ENGINEERING NARRATIVE

1. INTRODUCTION

Illinois Solar Decathlon is an interdisciplinary registered student organization at the University of Illinois at Urbana-Champaign seeking to lead innovation in design and construction to advance towards an environmentally sustainable future. We are thrilled to present our latest project, RENU House.

RENU House is a 1,510 SF energy net-zero home. RENU represents the four guiding principles of our design and construction processes: Renewable, Economical, Nourishing, and Universal.

RENEWABLE
The most important feature of the project is energy net-zero status, but we have also striven to reduce the effect on the surrounding environment in every other aspect of the home.

RENOMICAL
Sustainable developments must be financially feasible to be adopted. We have prioritized cost efficiency in every design choice to ensure the home remains affordable for our target clients.

RENOURISHING
The design seeks to encourage fulfilling lifestyles by prioritizing accessibility for all abilities and emphasizing the mental and physical health of occupants.

RENIVERSAL
This design can be replicated in similar small-town markets across the United States, potentially bringing sustainable innovation to communities throughout America.

RENU House is nestled in the village of Rantoul, Illinois, a town of roughly 12,000 people fifteen miles north of the University of Illinois at Urbana-Champaign. Illinois Solar Decathlon has partnered with the Village of Rantoul Urban Planning Committee and the local Champaign County chapter of Habitat for Humanity for the build, consistently communicating with local stakeholders to ensure the home meets the needs of the occupants while effectively integrating into the small-town community.

RENU House was designed as a family residence, and can accommodate a diverse range of family dynamics such as a single parent or multigenerational household. Upon completion of the Department of Energy Solar Decathlon competition, the home will be fully donated to a local Habitat for Humanity family in need: Elonda, a single mother and intermittent wheelchair user, and her daughter, Monae, who is pregnant with her first child.

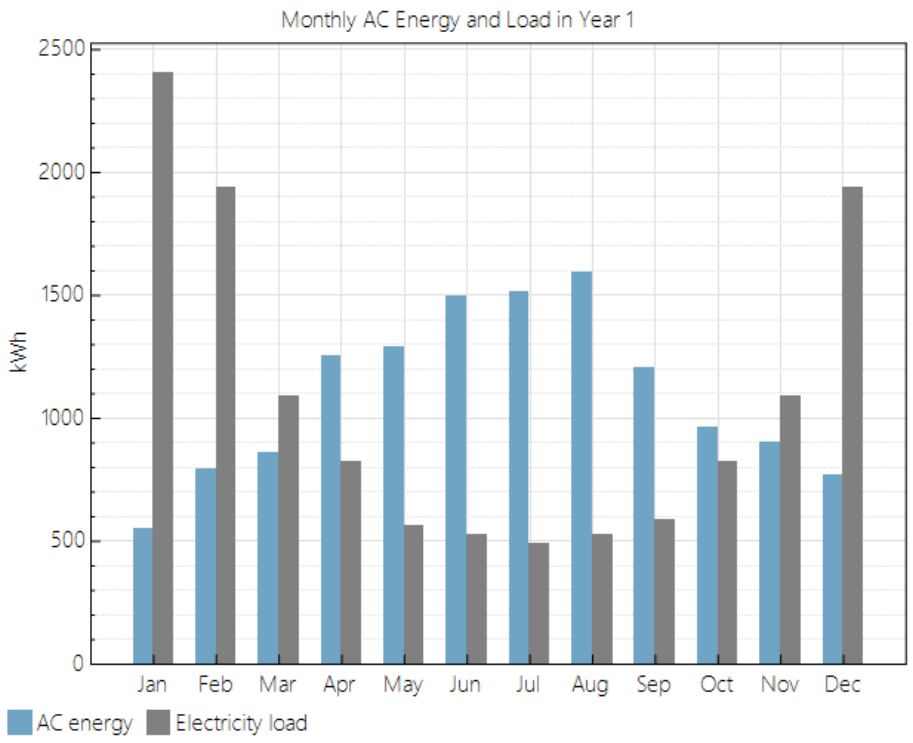
2. PHOTOVOLTAIC AND ELECTRICAL

When designing a photovoltaic and electrical system for RENU House, we considered several factors to optimize our system performance. Ultimately, we wanted to design an efficient solar system that meets the needs of our resident family. From the initial design stages, we consulted and collaborated with various individuals, including ARUP's electrical engineers, professors specializing in power & energy systems, and students across the ISD teams. Thorough research was conducted on the performance of each system component and how the whole system would interact with our loads. We investigated market-leading technologies in the solar industry and partnered with recognized companies to gain technical guidance on what would best fit our goals of powering a net-zero home. The partnering utility for RENU House is the 'Village of Rantoul', and based on their Ordinance No.2435, they follow the IEEE 1547 standard and offer solar net metering credits. With the ability to interconnect to the grid at an annual credit of 8.16cents/kWh, our family is reassured that the initial costs of installing solar will pay off their electric bills over time. While keeping the technical goals in our design approach, we also heavily considered the financial feasibility of having residential solar. This is elaborated on in our market analysis section.

To have a net-zero home, we need our production to outweigh our consumption. As a team, we had to juggle several design constraints and demands to accomplish this. Whether it was the physical design constraints, the innovative yet energy-intensive radiant slabs, the different types of water heaters, or any other design factors we had to negotiate the best solution to meet these demands from an engineering standpoint but also to build a practical home for our client family, prioritizing longevity and sustainability. We modeled our predicted load consumption through BEOpt and Ekotrope to actively update subsystem loads and maintain net-zero.

2.2 Energy Analysis

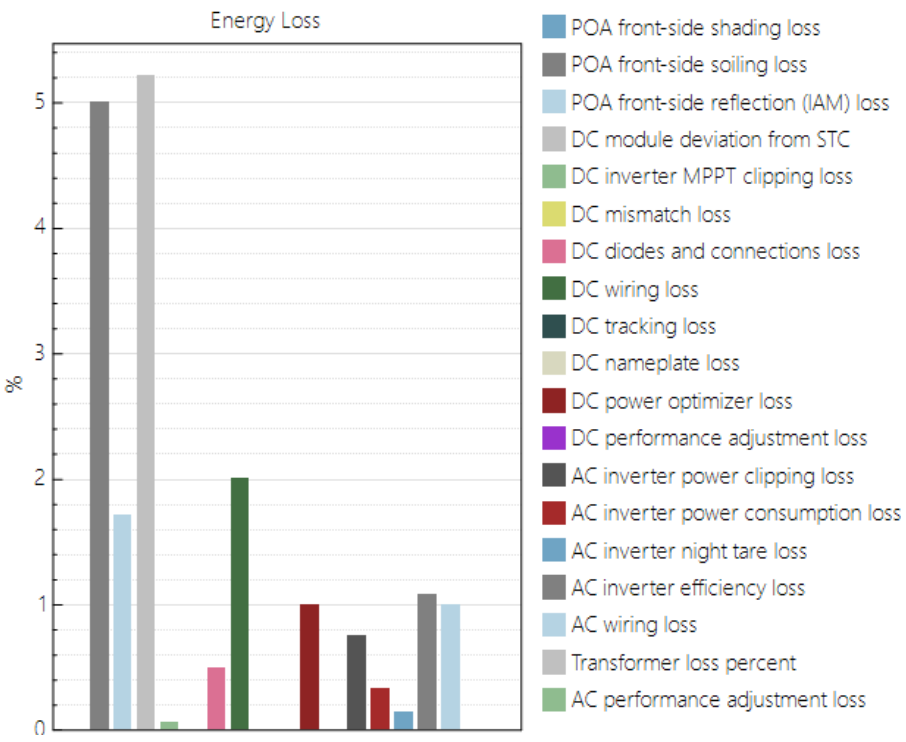
We utilized NREL's System Advisory Model software to model the integration of the components we selected. The total PV sizing is 9.46kWDC, with two strings of 11 430W solar modules, individually paired with power optimizers, to a 7.6kWAC rated inverter, leaving us with an optimal 1.24 DC to AC ratio. In total, our PV system is expected to produce 13,184 kWh/yr.



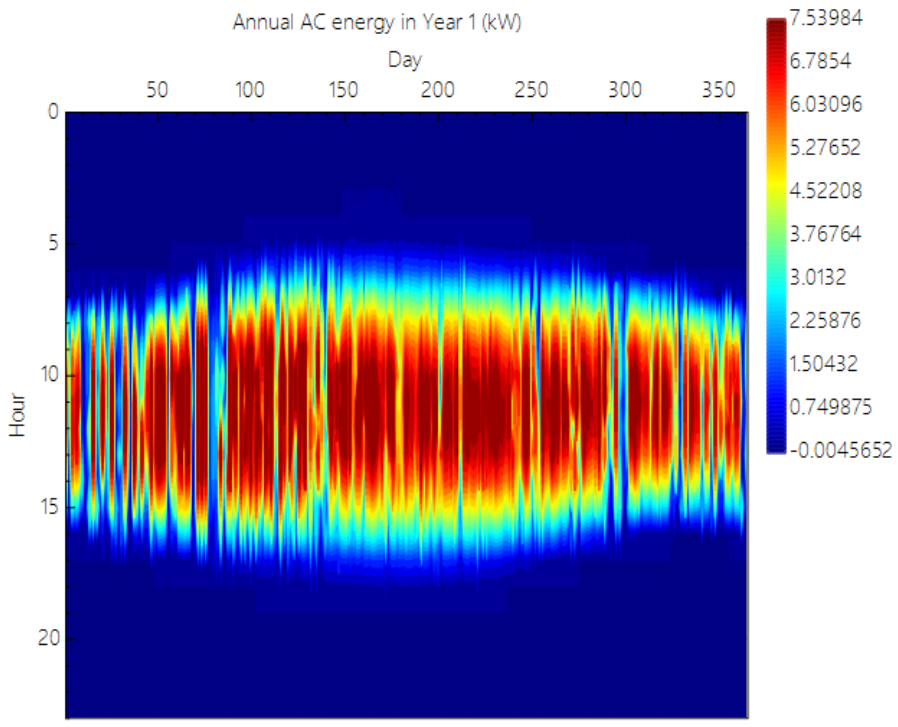
Estimated Annual Solar Production & Consumption

Month	AC energy (kWh/mo)	Electricity to/from grid (kWh/mo)	Electricity load (kWh/mo)
Jan	551.191	-1854.28	2409.63
Feb	792.769	-1145.48	1942.42
Mar	857.258	-231.392	1092.82
Apr	1255.7	431.119	828.75
May	1287.68	727.169	564.67
Jun	1495.67	972.184	527.66
Jul	1511.45	1021.1	494.51
Aug	1592.91	1069.42	527.66
Sep	1206.1	621.676	588.59
Oct	964.108	139.528	828.75
Nov	903.42	-185.23	1092.82
Dec	765.958	-1172.29	1942.42

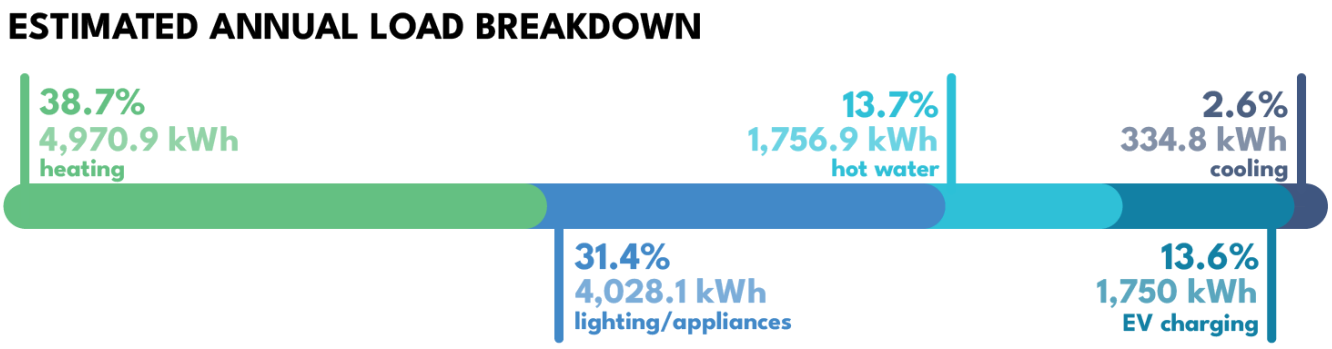
Estimated Monthly Electricity Data



Estimated System Losses



Estimated Annual AC Energy Hour Breakdown



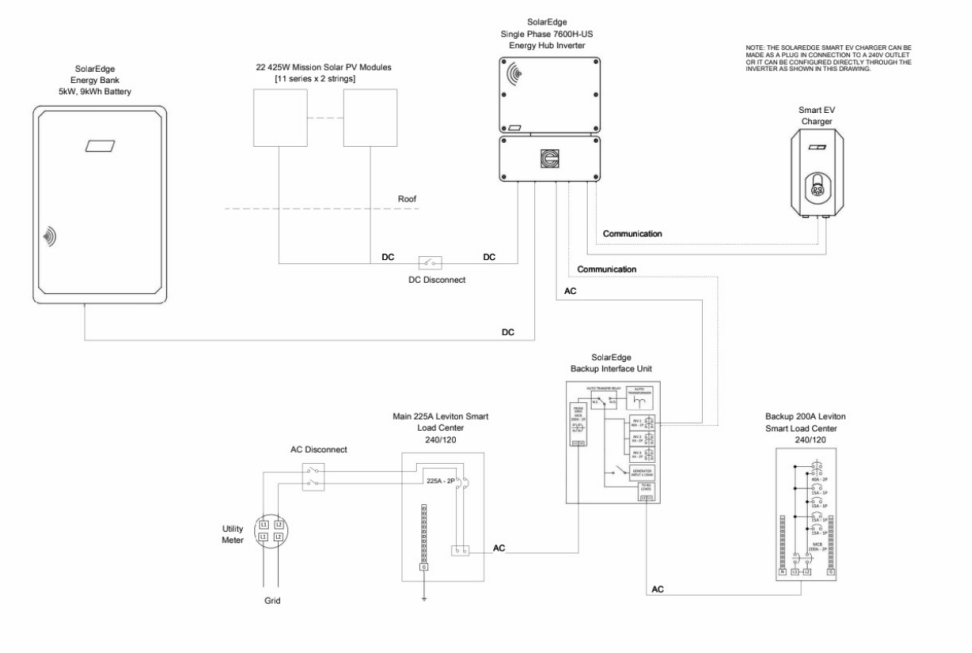
Estimated Annual Load Breakdown

As for our energy consumption, it is estimated to be a total of 12840.7 kWh/year, of which 11090.7 kWh is from the house and 1750 kWh is from EV usage. We estimated these values using Ekotrope, a HERS rating software initially to find our theoretical HERS score. However, it also resulted in us making design changes later to decrease our total energy consumption. Since Ekotrope does not produce monthly consumption values, we estimated the breakdown based on historic data regarding monthly temperatures and the solar irradiation data. Another estimate we made was the EV consumption. Assuming that an EV is driven 20 miles per day as the competition states, the EV consumes about 1750kWh/year, referenced with the 4.17 mile/kWh efficiency of a Tesla Model 3.

Some key inputs such as our exterior wall R-value is significantly higher than an average residential home. Instead of being within the recommended R-13 to R-23 by Energy Star, our exterior wall is rated at R-30.5, which decreases the rate that heat can be transferred and lost to the outside. As for our ceiling, we are in the higher quartile for insulation. The recommended range is R-38 to R-60 and ours is R-57, which is just solely coming from the cellulose insulation and does not factor in the roof material R-values. In addition, the hot water lines are also insulated with R-3 material, which reduces heat loss in our recirculating pump loop.

Another key aspect of our analysis is the infiltration of outside air. Since we do not want any air leaks for potential heat loss, we are currently quoted at an ACH50 value of 0.7 by an air sealing company, which brings down our heat loss by a significant amount. This reduces our heating load and was a key factor in keeping us at net zero with Ekotrope's analysis.

2.4 Solar System Components



Photovoltaic & Electrical One-Line Diagram

2.4.1 Mission Solar MSE430SX9Z Modules

We selected Mission Solar's 430W modules that have an efficiency rating of 19.6% with a temperature coefficient of -0.347/°C , meaning that the loss in power with an increase of temperature is extraordinarily low compared to conventional solar modules. Unlike standard solar modules on the market, these modules utilize PERC (passivation emitter rear contact) technology. The difference mainly lies on the insulating film that adheres to the back of the module which improves the current flow and increases energy produced. In industry parameters, PERC has enabled 6% to 12% more energy production than conventional solar panels. A drawback of common PERC technology is that it becomes prone to potential induced degradation (PID); however, our model accounts for this and is PID resistant. In addition, our panel has 9BB solar rather than 5BB, meaning it has 9 bus bars rather than 5. This factor increases the efficiency of conducting electricity and reduces losses.

From an economic perspective, third-party testing has shown that Mission Solar Energy modules have the highest PTC ratings of any American-manufactured module. As a result, our residents will be eligible for solar rebate programs in Illinois.

When researching for the optimal brand, initially, getting the highest efficiency module, power output, and solar panel type were our priorities. Additionally, economic feasibility was thoroughly accounted for considering that our resident is a single mother with a millennial daughter expecting a child. Therefore, we concluded that Mission Solar fit our situation the most with an added benefit of a better LCA analysis.

2.4.2 SolarEdge (string inverter + power optimizer)

Because our climate in Illinois is not 100% irradiant year round, power optimizers were the best choice to maximize solar power production. Power optimizers are DC-DC buck boost converters that find the optimal point on the IV curve that produces the max power generated. As a result, we are able to extract maximum efficiency. MPPT and voltage management are handled separately for each solar module by the SolarEdge S440 power optimizer (rated at 8-60VDC with 99.5% efficiency) and the SE7600H-US single phase home hub inverter (rated at 7.6kWAC with 99.2% efficiency) converts the DC generated electricity into AC. We chose a combination of pairing SolarEdge's inverter with the power optimizer technology over opting for microinverters in order to make the house as low-maintenance, comforting, nourishing, universal, and economical as possible. It is often more expensive to install a microinverter, and it's easier to keep track of based on the number of parts to monitor. Our site also has no shading issues, so the string inverter paired with the power optimizers is more advantageous over the possible benefits of microinverters. The fixed string voltage also ensures operation at the highest efficiency at all times independent of string length and temperature, making it also durable under adverse weather conditions while producing the same power output. In addition to its functionality as a DC-optimized PV inverter, the single phase inverter also manages battery and system energy as part of the solaredge home solution.

2.4.3 SolarEdge Backup Interface Unit

SolarEdge Backup interface unit is a central communication hub that automatically controls the disconnect of house loads during power outages. This product is designed for homeowners to have full control of which loads will remain intact, and allow an easier transition between the main loads and critical loads for our design with two load centers. The backup interface is also connected via 5 wire cables to the inverter from ports located on the bottom of both units. Using data from the inverter, the backup interface is able to recognize when the electrical system is disconnected from the grid, automatically switching from the main to critical load center and powering these loads using the battery. The SolarEdge Backup interface also has the option of rapid shutdown, which is enabled through the press of an external rapid shutdown switch allowing user safety control. Through the HomeAssistant application our team developed, the homeowner will be notified of these changes in the system. A CAT6 cable is also connected between the inverter and backup interface to enable communication, which allows for the monitoring of power production. This information then shows up on the app, which residents can view with the simple touch of their finger.

2.4.4 SolarEdge Energy Bank Battery

A UL1973 Lithium-Ion DC coupled battery in conjunction with our system allows for maximum system efficiency from PV to grid. Since our PV system is grid-tied, meaning we can utilize net metering to send excess production back to the grid and buy back later, the battery can serve as a reservoir for storing energy. The estimated consumption of the house per hour is 1.34kW, and with a 10kWh battery it can power the home for about 7.5 hours. The SolarEdge 10 kWh battery has a 94.5 roundtrip efficiency, providing power in the times we want to rely on our energy storage rather than the grid. Through the Home Hub inverter, we can program the inverter to store excess energy into the battery and discharge it whenever we want, either to power the house during a low production day, a peak electricity hour period, or a grid outage. Further information regarding the strategy of utilizing the battery and backup interface is elaborated in our Durability & Resilience documentation.

2.4.5 SolarEdge Smart EV Charger

The SolarEdge Smart EV Charger is a level 2 charger with many features that can not only reduce the impact of carbon emissions, but also reduce costs of transportation by having an EV charging station right at the resident's home. Some of these features include weather resistivity, a 5-year warranty,

Wi-Fi communication, and supplies up to 9.6kW of charging power. The EV charger also synchronizes with all other SolarEdge products that we have included and has faster charging with the unique Solar Boost mode, which can utilize both grid and available PV simultaneously. This system is also connected to the solar edge app and has potential to be used as a smart device.

2.4.6 Leviton Smart Load Center

For our load centers, we decided to opt for a combination of smart load centers, smart circuit breakers, and a smart breaker data hub from Leviton that all support our app integration goals. The Leviton load center serves as our main and critical service panel with smart energy monitoring circuit breakers whose performance the occupant can view in real-time through the app. The smart nature of the system will also allow occupants to remotely trip breakers, allowing for overall ease of interaction with the electrical system for the occupant.

The Leviton Smart Load Center's design increases job site efficiency and provides ample room for hands to move and work freely. The smart load center features remote monitoring capabilities through the My Leviton app as well as Hydraulic Magnetic technology where circuit breakers are precisely tripped during extreme temperatures. Since our system also uses Leviton smart breakers, occupants can check any circuit's status in real time and are notified if any loads trip remotely. For safety purposes, the user would have to turn the breakers back on physically. The occupant also has the ability to remotely turn off certain breakers, i.e. in the case of a voluntary load-shedding call from the utility. This occurs when a public announcement is made from the utility asking customers to reduce electricity usage during a certain time or area. Demand response programs are another example of a voluntary load shedding opportunity, where customers are compensated for reducing their electricity demand at times of peak usage. With this Leviton Smart Load Center, we enable our future homeowners to be able to participate in these programs by using just their tablet.

2.4.7 Unirac Solar Mount Racking System

Unirac's Solar Mount is UL 2703 certified, which reassures that there will be proper grounding of our PV system to support safe use. In addition, this standard ensures its fire classification of a rooftop-mounted PV system is up to date with building code requirements. Our choice of a 25 degree tilt was based on SAM calculations where it was identified as the fixed angle for the most optimal efficiency of the system. Our choice of a fixed racking system instead of a tracking system was based on multiple ideas. Compared to tracking systems, fixed racking systems are much more cost-effective in terms of installation cost during construction as well as maintenance costs during operation. Fixed racking systems are also easier to install and do not require as many repairs due to their simplistic design compared to trackers whose moveable parts require regular maintenance. As our future occupants are busy mothers and are physically disabled, we wanted to eliminate the need for any unnecessary maintenance calls to the house. These systems are also more durable in different climatic conditions, which makes them a more resilient choice to deal with Midwestern climate.

3. WATER

For the plumbing design of RENU House, we investigated market-leading technologies with the goal of cost-effective and energy-efficient solutions. Given that one of the occupants has a physical disability, we made an effort to make the system as accessible and long-lasting as possible in order to provide a sense of security and comfort. With this goal in mind, we consulted industry experts from ARUP, local architectural firms, and alumni resources to go over our general plumbing strategy and what technologies we could use to accomplish this.

Since we wanted to provide a high level of comfort to our occupants while still being environmentally conscious, we decided to go with a home-run system which not only would provide faster hot water but also works to reduce water consumption. In this system, separate lengths of ½" PEX tubing is extended from the manifold at the water heater to each fixture.

Our EcoSmart 36 water heater has a thermal efficiency rating of 99%, meaning that it uses energy only when hot water is being delivered. The tank's initial dimensions were also designed to accommodate a somewhat bigger house, allowing for future adaptation should the homeowner choose to build on an extra module. Our heater also has self-modulating technology in the form of a flow rate and temperature sensor that balances the hot water output, adding to the overall energy-efficiency of the plumbing system.

EcoSmart tankless heater with Aquamotion recirculating pump

RENU house's low flow fixtures and water efficient appliances are designed to limit indoor water consumption without compromising product quality.

According to the US Geological Survey, 80 gallons of water per person per week is a conservative estimate for an average person in the United States. For a two person household, this totals to 1,120 gallons of water in a week. Comparing this to a liberal water use estimate from our two RENU house residents of less than 850 gallons, we can expect at least a 25% reduction in water use as seen in the table below. This, along with the fact that our EcoSmart heater has an 0.3 GPM activation flow which leads to a faster response to low flow hot water demand, results in a more efficient distribution of hot water.

Our system also incorporates an on-demand recirculating pump that, when activated with a wireless remote, moves water that has been cooling down in the hot water pipes back to the tankless heater through the cold supply line. Hot water is then sent back to the fixtures essentially making sure there

is always hot water available when needed without any water being wasted down the drain. A specialized bypass valve is also utilized at each hot water fixture that automatically adjusts to maintain a 95°F temperature as long as the circulator is operating which helps to further reduce the energy load on our water heater.

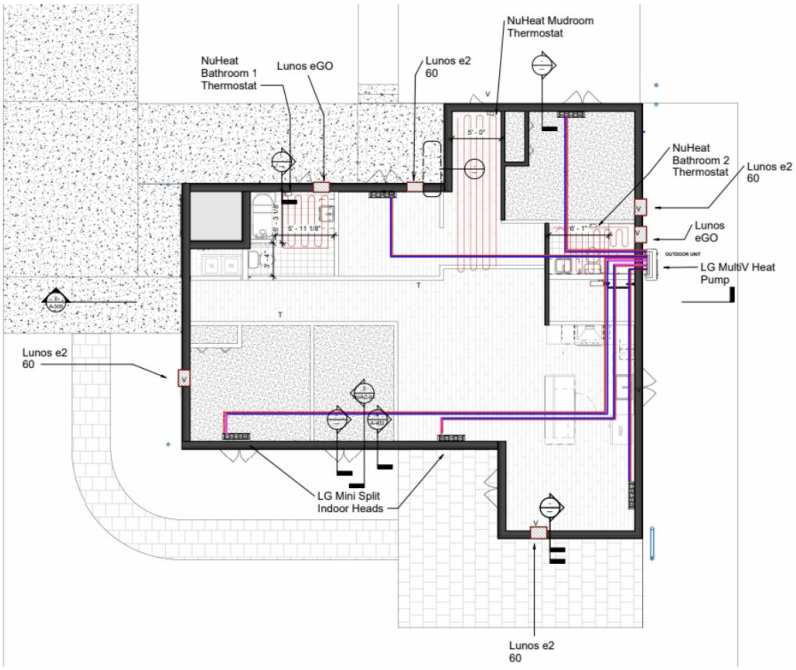
RENU Water Usage Table

Water Use	#	Volume per Cycle (gal)	Times used per Day	Volume per Week (gal/week)	Justification
Dishwasher	1	4.00	1	28.00	EnergyStar Certified dishwashers use less than 4 gallons per cycle.
Washing Machine	1	14.00	1	98.00	EnergyStar Certified washing machines use less than 14 gallons per cycle.
Kitchen Faucet	1	7.50	4	210.00	Each use of the kitchen sink is defined to be on average 5 minutes, and be used 4 times a day.
Shower	2	17.50	2	245.00	Estimating a shower to last 10 minutes (water is instantly hot).
Toilet	2	1.28	10	89.60	On average, a person uses the toilet 5 times a day. (watercalculator.org)
Bathroom Faucet	2	2.20	10	161.00	2 minutes per cycle, including washing hands after each use of the toilet, plus 2 uses before and after bed.
			Total	831.60	

4. HEATING, VENTILATION, AIR-CONDITIONING, AND COOLING

To finalize an HVAC system for RENU House, we worked and discussed a multitude of ideas with engineers from industry leaders such as ARUP, Architectural expressions, Watts piping and LG solutions. The initial plan was to have an integrated H/AC and water heater system, using radiant floor heating and cooling. Apart from the apprehensions from our contractor, one major reason to avoid this system was an engineering issue. Even though a radiant heating solution could prove to be a more efficient system for the floor area, in order to incorporate the multiple systems into our battery backup system, we would require a 5 ton condenser unit. This is 2 grades above the 3 ton mini split finally chosen, which was modeled using a separate tankless heater. Moreover, having a 5 ton system would also require us to upsize our battery system which would end up costing multiple times more and take up a larger physical space.

A primary focus throughout the contest was to make our system as accessible and user friendly for our prospective tenants. Based on those aspects, we decided from the beginning to avoid the use of ducts completely. As we researched leading ductless technologies for our ventilation system, we stumbled across Lunos' state-of-the-art ventilation units.



Finalized HVAC Layout

After finalizing our DDOAS(Decoupled Dedicated Outdoor Air System), we worked our way back to find the most efficient heating and cooling system.

4.1 LG AWHP MiniSplit

Temperatures in Champaign average -15C(5F) during peak winters and 35C(95F) during peak summers. It was important for us to choose a system that can work optimally in these conditions without overloading our electric system or worse, breaking down. The LG Multi V can operate at temperatures as low as -20C(-4F) and 50C(122F) through the smart load control that automatically adjusts operation requirements by sensing both indoor and outdoor conditions. For a climate like Champaign, this wide range in operating temperatures provides headache free use throughout the year without having to worry about system overloads. The 3-Ton system was chosen to make sure to provide a 4000 CFM airflow, based on our design calculations.

The LG Multi V offers overall increased flexibility and efficiency due to it being an air-to-water heat pump. An AWHP reduces heating and cooling costs as well as minimizing the overall carbon footprint of the house, and the LG MultiV system has a compact AWHP system with a seasonal coefficient of performance of up to 4.65. The system also requires ZERO ductwork, thus allowing us to have water pipes running along the ceiling and avoiding clashes and giving less complexity in our engineering design. This way we also have no worries about any leakages or pipe bursts affecting the HVAC units, especially during the harsh winters in Champaign. Ductless systems have smaller physical footprints, which makes our design adaptable to renovations in the future as well. The inverter compressor on the Multi V, the “R1 Compressor”, utilizes a hybrid scroll structure that expands the operating range, which allows the system to closely match compressor speed with output demand, thus translating to a higher energy efficiency. The shaft-through bottom-compression structure eliminates tilt at low loads which improves stability and efficiency. This hybrid scroll technology also aids in reduction of noise and vibration. In all, this system promises more durable operation, lower maintenance, and a longer lifespan.

As mentioned earlier, occupant comfort was always a priority for us. Having a centralized unit would

often mean a similar average temperature across the entire home. This can often prove to be too cold or too warm for one's liking based on their personal preferences. Having an Individual Zone Control, allows our occupants to control the space to the precise temperature desired.

4.2 Efficiency, Performance, Innovations

Some other engineered advantages that the system has is listed below.

V-Shaped Heat Exchanger: The V-shaped heat exchanger design enhances the system's performance by increasing the heat transfer area, reducing the pressure drop, and thus minimizing the refrigerant charge.

Auto Cleaning: The Auto Cleaning function cleans the indoor unit's heat exchanger and prevents the growth of harmful bacteria and mold, ensuring clean and healthy air. Thus avoiding the need for an expert technician, and especially great for our future occupants who plan on starting a family in this house.

Quiet Operation: The system operates quietly due to the use of a DC fan motor and a large-diameter axial flow fan, which reduces noise levels to as low as 23dB(A). Research out of Harvard stated that, "noise pollution not only drives hearing loss, tinnitus, and hypersensitivity to sound, but can cause or exacerbate cardiovascular disease; type 2 diabetes; sleep disturbances; stress; mental health and cognition problems, including memory impairment and attention deficits; childhood learning delays; and low birth weight." For 6-7 months of the year, the condenser unit is expected to run 24*7 for heating and for an expecting mother like Monee, we wanted to design a home that eliminates any of the supposed health effects.

Energy Efficiency: The system is highly energy-efficient, with a SEER rating of 26 which helps reduce energy consumption and lower energy bills.

We also wanted to make sure our condensate lines wouldn't create a high pressure drop when it penetrated our airtight building envelope. To avoid this, we rerouted these pipes to exit through the exterior walls, right above the pressure treated sill plates, about 8" above grade. The initial plan was to have the pipes run through a PVC elbow placed on the edges of the home within the concrete floor. However this proved to be cumbersome during construction and a new design was implemented.

4.3 Lunos Ventilation Units

Coming to our DDOAS, the Lunos E2 60 ventilation system is a decentralized and energy-efficient ventilation system that uses ceramic cores to exchange heat between incoming and outgoing air streams.

Barring our core "no ductwork" principle, there are a few reasons we went with this innovative tech.

1. *Ceramic cores:* The Lunos E2 60 and eGOs use ceramic cores to exchange heat between incoming and outgoing air streams. These ceramic cores are highly efficient and can recover up to 90% of the heat from outgoing air, reducing the amount of energy needed to heat incoming air.
2. *Decentralized system:* Unlike traditional ventilation systems that have a central unit, the Lunos E2 60 is a decentralized system that uses individual units to ventilate each room. This reduces the complexity and cost of installation, as well as the energy needed to power a central unit.
3. *Multi-speed operation:* The Lunos E2 60 has three-speed operation, allowing it to adjust its ventilation rates from 10 CFM to 35 CFM based on the needs of the room. This helps to conserve energy by reducing ventilation rates when it's not needed.
4. *Summer bypass:* The Lunos E2 60 has a summer bypass feature that allows cool

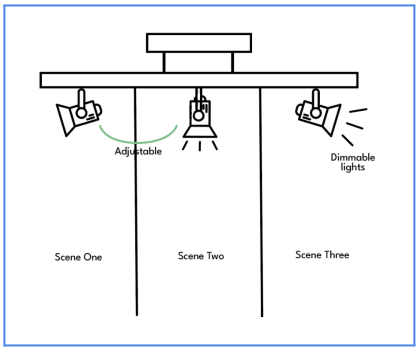
outdoor air to bypass the heat exchanger and directly enter the room. This helps to keep the room cool during hot summer months.

5. *Low-noise operation:* Just like our H/AC system, our ventilation units also operate at very low noise levels, making it ideal for use in bedrooms and other quiet spaces. The Merv 5 filter has a further reduction of sound by 6db, and the exit hood material has sound absorption properties, reducing sound by another 6db.
6. *Ease of maintenance:* And finally, The Lunos units are designed for easy maintenance, with easily replaceable Merv 5 filters and removable ceramic cores. Often the issue with a ducted or more complex OA system, is the need for a trained technician to come in every few months to conduct routine maintenance. Based on our expected occupant, having such an expert to do this every once in while would not only be financially infeasible, but also be physically and emotionally taxing. Thus such a system helps keep the system operating at peak efficiency and prolonged lifespan despite just regular home maintenance.

5. LIGHTING, APPLIANCES, HOME AUTOMATION

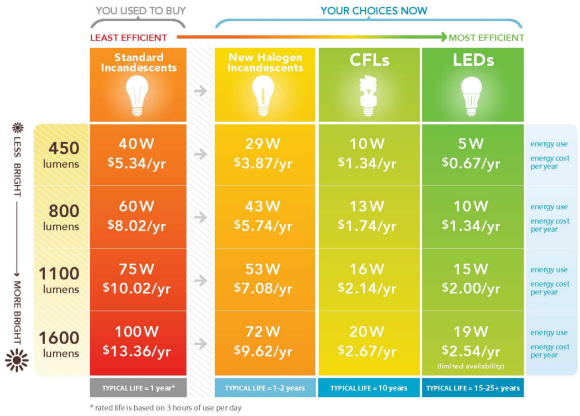
Our design approach for finalizing our lighting, appliances, and home automation features was led by researching the energy star usage values the appliances promised. Many of the appliances we selected are rated to be Energy Star Most Efficient 2022/2023. Several of the appliances include innovative energy-efficient technologies such as induction heating, prewash steaming, and a dual inverter heat pump. As for the lighting design, we coordinated with the Architectural team and industry experts from ARUP to determine the optimal lighting levels for comfort and aesthetic cohesion.

5.1 Lighting



The lighting design of the RENU house focuses on allowing the user to configure a wide range of possible moods and brightness levels throughout the home while complimenting any natural light brought in from the windows. All the lighting fixtures in the home are highly efficient dimmable LEDs and surface mounted to reduce energy consumption as much as possible. We chose surface mounted lighting fixtures as opposed to recessed lighting in order to maintain as much continuity in our ceiling insulation as possible. This reduces infiltration from the vented attic and contributes to further overall reduction of HVAC loads.

Energy Star rated LED Track lighting was the fixture of choice for the communal spaces in the home because they offer light that can be bright and balanced or directed to highlight elements of the space or wash walls creating many different moods. The tracks were carefully aligned with walls and positioned to highlight family space while small minimalist downlights were arranged systematically to create even adjustable lighting in the bedrooms and hallways at any time of day with enough brightness for any activity. The high efficiency and longevity of LEDs consequentiality also has benefits with respect to occupant costs, making LEDs not only optimal for net-zero, but also long term costs. All the lights in the home are the same temperature of 3000K. This along



with the all black finishes of fixtures create consistency throughout the design. Overall, the lighting design of the home is dynamic and complimentary to the architecture and needs of the home.

5.2 Appliances

As mentioned earlier, our design approach when selecting appliances was based on energy efficiency, performance, and user experience.

We chose the Samsung NE63B8611SS induction stainless range because it won an Energy Star Emerging Technology award for its efficient induction cooktops with an integrated annual energy consumption of 112kWh/year. There are many benefits to induction cooking technology based on energy efficiency and user experience. An induction stove can reduce the energy consumption of our house both directly and indirectly. Instead of the pan being heated by being in contact with a flame or a hot plate, magnetic currents directly heat up the pan itself. One of the main benefits of this technology is that it doesn't require as much energy loss on the way to the pan. This is reflected in the ~90% efficiency of induction stoves as opposed to the ~50% or ~70% efficiency of gas and electric stoves. Indirectly, this also reduces the strain on the HVAC system because less heat escapes from the stove into the air, and our range hood will ventilate the heat and vapor produced from cooking. Our range hood can also be synced with our cooktop to control the fans and lights.

Our washer and dryer system are both among Energy Star's most efficient of 2023, with a combined consumption rate of just 253 kwh/year. In comparison, the average household washer uses 291kwh/year and the average dryer uses 236kwh/year. Our refrigerator uses a total of 417kwh/y making it one of Energy Star's most efficient of 2023. Our dishwasher makes up for its lack of efficiency with its convenience of use and indirect energy savings through features like a pre-wash steam to loosen up food and bottle jets to effectively clean bottles and cups. Although these extra features may translate to higher power usage, it provides a great convenience for the home-owner.

5.3 Home Automation & App Development

For our home automation system, we wanted a system that was flexible, private, fast, and reliable. To meet all of these requirements, we choose to go with an open-source installation of Home Assistant rather than using other solutions such as Google Home or Apple Homekit. We decided to use HomeAssistant, a popular open source software used for non-commercial home automation applications. Due to the nature of open source software, this is an economical option as it is free to set up and maintain, highly customizable, and universal. Home Assistant allows us to tie in a broader range of technologies and data to one place, such as tracking the energy production of solar panels, energy consumption of the entire house, the amount of excess energy produced and sent to the grid, and the percentage of energy consumed that is produced by the house. This will be done through API calls to the SolarEdge system. The Home Assistant installation will run locally inside the home on a low-power Raspberry Pi server, which means that data is processed fast and with maximum privacy within the home, so that the internet is not a requirement for the system to function. In addition, user accounts can be secured with a two-factor authentication to prevent access even if the user password is known by the attacker.

HomeAssistant UI/UX Design

To support our home automation system and future residents, 3 ethernet networking drops were strategically placed throughout the house in the master bedroom, flex space, and living room to support high-speed, reliable networking to areas projected to have high demand. While our wireless networking solution will be using a powerful Wi-Fi 6 access point, a wired ethernet connection will provide the highest in speed and reliability, supporting work from home environments and future data needs.

By providing an app that centralizes and combines the controls and monitoring for all devices and systems in the home, we are providing a simpler way to track and use the devices. The app will have a dashboard that displays a summary of all the devices and systems in the house, such as the smart dimmable lights and smart appliances. The simple and straightforward user interface of the app is designed to be nourishing as it is created in an effort to make smart technology more accessible and understandable to non-tech savvy users.

MyLeviton Application

To integrate the Leviton Smart Load Center, HomeAssistant will have the ability to open up the My Leviton app, which is an official app developed by Leviton. Information regarding this app is discussed in the earlier sections.