPICAL)



I1: SMA-5000TL

METRIC	VALUE
ENERGY	196 kWh
CAPACITY FACTOR	0.4%
KWHAC/KWDC	35 kWh/kW
PERFORMANCE RATIO	0.85

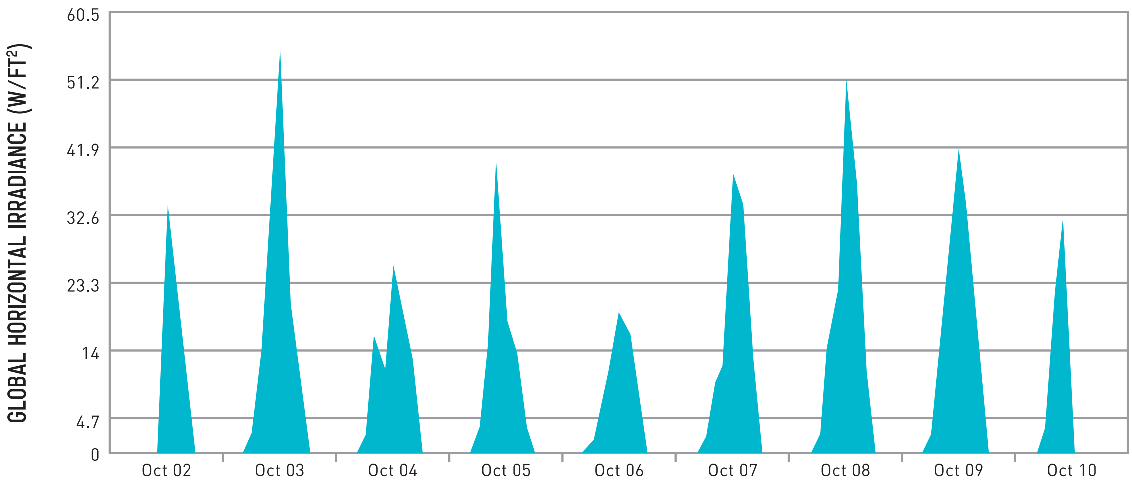
I2: SMA-3000TL

METRIC	VALUE
ENERGY	116 kWh
CAPACITY FACTOR	0.4%
KWHAC/KWDC	34 kWh/kW
PERFORMANCE RATIO	0.84

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5C: SAM PRODUCTION MODELS

COMPETITION AC PRODUCTION (LOW IRADIANCE MODEL 1995)



I1: SMA-5000TL

METRIC	VALUE
ENERGY	90 kWh
CAPACITY FACTOR	0.2%
KWHAC/KWDC	16 kWh/kW
PERFORMANCE RATIO	0.83

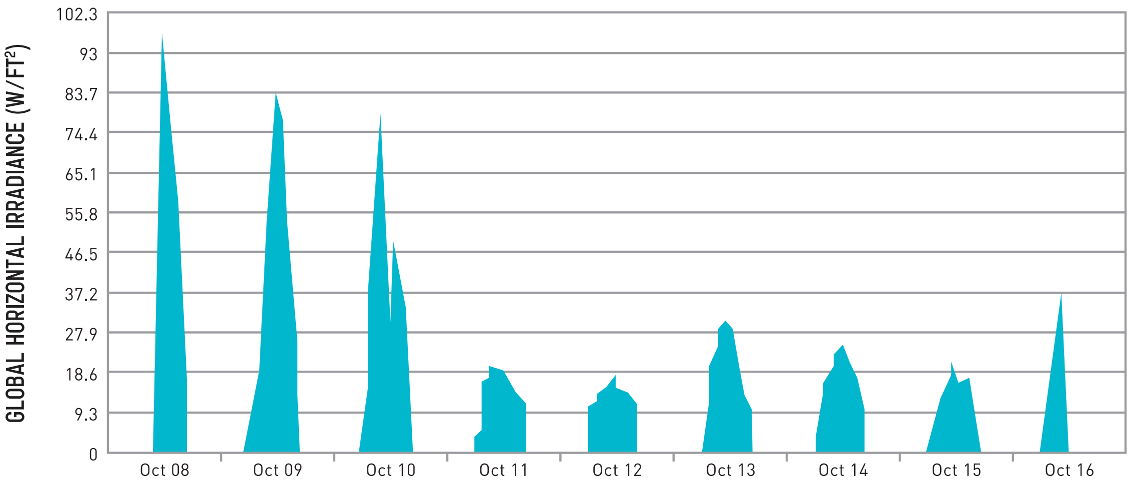
I2: SMA-3000TL

METRIC	VALUE
ENERGY	52 kWh
CAPACITY FACTOR	0.2%
KWHAC/KWDC	15 kWh/kW
PERFORMANCE RATIO	0.80

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5C: SAM PRODUCTION MODELS

COMPETITION AC PRODUCTION (LOW IRADIANCE MODEL 2005)



I1: SMA-5000TL

METRIC	VALUE
ENERGY	116 kWh
CAPACITY FACTOR	0.2%
KWHAC/KWDC	21 kWh/kW
PERFORMANCE RATIO	0.83

I2: SMA-3000TL

METRIC	VALUE
ENERGY	68 kWh
CAPACITY FACTOR	0.2%
KWHAC/KWDC	20 kWh/kW
PERFORMANCE RATIO	0.81

The above diagrams detail changing irradiance over a simulated competition. These graphs represent weather files that were synthesized in Elements and imported into SAM. Actual simulation results can be seen in the summary tables above.

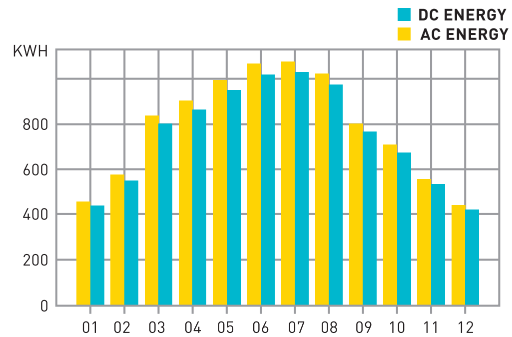
SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5C: SAM PRODUCTION MODELS

FIGURE 5C-3: AC ANNUAL PRODUCTION (BELMAR)

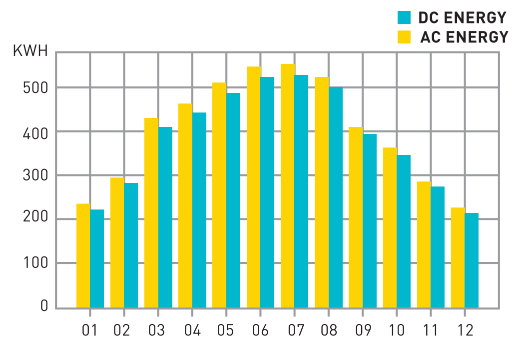
I1: SMA-5000TL

METRIC	VALUE
ANNUAL ENERGY	7,720 kWh
CAPACITY FACTOR	15.6%
FIRST YEAR KWHAC/KWDC	1,366 kWh/kW
PERFORMANCE RATIO	0.88



I1: SMA-3000TL

METRIC	VALUE
ANNUAL ENERGY	4,4633 kWh
CAPACITY FACTOR	15.6%
FIRST YEAR KWHAC/KWDC	1,366 kWh/kW
PERFORMANCE RATIO	0.88



12,353 KWH

TYPICAL ANNUAL IRRADIANCE MODELED PRODUCTION (BELMAR, NJ)

***0.85 = 10,500 KWH**

"OFF YEAR" -85% OF TYPICAL ANNUAL IRRADIANCE MODELED ENERGY PRODUCTION (BELMAR, NJ)

The figure above details simulated annual production for SURE HOUSE in Seaside Park, NJ (TMY3 BelmarFarmingdale.)

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5D: DC OPTIMIZER ANALYSIS

DC optimizers were evaluated and omitted because SURE HOUSE's roof structure was designed to accommodate a uniformly tilted and significantly obstructionfree solar array. DC optimizers were considered for the western string of the array to mitigate the effects of partial shading from the condensing unit during the early morning and during the mid evening. However, it was determined that this would be insignificant compared to the overall production and the associated cost and complexity. DC optimizers would only increase production by approximately 5 percent on the affected string (2 percent overall) which could more easily and less expensively be accomplished by adding an additional module to the string.

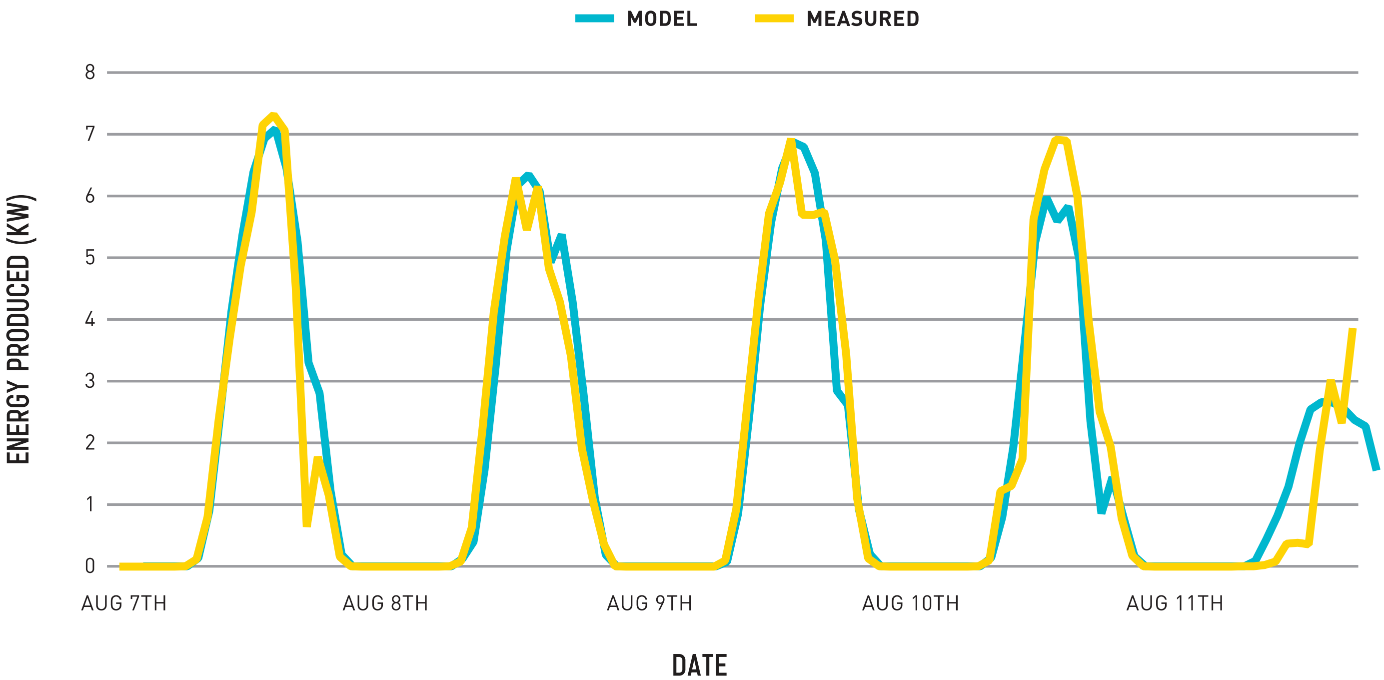
Using Revit 2015's solar tool to estimate the hard shaded portion of the array on an hourly basis and string voltage drop characteristics to determine the reduction in power production by percent, hourly percentages were weighted by a typical hourly power distribution and summed to determine an applicable derate due to shading conditions. By comparing this to a similar calculation without allowing voltage drop to affect subsequent panels and adding the 3.1 percent boost to production due to mitigation of soft shading (simulates DC optimizers based on data collected in Gaia Energy Systems Tigo Energy Harvest Case Studies), the team found that DC optimizers could increase system performance by 5 percent for the 3000TL inverter system. The performance increase generated by the DC optimizers was outweighed by their cost, therefore they were not used in the final SURE HOUSE design.

SECTION 5: AC GRID-TIED PV SYSTEM SIZING

SECTION 5E: DRY RUN DATA ANALYSIS

In order to test the Solar array at the Hoboken, NJ construction site, the team created another SAM Production model to evaluate system performance. Using local predicted weather scenarios (TMY3 data) and accounting for system orientation and losses a direct comparison could be made between actual testing conditions and the SAM Model. Testing results showed that SURE HOUSE produced 205 kWh compared to the predicted 212 kWh over a four and a half day testing period. This exceeded expectations considering nonideal weather conditions.

FIGURE 5E-1: SOLAR GENERATION VS ACTUAL – HOBOKEN, NJ



SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

The SURE HOUSE custom designed and uniquely implemented PV DHW system was tested extensively to model its performance using the System Advisor Model, TRNSYS Hot Water Model, and SURE HOUSE's discrete Solar Hot Water Model. The discrete Solar Hot Water Modeling tool was designed and created by the SURE HOUSE team expressly to simulate the various inputs, outputs, and associated energy use of the PV DHW System..

FIGURE 6A-1: PV ELECTRIC HOT WATER HEATING

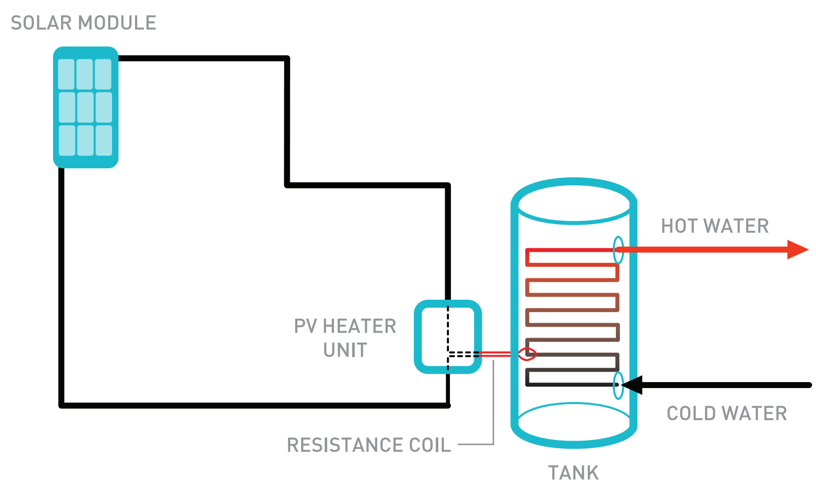
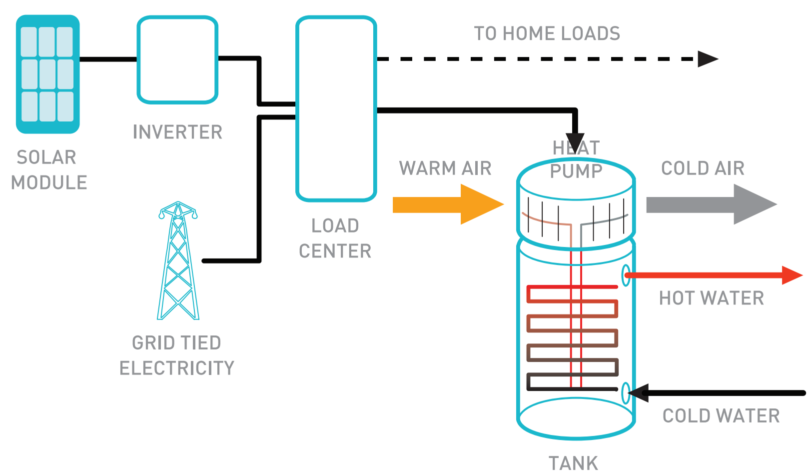


FIGURE 6A-2: HEAT PUMP HOT WATER

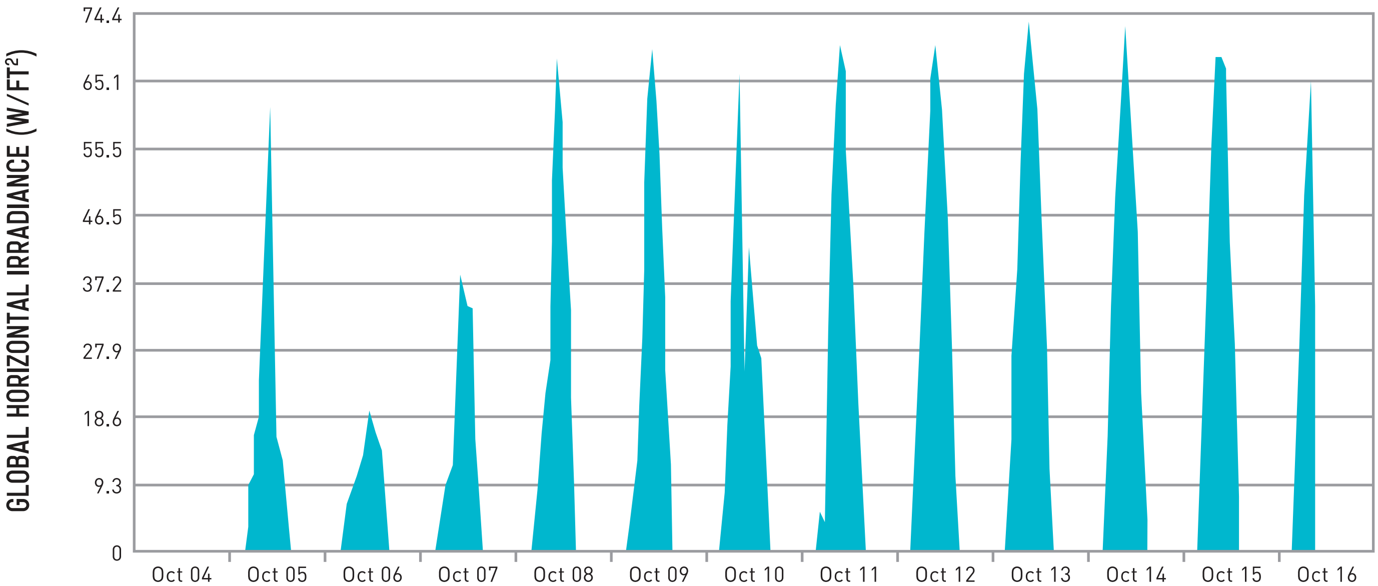


SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6A: PV HOT WATER OVERVIEW

FIGURE 6A-3: SAM PRODUCTION MODELS

COMPETITION DC PRODUCTION PV DWH (TYPICAL)



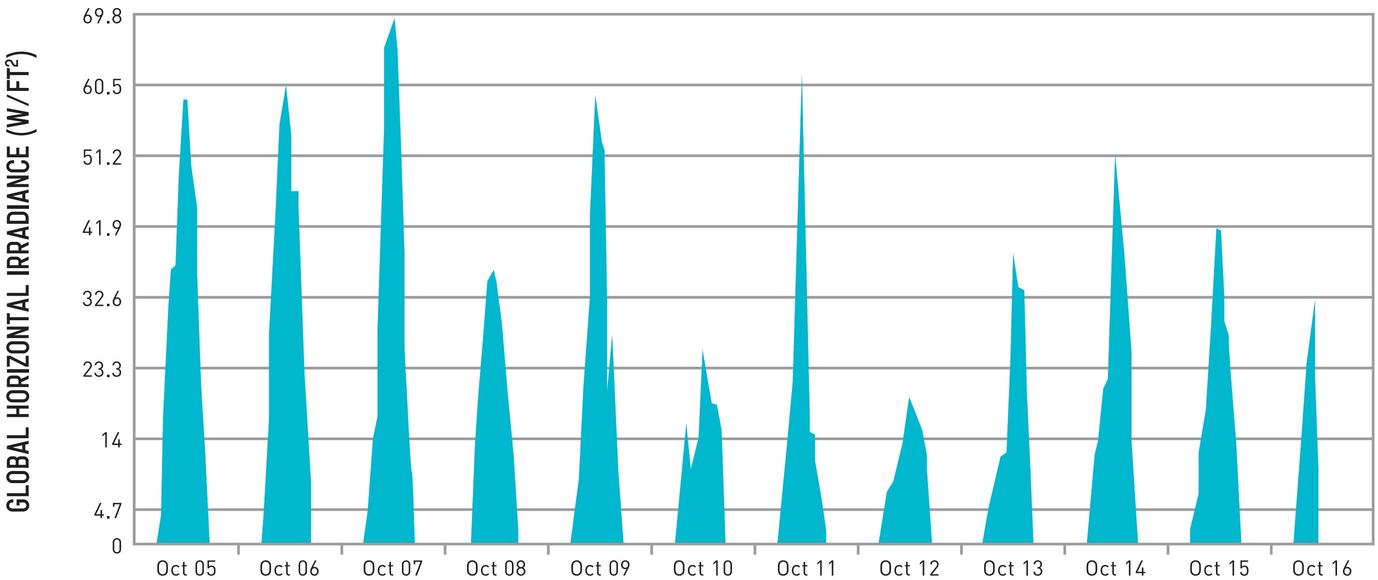
AE PV HEATER

METRIC	VALUE
ENERGY	76 KWH
CAPACITY FACTOR	0.5%
KWHAC/KWDC	41 KWH/KW
PERFORMANCE RATIO	0.83

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6A: PV HOT WATER OVERVIEW

COMPETITION DC PRODUCTION PV DWH (LOW IRADIANCE 1995 MODEL)



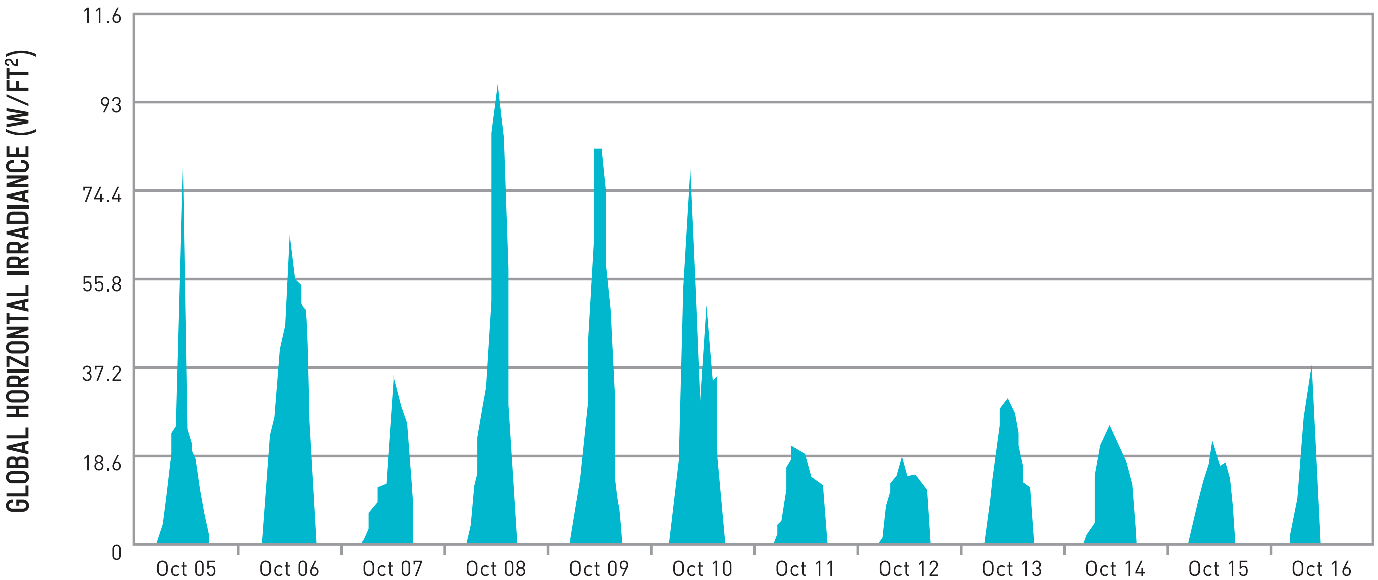
AE PV HEATER

METRIC	VALUE
ENERGY	52 KWH
CAPACITY FACTOR	0.3%
KWHAC/KWDC	28 KWH/KW
PERFORMANCE RATIO	0.82

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6A: PV HOT WATER OVERVIEW

COMPETITION DC PRODUCTION PV DWH (LOW IRADIANCE 2005 MODEL)



AE PV HEATER

METRIC	VALUE
ENERGY	57 KWH
CAPACITY FACTOR	0.4%
KWHAC/KWDC	31 KWH/KW
PERFORMANCE RATIO	0.82

SAM Models including synthetic weather files for AE PV Heater system

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6B: DISCRETE HOT WATER MODEL

Sizing the PV heating system for SURE HOUSE was difficult because required design criteria was vastly different from typical solar domestic hot water systems. Firstly, there is not a lot of performance and sizing data readily available for the AE PV Heater unit and secondly, all available resources for sizing solar hot water systems assume solar fractions of around 50 percent are desired annually. For SURE HOUSE, in order to meet extremely low electrical consumption requirements, the team desired a solar fraction in excess of 75 percent for the competition period. When designing a system with the capability to provide for the majority of hot water demands, the solar thermal system must be powerful enough to meet demands in the worst weather conditions while managing excess heat in situations where there is an excess of irradiant energy. It is for this reason, that solar thermal systems are rarely designed to cover all of a home's domestic water needs. These differences forced the SURE HOUSE team to develop a custom sizing system by creating a model that tracks internal tank temperature throughout the duration of competition.

Main inputs to the model were defined as the input energy from the shutter panels and the backup heat pump's supplemental effect. Solar input energy was imported in kwh from SAM. Input energy was modified to account for efficiency and changing specific heats as tank temperature changed. The heat pump was modeled in order to provide additional heat to the system when heating load was greater than the capacity of the shutter PV panels.

The most significant energy output in the model was the effect of hot water draws. This was modeled using mixing equations for the thermostatic mixing valve and for the tank as cold water entered the tank following the competition's scheduled hot water draws. The second important heat output for the domestic hot water tank model was the effect of heat loss through the sides and bottom of the hot water tank.

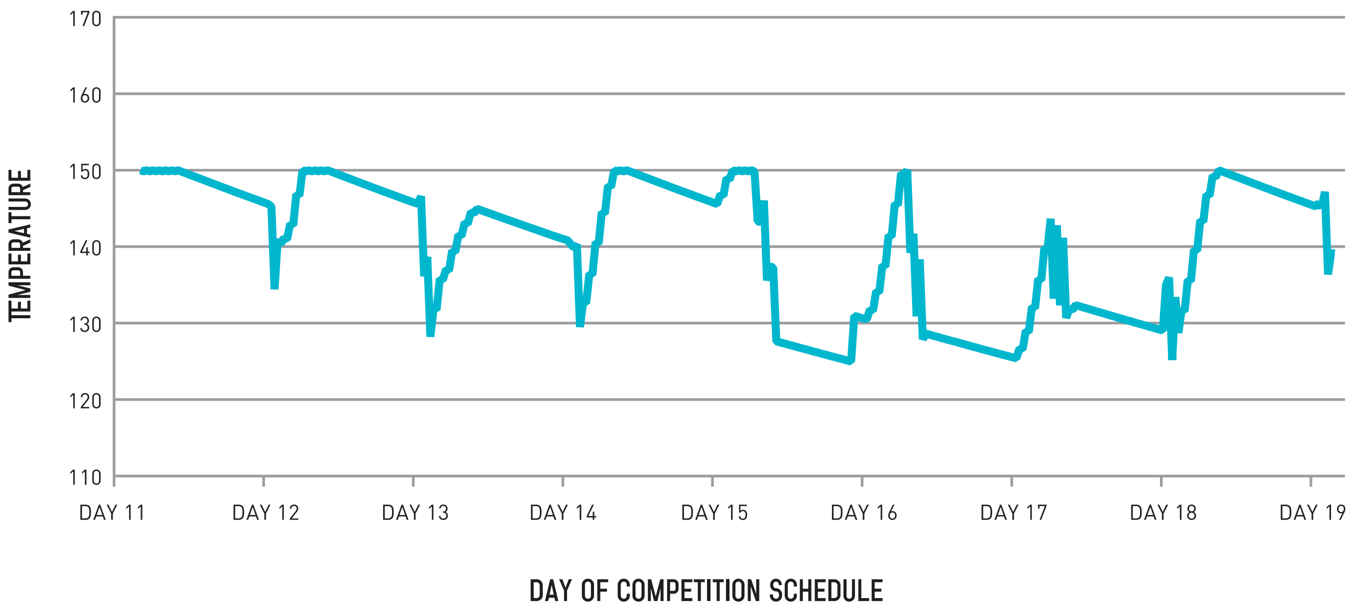
By monitoring tank temperature and limiting AC energy consumed by the backup heating elements, model variables and equipment specifications were modified and tested in order to achieve the most desirable configurations. The table below details the results of the model.

	PV HEATER + HEAT PUMP (AC KWH)	HEAT PUMP	AC COIL	PV HEATER + AC COIL
TYPICAL CONDITIONS	5.975	20.167	65.544	19.425
LOW IRRADIANCE CONDITION	8.216			26.703

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6B: DISCRETE HOT WATER MODEL

FIGURE 6B-1: HOT WATER TANK TEMPERATURE COMPETITION MODEL

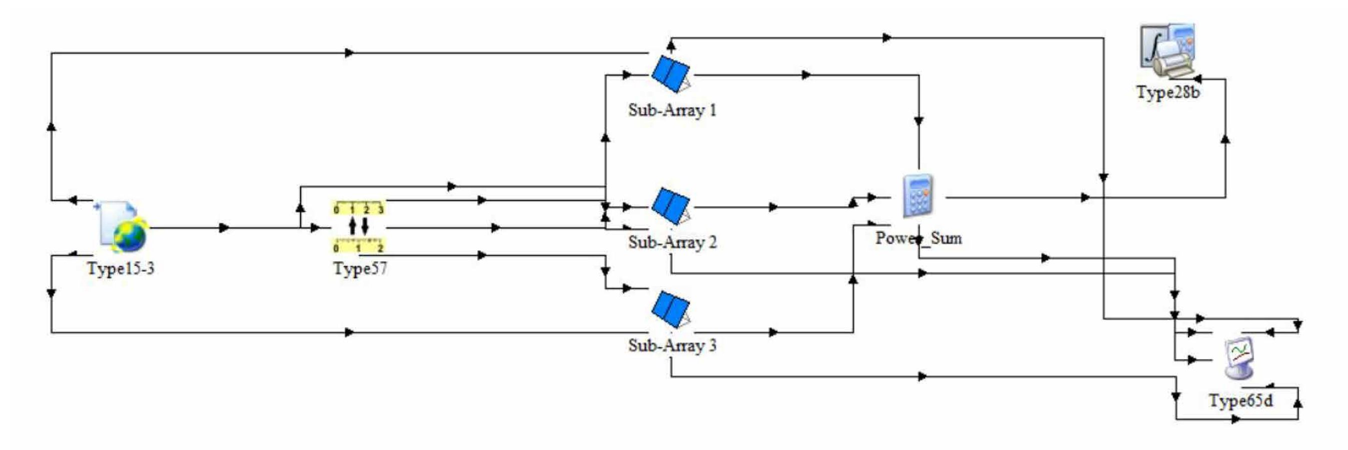


Sample model output for internal tank temperature over the course of the Energy Balance Competition.

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6C: TRNSYS HOT WATER MODEL

FIGURE 6C-1: DC TRNSYS BLOCK MODEL

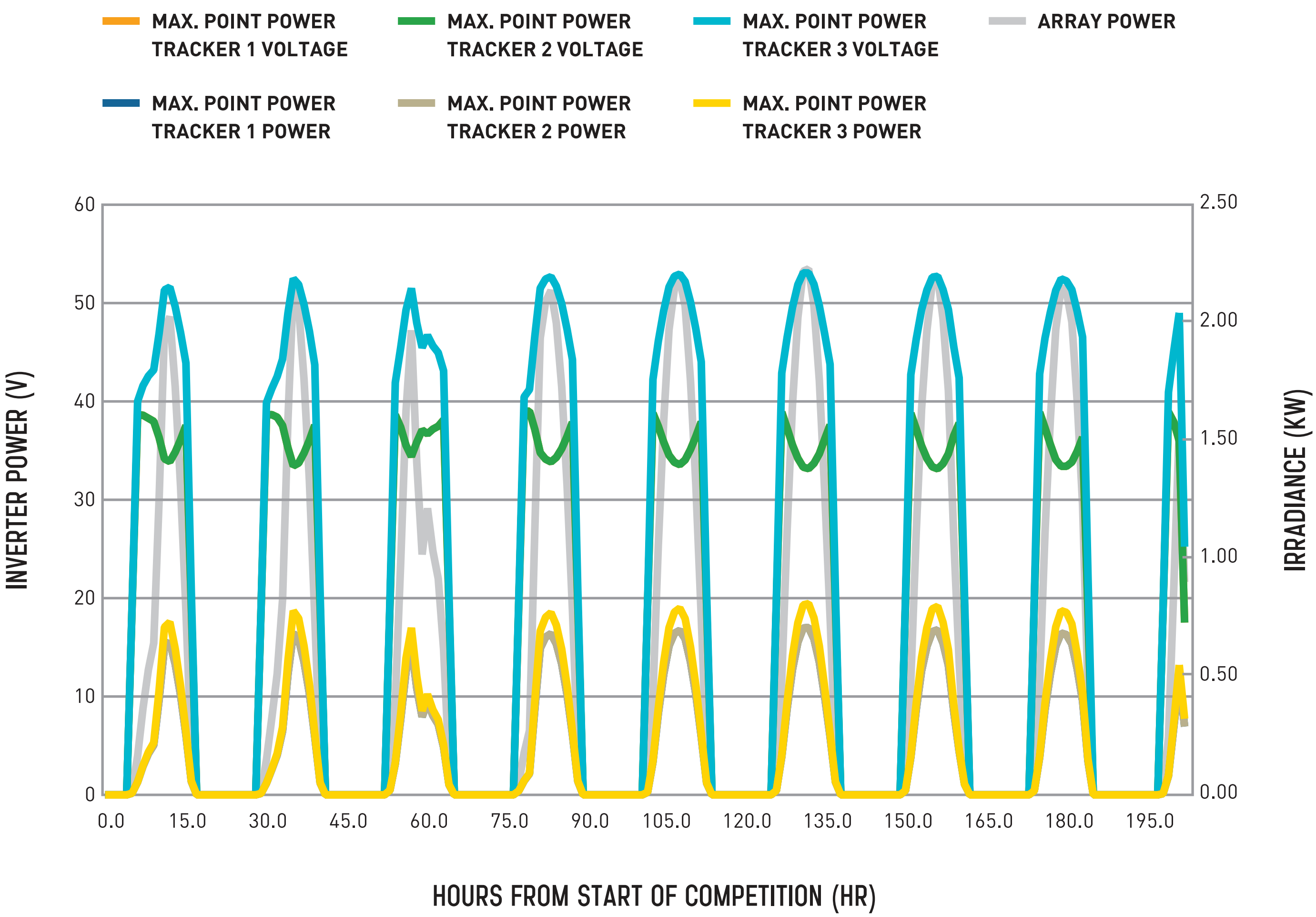


TRNSYS was also used to model the solar inputs for the PV Heater Unit. The system input consists of TMY3 Irradiance data. The three separate MMPT trackers were represented as separate subarray blocks and then added to determine the system output.

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6C: TRNSYS HOT WATER MODEL

FIGURE 6C-2: TRNSYS RESULTS

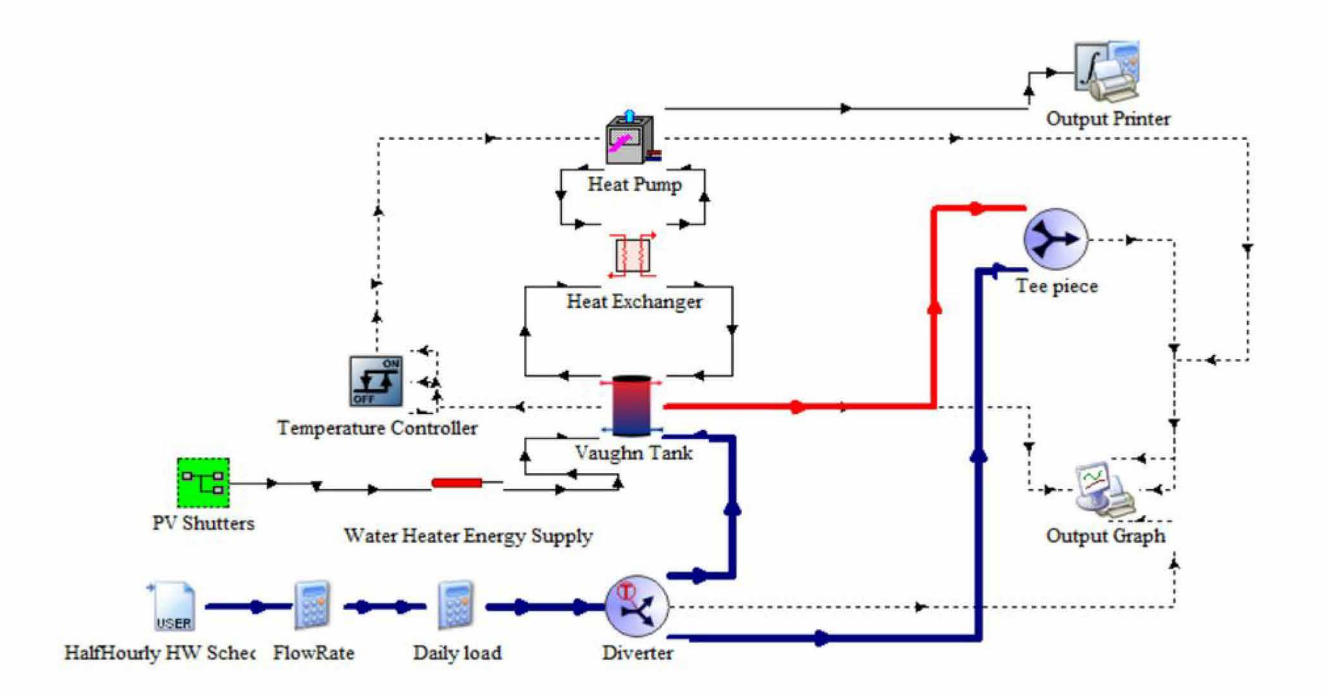


Irradiance values and power production over the course of the simulated competition period in Irvine, CA are shown above. Power production is both broken down by MPPT and displayed as a total.

SECTION 6: DC SOLAR ELECTRIC DOMESTIC HOT WATER ANALYSIS

SECTION 6C: TRNSYS HOT WATER MODEL

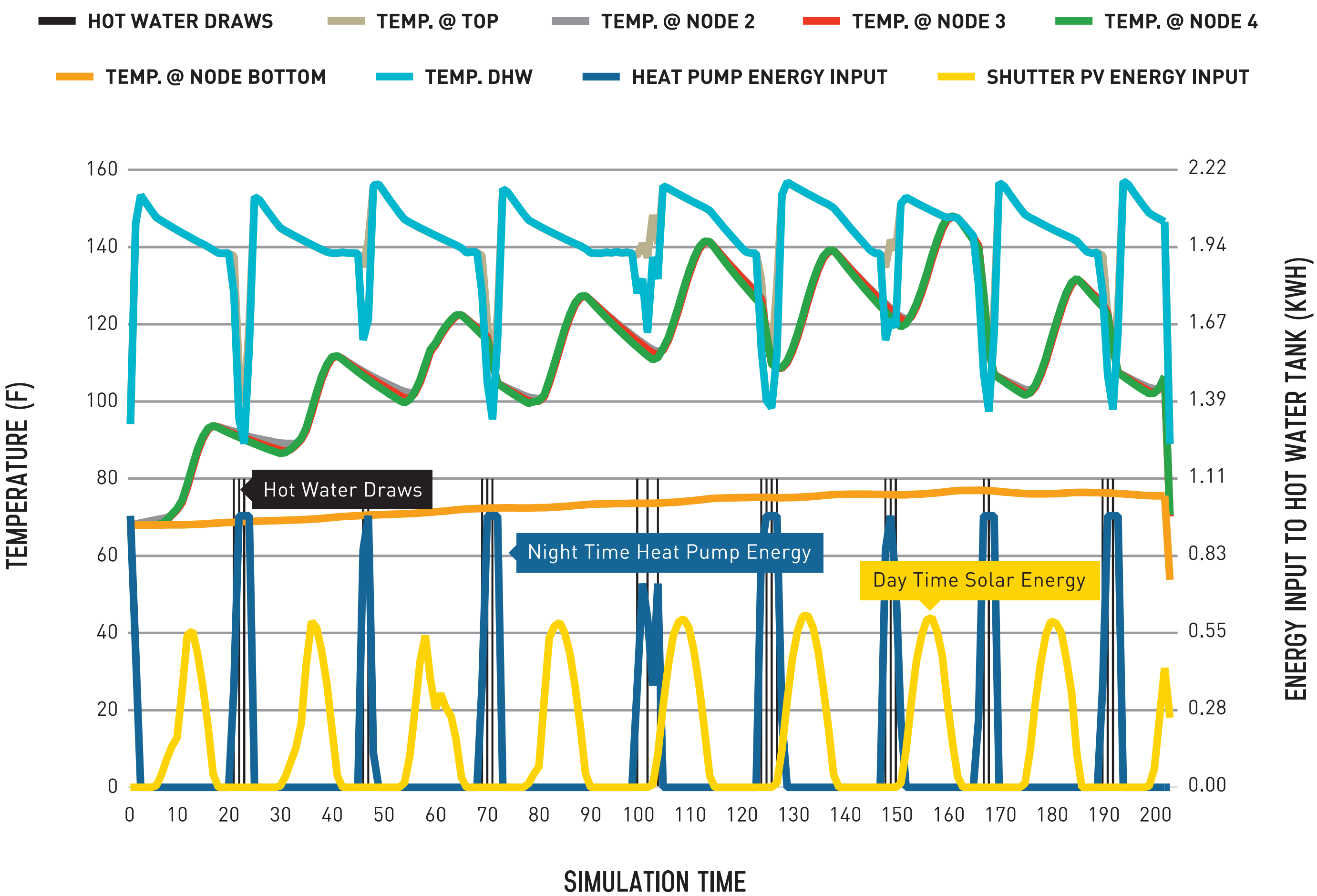
FIGURE 6C-3: HOT WATER TRNSYS BLOCK MODEL



Solar inputs were fed into a model of the hot water system where they are converted to heat and added to the tank according to the energy conversion efficiency. Water draws are specified by flowrate and load; then a diverter valve allows water to flow through the mixing valve and to the DHW, replacing the drawn hot water. Proper amounts of hot and cold water are allowed to flow through the thermostatic mixing valve in order to meet the specified water draw temperature for the extent of the demand. The temperature controller block determines the desired tank temperature. The heat pump block inputs additional heat to the Vaughn tank when the actual temperature is below the set point parameter.

SECTION 6C: TRNSYS HOT WATER MODEL

FIGURE 6C-4: DC AND PV DHW TRNSYS RESULTS

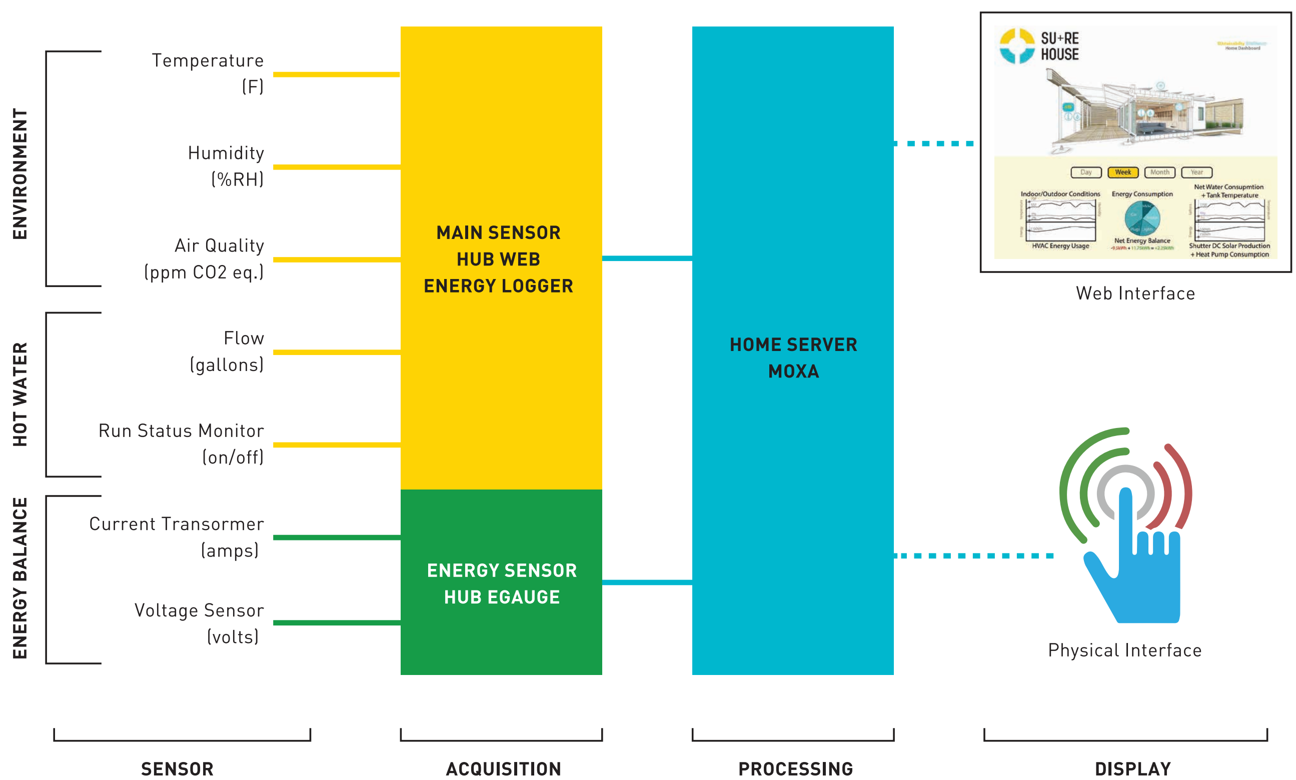


The figure above shows internal tank temperatures at different water levels and the heat transfer rates between and distributed by the different elements of the solar hot water system.

SECTION 7: MONITORING SYSTEM

SURE HOUSE's monitoring system collects environmental data and evaluates it to ensure interior comfort and healthy air quality. Running status monitors and flow meters help to determine the efficiency of the hybrid DC photovoltaic, heat pump, and AC electric hot water system. Energy data is gathered from the circuits running in the house to determine precise consumption from the various appliances as well as energy production from the solar inverters. This information is then formatted to be easily understood by the homeowner and output to a home dashboard, so that they may monitor their own energy consumption and budget in realtime.

FIGURE 7-1: SENSOR AND MONITORING SYSTEM



SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-1: UNIVERSAL FLOOD DESIGN PARAMETERS AND SOLUTIONS

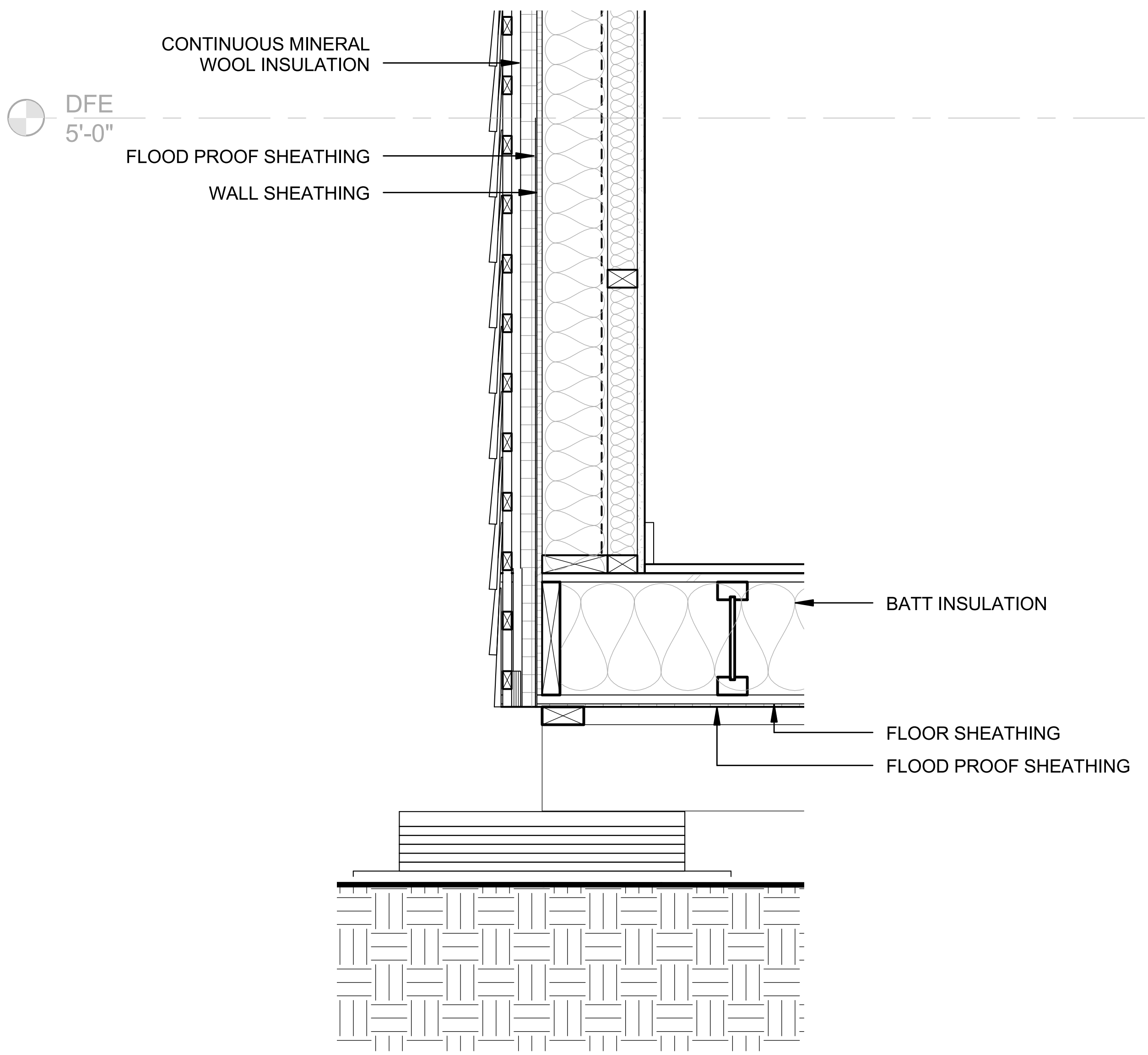
SURE HOUSE has been designed for an AE FEMA flood zone (noncoastal A designation) up to a DFE (including freeboard) of five feet from grade. An AE flood zone is defined as excluding crashing waves and high velocity flow above five feet per second. V zones incorporate crashing waves greater than three feet, extreme high velocity flow, and flood depths over 8 feet. Residential development in V zones does not make sense because of the high likelihood of repeated storm events and extreme loads put on the structure, but in AE zones the loads and DFEs allow for economical and safe dry flood-proof design. For these reasons, dry flood-proofing in AE zones is allowed under FEMA code for nonresidential buildings and the SURE HOUSE team believes that dryflood-proofing techniques can be safely adapted to homes.

FIGURE 8A-1A: SURE HOUSE DESIGN LOAD CONDITIONS

LOAD TYPE	LOAD LOCATION	LOAD VALUE	LOAD UNIT
DEAD	House Floor	15	psf
	Deck Floor	16	
	Roof	17	
LIVE	House	50	psf
	Deck & Ramps	100	
EARTHQUAKE	House Modules	7.87	k
	South Deck	1.65	
	North Deck	0.74	
	Ramp	0.76	
SNOW	House & Decks	25	psf
	Ramp	5	
WIND SPEED	-	130	mph
LATERAL WIND LOAD	-	39	psf
LOUVER UPLIFT	-	209.35	plf
LOUVER LATERAL	-	230.32	plf
FLOOD ZONE	-	AE (noncoastal A)	
DFE	-	5	ft
FLOOD VELOCITY	-	5	ft/s
HYDROSTATIC	(Value is max of triangular load)	250	plf
BUOYANT	Up under floor	250	psf
DEBRIS	Point load	1000	lb

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

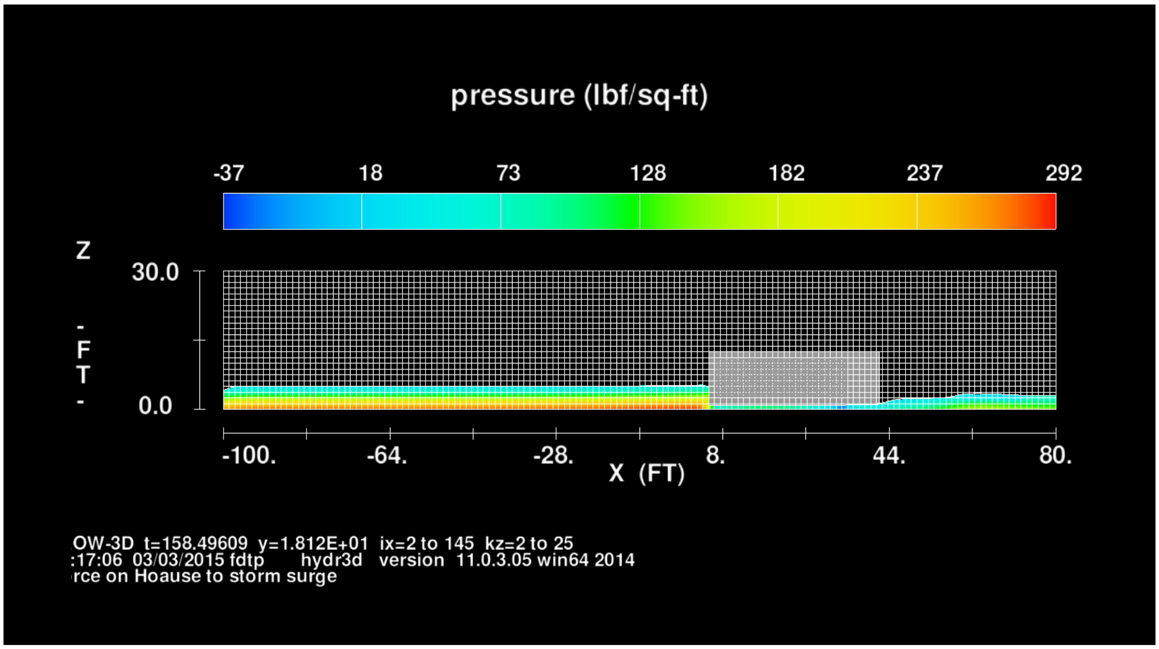
FIGURE 8A-1B: FLOOD PROOFING SECTION



SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-2: FLOOD SIMULATION MODELING

FIGURE 8A-2A: FLOOD MODELING RESULTS

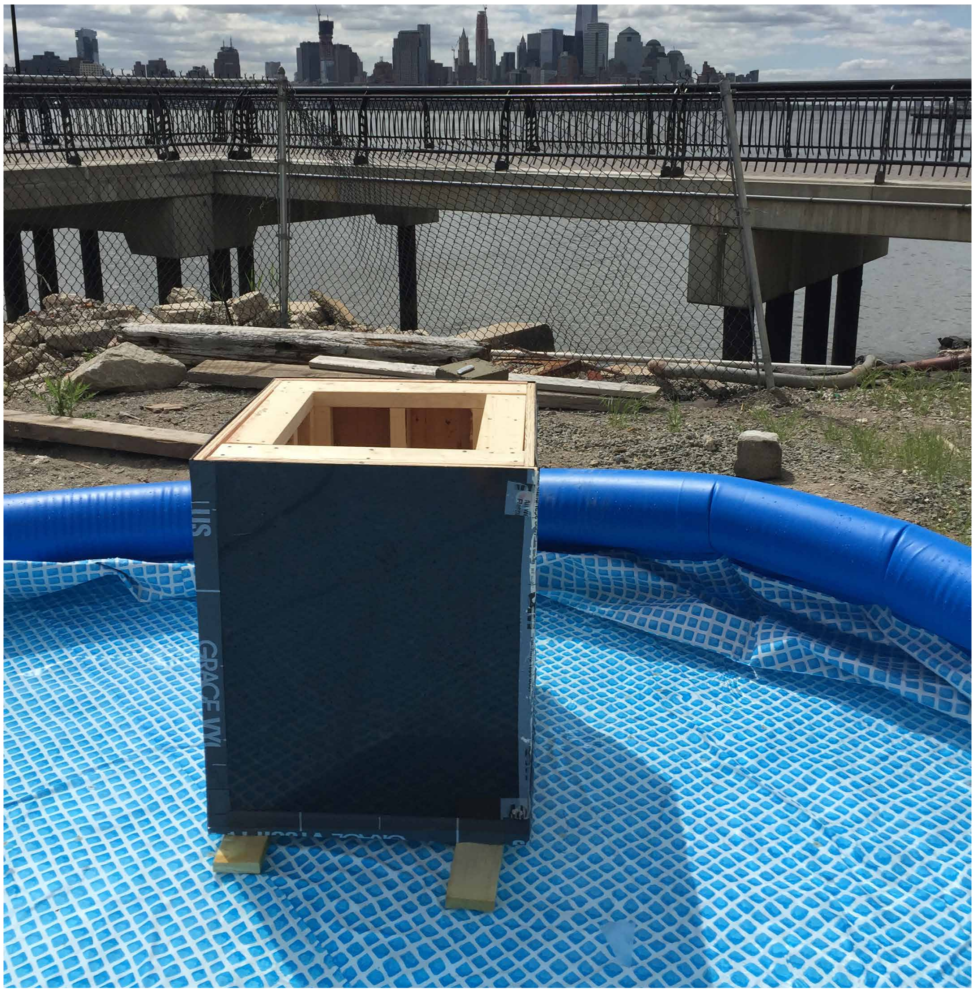


Students completed flood modeling at the Davidson Laboratory for the SURE HOUSE to the 5' DFE to verify loading conditions utilized in design. Dynamic models were created showing the rise of floodwaters and incoming tides and their effects on the load conditions of the SURE HOUSE. Because the SURE HOUSE is located in an AE flood zone, only rising tides were considered (without crashing waves) at a velocity of 5 ft/s in this modeling. This flow velocity is higher than will be expected in the house's final location, but it was utilized to meet FEMA standards so that structural design is applicable for all eastern coast communities and is not site specific.

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-3: FLOOD SIMULATION TESTING

FIGURE 8A-3A: BOX #1 TESTING – TAPE SELECTION



The first round of flood testing completed by the SURE HOUSE team focused on identifying which type of tape would be best to utilize on the house as a redundant layer of defense against flood waters. Two types of tape were tested with two identified taping schemes each to determine which was the most effective. Grace Vycor Plus tape was decided upon for use in the house as a result of this round of testing because it was the most successful at keeping water from penetrating the edges and corners of the box.

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-3B: BOX 2 TESTING – ABS SHEATHING AND SEALING

FIGURE 8A-3B-1: STEP 1

The second box was aimed at testing the primary waterproofing capabilities of the sheathing edge conditions and penetrations. This box was also built utilizing the same construction methods as the asbuilt condition of the house. This enabled the team to accurately predict any deflection of the box or sheathing and determine if that would have any effect on waterproof characteristics. In this step, acrylonitrile butadiene styrene (ABS), the thermoplastic sheathing used to waterproof the walls of SURE HOUSE, is first sanded at connection locations, cleaned to remove debris and dirt, and then applied to faces of the walls with gasketed roof screws. All joints are filled with 3M 5200 marine adhesive to create a seal.

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-3B: BOX 2 TESTING – ABS SHEATHING AND SEALING

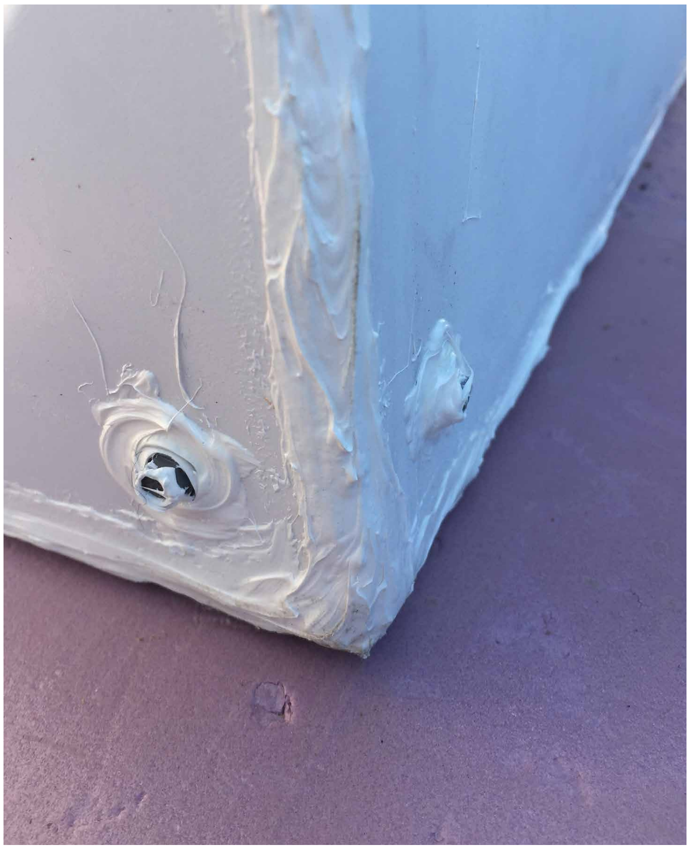
FIGURE 8A-3B-2: STEP 2

Blocking was added for exterior finish with standard exteriorgrade screws. 3M 5200 Marine Adhesive caulk was applied around all blocking and around all screws. Holes through the sheathing for all blocking penetrations were pre drilled and filled with caulk prior to screwing so that caulk is both on top of and around all nongasketed screws.

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-3B: BOX 2 TESTING – ABS SHEATHING AND SEALING

FIGURE 8A-3B-3: TYPICAL FLOOD-PROOFING DETAILS



Above are typical waterproofing details for penetrations into and edges of sheathing panels. Extra adhesive caulk was used in the waterproofing details to ensure sealing redundancy in the seams and penetrations through the waterproof layer.

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-3B: BOX 2 TESTING – ABS SHEATHING AND SEALING

FIGURE 8A-3B-4: STEP 3

The box was tested in 24” of water up the side of the box. It was elevated slightly off the bottom of the test pool with 2” x 4”s to simulate the asbuilt condition in which water is free to flow under the structure. The cinderblocks seen above were used to combat buoyant forces. The box was submerged for 80 hours (longer than the required 72 hours for standard hurricane floods) without any water leakage. Images were taken inside the box every 15 minutes for the first 5 hours to ensure there were no leaks, and every 8 hours for the remainder of the test period. There were no leaks for the entire test period; testing was concluded due to time constraints. This effectively proves that the flood-proofing details employed in the construction of SURE HOUSE are effective to keep out water in a hurricane event. Although the ABS did deflect some in the hot sun, this deflection was not enough to affect the waterproofing characteristics of the details even on days hotter than 90 degrees F, rendering it inapplicable to the extents of this test. The ABS is covered in the asbuilt condition so that it will not receive direct sunlight

SECTION 8A: FLOOD-PROOF DESIGN – UNIVERSAL FLOOD DESIGN

SECTION 8A-3B: BOX 2 TESTING – ABS SHEATHING AND SEALING

FIGURE 8A-3B-5: AS-BUILT FLOOD-PROOF CONDITION

Different stages in the construction of flood-proofing in the final prototype can be seen above. SURE HOUSE was constructed using the same adhesive caulking and connection details as box #2. Grace Vycor Plus tape was applied over the caulk details tested in box #2 to protect them and provide a second layer of waterproofing. This adds redundancy into the flood-proof design in the case that one method of flood-proofing is damaged or does not perform as predicted. Architectural finishes were applied over the visible blocking.

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

Three rounds of small-scale physical models and two full scale prototypes were undertaken during the design of the flood proof shutters and plugs to gain an understanding of fabrication and integration challenges. Design of the shutters included considerations in geometry and motion of the panels, material and structural design, as well as hardware specification and detailing. Rapid prototyping enabled quick feedback between construction and research periods.

SECTION 8B-1: MOTION ANALYSIS

FIGURE 8B-1-A: TYPICAL BIFOLDING DOOR

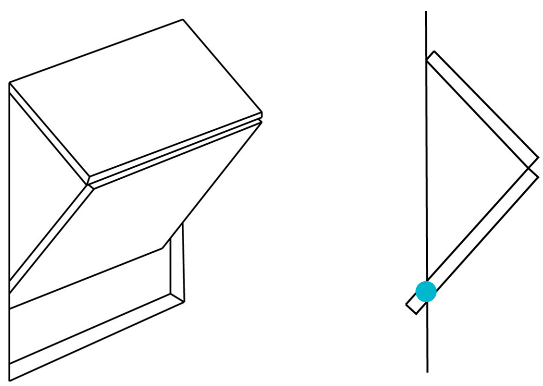
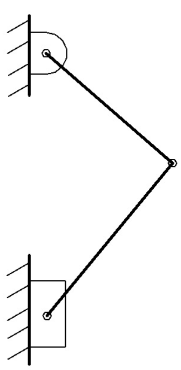


FIGURE 8B-1-B: BIFOLDING DOOR LINKAGE



Problem:
Fixed axle remains in same vertical plane of door frame. Door must cross through frame to complete motion. SURE HOUSE storm shutters must remain outside of structure in order to have a continuous contact surface for gasketing.

Analysis: Linkage Study
The system can be represented as a four-bar slider-crank linkage. Solve for Mobility (M), or total degrees of freedom of system

Link 1 (Ground): Structural frame
Link 2: Top panel
Link 3: Bottom Panel
Link 4: Roller (represented as slider)

Number of Links (N) = 4
Full Joints (one degree of freedom) (J) = 4
Half Joints (two degrees of freedom) (I) = 0

Gruebler's Equation:

$$M = 3(N - 1) - 2J - I$$

$$M = 3(4 - 1) - 2(4) - 0$$

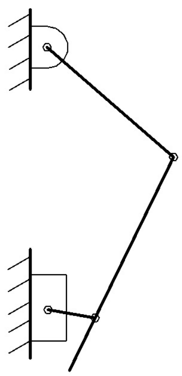
$$M = 1$$

A traditional bifolding door has one degree of freedom, and therefore one output motion: travelling along the tracks. In order to achieve the desired output motion, an additional degree of freedom is required.

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-1: MOTION ANALYSIS

FIGURE 8B-1-C: SURE HOUSE DOOR LINKAGE



Solution: Add link

Link 1 (Ground): Structural frame
Link 2: Top panel
Link 3: Bottom Panel
Link 4: Added Axle Link
Link 5: Roller (represented as slider)

N = 5
J = 5
I = 0

$$M = 3(N - 1) - 2J - I$$
$$M = 3(5 - 1) - 2(5) - 0$$
$$M = 2$$

The modified system has a total of 2 degrees of freedom. The two possible output motions are a vertical movement up and down the track as well as a rotation about the roller.

FIGURE 8B-1-D: SURE HOUSE BIFOLDING DOOR

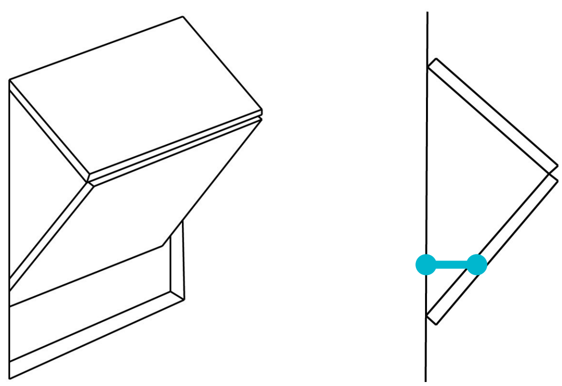
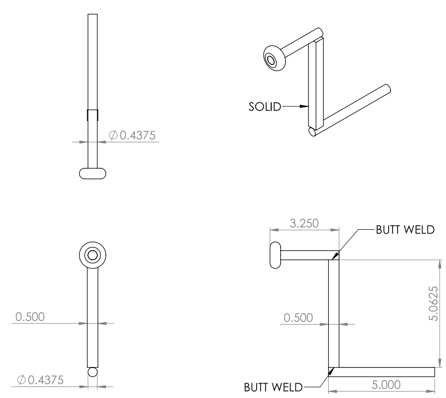


FIGURE 8B-1-E: TWO BEND ROLLER AXLE



The additional degree of freedom allows the horizontal distance between the structural frame and the axle attachment point on the shutter can vary as the shutter moves through its range of motion. This allows for the shutter to remain outside the frame through its full range of motion.

SECTION 8B-2: GASKET SELECTION ANALYSIS

FIGURE 8B-2A: WATER SEALING

An EPDM gasket was selected due to its market availability and performance under low compression. Source: Technical Sealing Guide, Rogers Corporation

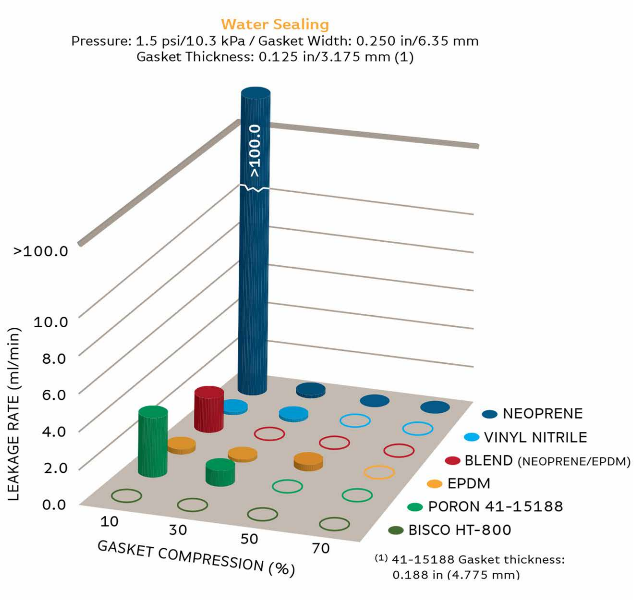


FIGURE 8B-2B: WEATHER RESISTANT BULB SEAL

A D-shaped bulb seal (with dimensions A=5/8" and B=3/8") was selected for its preferred compression rate. Source: McMaster Carr

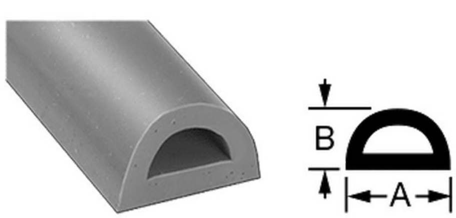
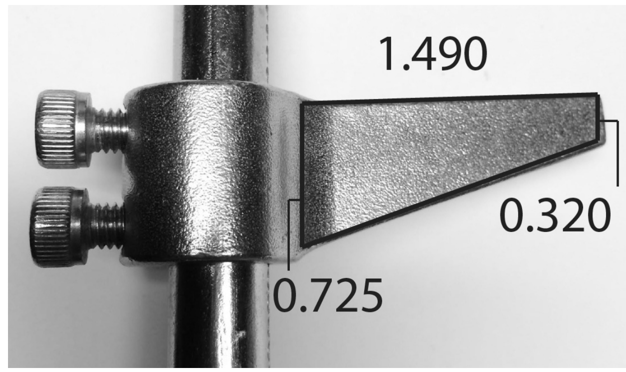


FIGURE 8B-2C: COMPRESSION LATCH FLAG

Units in inches.



The system was designed for a desired compression of 80% to allow tolerance for variances in construction while maintaininga watertight seal. To determine lateral latch placement:

$$\frac{\Delta y}{\Delta x} = \frac{0.725-0.320}{1.49} = \frac{0.405}{1.49} = 0.2718 \;\; (from\ latch\ dimensions)$$

$$\Delta y_{100\%} = 0.3750 - 0.1205 = 0.2545\ in.$$

To achieve 80% compression:

$$\Delta y = (0.80)(0.2545) = 0.2036\ in.$$

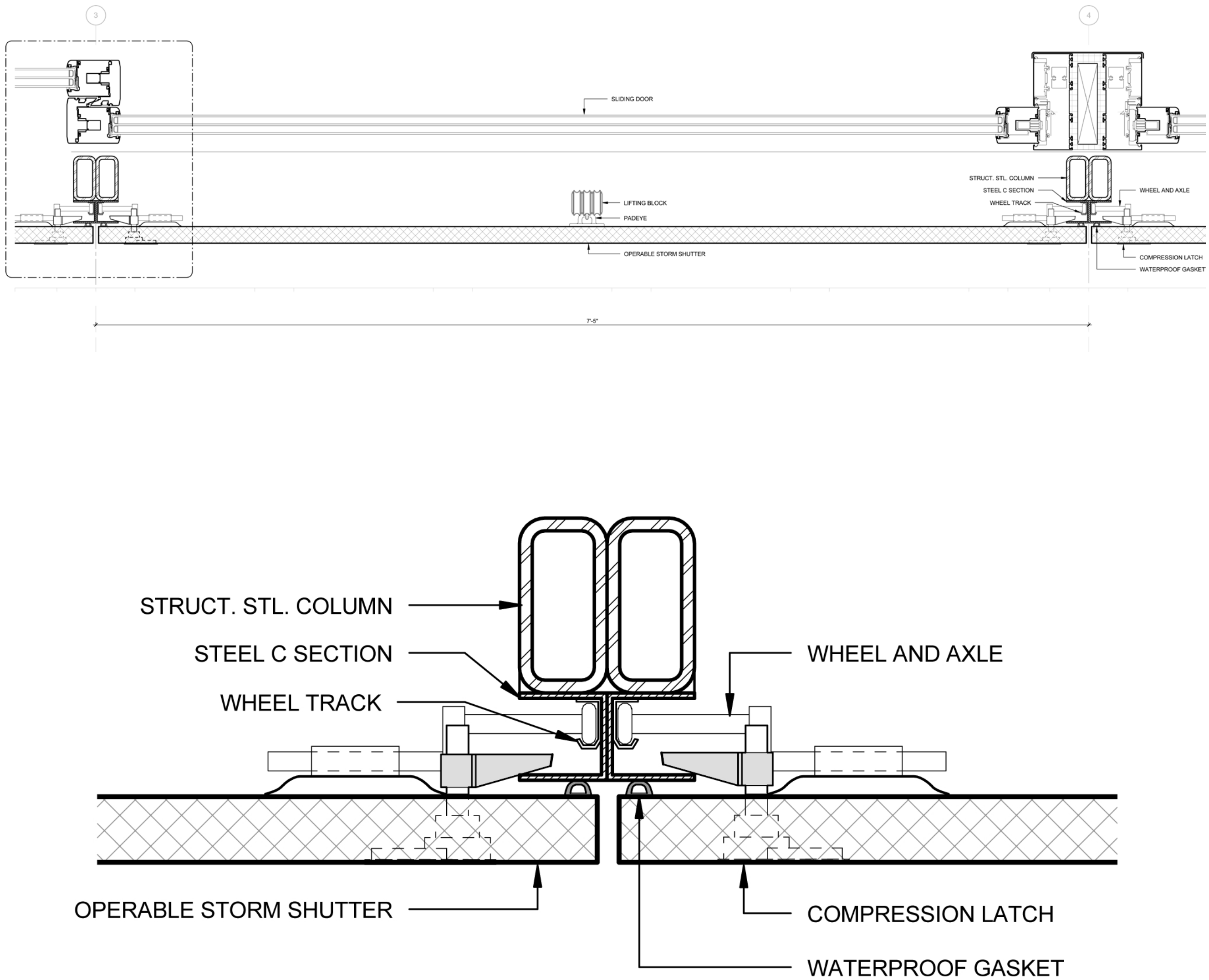
$$\Delta x = \frac{0.2036}{0.2718} = 0.749\ in.$$

The latches are positioned to have a lateral overlap of ¾" over the steel channels to provide 80% compression on the gaskets.

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-2: GASKET SELECTION ANALYSIS

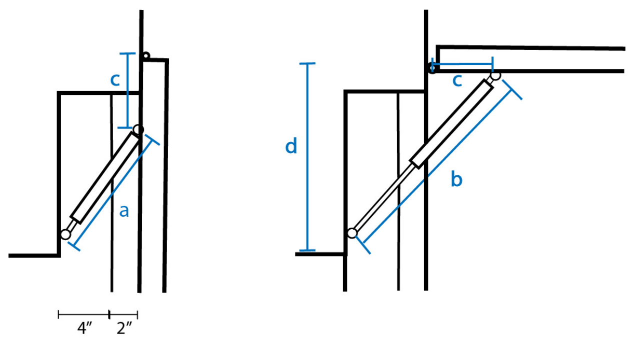
FIGURE 8B-2D: TYPICAL COMPRESSION LATCH AT COLUMN



SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-3: GAS SPRING ANALYSIS

FIGURE 8B-3A: GAS SPRING LOCATION



Geometric Analysis:

a ≡ Compressed spring length

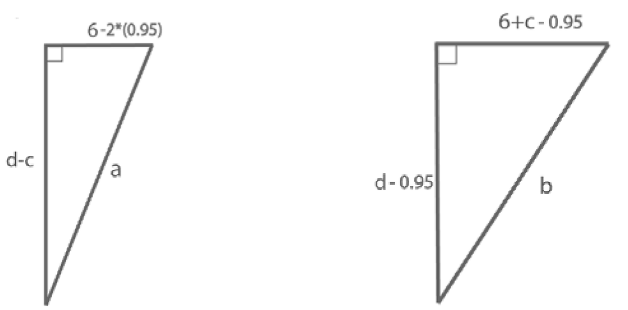
b ≡ Extended spring length

c ≡ Distance from top edge of shutter to cylinder connection on panel

d ≡ Vertical distance from hinge attachment point to cylinderhouse connection

Cylinder will be fully compressed in the closed position and fully extended in the open position.

FIGURE 8B-3B: GAS SPRING GEOMETRY (not to scale)



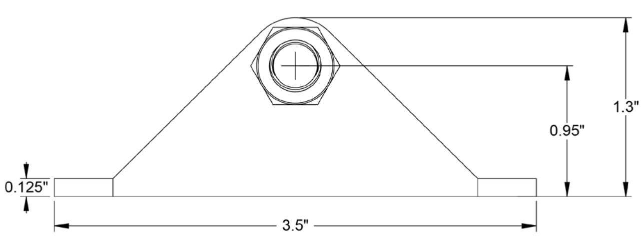
Goal: Maximize c to generate greatest moment arm.

Constraints: d < 16” for window frame interference.

Governing Equations: Select product dimensions (a and b) from McMaster Carr and solve for mounting points (c and d).

Note: Selected corrosion resistant springs from McMaster Carr utilize mounting brackets, shown on the left. The 0.95inch dimension must be taken into account.

FIGURE 8B-3C: GAS SPRING BRACKET



Source: McMaster Carr

Solve:

$$4.1^2 + (d - c)^2 = 12.5^2$$

$$(5.05 + c)^2 + (d - 0.95)^2 = 18.5^2$$

$$c = 4.80''$$

$$d = 16.61''$$

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-3: GAS SPRING ANALYSIS

Moment Analysis:

FIGURE 8B-3D: SHUTTER SECTION - OPEN

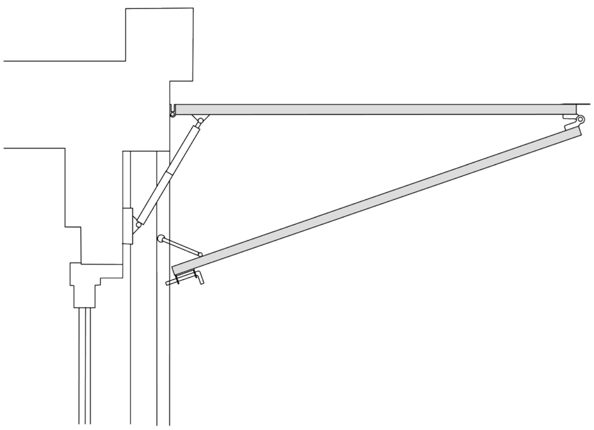
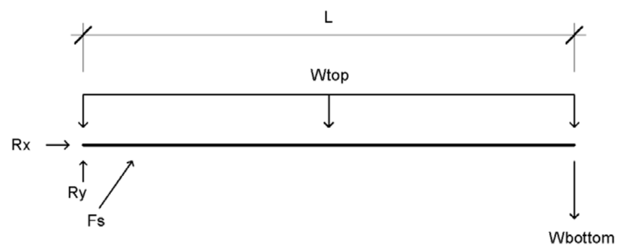


FIGURE 8B-3E: TOP PANEL FREE BODY DIAGRAM



What would be the required force to hold up the shutter if the springs are mounted at the specified point (4.80 inches)?

$$\sum M_{hinge} = 0$$

$$\sum M = (F_{spring})(\tfrac{d}{b})(c) - (W_{top})(\tfrac{L}{2}) - (W_{bottom})(L) = 0$$

$$(F_{spring})(\tfrac{16.61}{18.5})(4.80) - (80)(\tfrac{61.25}{2}) - (85)(61.25) = 0$$

$F_{spring} = 1777\ lb$ Total for all springs

The role of the gas springs is to assist manual lifting and closing of the shutter, not to automatically lift and hold open in a fixed position. Considering the 6:1 mechanical advantage of the pulley system to assist lifting and friction in the line to slow closing, the team found it appropriate to size the gas springs for 50–60% of the force required for traditional applications. shutter up indefinitely. Two 500lb. gas springs were selected, providing 56% of the calculated force for a static system.

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-4: LIFTING AND SAFETY SYSTEMS

FIGURE 8B-4A: MOTION DIAGRAM

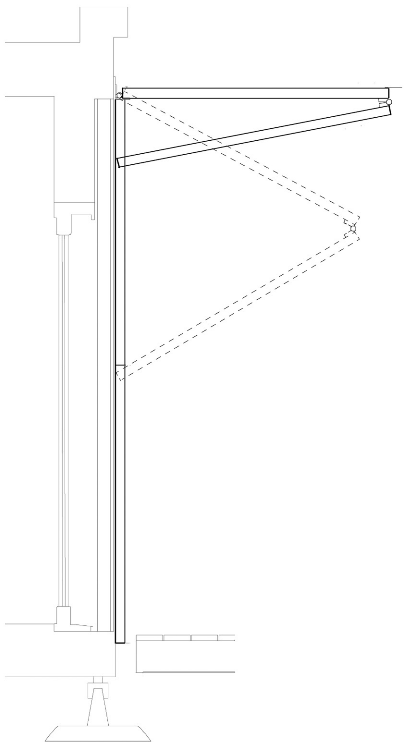


FIGURE 8B-4B: MANUAL LIFTING AND RIGGING

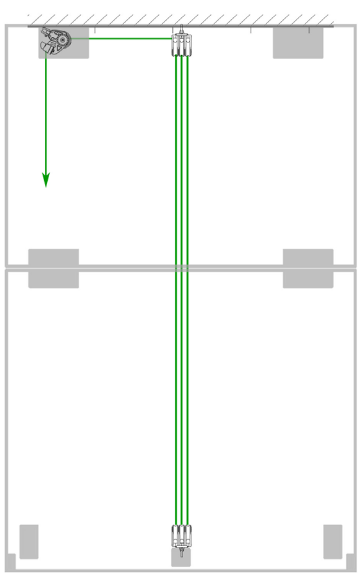


FIGURE 8B-4C: SHUTTERS IN ACTION

FIGURE 8B-4D: RIGGING DETAIL

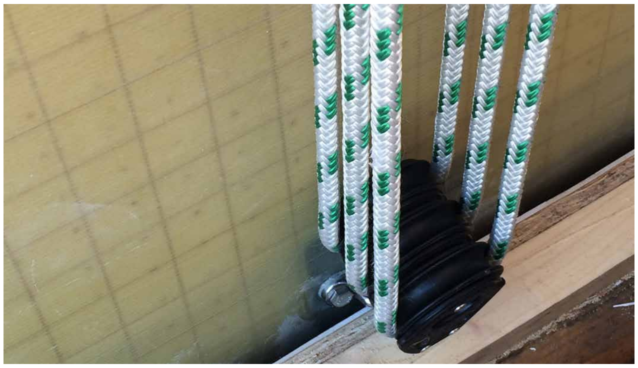
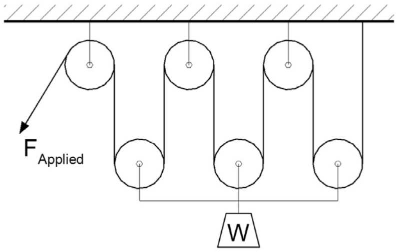


FIGURE 8B-4E: 6:1 BLOCK AND TACKLE



If lifted at a constant velocity:

$\sum F_y = mg$
$6T = W$

Tension is constant for all parts of line therefore:

$F_{Applied} = T = W/6$
$F_{Applied} = 165/6$
$F_{Applied} = 27.5\text{lbs}$

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-4: LIFTING AND SAFETY SYSTEMS

FIGURE 8B-4F: PRIMARY LOCKING

Cam cleat holds 6:1 manual lifting line in place.

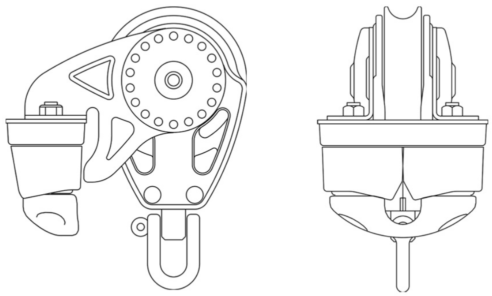


FIGURE 8B-4G: LOCKING SAFTEY

1/2" Spring loaded locking pin prevents panels from closing in event of cleat failure

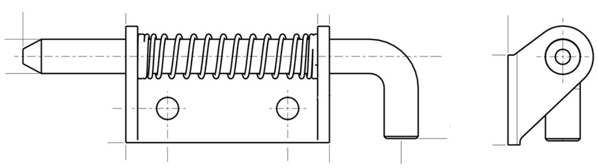
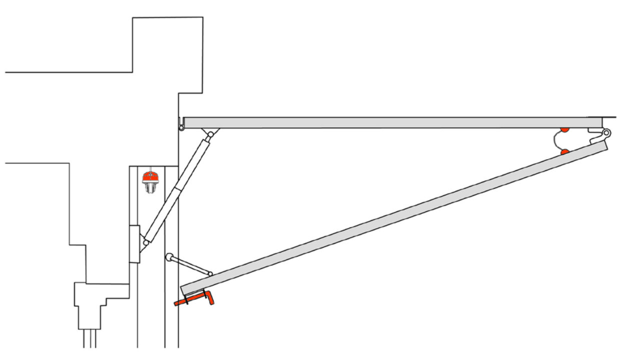
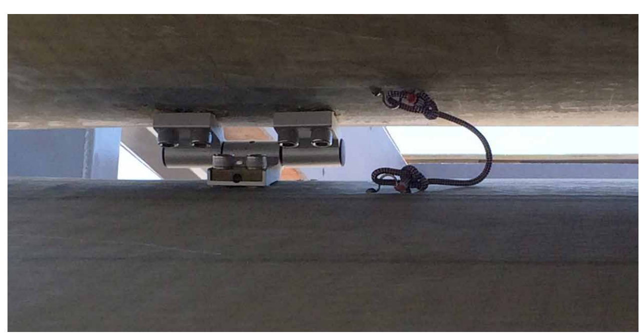


FIGURE 8B-4H: PANEL TO PANEL SAFTEY

5mm high strength, low stretch line prevents bottom panel from falling away from top panel in the event of catastrophic hinge failure.





SECTION 8B-5: LAMINATE SCHEDULES

FIGURE 8B-5A: PROTOTYPE V1 LAMINATE SCHEDULE

Produced at IYRS 02/27/15

	Lay Up: TOP PANEL		
	Material	**Fiber Orientation**	**Location**
1	3oz CSM	- - -	FULL
2	2408 Triax	+ / - 45 / 90	FULL
3	1208 Biax	0 / 90	FULL
4	CORE	- - -	FULL
5	1208 Biax	0 / 90	FULL
6	2408 Triax	+ / - 45 / 90	FULL

	Lay Up: BOTTOM PANEL		
	Material	**Fiber Orientation**	**Location**
1	3oz CSM	- - -	FULL
2	2408 Triax	+ / - 45 / 90	FULL
3	1208 Biax	0 / 90	FULL
4	1208 Biax	0 / 90	FULL
5	CORE	- - -	FULL
6	1208 Biax	0 / 90	FULL
7	1208 Biax	0 / 90	FULL
8	2408 Triax	+ / - 45 / 90	FULL

FIGURE 8B-5B: PROTOTYPE V1 IN PRODUCTION

Laminate schedules were developed through full scale prototypes to determine the most durable and lightweight design. The V1 prototype began with an initial glass fiber laminate approximation which utilized a 2" core thickness.

FIGURE 8B-5C: PROTOTYPE V2 INSTALLED

Produced at ACC 04/14/15

	Lay Up: TOP PANEL		
	Material	**Fiber Orientation**	**Location**
1	1208 Biax	0 / 90	FULL
2	1208 Biax	+ / - 45	FULL
3	CORE	- - -	FULL
4	1808 0/90	0 / 90	FULL

	Lay Up: BOTTOM PANEL		
	Material	**Fiber Orientation**	**Location**
1	2408 Triax	+ / - 45 / 90	FULL
2	1208 Biax	+ / - 45	FULL
3	CORE	- - -	FULL
4	2408 Triax	+ / - 45 / 90	FULL

FIGURE 8B-5D: PROTOTYPE V2 INSTALLED

Warping effect of unbalanced lamanate evident in bottom panel.

Weight reduction was a strong consideration for V2. The core thickness was reduced to 1.5" and the fiber laminate minimized to an unbalanced layout based on an initial analysis from Gurit. The resulting panels developed a slow warping. The effects of this can be seen in Figure 8B-5-2 and described further in Figure 8B-5-3.

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-5: LAMINATE SCHEDULES

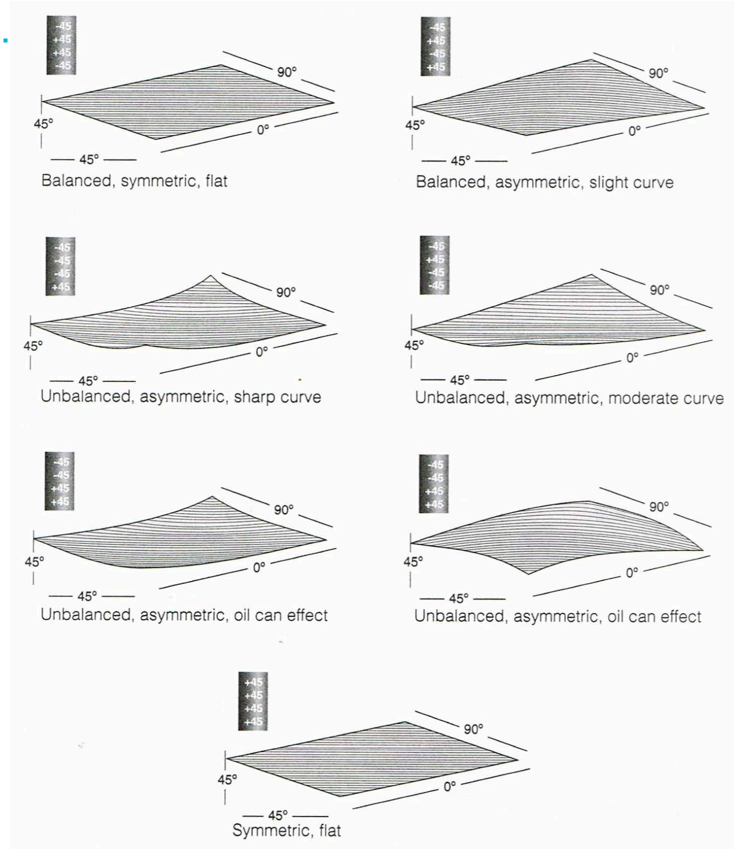
FIGURE 8B-5E

a. Effect of balance and symmetry in +/-45° laminates.

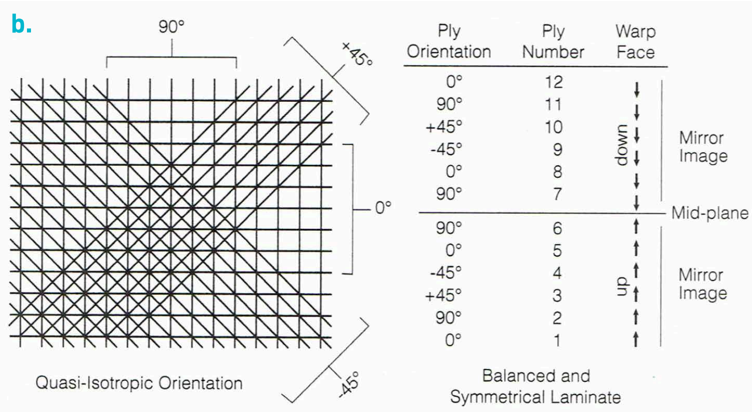
b. Quasi-isotropic laminates.

Source: Essentials of Advanced Composite Fabrication and Repair, Dorworth, Gardiner, and Mellema

a.



b.



SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-5: LAMINATE SCHEDULES

FIGURE 8B-5F: FINAL PRODUCTION LAMINATE SCHEDULE

A balanced laminate was derived for final production in conjunction with a second finite element analysis at Gurit (Section 8B-6). Each panel was tracked and documented; initials indicate the composite technician affirming proper placement and orientation of each ply. This ensures correct loading characteristics as modeled and if a repair is required, layers can be retraced and rebuilt as originally specified.

Stevens Institute of Technology
SURE HOUSE Storm Shutter Production: ACC
05/18/15 tk 1 of 6

Material:

Vectorply .75oz Chop Mat
Vectorply 2408 Triax Fiberglass
Vectorply 1208 Biax Fiberglass
CCP IVEX C-410 Vinylester Infusion Resin
PolyCel 2lb Density Polyurethane Core, 1.5" thickness
SP Gurit PVC-60

Mould Prep	**Initial:**
Wax Mould Surface as per Manufacture process.	JL
Gel Coat CCP 'Coca Cola' White as per Manufacture process.	BB
Apply Skin Coat with .75oz Chop after gelcoat has tacked	BB K KH
Bubble pop and squeegee to be sure no air remains	BB K KH

Lay Up: TOP PANEL Smaller

ply	Material	Fiber Orientation	Location	Initial:
1	1208 Biax	0 / 90	FULL	KH
2	1208 Biax	+ / - 45	FULL	KH
3	Poly Cel CORE	- - -	FULL	KH
4	1208 Biax	+ / - 45	FULL	KH
5	1208 Biax	0 / 90	FULL	KH

Vacuum Reading: 27.5 Drop Test: PASS

Notes: TWO PATCHES 1208 BIAX OVER TOP HINGE REINFORCEMENT K
ONE PATCH 1208 BIAX OVER MID HINGE K

Lay Up: BOTTOM PANEL Larger

ply	Material	Fiber Orientation	Location	Initial:
1	2408 Triax	+ / - 45 / 90	FULL	KH
2	1208 Biax	+ / - 45	FULL	KH
3	Gurit CORE	- - -	FULL	K
4	1208 Biax	+ / - 45	FULL	K
5	2408 Triax	+ / - 45 / 90	FULL	K

Vacuum Reading: 28.0 Drop Test: PASS

Notes: ~~TWO~~ ONE PATCH OVER ALL REINFORCEMENTS K

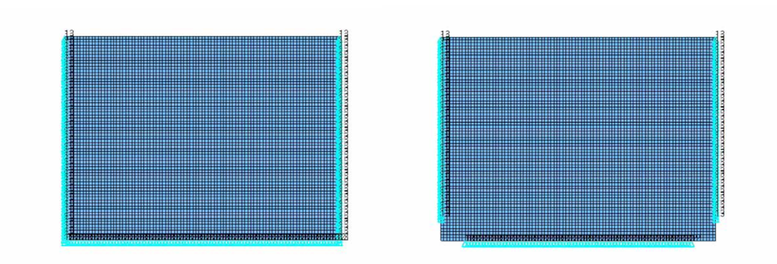
SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-6: BOTTOM PANEL FINITE ELEMENT ANALYSIS

Lower Shutter Panel Model Overview:

- Modeled and analysed using Hyperworks 12.0
- Linear static analysis Optistruct bulk solver
- Ply-based modeling

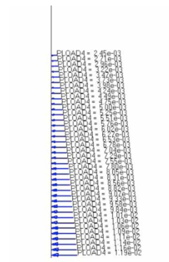
FIGURE 8B-6A: PANEL CONSTRAINTS



Panel 1 Constraints:
1,3 on verticals
1,2 on lower edge

Panel 2 Constraints:
1,3 on verticals
1,2 on lower edge
Constraints removed 200mm (7.87") from lower corners

FIGURE 8B-6B: PANEL LOADING



Loadcase Summary:
Tapered Pressure
12–2.4kPa (250lb/ft^2 – 50lb/ft^2)
Hydrostatic + Hydrodynamic

Laminate Schedule:
Gelcoat
.75oz Mat - Hand Laid
2405 Vectorply Triaxial (aligned 90/+45/45)
1208 Vectorply Double Bias (aligned +45/45)
Core Gurit PVC60 1.5" (38.1mm)
1208 Vectorply Double Bias (aligned +45/45)
2405 Vectorply Triaxial (aligned 90/+45/45)

FIGURE 8B-6C:
2405 VECTORPLY TRIAXIAL GLASS FIBER

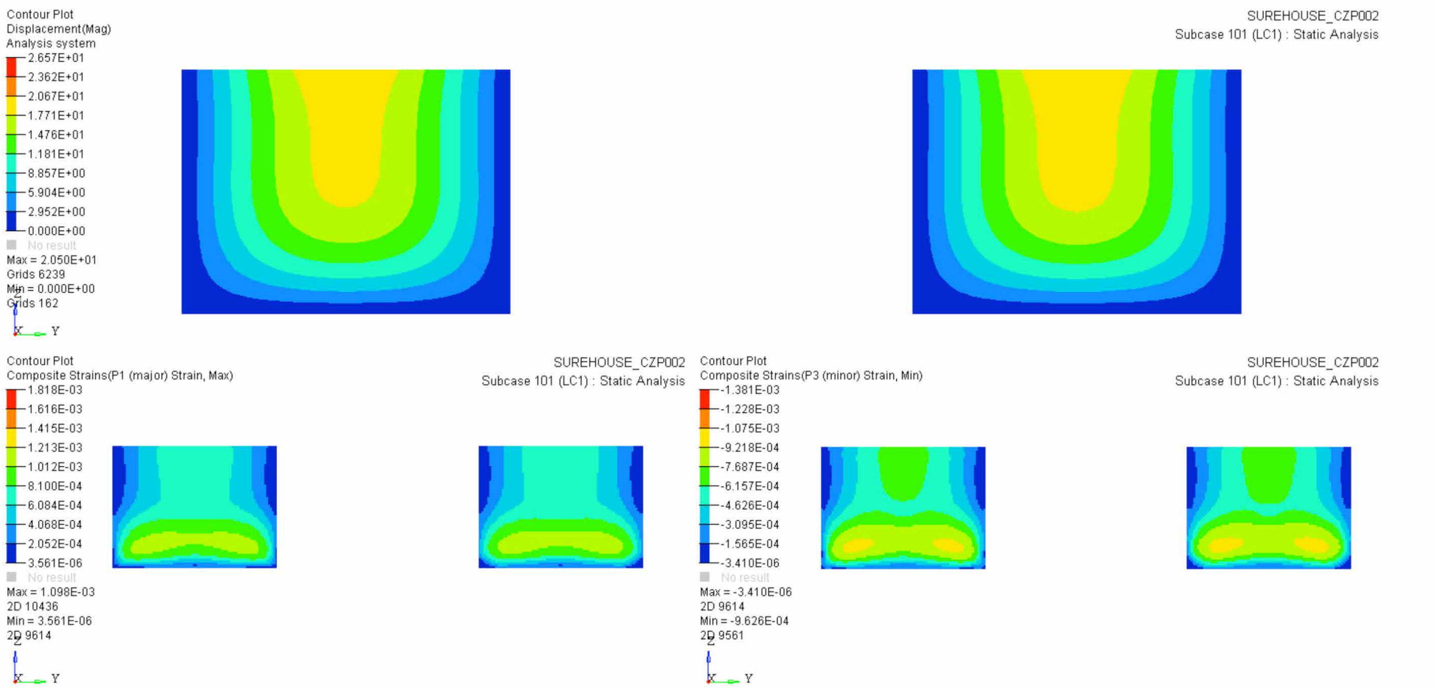
Finite element analysis performed with composite engineers at Gurit conclude that the bottom panel, when subjected to the highest load case, will deflect minimally at critical gasket seal locations (lower corners unsupported), as well as well as perform above margins of safety on fiber strain and microcracking of the laminate matrix.

SECTION 8B-6: BOTTOM PANEL FINITE ELEMENT ANALYSIS

FIGURE 8B-6D: FEA RESULT SUMMARY

Peak Deflection: 20.5mm (.807") Corners lift < 2.5mm (.098") on Panel 2.

Principal Strains: Significant margin of safety on failure due to strains, over 2.5x margin of safety on micro cracking.

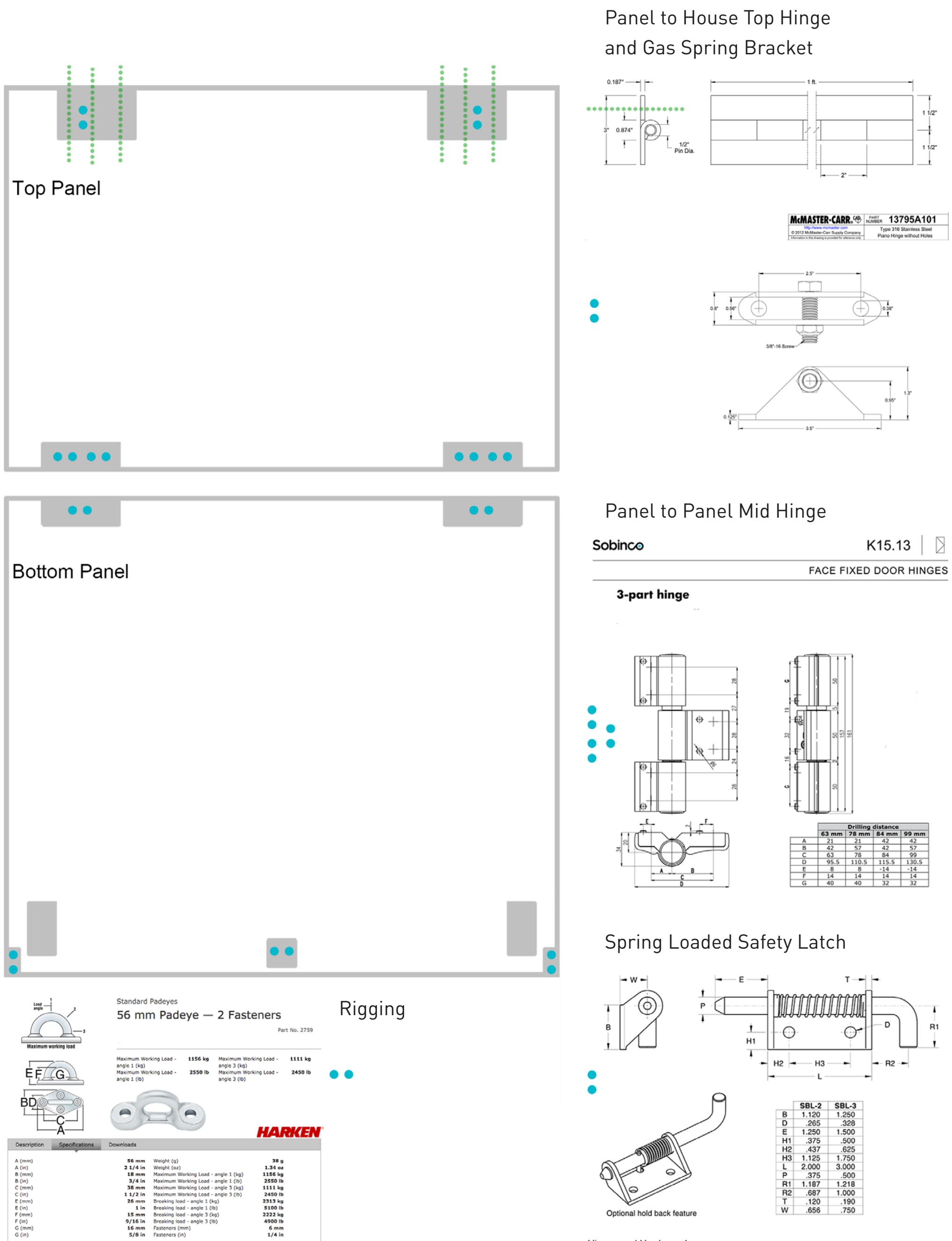


SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-7: STRUCTURAL CORE REPLACEMENT

FIGURE 8B-7A: CORE REPLACEMENT DIAGRAM

Relationships with the International Yacht Restoration School, Aquidneck Custom Composites, and Gurit allowed for detailed analysis of manufacturing processes and load case design. Critical hardware mounting locations were strengthened with 24lb/ft 3 glass fiber reinforced core and additional localized laminate.

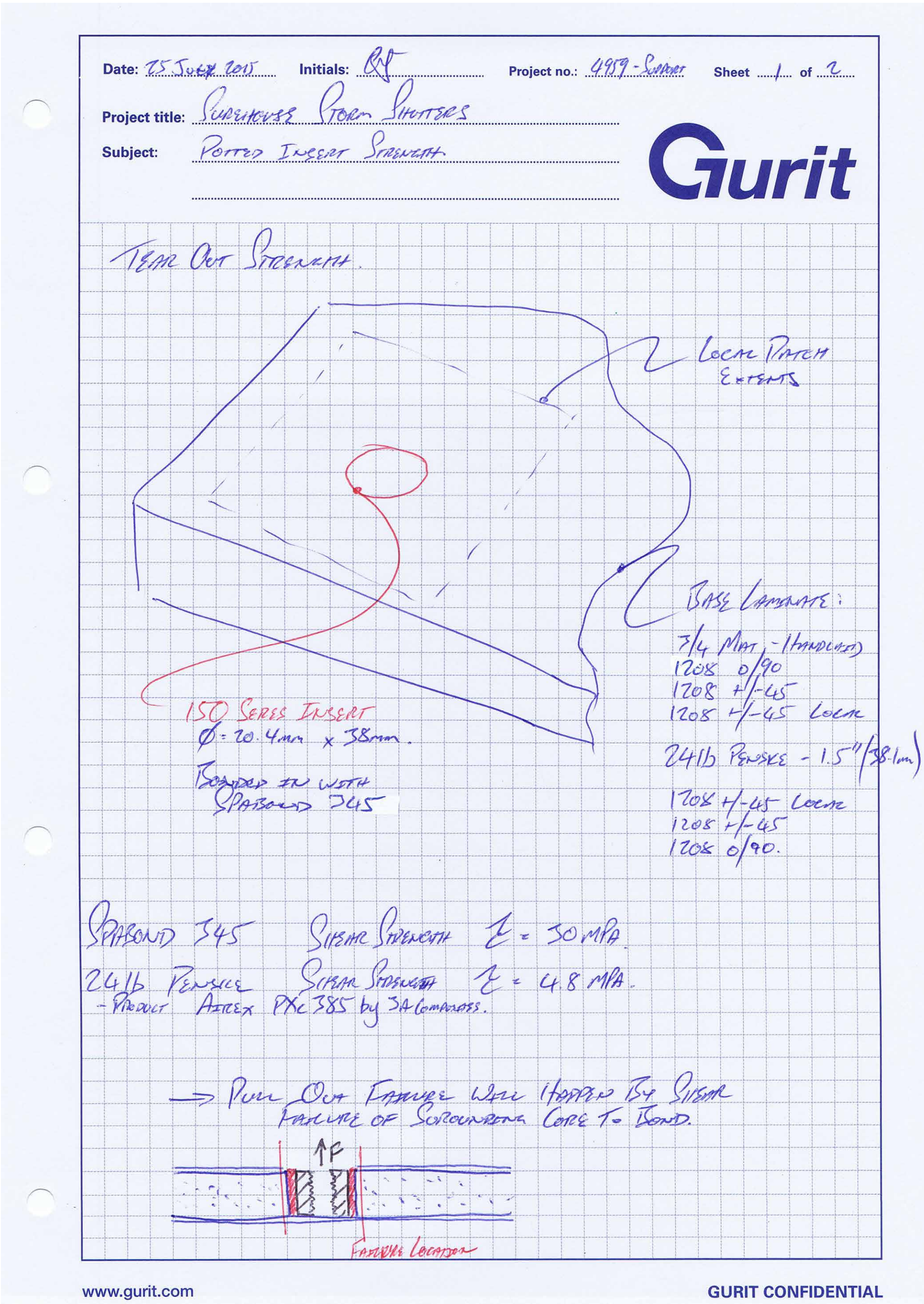


SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-8: POTTED INSERT STRENGTH ANALYSIS

FIGURE 8B-8A:TEAROUT STRENGTH CALCULATIONS (1 OF 2)

Provided by Gurit. Limit load is calculated to be 1,579 lb.


Date: 25 July 2015 Initials: RJ Project no.: 4959 - Sure Sheet 1 of 2

Project title: Surehouse Storm Shutters

Subject: Potted Insert Strength

Gurit

Tear Out Strength.

Local Patch Extents

Base Laminate:
3/4 Mat - (Handlaid)
1208 0/90
1208 +/-45
1208 +/-45 Local
24lb Penske - 1.5" (38.1mm)
1208 +/-45 Local
1208 +/-45
1208 0/90.

150 Series Insert
Ø = 20.4mm x 38mm.
Bonded in with Spabond 345

Spabond 345 Shear Strength τ = 30 MPa.
24lb Penske Shear Strength τ = 4.8 MPa.
- Product Airex PXc 385 by 3A Composites.

→ Pull Out Failure Will Happen By Shear Failure of Surrounding Core to Bond.

↑F

Failure Location

www.gurit.com GURIT CONFIDENTIAL

SECTION 8B-8: POTTED INSERT STRENGTH ANALYSIS

FIGURE 8B-8B:TEAROUT STRENGTH CALCULATIONS (2 OF 2)

Provided by Gurit. Limit load is calculated to be 1,579 lb.

Date: 25 July 2015 Initials: CJ Project no.: 4959-[illegible] Sheet 2 of 2

Project title: SureHouse Strom Shutters

Subject: Potted Insert Strength

Gurit

Core Area To Fail.

$$A = \pi \varnothing \times t$$

$$A = \pi \times 0.0204 \times 0.038$$

$$A = 2.44 \times 10^{-3} \ m^2$$

@ $\tau = 4.8 MPa \times 0.9$

90% of Manufacturers Datasheet Average Assumed

$$F = \tau \times A$$

$$F = \underset{Pa}{4.8 \times 10^6} \times \underset{\%}{0.9} \times \underset{m^2}{2.44 \times 10^{-3}}$$

$$F = 10,540 \ N$$

Max Design – Limit Load.

Limit → Ultimate = 1.5

$$\text{Limit Load} = \frac{10,540}{1.5}$$

$$= 7027 \ N$$

$$= 716 \ kg \ (1,579 \ lb)$$

www.gurit.com GURIT CONFIDENTIAL

SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-9: HINGE INSTALLATION AND ASSEMBLY

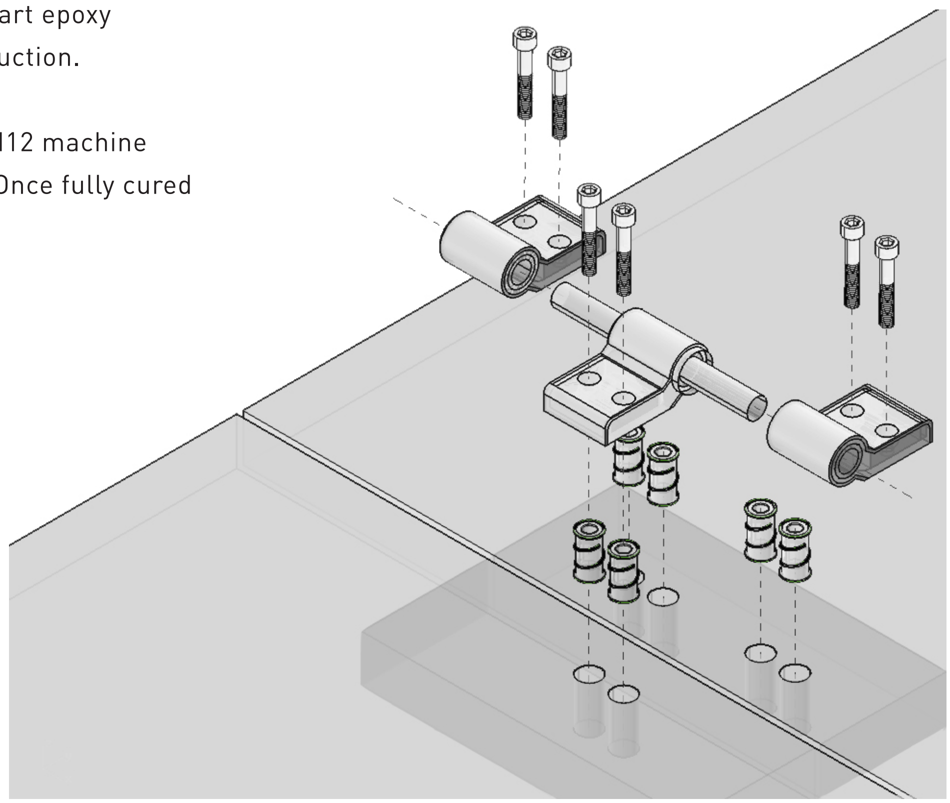
1. Align top and bottom panels.

2. Drill into back side of structural core to accomidate for Wtten 150 Series potted insert.

3. Clear and clean hole and surface of debris. Clean insert with solvent to remove accumulated dirt and oil.

4. Glue insert into core with two part epoxy adhesive as per engineering instruction.

5. Set hinge and partially install M12 machine screws before adhesive is cured. Once fully cured tighten and recheck alignment



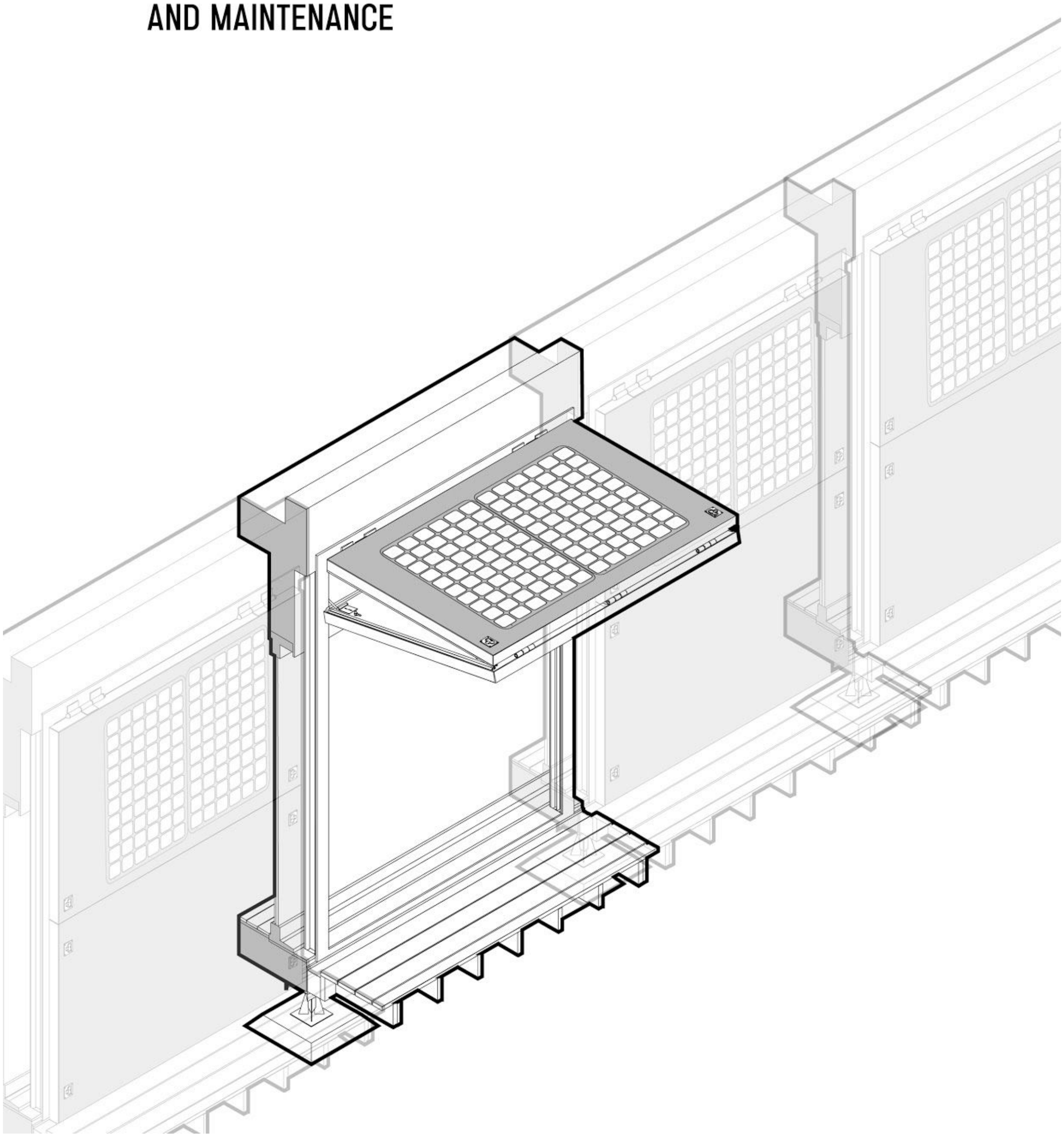
SECTION 8B: FLOOD-PROOF DESIGN – SHUTTERS AND PLUGS

SECTION 8B-10: SHUTTER OPERATION AND MAINTENANCE

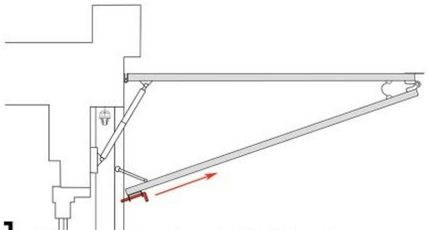
The fiber composite industry has been designing highly loaded and complex solutions since its beginning. Engineers and manufacturers are expanding into industrial design, architectural, and structural applications. This integrated technology is readily available and will become more accessible to homeowners.

SU+RE HOUSE

STORM SHUTTER OPERATION AND MAINTENANCE

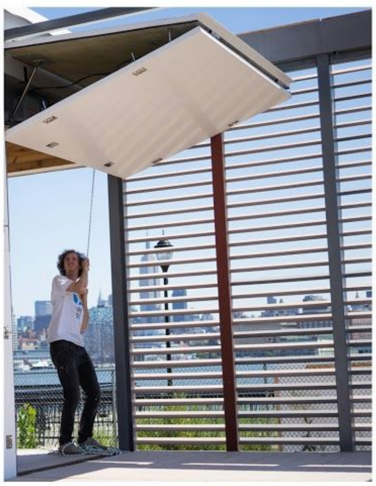


OPERATION: Close

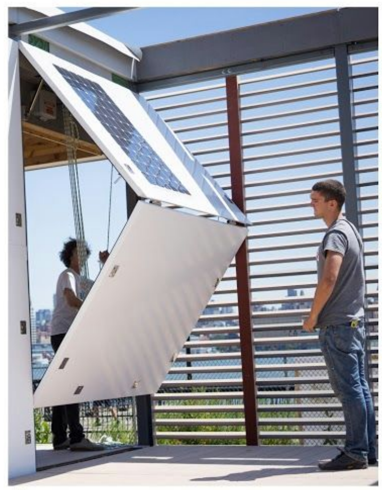


1. Release Spring Loaded Safetly Pins, two (2) per shutter.

2. Remove section of deck nearest to house.



3. Release Cam Cleat on 6:1 manual block and tackle system.



4. Lower Shutter manually.

5. Guide Shutter into gap between house and deck

6. Close and lock latches, eight (8) per shutter.

OPERATION: Open

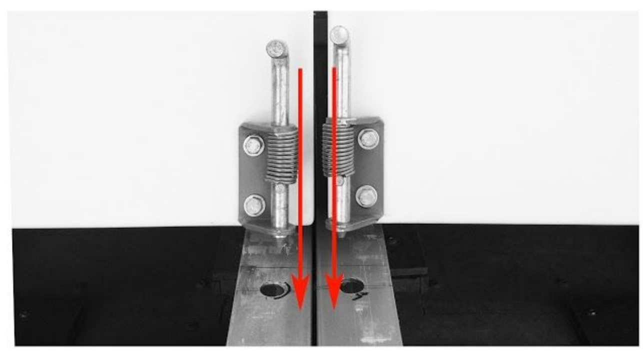
To open, reverse closing procedure:

1. Unlock and open latches, eight (8) per shutter.

Filp handle out, turn 90˚to release.

2. Guide shutter out of gap between house and deck by raising slowly.
3. Raise shutter to open positom with 6:1 manual block and tackle system.
4. Replace deck section.

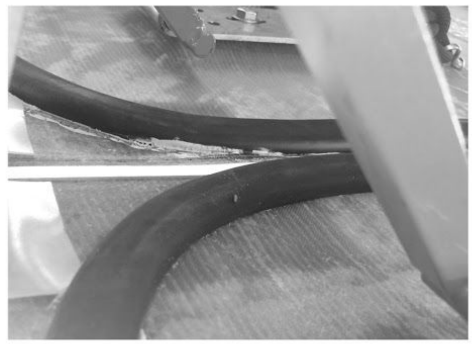
5. Lock spring loaded safetly pins, two (2) per shut-



MAINTENANCE

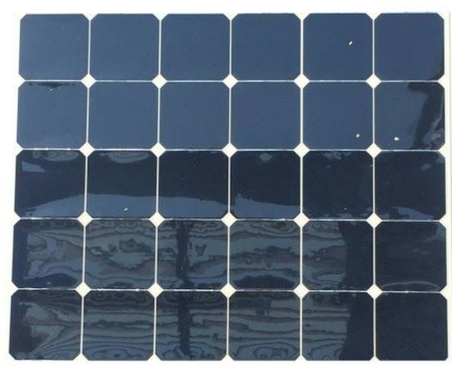
Operation:

Quarterly testing of the storm shutters will ensure that in the event of a storm or flood, the system will operate properly. Lower and rasie all shutters, inspect rigging and tracks for excessive wear or damage.



Gaskets:

Visually inspect each gasket for cracks, tears or wear. Check for separation between shutter and gasket. Repair or replace as needed. Gaskets are well hidden from UV exposure.



Photovoltaic Modules:

Clean modules with mild soap and water. This will allow for maximum effeciency and service life of PV.

Finish Paint:

To keep the gelcoat finish looking its best, clean with mild soap and water when required. Coat at least once per year with Starbrite® Marine Wax with PTEF® or equivalent.

Damage:

In the event of incurred damage, remove effected panel(s) and deliver to local composite shop for proper repair. Contact the SURE HOUSE team for recommendations, proper laminate schedules and repair techniques.

SECTION 9: REFERENCES AND WORKS CITED

Dorworth, Louis C., Ginger L. Gardiner, and Greg M. Mellema. Essentials of Advanced Composite Fabrication and Repair . Newcastle, WA: Aviation Supplies & Academic, 2012. Print.

“Hurricane/PostTropical Cyclone Sandy, October 22–29, 2012.” NOAA Service Assessment (2013): pg iv. US Department of Commerce. Web. 10 Aug. 2015.

McMasterCarr: New Jersey . 121st ed. Robbinsville, NJ: 2015. Web. Spring 2015.

Technical Sealing Guide . Tech. Woodstock, MA: Rogers Corporation, 2011, 2012. Web. 12 December 2015.