



D.O.E. RACE TO ZERO COMPETITION

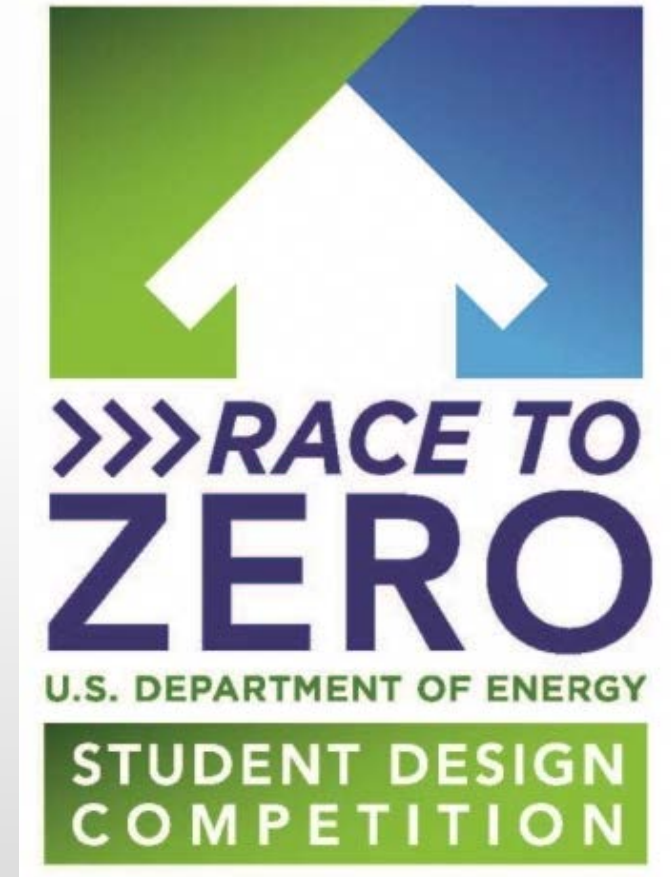
Dorothy Gerring and Rob Wozniak Presenting

PENN COLLEGE[®] - WILLIAMSPORT TEAM

April 2015 Competition

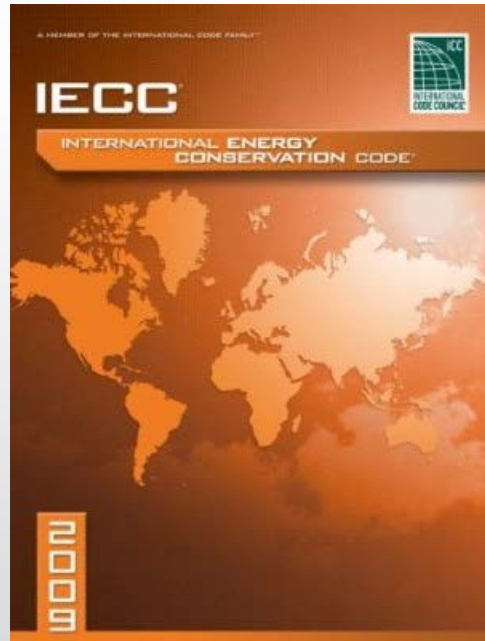
About the Competition: information

- Zero = Zero Net Energy (ZNE) and Zero HERS rating (make as much energy as use annually)
- Highly efficient building = big energy savings
- CA requiring all residential buildings to be ZNE by 2020 (commercial by 2030)
- Annual competition, started 2014
- This project is 2015 Grand Winner Finalist



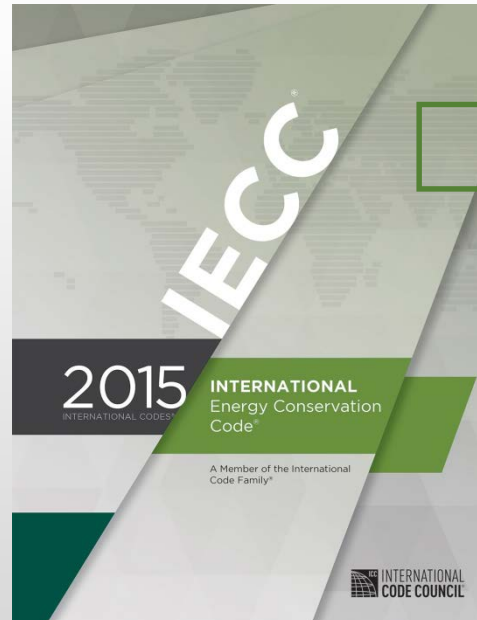
Home Energy Rating System (HERS Index) – Using the Building Code standard

Minimum
prescriptive Standards



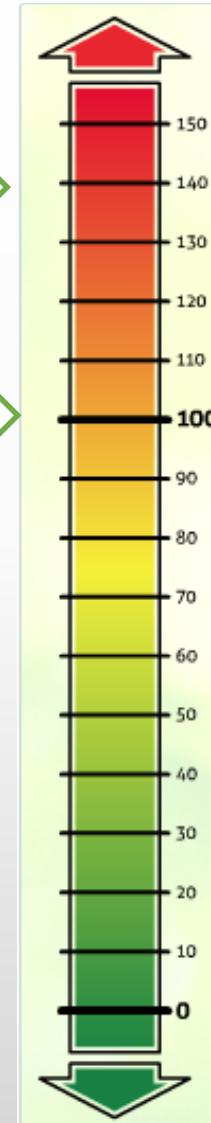
Most older homes use 40% more energy than 2009 code minimum

2009 IECC—Current PA law



2015 IECC

2015 IECC requires a maximum HERS rating of 65



Penn College Design Team



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CIVIL ENGINEERING, ARCHITECTURAL TECHNOLOGY AND BUILDING SCIENCE & SUSTAINABLE DESIGN



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MATTHEW VENT

RESIDENTIAL CONSTRUCTION TECHNOLOGY & MANAGEMENT, ARCHITECTURE TECHNOLOGY MINOR

Design Goals

Influential Programs

- Habitat for Humanity
 - Fit the neighborhood
 - Space and energy efficient
 - 2-3 bedrooms per unit
 - 1-1.5 baths
 - Slab on grade, no basement
 - Washer, dryer, dishwasher
 - Simple construction
 - Homeowners earn 30-80% of median Williamsport income
 - Unit cost \$100,000-\$120,000



Primary Goals

- Extreme affordability
 - Low utility bills
 - Quickly pay off mortgage
- PHIUS Certified
 - Super insulated
 - Super sealed
 - Renewable energy ready
- ADA design
 - House-wide accessibility

Neighborhood Context

- Community

- Density: 3,456/ sq mi
- MFI: \$56,400
- Mix of owned and rented homes
- Stores and shops in walking distance
- 2 blocks away from public park, Bowman field, and 3 public bus lines
- Located near highway

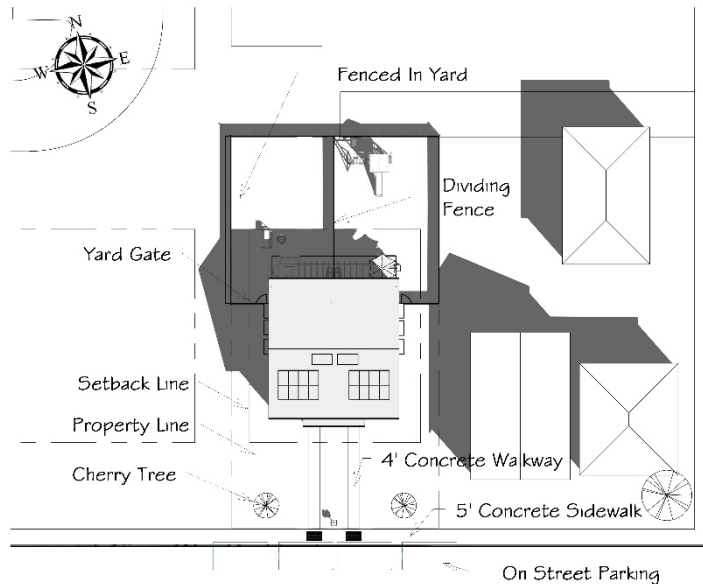
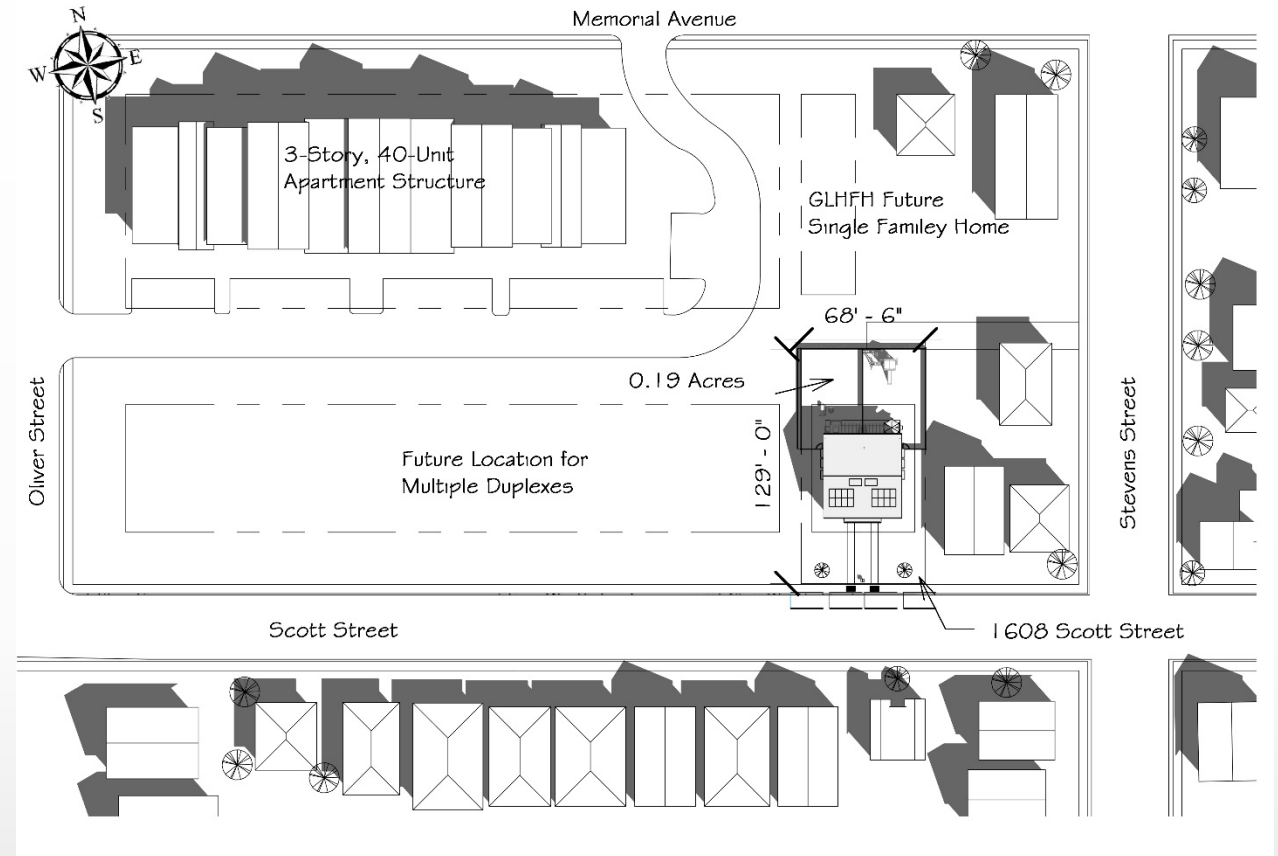
- Home fit to site

- Blends aesthetics of surrounding buildings
- Colonial style with craftsman touch
- 2 stories
- Gable roof
- Shed roof porch



Site

- Brownfield
- 68'-6" x 129'-0"
- 0.19 acres
- Linkage to Outdoors
 - Front yard creates space from street
 - Small footprint allows for side yards
 - Large private backyard



Design

- House Type
 - Single family attached, duplex
- Square Footage
 - 1644 SF / unit
- Size
 - 2 Stories
 - 3 Bedrooms
 - 1.5 Bath
- Open Floor Plan
 - Flooding of natural daylight
 - Easy circulation of air
 - Open flow, communication, direct sightline
 - Increases apparent size and feel
 - Barrier free design
 - Minimal circulation
 - No wasted space

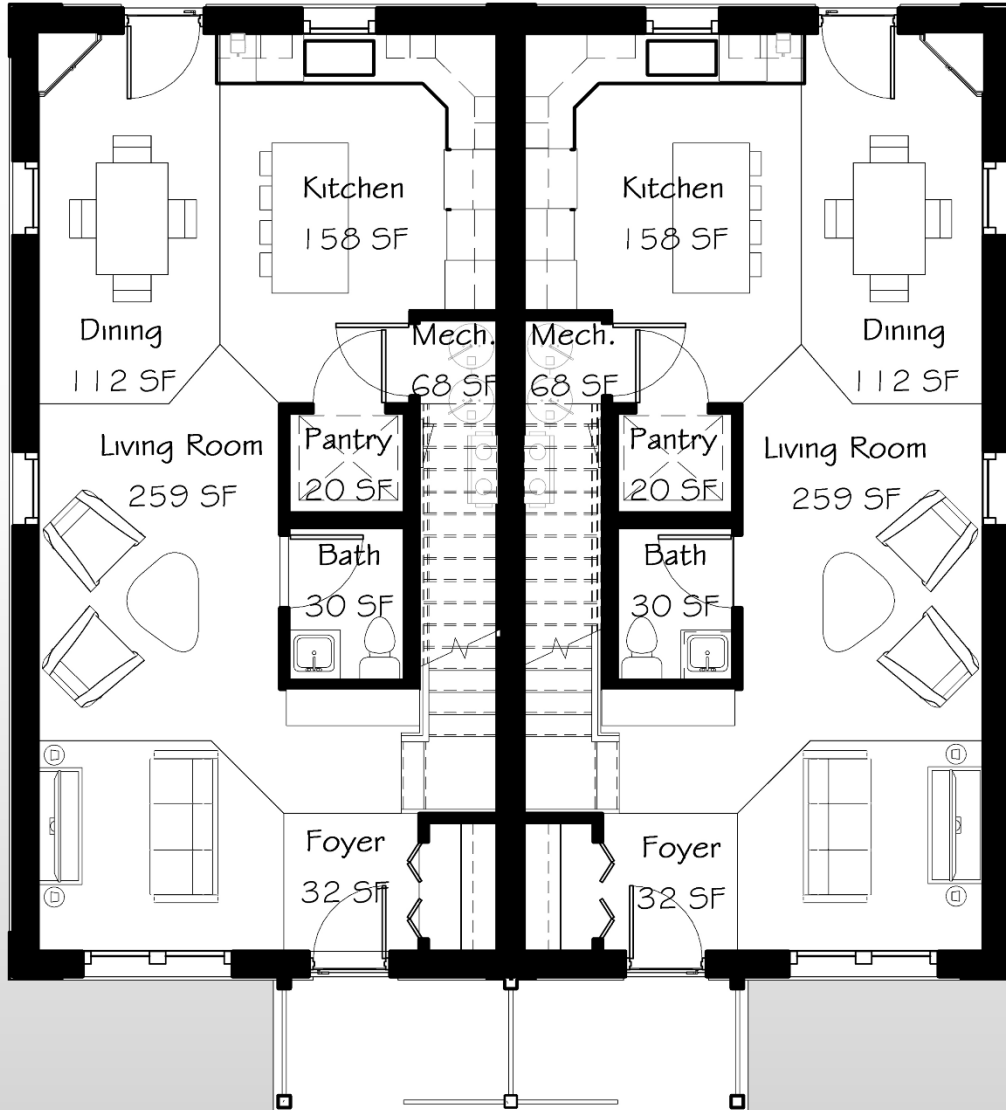


Interior View: Facing Kitchen

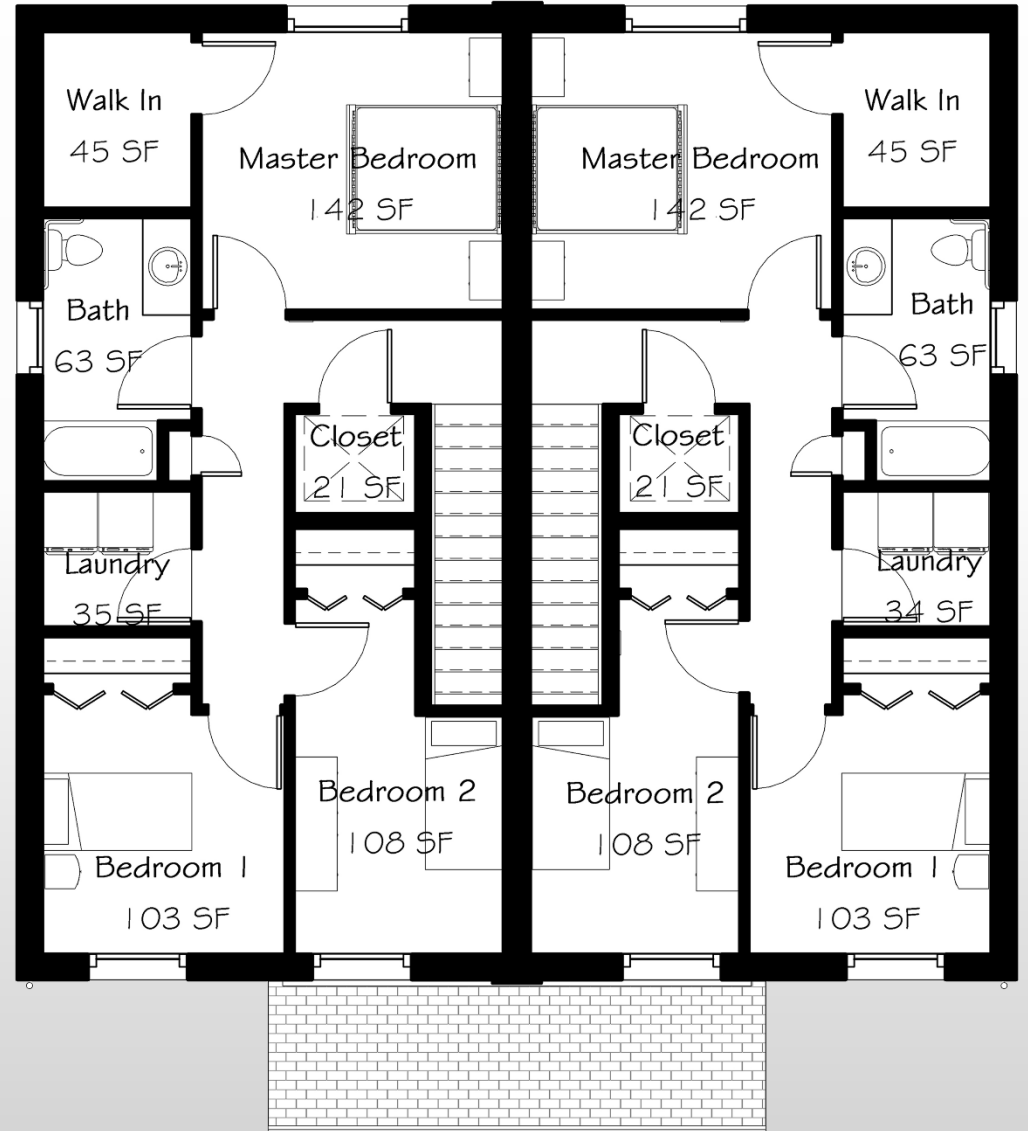


Interior View: Facing Living Room

Design



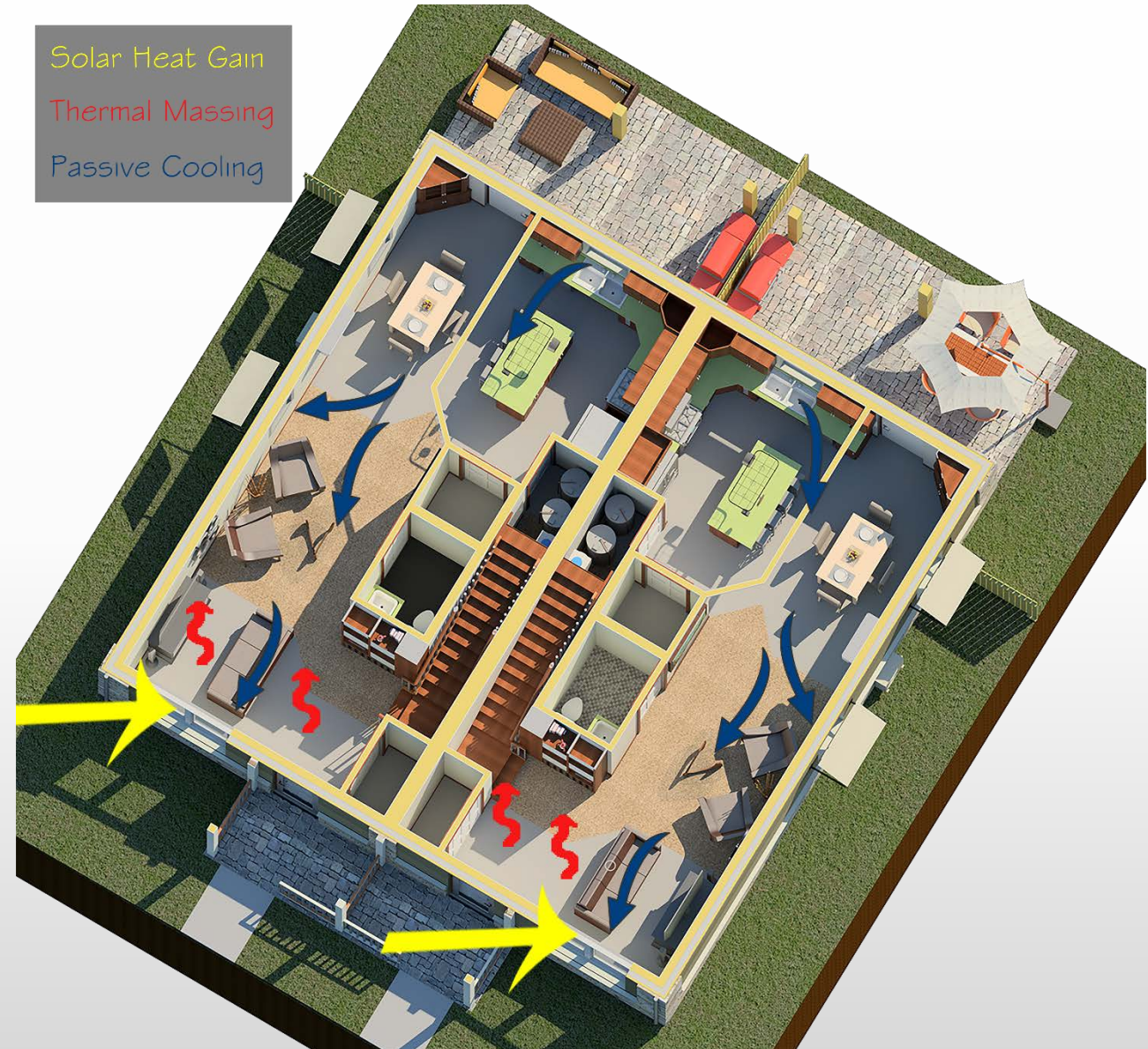
First Floor Plan



Second Floor Plan

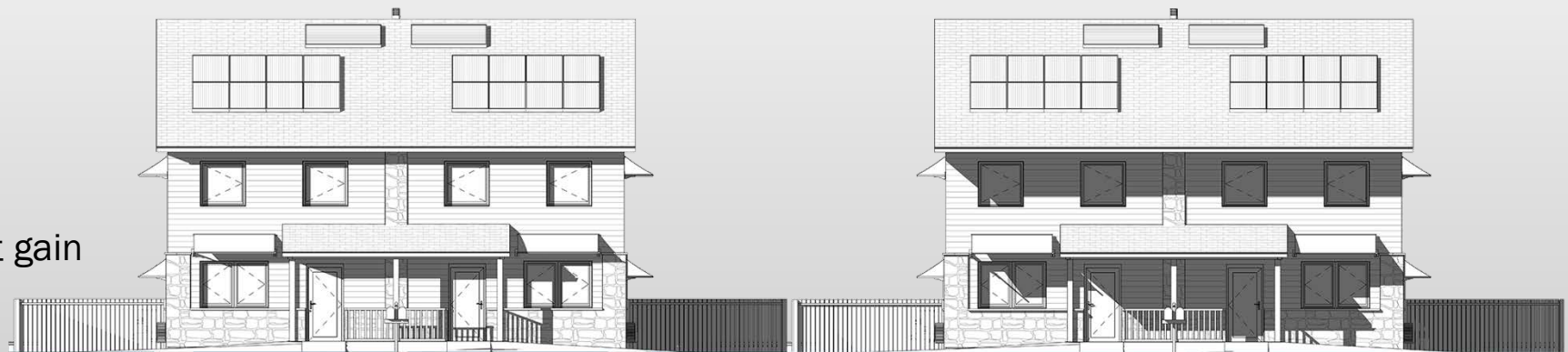
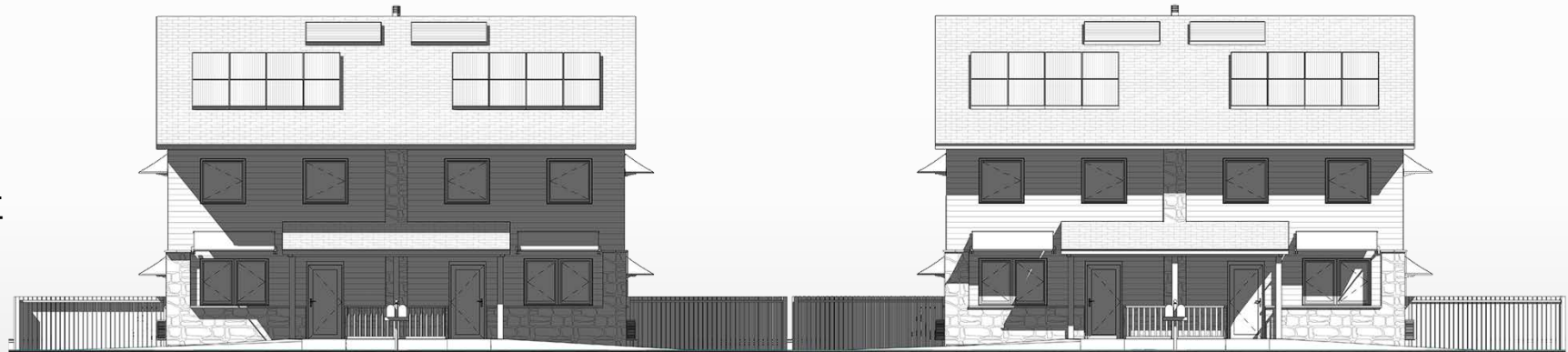
Passive Strategies

- Solar Orientation
 - South 11° West
 - Within 15° of true South
 - Large living room windows
- Thermal Mass
 - Stamped concrete flooring in foyer
 - 4" concrete acts as heat sink
 - Absorbs heat gain from southern windows
 - Controls diurnal temperature range
 - Increases comfort throughout year
- Natural Ventilation
 - Operable windows at 3' sill height
 - Open inward swinging casement
 - Open inward like hopper



Passive Strategies

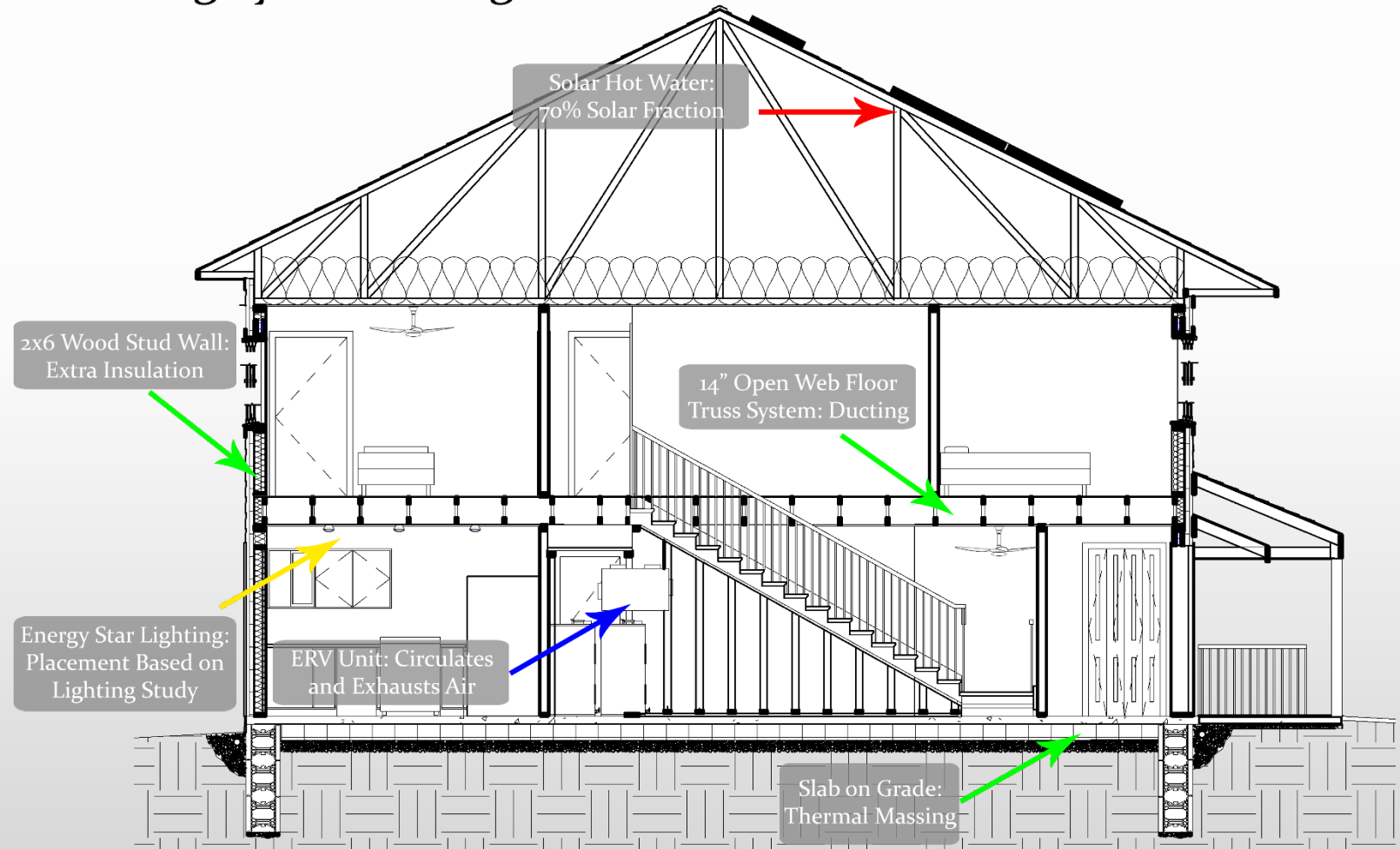
- Natural Shading
 - Weeping Cherry trees
 - Large maple south of site
- Solar Shading: South
 - Designed overhangs
 - Fixed awnings
- Solar Shading: East & West
 - Adjustable awnings
- Over-heated period
 - May – September
 - Fully shades
- Under-heated period
 - September – May
 - Allows direct solar heat gain



Integration

- Structural System
 - Slab on grade
 - 2x6 wood stud wall
 - 14" open web floor truss system
- HVAC System
 - ERV used to circulate and exhaust
 - Mini split pumps w/ dehumidification
 - Supplies to common areas
 - Exhausts from bedrooms
- Plumbing System
 - Solar hot water system: 70% solar fraction
 - Condensed plumbing, efficient pipe length
- Lighting System
 - Fixtures placed based on daylighting study
 - 90% ENERGY STAR fixtures
 - LED bulbs

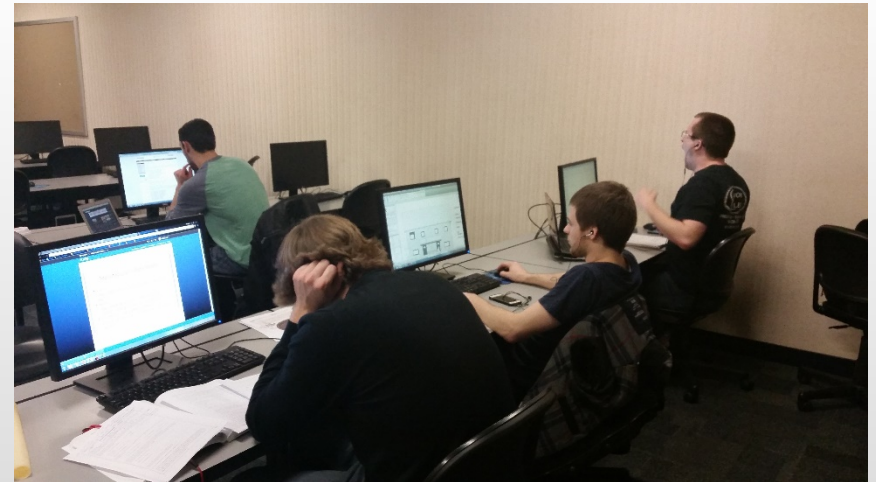
Building Systems Integration



Integration



- School Wide Meeting
 - Students from all majors
 - DOE competition
 - Passive house design
 - Habitat for Humanity
- Weekly Meetings
 - Discussed design goals
 - Collaborate between group members
- Designated Section Leaders
 - Based on academic major
 - Decisions based on all sections input
- “Group Me” Application
 - Continuous flow of information
 - Well informed design decisions
- Central Work File
 - Easily share and access project files and documentation



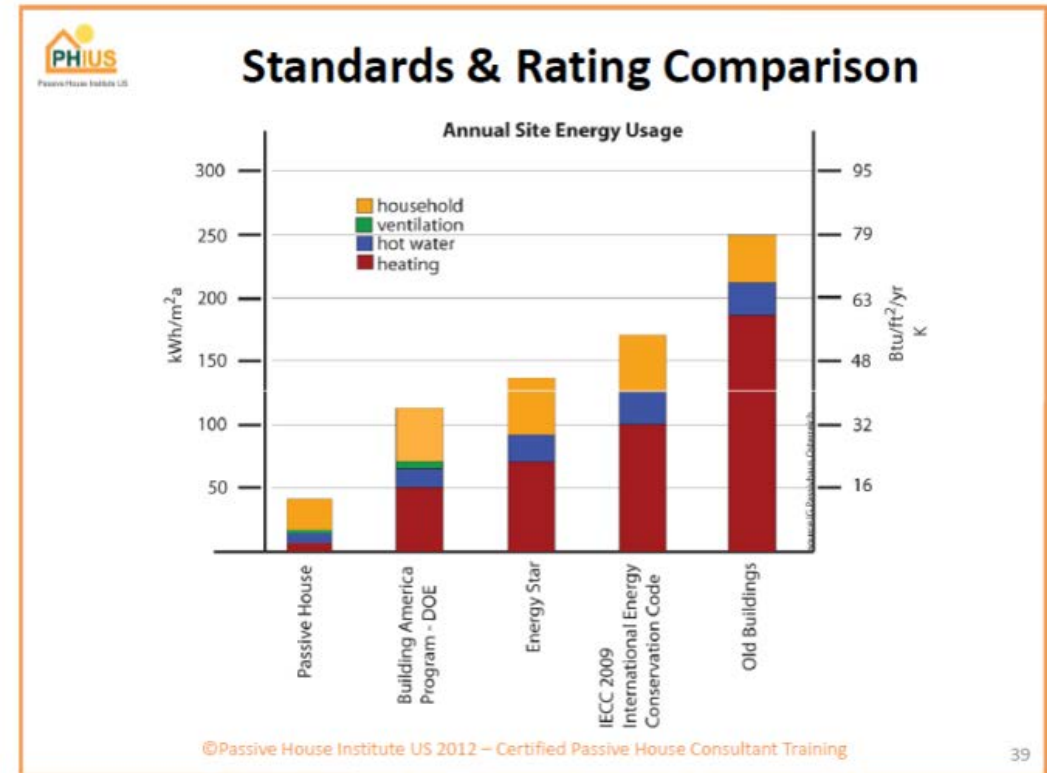
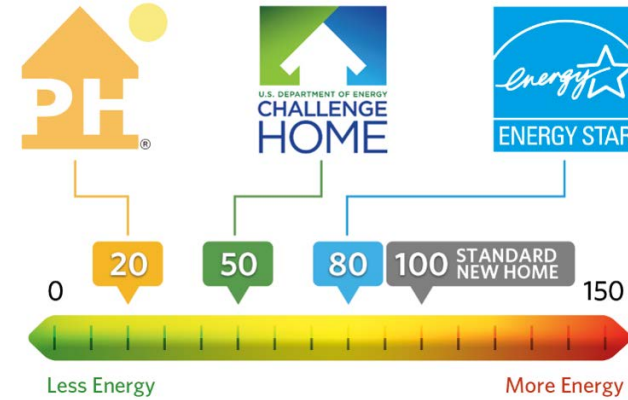
Sustainability

- 1) Local & readily available materials, donated locally
- 2) Easy to use products for quick and simple construction
- 3) Low maintenance & high durability
- 4) High performance: cost ratio
- 5) Minimized finishes with off gassing potential



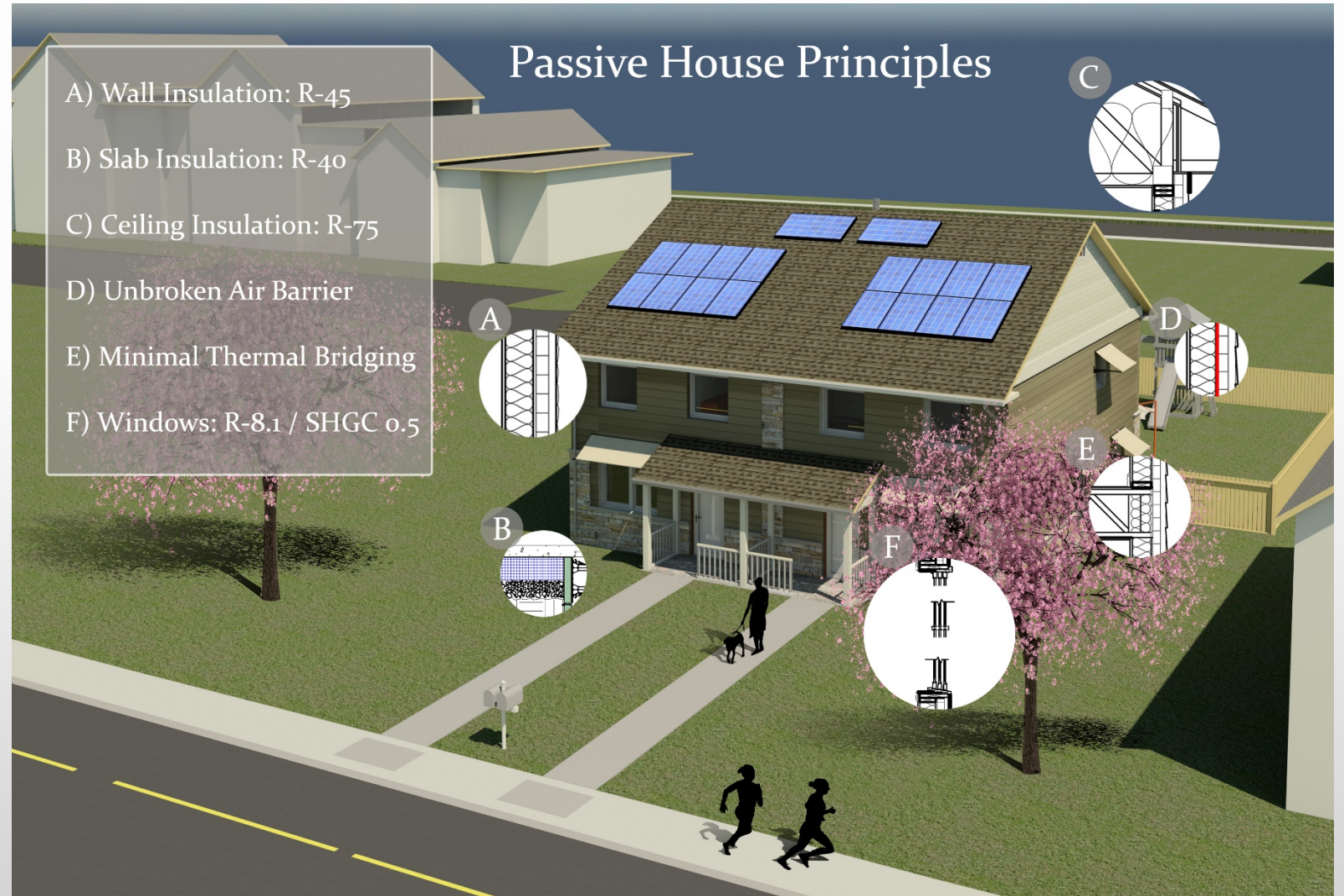
Standards

- DOE Zero Energy Ready
 - HERS 50 or lower
 - Energy Star qualified homes Version 3
 - Energy Star fenestration requirements
 - 2012 IECC ceiling, wall, slab insulation
 - HVAC ducting within thermal boundary
 - Hot water delivery efficient design
 - Energy Star appliances
 - 80% Energy Star fixtures
 - EPA Indoor airPLUS certified
 - Renewable Energy Ready



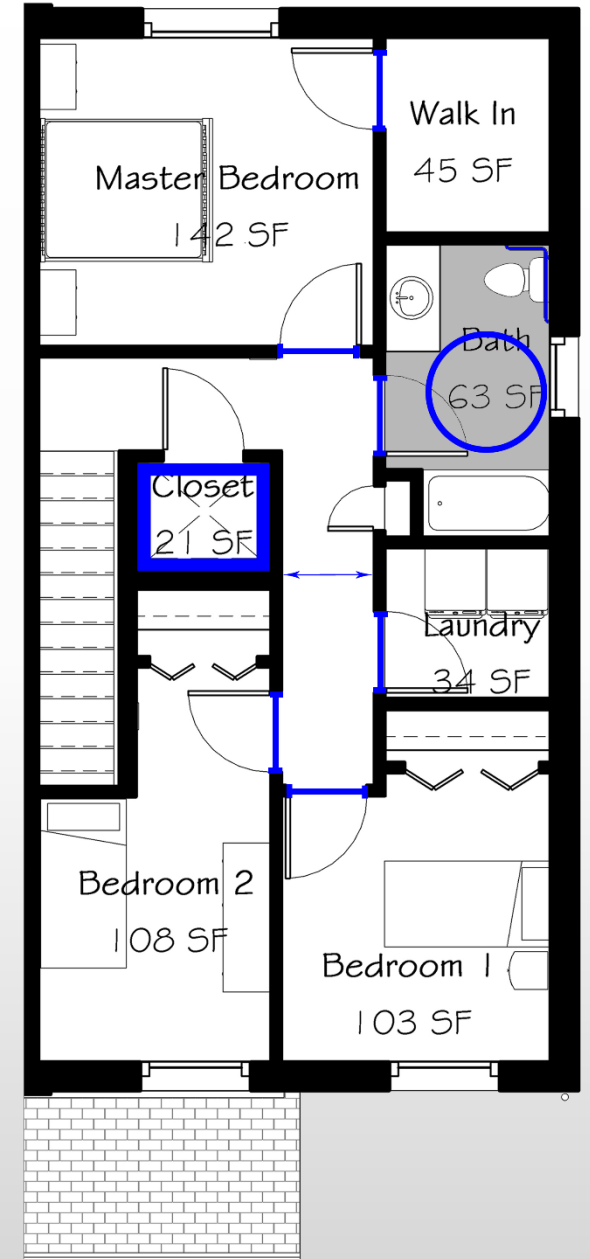
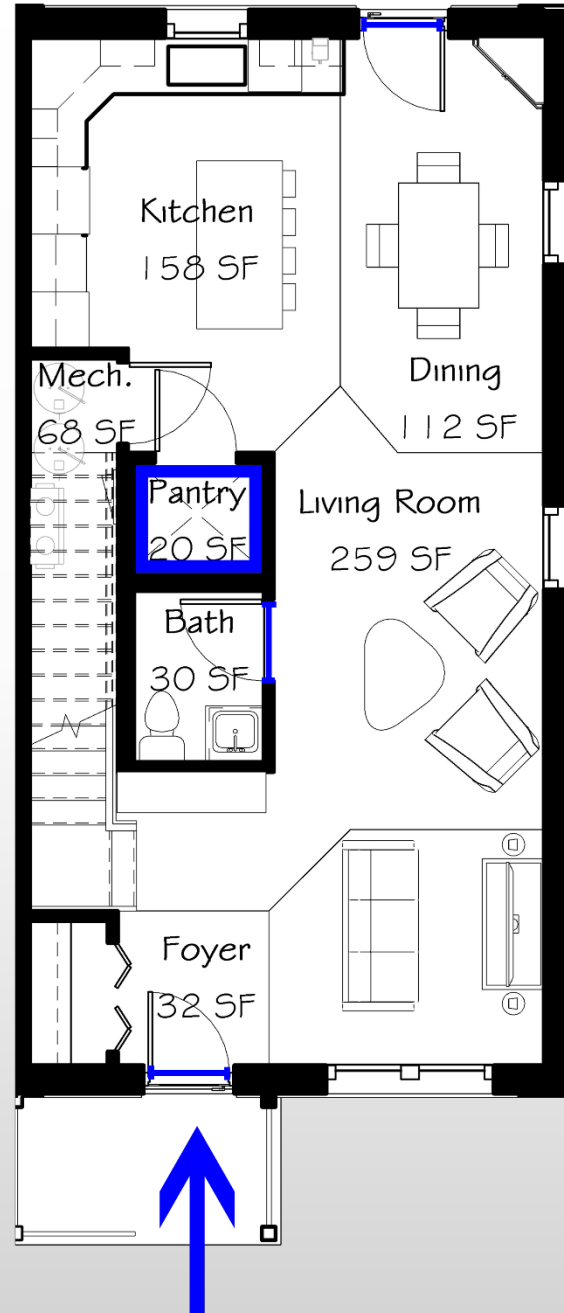
PHIUS Standards

- Required
 - 4.75 kBTU/sf/yr heating
 - 0.6 ACH @ 50 Pascal's
 - 38 kBTU/sf/yr energy
- Actual
 - 4.70 kBTU/sf/yr heating
 - 0.6 ACH @ 50 Pascal's
 - 21.27 kBTU/sf/yr energy



Standards

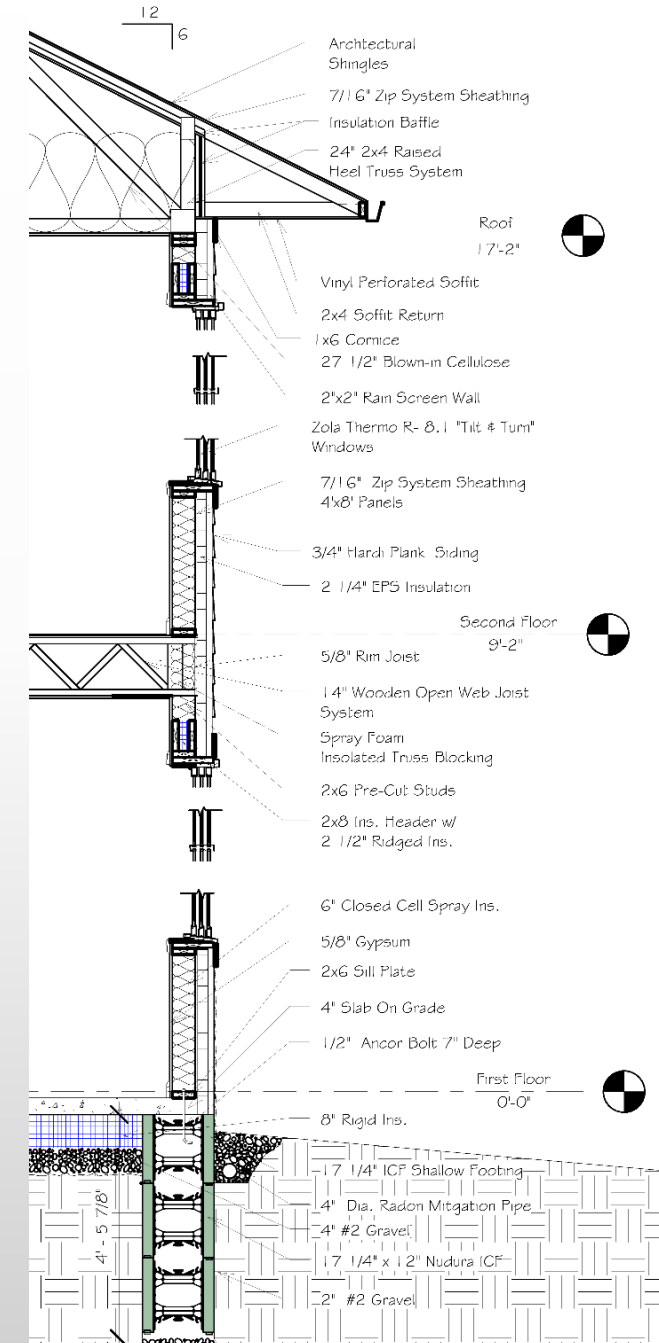
- Accessible Design
 - Accessible building entrance
 - Open floor plan with 3' hallways
 - Pantry can be retrofitted for elevator
 - 32" clearance at all doors
 - Accessible bathroom with nonslip floors and grab bars
 - Light switches at 36" above floor
 - Electrical outlets at 18"-24" above floor



Envelope Durability

Building Envelope

- Designed for several maximum requirements
 - Air tightness
 - Continuous Envelope
 - Insulation
 - Moisture Protection
 - Constructed with Economy in mind
 - Durability
 - Shallow ICF Footing
 - Below frost line
 - Above potentially contaminated soil



Energy Star Rating & PHIUS Requirements

- Building Envelope Development
 - Insulation thickness
 - Window types and placement
 - Raised Heal Truss Height
 - Built beyond code standard
- Case 10 - Original case to estimate overall R values required. R-54 ceiling, walls, slab.
- Case11 – R-54 ceiling, walls, slab. Case 10 + larger windows on the south
- Case 12 – R-54 ceiling, walls, slab. Case 11 + larger windows on the south
- Case 13 – Same as case 12, with R-values adjusted to R-40 slab, R-45 walls, R-75 ceiling

| Acceptable R-value combinations | | | |
|---------------------------------|----------|----------|---------|
| slab | 14" wall | 12" wall | ceiling |
| 32 | 50 | 48 | 75 |
| 32 | 48 | 46 | 84 |
| 40 | 48 | 45 | 75 |
| 40 | 46 | 44 | 84 |
| 48 | 44 | 42 | 84 |
| 48 | 42 | 40 | 92 |

PASSIVHOUSE ENERGY PASS

2

BUILDING INFORMATION

General information

| | |
|-----------------------|--------------------|
| Type: | Residential |
| Year of construction: | |
| Dwelling units: | 2 |
| Number of occupants: | 7.1 (Verification) |

Boundary conditions

| | |
|-----------------------|-----------------------------|
| Climate: | WILLIAMSPORT REGIONAL AP PA |
| Internal heat gains: | 0.7 Btu/hr ft ² |
| Interior temperature: | 68 °F |
| Overheat temperature: | 77 °F |

Building geometry

| | |
|----------------------|------------------------|
| Enclosed volume: | 35925 ft ³ |
| Total area envelope: | 6815.8 ft ² |
| AV ratio: | 0.2 1/ft |
| Treated floor area: | 2669 ft ² |

PASSIVEHOUSE REQUIREMENTS

Certificate criteria: European

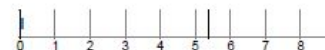
Heating demand

| | |
|---------------|-----------------------------|
| Specific: | 4.7 kBtu/ft ² yr |
| total: | 12599.7 kBtu/yr |
| peak (month): | 1.4 kBtu/ft ² |



Cooling demand

| | |
|--------------------------|-----------------------------|
| Specific: | 0.6 kBtu/ft ² yr |
| total: | 1547.8 kBtu/yr |
| peak (month) - sensible: | 0 kBtu/ft ² |
| latent: | 0 kBtu/ft ² yr |



Heating load

| | |
|-----------|----------------------------|
| Specific: | 3.1 Btu/hr ft ² |
| total: | 8177.9 Btu/hr |



Cooling load

| | |
|-----------|----------------------------|
| Specific: | 0.9 Btu/hr ft ² |
| total: | 2487.6 Btu/hr |



Primary energy

| | |
|-----------|------------------------------|
| Specific: | 24.1 kBtu/ft ² yr |
| total: | 64412.2 kBtu/yr |



Air tightness ACH50 0.6 1/hr



Indoor Air Quality Evaluation

Moisture Control

- Humidity control in super-tight structures is critical
- Conventional AC systems cool air too quickly in low-load buildings
- Rapid cooling satisfies sensible heat demands LONG before humidity is removed from air
- Decoupled dehumidification is the most energy efficient approach
- Solution: mini-splits with dehumidification
- We accomplish <0.5 ACH with appropriate sealing and air barriers
- These barriers & screens at opening ensure pest control
- Filtration of all outdoor air is ensured through positive building pressure, and high levels of mechanical filtration

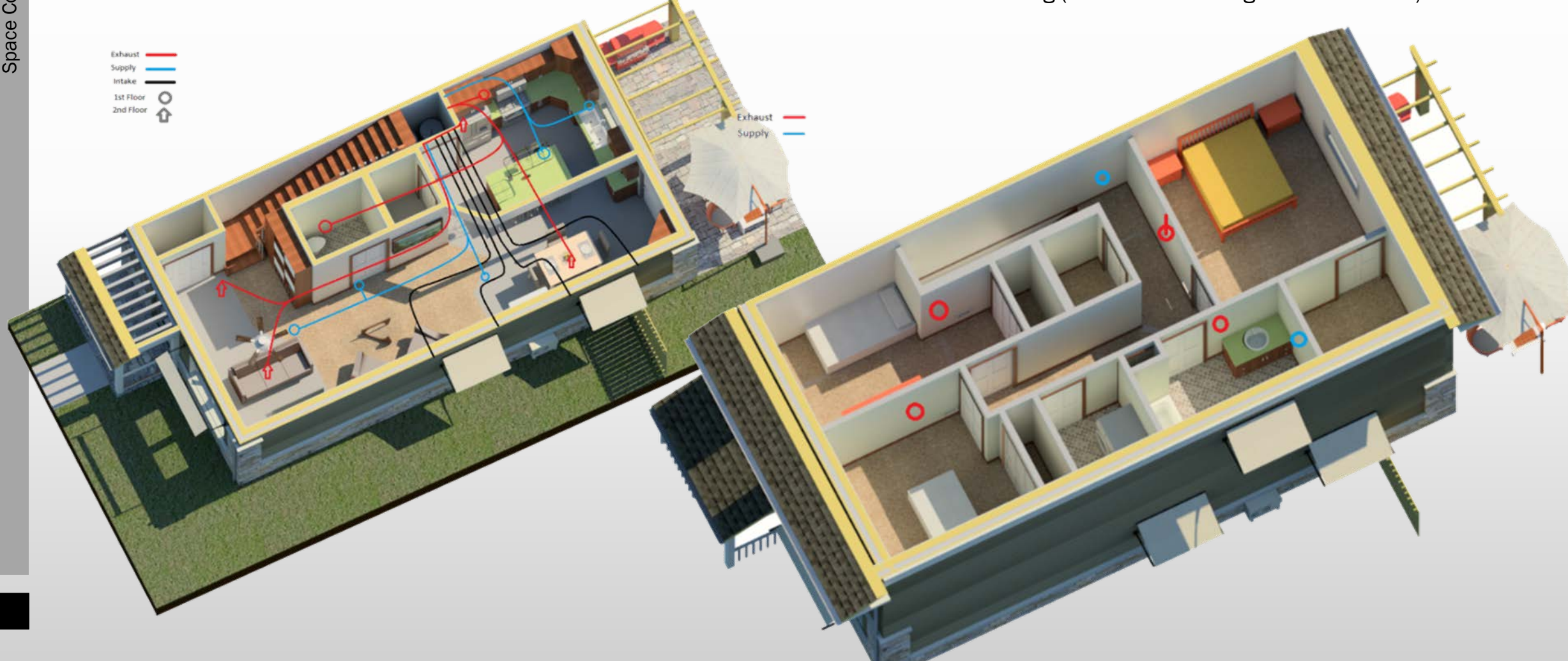
HVAC Systems

- Mini-split Heat Pump
- DX-200 Ultimate Air ERV
 - 2 ERV's providing 24/7 fresh air ventilation
 - exhausts from the bedrooms, and supplies to the upstairs/downstairs common areas
 - CO2 sensor to supplement regular occupancy expectations with limit-based additional ventilation
 - 1 waste ERV exhausts the less desirable rooms (bathroom, kitchen, laundry) 24/7 to prevent moisture, smells, and pollutant build up
- The ERVs have standard pretreatment heaters (Mfg. specific), however these can be replaced or supplemented with glycol water coils to utilize the DHW energy supplied by the solar panels (balance being between Solar Thermal/ Solar Electric) making them scalable in energy economies



Building Science

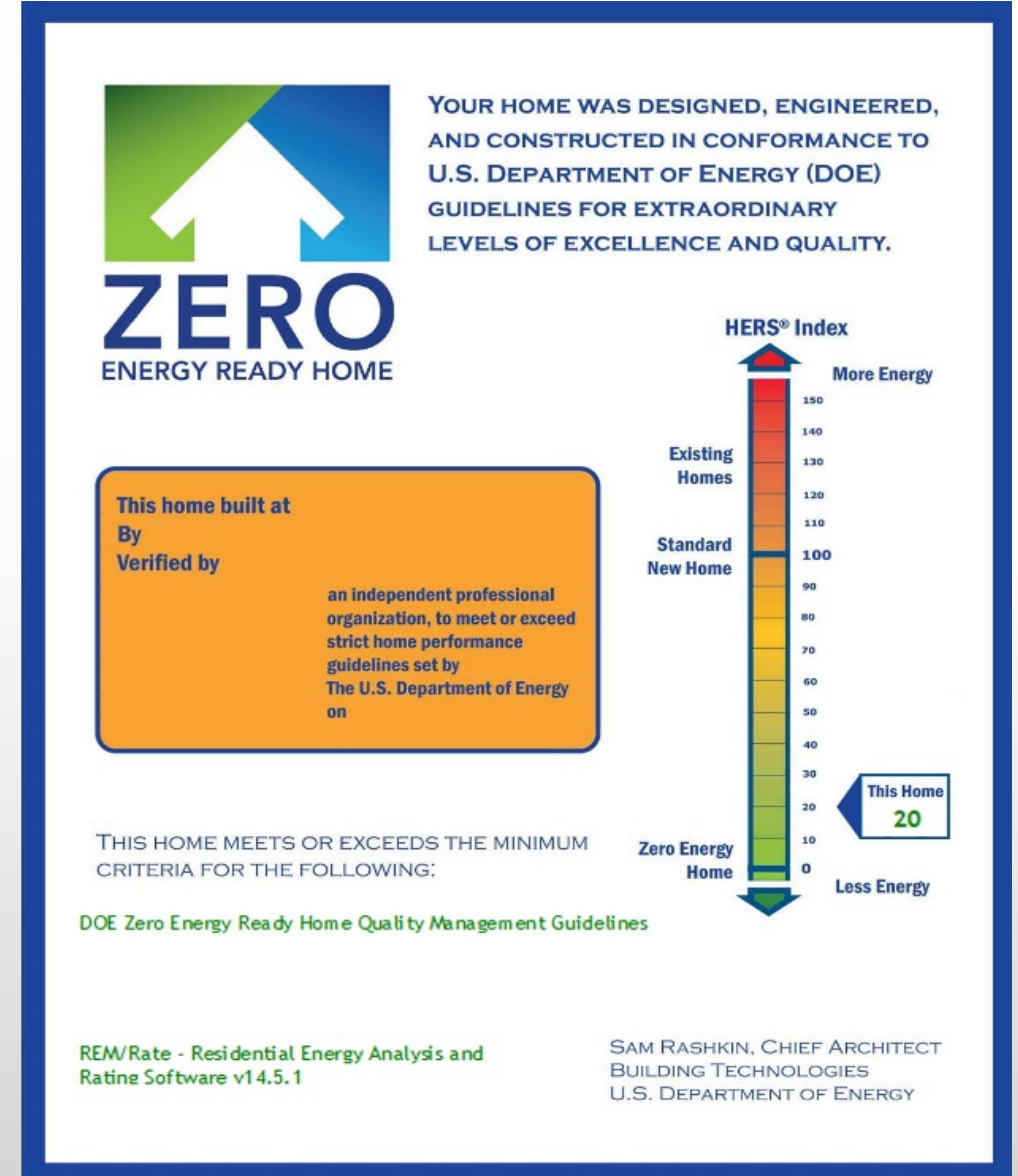
- Eliminate documented “cold bedroom” effect
 - Happens because cool supply air provided at night, pools in bedrooms
 - Exhausting from bedrooms forces air exchanges without drafts
- Space conditioning requirements are satisfied by a dual indoor unit mini-split heat pump
- We placed a head on each level to offset the natural stratification of air in the building
- The upstairs unit does the bulk of dehumidifying and cooling (Hot, humid air rising to the top of the building)
- The downstairs unit does the bulk of the heating (with cold air falling to the first floor)



Energy Analysis

Challenges / Constraints

- Building Occupancy
- Plot Size
- Budget
 - 20-60% Less than Current Williamsport MFI
- Maximize Usable Space
- Maximum Heating and Cooling Load
 - 162.76 kWh per Year
- Maximum Energy Consumption
 - 564.60 kWh per Year



HERS Baseline Rating – 33

Home Energy Rating Certificate



Projected Rating: Based on Plans - Field Confirmation Required.

General Information

| | | | |
|--------------------|-----------------|------------|---------------------|
| Conditioned Area | 1654 sq. ft. | House Type | Duplex, single unit |
| Conditioned Volume | 13232 cubic ft. | Foundation | Slab |
| Bedrooms | 3 | | |

Mechanical Systems Features

| | |
|-------------------------|--|
| Water Heating: | Conventional, Electric, 0.95 EF, 80.0 Gal. |
| Air-source heat pump: | Electric, Htg: 9.0 HSPF. Clg: 19.5 SEER. |
| Duct Leakage to Outside | NA |
| Ventilation System | Balanced: ERV, 47 cfm, 47.6 watts. |
| Programmable Thermostat | Heat=Yes; Cool=Yes |

Building Shell Features

| | | | |
|-------------------|--------|-------------------|-----------------------------|
| Ceiling Flat | R-75.0 | Slab | R-40.0 Edge, R-40.0 Under |
| Sealed Attic | NA | Exposed Floor | NA |
| Vaulted Ceiling | NA | Window Type | U-Value: 0.130, SHGC: 0.550 |
| Above Grade Walls | R-46.0 | Infiltration Rate | Htg: 0.60 Clg: 0.60 ACH50 |
| Foundation Walls | NA | Method | Blower door test |

Lights and Appliance Features

| | | | |
|---------------------------|--------|------------------------|----------|
| Percent Interior Lighting | 100.00 | Range/Oven Fuel | Electric |
| Percent Garage Lighting | 0.00 | Clothes Dryer Fuel | Electric |
| Refrigerator (kWh/yr) | 584.00 | Clothes Dryer EF | 3.01 |
| Dishwasher Energy Factor | 0.46 | Ceiling Fan (cfm/Watt) | 0.00 |

REM/Rate - Residential Energy Analysis and Rating Software v14.5.1

This information does not constitute any warranty of energy cost or savings. © 1985-2014 Architectural Energy Corporation, Boulder, Colorado. The Home Energy Rating Standard Disclosure for this home is available from the rating provider.

| | | | |
|------------------------|----------------------|---------------|--|
| Registry ID | | Rating Number | |
| Certified Energy Rater | | Rating Date | |
| Rating Ordered For | Habitat for Humanity | | |

| Estimated Annual Energy Cost | | | |
|------------------------------|-------------|--------------|-------------|
| Use | MMBtu | Cost | Percent |
| Heating | 1.4 | \$34 | 6% |
| Cooling | 1.4 | \$32 | 5% |
| Hot Water | 3.1 | \$72 | 12% |
| Lights/Appliances | 17.2 | \$404 | 67% |
| Photovoltaics | -0.0 | \$-0 | -0% |
| Service Charges | | \$60 | 10% |
| Total | 23.1 | \$602 | 100% |

| Criteria | |
|--|--|
| This home meets or exceeds the minimum criteria for the following: | |

HERS w/ PV Rating – 20

Home Energy Rating Certificate



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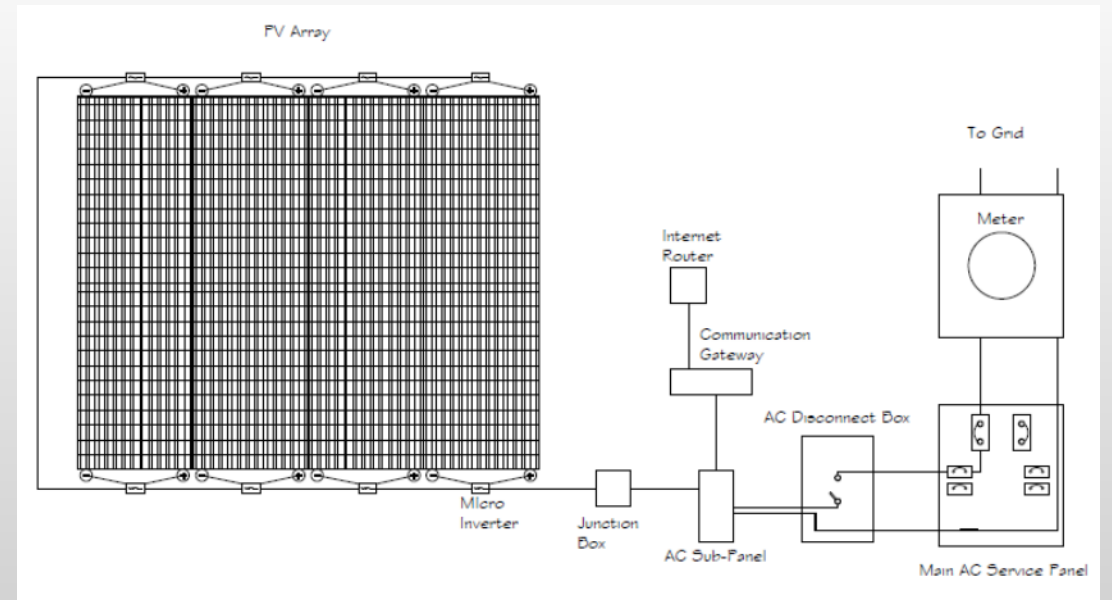
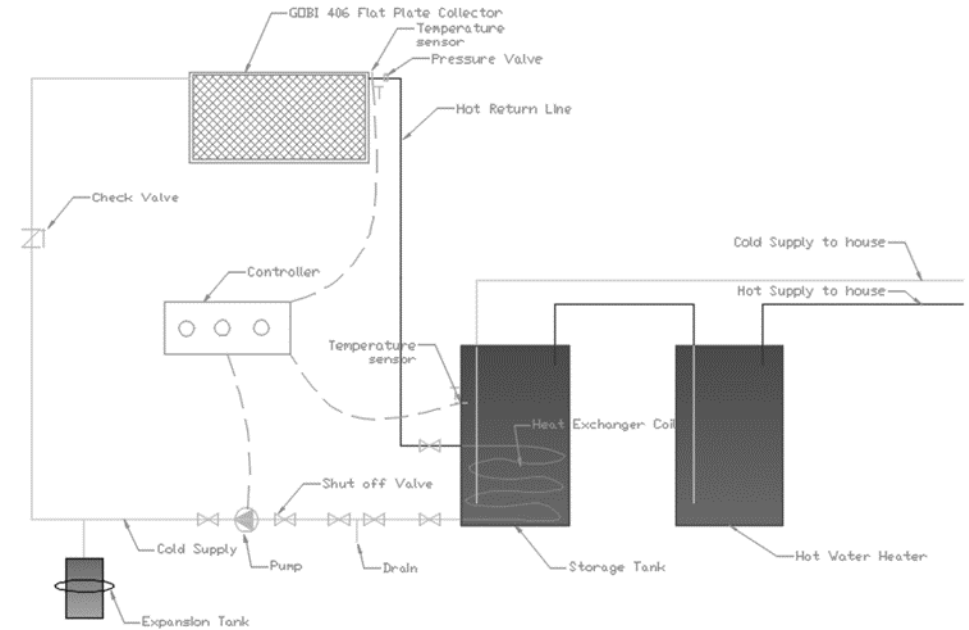
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| Use | MMBtu | Cost | Percent |
| Heating | 1.4 | \$34 | 9% |
| Cooling | 1.4 | \$32 | 8% |
| Hot Water | 3.1 | \$72 | 19% |
| Lights/Appliances | 17.2 | \$404 | 106% |
| Photovoltaics | -9.4 | \$-221 | -58% |
| Service Charges | | \$60 | 16% |
| Total | 13.7 | \$381 | 100% |

| Criteria | |
|--|--|
| This home meets or exceeds the minimum criteria for the following: | |

Renewables Details

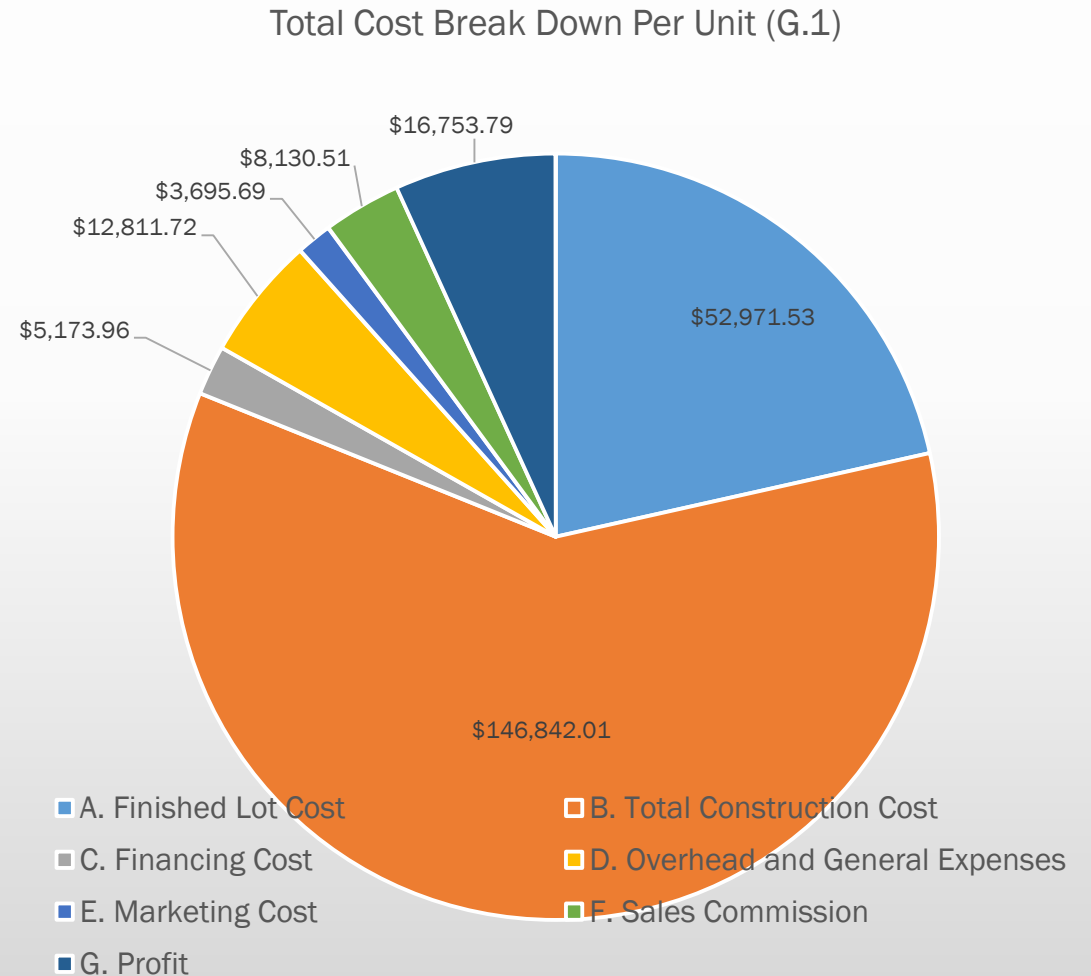
- Closed Loop DWH system
 - 24.91 SqFt
 - 70.2% Solar Fraction
- Photovoltaics
 - 2,080 Watts
 - 2252 kWh per year
- Meets RERH Standards
- 4" capped chase to attic
- 1" conduits for DC wire run.
- Micro Inverters on solar Panels



Financial Analysis

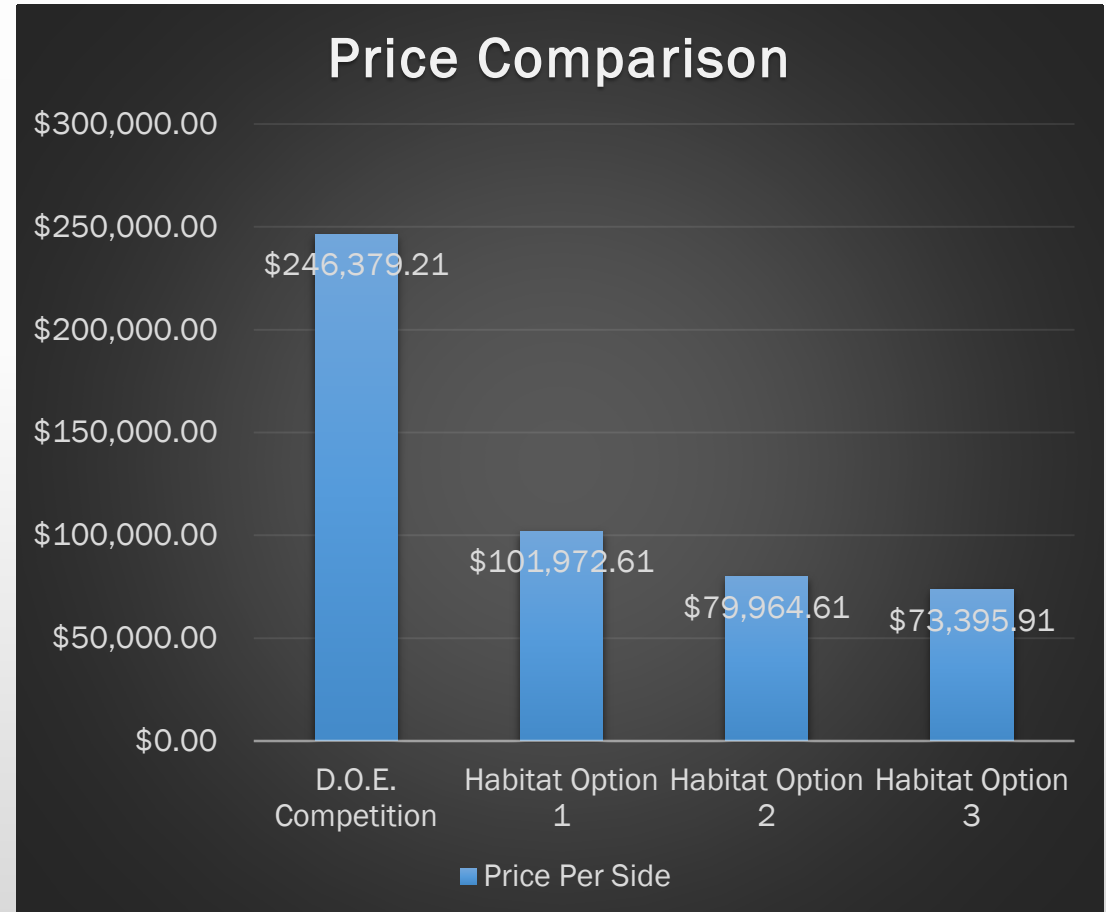
Financial Analysis of Cost & Affordability

- “Speculative design” approach
 - regional median family income
- Habitat for Humanity
 - 20%-50% lower median family income
 - Lower materials costs
 - Significant labor reductions



Cost Breakdown Options

- D.O.E. Competition Total Per Side
 - \$246,379.21
- Habitat For Humanity Option 1: Renewables and ADA Accessible Per Side
 - \$101,972.61
- Habitat For Humanity Option 2: Renewables and ADA Ready Per Side
 - \$79,964.61
- Habitat For Humanity Option 3: Base Model Per Side
 - \$73,395.91





Electrical Loads & DHW

Plumbing Layout

Separate Meter Locations

- Convenience for occupants

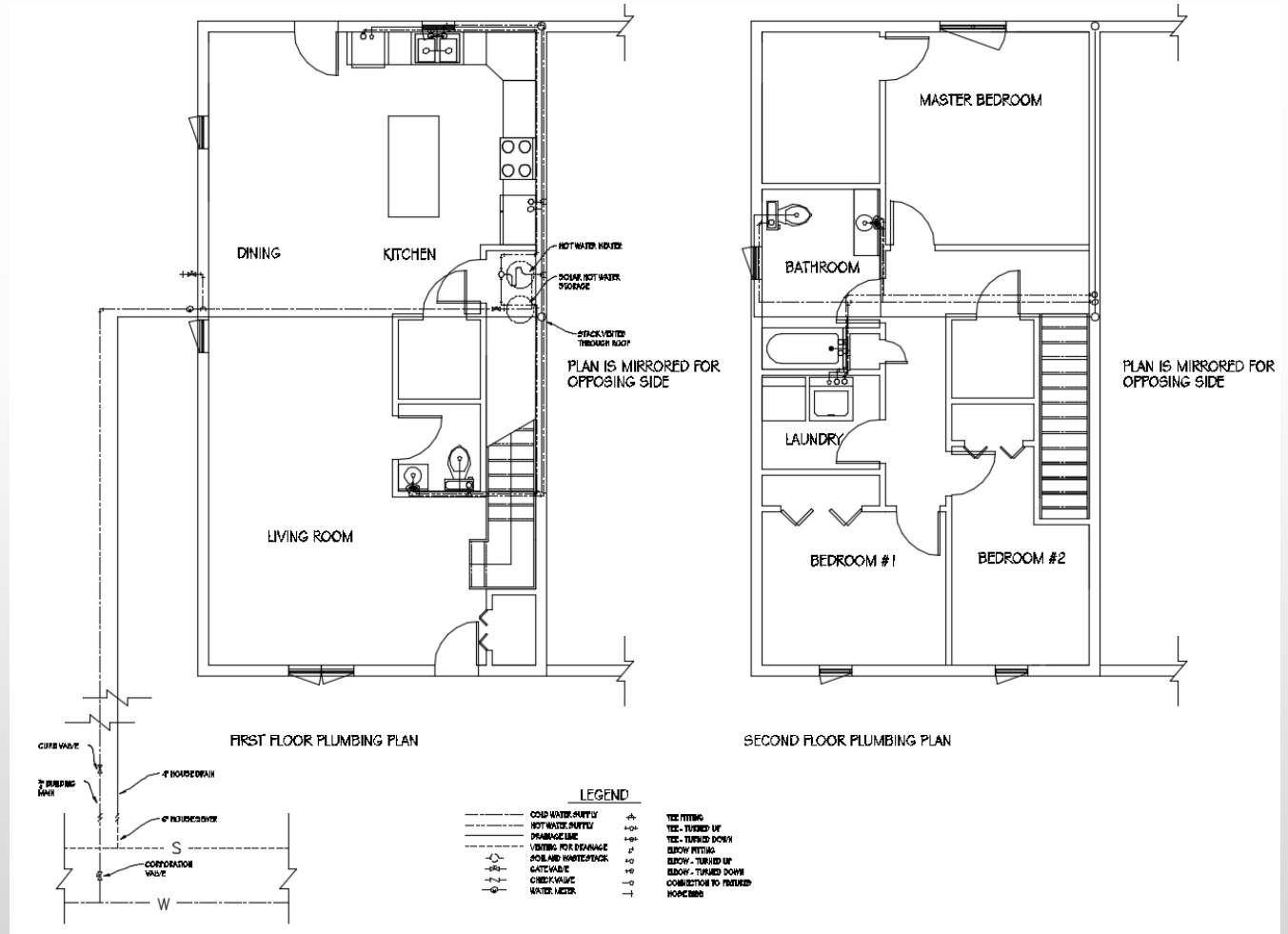
Centralized Plumbing Chase Wall

- Fewer wall penetrations
- Follows overall house design
- Saves on plumbing materials

EPA Water Sense Compliance

- No more than 0.5 Gal in system from Hot Water Heater to Hot Fixture

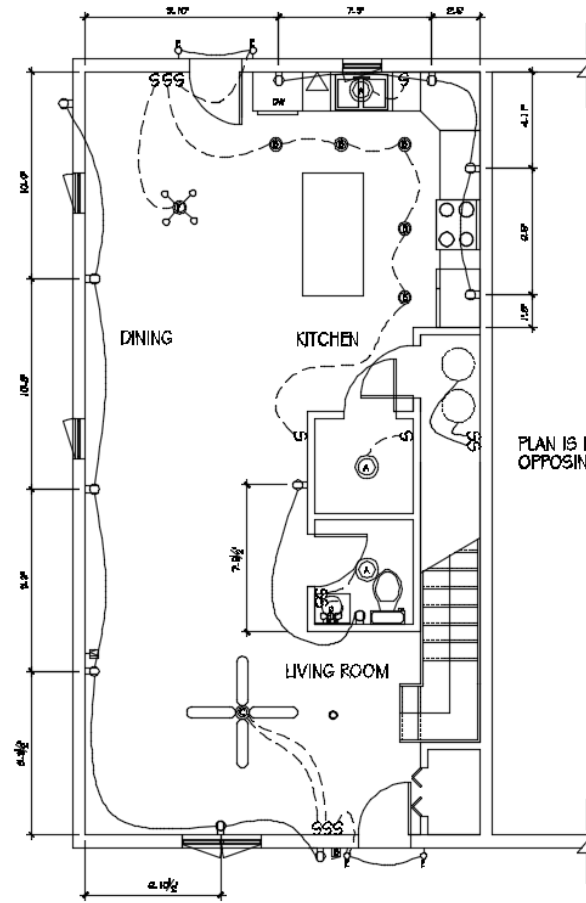
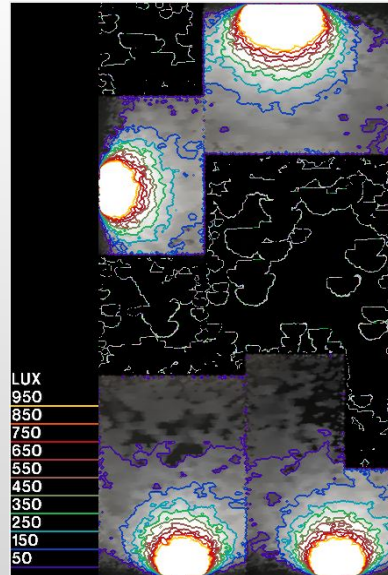
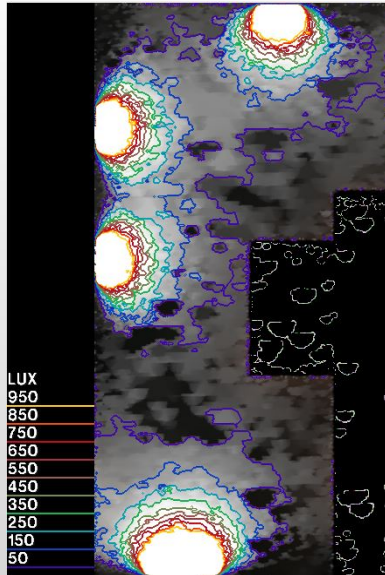
| EPA 3.3 Water Sense | | | | | |
|--|------|----|---------------|-----------|--------------|
| No More than 0.5 Gal from Hot Water Supply | | | | | |
| Fixture | Feet | In | Diameter (In) | Area (In) | Volume (Gal) |
| Kitchen Sink | 23 | 6 | 0.5 | 0.196 | 0.240 |
| Half bath Sink | 23 | 1 | 0.5 | 0.196 | 0.235 |
| Full Bath Sink | 29 | 0 | 0.5 | 0.196 | 0.296 |
| Full Bath Tub | 29 | 3 | 0.5 | 0.196 | 0.298 |
| Washer | 32 | 0 | 0.5 | 0.196 | 0.326 |
| Diswasher | 27 | 8 | 0.5 | 0.196 | 0.282 |



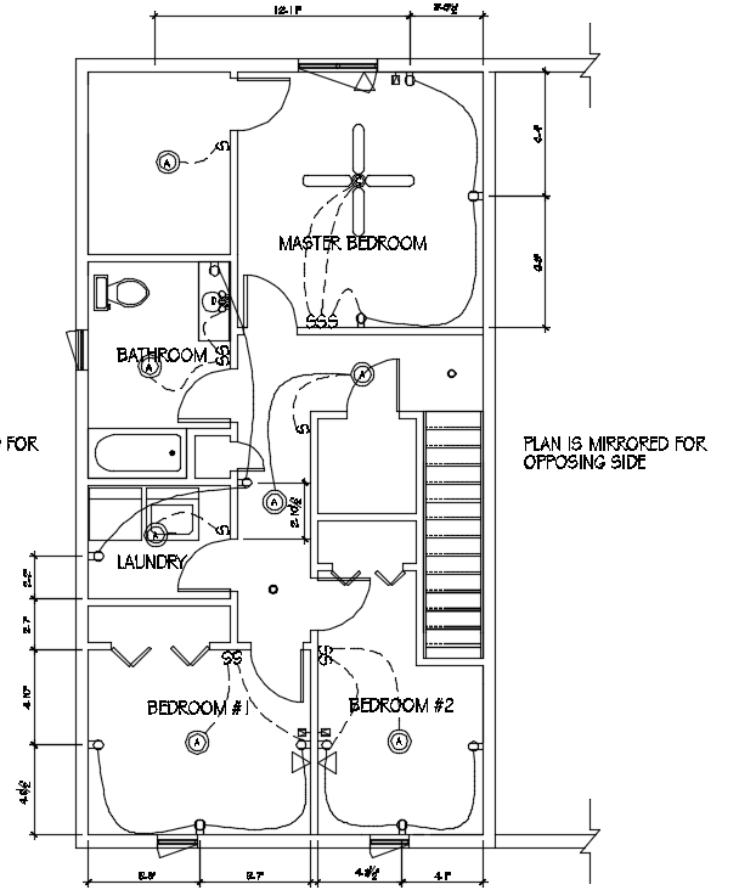
Electrical Layout

Task Lighting

- Deep corners where daylight does not reach
- Night time use



FIRST FLOOR ELECTRICAL PLAN



SECOND FLOOR ELECTRICAL PLAN



| ELECTRICAL FIXTURE SCHEDULE | | |
|-----------------------------|-----------------------------|-----------------------|
| LET. | TYPE | REMARKS |
| A | CEILING LIGHT FIXTURE | CEILING MOUNTED / LED |
| B | RECESSED CAN LIGHT FIXTURE | CEILING MOUNTED / LED |
| C | CEILING FAN / LIGHT FIXTURE | 3 SPEED FAN / LED |
| D | BATHROOM WALL LIGHT FIXTURE | 3 LIGHT / LED |
| E | EXTERIOR WALL LIGHT FIXTURE | WALL MOUNTED / LED |
| F | CHAIR PLUG | 4 LIGHT / LED |

Appliances

Energy Star Appliances

- Refrigerator, Dishwasher, Hot Water Heater, Clothes Washer

Highly Efficient Hot Water Heater

- Overall cost turnaround within two years by energy savings

Vent-Less Dryer

- Reduce building envelope penetrations

Microwave With Vent

- Maintain Minimal ERV airflow

Home Energy Monitoring System

- Inform the owners to their homes environmental impact
- Recognize areas of high energy loads

Lighting Fixtures

- 90% ENERGY STAR Certified
- LED Bulbs



Industry Partners

Industry Partners

- Tina McDowell – *Executive Director, Greater Lycoming Habitat for Humanity, Williamsport PA*
 - Tina came on campus and presented to students what Habitat was looking for and what the neighborhood residents wanted. She provided documents for site. Students had continuing dialog of questions and direction. Students also visited her office to present ideas. She will also be essential after this competition in getting our building constructed in Williamsport.
- Carlene Keyte - *Assistant Vice President-Mortgage Lending, Woodlands Bank, Williamsport PA*
- Kristi Eberhart - *Mortgage Banker, Woodlands Bank, Williamsport PA*
 - Carlene and Kristi assisted by developing a spreadsheet relating to the financing/construction costs for the competition. The design team met with Carlene to review and revise financing numbers. They were essential in the formatting of our financial information.
- Jim Phelps - *Certified Passive House Consultant, Quality Assurance Manager, Performance Systems Development, Liberty PA*
- Mary Graham - *Certified Passive House Consultant, Energy Consultant, Tip to Toe Energy, Trumansburg, NY*
 - Jim came on campus twice to lecture on PHIUS and train students on how to use RemRate. Jim and Mary acted as energy consultants on the project, running WUFI reports on designs and recommending improvements to the design based on building models which were provided by the design team. There was constant dialog between the design team and both Mary and Jim, whether it came via phone or email. Mary and Jim were essential in the completion of the project.
- Keevin Larson - *President of K.C. Larson, Inc, mechanical, electrical and renewable energy contractors, Williamsport PA*
- Jamie Sherman – *Office Manager and Renewable Energy, K.C. Larson, Inc., Williamsport PA*
 - Keevin and Jamie met with students and reviewed mechanical system design, gave advice on the solar thermal design based on their experiences (recommended closed loop system without a heat dump vs. a drain-back system), and reviewed PV design. Provided information on preferred supplier and where to look for costing.

Conclusion



Project Data

- **Location:** Williamsport, Pennsylvania
- **Climate:** IECC Zone 5
- **Square Footage:** 1644 SF/unit
- **Size:** 2 Stories, 3 Bed, 1.5 Bath
- **HERS Rating:** 20
- **Monthly Energy Cost:** \$39.96

Technical Specifications

- **Wall Insulation:** R-56
- **Foundation Insulation:** R-40
- **Roof Insulation:** R-75
- **Window Performance:** R-8.1/ SHGC: 0.5
- **HVAC:** 1.5 ton/ 19.5 SEER/ 9 HSPF mini-split Heat Pump

