THE BEACH HOUSE JURY NARRATIVE: ENGINEERING

BEACH is an acronym for Building Efficient, Affordable, and Comfortable Homes. This acronym was used throughout the design process to guide the team's decisions. Efficient, affordable, and comfortable, these attributes were chosen because they meet the needs and desires of the target market in Daytona Beach. While engineered systems of a home may typically be seen to only affect the *efficiency* portion of the design, Team Daytona Beach believes that the engineered systems should also increase the *comfort* and *affordability* of the home.

A NEW BEGINNING FOR AN OLD CITY

Daytona Beach, the "World's Most Famous Beach," is best known for its wide, white-sand beaches. These hard-packed sand beaches hosted car races in the 1920s which led to the foundation of NASCAR. Today the hard-packed beaches allow the unique experience of driving to your favorite surf spot. Nestled just north of Cape Canaveral on Florida's east coast, the city boasts year-round mild weather with easy access to the Atlantic Ocean, the Intracoastal river, and natural springs. Thousands of visitors come to Daytona Beach each year to enjoy the beautiful beaches, partake in the Daytona 500 experience, or cruise on historic A1A during Bike Week.

Daytona Beach's primarily tourism driven economy was greatly affected by the economic recession of the 2010's. An already aged infrastructure and the failing economy lead to the historic ocean and riverfront areas of the city becoming dilapidated. However, the economic lull provided an opportunity for investors and city leaders to revitalize the city. Daytona Beach and the surrounding areas are in the midst of a master plan to breathe new life into the area. Daytona International Speedway has completed a $400 million re-imaging of the speedway and has 1.4 million square feet of retail and entertainment center, Daytona One, under construction just north of the track. A multi-million dollar rejuvenation of the historic waterfront areas including Beach Street and the Main Street Pier is underway that includes adding entertainment venues and rehabilitating classic hotels. The city also has plans to gentrify housing sections near the river and ocean, and an expansive 6900 home senior-living development, Latitude Margaritaville is in the construction phase. The city's revitalization is perfectly timed to coincide with the upcoming boom in housing for America's aging population.

As the Baby-Boomer generation ages, the need for senior-friendly living arrangement increases. It is expected that the population of persons over the age of 65 years will grow by nearly 30 million in the next 20 years, resulting in one out of three households being led by a person in this age group. Nursing homes and other traditional senior-living arrangements are less sought after as in-home care gains popularity. These trends create a demand for senior-friendly, single-family homes that are affordable and accessible. Like many coastal Florida cities, Daytona Beach is a retirement destination. Florida has seen a 2.1 percent increase in persons 65 years-of-age and older between 2010 and 2014, giving a total of 4 million persons in this age bracket. Baby Boomers and Generation X are more likely to care about sustainability and green living than past generations. As the need for senior housing increases, there should be a conscious effort to meet the green demands of the aging population. The goal of The BEACH House is to provide an energy-efficient and sustainable housing option for current and future seniors.

Figure 1: Welcome sign at Daytona Beach's beach access ramp for vehicles

Figure 2: Colorful, water-centered signage along Daytona Beach's beachside boardwalk

DESIGNING THE BEACH HOUSE

Team Daytona Beach was inspired by the rehabilitation of their home city. The team wanted to design a house that exemplified the sustainability of new construction with the distinct style of old Florida. The team wanted to design a home that met the needs of the growing senior demographic, but that also appealed to the city's current homeowners. Team Daytona Beach wanted to design The BEACH House.

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The main design obstacle that had to be overcome was the transportation of the house. Early on, it was decided that the house would be modularized and broken into three parts. This allowed the team to have the house transported almost 2000-miles from Daytona to Denver via an oversized semi-truck. All systems were then built with this design choice in mind. Between each of the modules, disconnects for plumbing and electrical are in place and the HVAC is a ductless system. These design choices were made to eliminate additional assembly at the competition site, while still meeting the team's main design goals of efficiency, affordability, and comfort.

STRUCTURAL SYSTEM DESIGN

The BEACH House was designed to be modular; however Team Daytona Beach did not want the home to feel modular. In order to meet this desire and keep the architectural style, a combination of post-and-beam and balloon-framing were used to design the structural system of The BEACH House.

Post-and-beam framing tied the house together, giving it a feeling of being a site-built home. Engineered lumber was used as the beams throughout the house, allowing for the cathedral ceilings. The beams also allowed for the clerestory windows to bridge the modules, blurring the seams and creating a unified look.

All exterior walls utilized a staggered-stud framing method. This method entails using 2x4 studs on a 2x6 base plate, where the studs alternate between being on the interior edge and the exterior edge. This construction method reduces thermal bridging between the indoor and outdoor temperatures, creating a higher R-value wall in a smaller footprint.

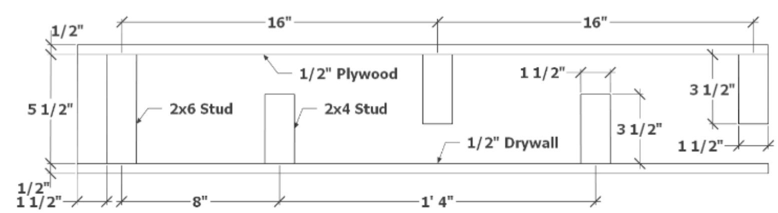

Figure 3: Schematic of Staggered-Stud Wall Construction

PLUMBING SYSTEM

The BEACH House utilizes a parallel, PEX plumbing system. A parallel system has separate lines running to each water fixture in the home. These systems are able to reduce water consumption by reducing the wait time for hot water. This is done by shortening the distance the hot water must travel through from the tank to the fixture in use. For example, water going to the shower of The BEACH House only has 10-feet of pipe to travel through in the parallel system. This distance would be increased if a traditional plumbing system designed to service both the bathroom and kitchen 16-feet away had been used. The separate lines connect to the hot and cold water supply at a central manifold. The manifold has valves on each line that allows for easy control of flow in each branch of the plumbing system. Having control over of water flow to each fixture simplifies routine maintenance by allowing the isolation of the fixture.

The BEACH House utilizes PEX, cross-linked polyethylene, as the primary supply lines. This piping is a smooth and flexible plastic that has a longer life than traditional rigid materials. The smooth surface of pipe reduces resistance to flow, lowering the required pumping power. The flexibility of PEX dampens water hammer and reduces pressure spikes in the line. These plumbing systems are also resistant to corrosion, an important feature for the salty environment of coastal Florida.[i]

MECHANICAL SYSTEM DESIGN

The Beach House utilizes a ductless system for the HVAC system. Ductless allows for more accurate climate control and a greater aesthetic appeal. The house can be broken up into three different zones, which allow for specific temperature control instead of one central AC system where controlling the temperature is specified by opening or closing vents to the main system. A ductless system allows for a specified temperature for an individual room without having the whole system running at one temperature. With a ductless system, the lack of complex duct routings allows an ease of modularity and reduction in potential home maintenance costs. The system uses 1/4-in and 3/8-in diameter pipes to run coolant between the heat pump and condenser. The small tubing sizes coupled with the ductless system provides an opportunity to utilize more insulation increasing home efficiency and comfort. The BEACH House uses three mini-split systems rated at 21 SEER between three separate zones:

- Zone 1 consists of the living room and kitchen, and is conditioned by an 18 kBTU/hr unit.
- Zone 2 consists of the master bedroom, and is conditioned with a 7 kBTU/hr unit.
- Zone 3 consists of the guest bedroom, and is conditioned with a 7 kBTU/hr unit.

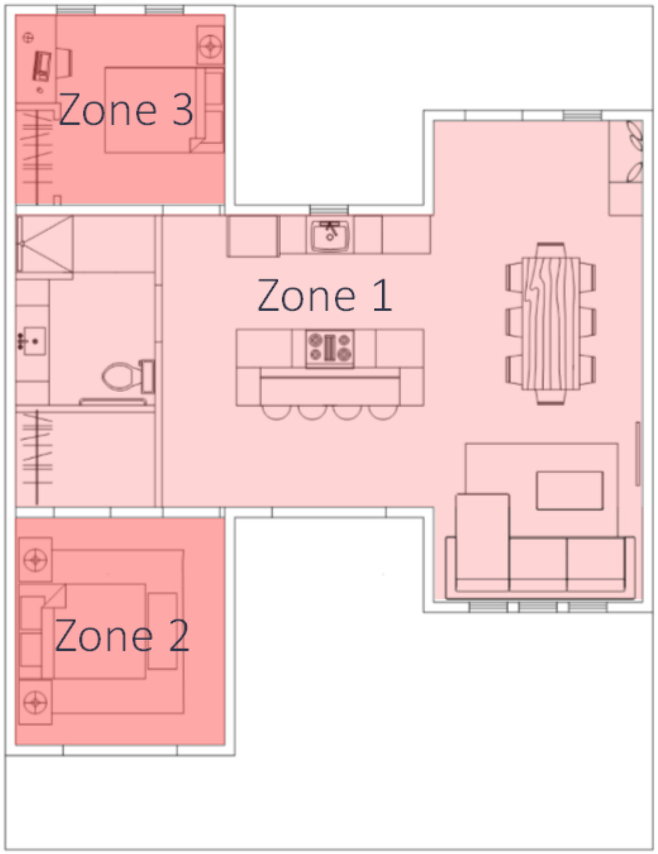

Figure 4: Zone locations in The BEACH House for the HVAC system

A heat and cooling analysis was conducted to size the units using Wright Soft and TRNSYS. Wright Soft is a program that simulates the internal conditions of the house based on location, the amount of people in the house, the appliances in the house and the time of year. The results are summarized in Table 1 and 2.

Table 1: Heating and cooling load analysis for Daytona Beach, FL

Zone	Heat [kBTUh]	Cool [kBTUh]
1	6.1	11.1
2	2.4	4.1
3	2.2	3.0

Table 2: Heating and cooling load analysis for Denver, CO

Zone	Heat [kBTUh]	Cool [kBTUh]
1	14.1	13.4
2	4.5	4.7
3	4.1	2.8

TRNSYS models the energy used by the system based on the time of day and the position of the sun. This provided us with a baseline value of 73 kW for the competition.

To continue to cut down on power consumption, an automated ventilation system was integrated into The BEACH House. The high ceiling under the south roof was designed to collect the hot air away from the main living space. Large clerestory windows were integrated directly under the high ceiling to passively vent this hot air out of the house. The north-facing clerestory windows will automatically open if the outdoor temperature and humidity conditions are more desirable than the indoor conditions. The four clerestory windows in the main living space will be connected to vent together, while the single clerestory window in the bathroom will be on its own system. The passive ventilation system in the main living area will be tied to the heat pump in Zone 1. Whenever the windows open the relay will shut off the heat pump as not to lose the heating or cooling.

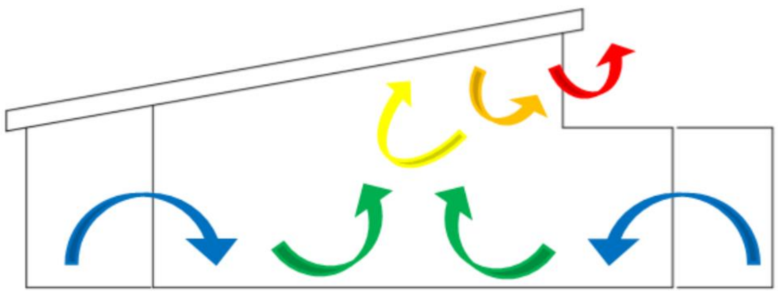

Figure 5: Air Flow through The BEACH House when Using Automated Clerestory Windows

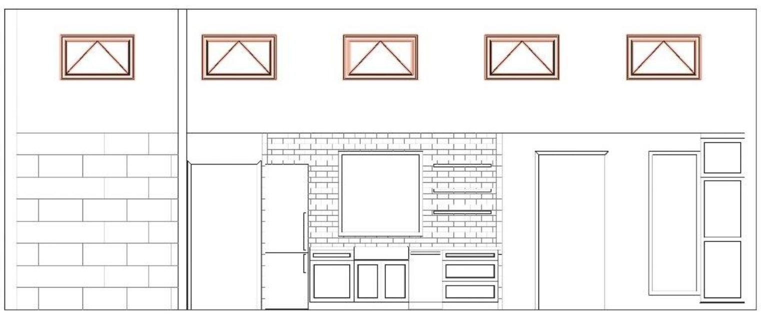

Figure 6: Automated Clerestory Windows of The BEACH House

Unlike a traditional ducted HVAC system, there is no way to integrate a humidification system directly with the heat pumps. To combat the dry conditions of Denver, Colorado, Team Daytona Beach has integrated an automated humidification system into the home. The humidification system will be tied to the automated clerestory windows and the Zone 1 heat pump, so that these systems are not working against each other. The humidification system detects the temperature and humidity in the home through the same set of sensors used for the clerestory windows. If the indoor conditions are outside of the pre-programmed comfort range, the system supplies water micro-droplets to the main living area, increasing the relative humidity.

ELECTRICAL SYSTEM

The BEACH House utilizes a grid tied solar panel array to power the home. The 9.3 kW PV system contains two kinds of panels, Jinko and Hyundai. The poly and monocrystalline panels have an efficiency of 15.7% and 16.6% respectively. Due to Florida's frequent tropical storms at the end of the wet season, an energy storage system (ESS) was integrated into the power system of The BEACH House. The ESS is a Tesla Powerwall 2, a lithium-ion battery pack. The battery will be used as a supplement to the PV array on a daily basis, performing peak-shaving at times of high demand and acting as a main source during the night. The BEACH House's battery can also power critical components of the house in case of utility grid failure after a storm.

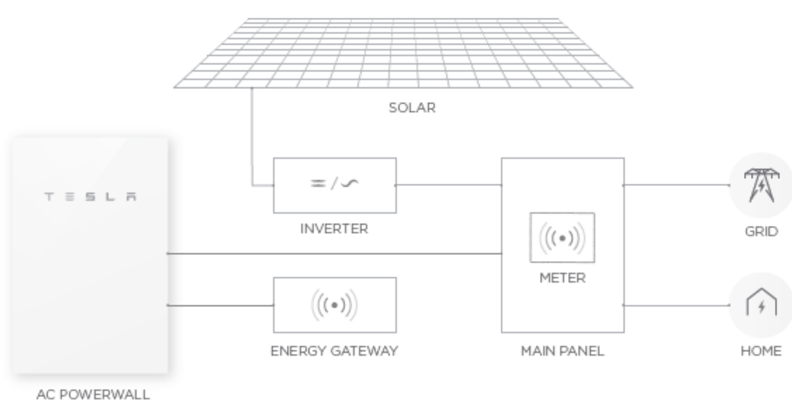

Figure 2: A basic overview of how the wiring for the electrical system is hooked up within The BEACH House[ii]

PHOTOVOLTAIC SOLAR ARRAY

The design of the array was chosen to be oversized for a multitude of reasons. One of the biggest hindrances to solar is the initial investment by the home owners. Being in the sunshine state, Team Daytona Beach wanted to capitalize on its state's most abundant resource, the sun. The size of the array allows the homeowners to see their return on investment years before their counterparts. Another aspect of the size of the PV was the roof real estate that could be allocated for energy generation. Due to design choices in plumbing and HVAC, there are only two vents that protrude from the roof and they were placed in areas where panels were unable to be located. This allowed for the majority of the roof to be covered in 625 ft^2 of solar PV panels.

OTHER DC COMPONENTS

The power generated from the solar panels will be converted into usable energy by the Sunny Boy 7700TL-US inverter. The panels are arranged so that there isn't any mismatch between the two different kinds of panels to maximize performance. A rapid shutdown system (RSS) is also utilized to comply with NEC 690.12. The RSS serves to turn off the photovoltaic array from the house in case of an incident. Home owners or emergency personnel could then enter the safely and address the issues without worrying about overhead electrical issues.

ENERGY STORAGE SYSTEM

The energy storage system (ESS) implemented in The BEACH House serves a dual purpose: to back up the critical loads designated by the owners and to decrease the peak consumption of the house by employing load shifting.

A fully charged Powerwall 2 will be able to run the critical loads of the house for over 24 hours without being charged by the grid or the 9.3 kW solar array. Power outages that seldom occur would only affect the owner for a split-second, they would experience dimming of the lights and a restart of components as the ESS started powering the necessary loads. The critical loads are well below the max continuous power (5 kW) of the ESS.

During extended periods of power outages that are known to affect Florida from time to time, mainly hurricanes, the ESS alongside the PV system would be able to power the house indefinitely. During off-peak times, in terms of incident solar radiation, the ESS would be able to fill in for the PV. Throughout the day the PV is either supplying power to loads of the house or sending the excess energy to the ESS.

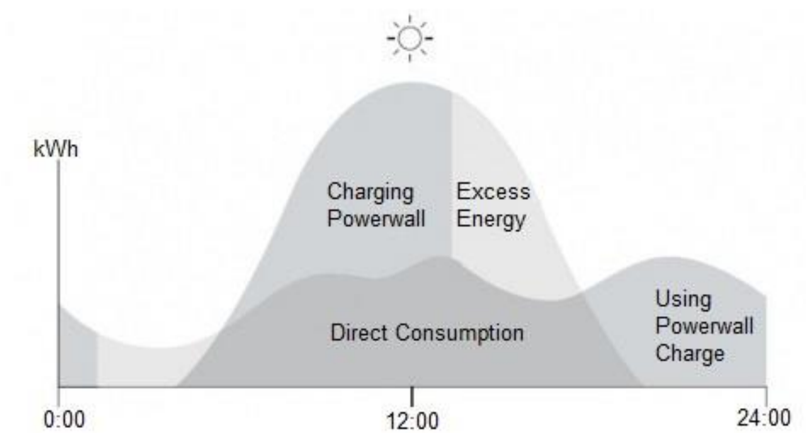

Figure 4: How the PowerWall 2 will operate throughout the day[iii]

Figure 1 shows that the majority of the loads are needed during off peak times, and how the PV is unable to power the house alone. The estimated power production of the house is 42 kWh per day in Denver, Colorado during October, while the average consumption throughout the competition week is 25 kWh per day. By utilizing the load shifting capabilities of the Powerwall, energy generated during midday can be used to power night time loads.

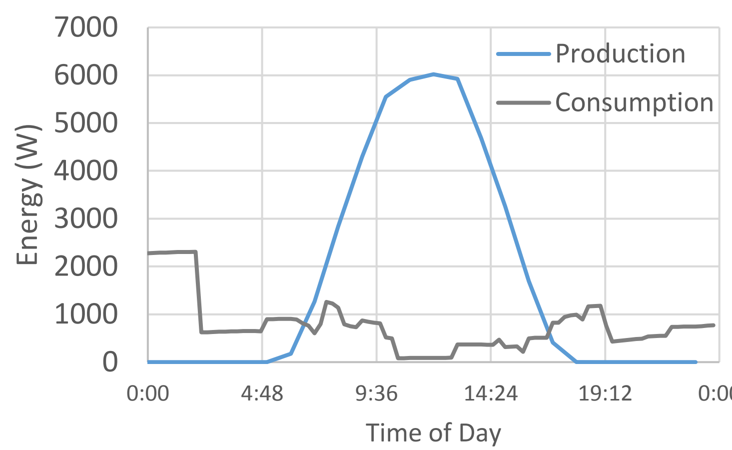

Figure 5: Average consumption of The BEACH House throughout the 9 days of competition and the estimated power output of the PV array

ENERGY BALANCE

For the sake of decreasing energy usage as much as possible, considerable research went into making the house passively consume less energy. Small details such as stud placement, window elevation, and insulated door and window headers allow the residents to live comfortably and economically.

When looking for appliances for The BEACH House, many factors were considered due to the complexity of the competition. Size, cost, life cycle, and aesthetic were all examined, but the largest factor that played a role in our selection was the energy efficiency. Everything from wattage of bulbs to the gauge of the wires was studied to make this home as efficient as possible. For the HVAC system, the house was modeled and then analyzed to ensure the size of the system would fit the house's needs. The majority of the appliances inside the house had their energy usage readily available from the Energy Star program, and for those that did not, their energy needed for the competition was calculated using the power ratings given from data sheets and adjusted for the time spent at the competition.

Table 3: The energy use of The BEACH House's appliances for both the competition and throughout the year.

House Loads	Competition Energy Use (kWh)	Annual Energy Usage	Calculation Method
Refrigerator	12.23	317.0	Energy Star Rating
Stovetop	14.40	265.0	
Washer/Dryer	15.00	225.0	
Car Charger	42.75	1733.8	Department of Energy
HVAC	57.12	2316.4	Wright Soft and Transys
Lighting	10.31	376.9	Power Ratings
Main Pump	0.96	38.9	
Hot Water Heater	3.50	141.9	
Home Electronics	2.31	93.7	
Hydroponics	4.60	186.4	
Total	163.18	5695.01	

For the nine days at the competition, the home will consume an estimated 173 kWh. For the monetary aspect of the energy balance, the team adjusted the time for each of the tasks to minimize the cost of energy that could be drawn from the grid. This strategy along with the oversizing of the solar array and the energy storage system's ability to peak shave will enable Team Daytona Beach to have an energy value of $10 or more.

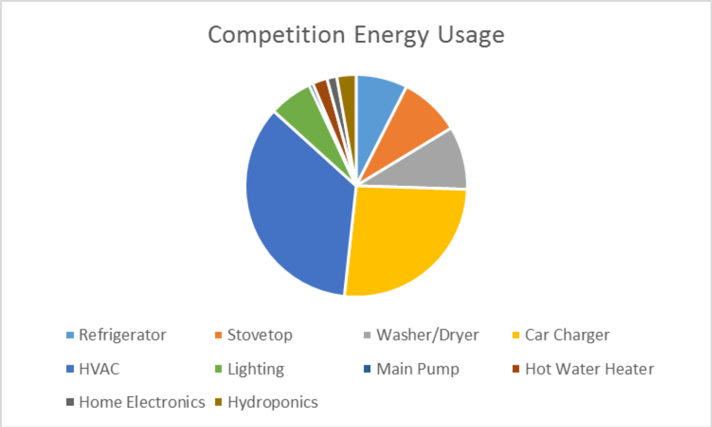

Figure 6: The energy use of The BEACH House's appliances at the competition.

[i] plasticpipe.org/pdf/design-pex-plumbing-systems.pdf, Aug. 10, 2017

[ii]Tesla. “Powerwall 2 AC Datasheet.” Tesla Inc.

[iii] Solar, Australia Wide. “Tesla Powerwall 2.” Australia Wide Solar, Australia Wide Solar, www.awsolar.com.au/tesla-powerwall/.

Annual Energy Summary

Wholehouse Summary

Team Daytona Beach	Project Title:	TMY_City:FL_DAYTONA_BEACH_INT
	The Beach House	Elec Util: Florida Average
,	Building Type: Rating14	Gas Util: Florida Average
		8/10/2017

End-Use	Energy Consumption	Annual Cost
Cooling Electric	723 kWh	$83
Cooling Fan	171 kWh	$20
Mechanical Vent Fan	0 kWh	$0
Total Cooling	**894 kWh**	**$102**
Heating Electric	225 kWh	$26
Heating Fan/Pump	35 kWh	$4
Mechanical Vent Fan	0 kWh	$0
Total Heating	**260 kWh**	**$30**
Hot Water	1181 kWh	$135
Hot Water Pump	0 kWh	$0
Total Hot Water	**1181 kWh**	**$135**
Ceiling Fans	369 kWh	$42
Clothes Washer	32 kWh	$4
Dehumidifier	0 kWh	$0
Dishwasher	112 kWh	$13
Dryer Electric	523 kWh	$60
Lighting	547 kWh	$63
Miscellaneous	875 kWh	$100
Pool Pump	0 kWh	$0
Range Electric	409 kWh	$47
Refrigerator	475 kWh	$54
Television	551 kWh	$63
Total (kWh)	6229 kWh	$713
Total (Therms)	0 Therms	$0
Total (Oil Gallons)	0 Gallons	$0
Total (Propane Gallons)	0 Gallons	$0
PV Produced (kWh) Assumes net metering	-11596 kWh	$-1328
Total Cost		$-615

Emissions (Calculated as Total - PV Produced)

SO_2 = -11.78 Lbs NOX = -5.49 Lbs CO_2 = -3.20 Tons