D.O.E. RACE TO ZERO COMPETITION

Volume 1: Solution Outline

PRESENTED BY:
Penn College-Williamsport

Faculty Advisers:
Dorothy Gerring
Robert Wozniak

STUDENTS:
Dustin Bailey
Samantha Callender
Michael Fonti
Peter Gauthier
Justin Iman
Adam Knoebel
Chris Master
Zach Robey
Matthew Vent

Pennsylvania College of Technology
PENNSTATE

TABLE OF CONTENTS

Pennsylvania College of Technology
PENNSTATE

TEAM QUALIFICATIONS & SUMMARY DESCRIPTION

Penn College: Sponsoring Institutions Qualifications, Education and Training

Penn College, and its predecessor Williamsport Technical Institute was established in 1914 to provide technical training and has continued over the decades to provide degrees that work. As one of its oldest curricular programs, the Architecture program has been offered since 1941. With the Community College Act of 1963, Williamsport Technical Institute was renamed Williamsport Area Community College. Starting in 1970, the institution has been accredited by the Middle States Commission on Higher Education. Then in 1989, with a Special Mission Affiliate status of Penn State University, the name was changed to be known as Pennsylvania College of Technology, or otherwise - Penn College.

Through the years, the hands-on, technical approach to applied technology has provided strength and success to all of its diverse educational certificate, associate and bachelor degree offerings, where most recently, Penn College has been named among the "top 10" best public, four-year colleges in the north region of the United States, according to the latest rankings of America's Best Colleges by U.S. News Media Group. With this, Penn College ranked 10th among public colleges and 33rd among all "best regional colleges (north)" in the 2013 rankings published by U.S. News & World Report.

Penn College's mission statement clearly communicates the commitment it has to the students: *"Pennsylvania College of Technology is a public institution providing comprehensive, hands-on technical education at the baccalaureate and associate degree levels. Every member of our College community endeavors to create and sustain excellence in a student-centered environment that promotes personal growth, social awareness, a shared commitment to diversity, and lifelong learning, all of which help prepare our graduates for success."* And, as the College recalls and celebrates its 100 year anniversary (1914 - 2014) of providing quality education, the vision statement has grown during the years from being: *Pennsylvania's Premier Technical College",* to more recently: *"Pennsylvania College of Technology; a national leader in applied technology education".*

Historically the institution has had a hands-on approach and has provided the opportunity for students to design and construct at least six residences in the community as well as two buildings on the campus: the Penn College Victorian House, used for college hospitality needs, and the Penn College Professional Development Center, used for college meetings and conferences. The construction and design majors have worked with local non-profit organizations, such as Habitat for Humanity, to provide drawings and construction experience for students. Through both coursework and clubs, students have designed many projects in the community, including new construction, handicapped entrances, repairs, and beautification efforts both for residential and public parks/sports facilities.

With its multiple degree programs that relate to the design and construction industry, it was in 2009 that it began a BS degree in Building Science and Sustainable Design. Looking for an opportunity to further its national presence, the *2014 DOE Challenge Home Student Design Competition* was a natural fit that also provided an opportunity for our students to develop Passive House Institute US (PHIUS) townhouse drawings for the Denver Housing Authority. Besides presenting in Denver last year, students and faculty presented at various venues to different audiences including the planning commission and the Lycoming County housing authority. The evidence that affordable, efficient, and aesthetically pleasing housing was clear and people were excited. As a result, for this year's *2015 DOE Race to Zero Student Design Competition*, the Greater Lycoming Habitat for Humanity (Williamsport, PA) has requested the student team to design a duplex using PHIUS Standards. The college has also been asked to participate with the city and county in setting and implementing sustainable development.

The Penn College - Williamsport (Net Zero Team) is an extra-curricular team effort made up of nine students from various programs, skills and academic grade levels. It is rewarding to see their technical building science skills that have been taught in the classroom, now being put to task in a collaborative project/competition, as they coordinate their efforts to meet this year's deadline - for the common good.

Project Team Profile: See Appendix A.1 for full biographical information

Lead Faculty / Team Advisors:

- Dorothy Gerring - *Associate Professor, Architectural Technology, RA, LEED-AP BD+C*
- Robert Wozniak - *Associate Professor, Architectural Technology, LEED-AP*

Expert Organization(s):

- National Sustainable Structures Center (NSSC), Williamsport, PA:
- John Manz - *Director (Manager of NSSC's infrastructure, training and technical assistance services, Assisted the US DOE to draft the National Resid. Energy Upgrade Guidelines)*
- Gerald Welshans - *Instructional Specialist, (PA-certified weatherization instructor, Level 1 Thermographer, BPI "Super Proctor", various BPI certifications)*
- John Wilson - *Consultant/Instructor (BPI certifications, PA-certified weatherization instructor)*

Industry Partners / Expert Advisors:

- Kristi Eberhart - *Mortgage Banker, Woodlands Bank, Williamsport PA*
- Mary Graham - *Certified Passive House Consultant, Energy Consultant, Tip to Toe Energy, Trumansburg, NY*
- David Iman – *Partner, Creative Cabinetry, LLC*
- Carlene Keyte - *Assistant Vice President-Mortgage Lending, Woodlands Bank, Williamsport PA*
- Keevin Larson - *President of K.C. Larson, Inc, mechanical, electrical and renewable energy contractors, Williamsport PA*
- Tina McDowell – *Executive Director, Greater Lycoming Habitat for Humanity, Williamsport PA*
- Jim Phelps - *Certified Passive House Consultant, Quality Assurance Manager, Performance Systems Development, Liberty PA*
- Jamie Sherman – *Office Manager and Renewable Energy, K.C. Larson, Inc., Williamsport PA*

Pennsylvania College of Technology
PENNSTATE

Student Team Members: See Appendix A.2 for full student biographies

At Penn College, the 2015 DOE Race to Zero Student Design Competition was open to students within the School of Construction and Design Technologies. Each of these students were charged to pursue the various required on-line DOE Building Science Training courses and as a result, some of the students have completed the on-line video training, most reviewed the readings, all students have been instructed and trained in Passive House requirements via Mr. Jim Phelps, listed above, and via applicable Penn College coursework listed below. During the regular meetings held throughout the week since late October 2014, the on-line DOE Training course materials have been referenced with intense discussion and productive results. Dorothy Gerring and Robert Wozniak affirm that these students have a solid understanding of building science and sustainability as required to participate in this competition.

Applicable Penn College Coursework

Along with the related on-line DOE Building Science Training course work, the Penn College School of Construction and Design Technologies students are enabled to design high-performance homes, not only meeting ENERGY STAR® and DOE Zero Energy Ready Home requirements, but also PHIUS Standards. Depending on the student Team members' degree(s), the related degrees/courses that apply to this competition include:

Architectural Department (AAS Degree in "Architectural Technology" and BS Degree in "Building Science and Sustainable Design"):

- **ACH128 Working Drawings – Residential** (develop complete set of drawings based on wood construction, using CAD drafting standards, efficient database organization, drawing clarity, thoroughness, and attention to dimensioning, cross-referencing, and plotting)
- **ACH119 Building Materials I** (residential building materials)
- **ACH241 Codes, Specifications & Estimating** (Introduction to the International Residential Code (IRC), the International Building Code (IBC), Americans with Disabilities Act (ADA) standards, specifications, and estimating)
- **ACH262 Sustainability: Building and Living Green** (Overview of the concept of sustainability including holistic living and building design that integrates solar concepts, energy efficiency, material ecology, and building science concepts)
- **BSD310 Sustainable Materials** (need, development and application of sustainable building materials, methods, and systems)
- **BSD330/332 Passive Design/Architectural Design Studio IV** (passive design strategies, climate analysis, site analysis, design)
- **BSD420 Renewable Energy Technologies** (theory and design of renewable systems including solar thermal and PV, building science concepts, energy efficiency)
- **BSD430/432 Whole Building Design/Architectural Design Studio VII** (integrated design approach, teamwork, involvement of stakeholders, benchmarking, design evaluation)

- **Heating, Ventilation and Air Conditioning Department** (AAS and BS Degrees in "Heating, Ventilation and Air Conditioning Technology"):
- **ACR119 HVAC Automated Design (working with electronic drawings related to the HVAC industry)**

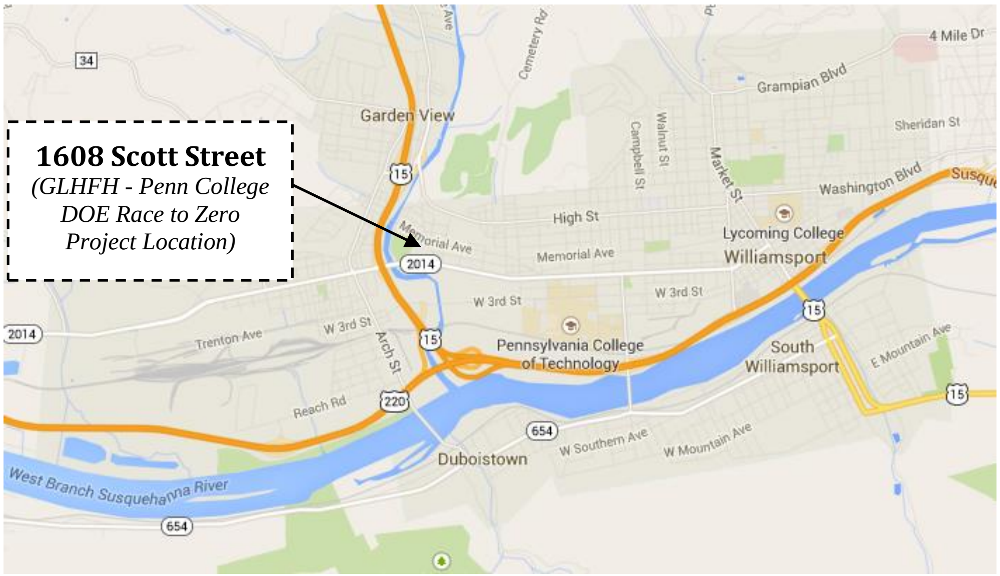
- **ELT252 HVAC Controls I** - Residential (Installation and operation of residential line and low voltage controls used in HVAC applications)
- **ACR251 Warm** – Air Heating and Duct Design (Emphasis on medium and high-efficiency technology for the HVAC industry).
- **PLH124 Mechanical Systems (**Emphasis on selection and application including fluid transfer mechanics, thermodynamic principles, ADA compliance and cost estimating.)
- **BHV316 Heating and Cooling System Configurations** (Indoor Air Quality analysis, HVAC design and drawings, ASHRAE Parallel Path Analysis or Finite Element Analysis, ACCA Manual J calculation or similar, EPA indoor airPLUS Checklist, Plumbing design and drawings, Homeowner Operation and Maintenance Checklist for mechanical and plumbing systems)

Building Construction Department (BS Degree in "Residential Construction Technology and Management"):

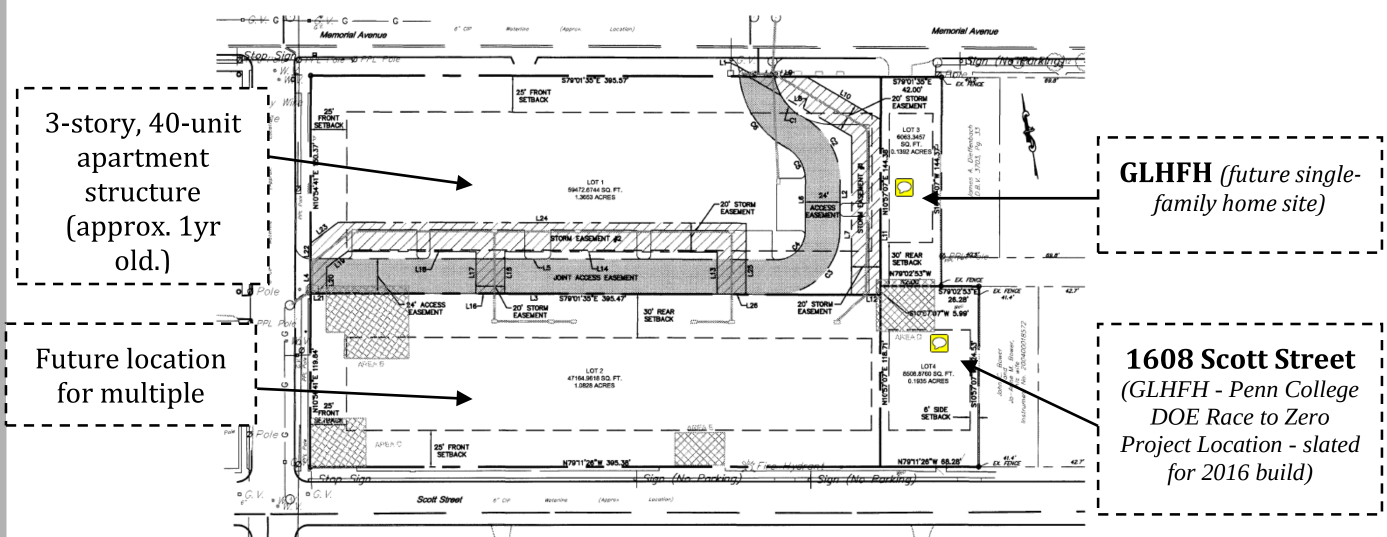
- **BCT104 Construction Safety and Equipment** (OSHA requirements and guidelines)
- **BCT109 Framing Principles** (Theory and application of framing for residential and light commercial construction)
- **BCT110 Site Preparation and Layout** (Site management, preparation and layout of structures)
- **BCT117 Construction Materials and Application I** (Residential building materials)
- **BCT107 Print Reading and Architectural Drafting** (Print reading and architectural drawing)
- **BCT255 Construction Estimating** (Estimating excavation, concrete, steel, masonry, carpentry, mechanical and electrical work)
- **BCT256 Residential Construction Planning, Scheduling and Management** (managing a project so on time and within budget)
- **BCT300/308 Residential Management I/II** (marketing, insurance, contracts, loans, cash flow)
- BCT305 Codes in Construction (Current International Residential Code**)**
- **BCT411 Advanced Residential Estimating and Scheduling** (scheduling, bidding, productivity, resources, sequencing)
- **BCT420 Advanced Mechanical Systems** (electrical and mechanical systems, energy conservation, environmental impacts)
- **BCT430 Contemporary Issues in Residential Construction** (LEED for homes, environmental impacts)

Neighborhood Impact of Project

The Greater Lycoming Habitat for Humanity (Williamsport, PA) asked Penn College students to design a PHIUS duplex on Scott Street, as shown on the maps below. This neighborhood is currently being redeveloped. Recently the City of Williamsport demolished a late 1800's abandoned warehouse that was a magnet for illegal activity. This made way for the *Brodart Neighborhood Improvement Project* - which includes a three story 40-unit apartment complex, two Habitat for Humanity projects (the Penn College designed duplex and a future single family home), plus several other duplexes for which the City has already secured designs. Per a recent local newspaper article, this neighborhood is made up of a total of 150 one- and two-family residences that will be receiving exterior improvements that are paid by Penn Marcellus Shale natural-gas impact fees.



Map by Google



Drawing by: L.R. Kimball

DESIGN GOALS

Meeting Consumer Expectations through Architectural Design

- Extremely affordable utility bills to focus on quick pay off of mortgage
- Net Zero House, Super insulated, super sealed, & designed to add renewable energy systems in the future
- ADA design for house-wide accessibility

Project Approach & Integrated high Performance Design Concepts

Home fit to site:

- Blends aesthetics of surrounding buildings
- Matches neighborhood context: 2 story, Gable roof, Similar building materials, Flat porch, Back yard, See Appendix B.1: Neighborhood Context

Solar Orientation:

- South 11 degrees West. Within 15 degrees of true south.
- Large South facing living room windows for natural lighting and solar heat gain

Solar Shading:

- Overhangs are designed to allow both direct sunlight and solar heat gain between the end of September and end of May and protect and shade from solar heat gain during the overheated periods of the year between May and September.
- Natural. Blends into neighborhood aesthetics and characteristics. Does not stick out. No additional construction costs, winter solar heat gain, Blocks solar radiation during overheated months of the year.
- Adjustable awnings on the east and west sides of the building to allow for adjustment as necessary throughout the year.
- Fixed awnings are present on the south side of the house and provide shading during the summer months and allows for natural daylighting and heat gain during the colder winter months.

Thermal Mass:

- Poured stamped concrete slab on grade, Absorbs extra solar heat gain from southern oriented windows, Acts as heat sink, Controls diurnal temperature range, Increases comfort throughout year.

Natural Shading:

- Site planted trees to provide shade from the South.

Natural Ventilation:

- Natural ventilation is provided from the operable windows located at a sill height of 3'. This level allows for wind to continuously flow through the home at a comfortable height providing maximum passive comfort to residents in all main living areas. Windows specified for the project are able to open inwards, similar to traditional casement windows but allow for exterior window screens to be utilized. The tilt and turn windows are also able to open inwards like hopper windows with two separate locking angles. The windows allow for continuous passive ventilation while maximizing efficiency and security.

Convenient Placement of Rooms:

- Front door leads straight to open living room
- Half bath is located straight off of the living room centralized to the first floor
- Dining room directly connected to the north of the living room allowing for open flow, communication, and direct sight line.
- Kitchen is located on the north side adjacent of the first floor to provide heating due to higher energy lost on the northern facade
- Stacked walk in pantry/closet accessible from kitchen allows for future addition of a personal elevator for accessible use.
- Master bedroom is located at the top of the steps on second floor overlooking the large back yard to the north.
- Restroom is centralized to the bedrooms on the second floor
- Laundry room located adjacent to bedrooms on second floor

Open Floor Plan:

- Allows for the flooding of natural daylight from southern oriented windows to fill first floor space
- Allows ERV system to easily circulate air around the homes conditioned space
- Helps to increase the apparent size and feel of actual floor area
- Barrier free design for universal access and maximum visibility

Minimal Wasted Space:

- Open floor plan
- Conveniently placed closets
- Takes full advantage of small foot print

Minimal Circulation:

- No hallways on first floor
- Minimal circulation on second floor
- Easy access to necessities

Varied Ceiling Height:

- One foot drop down soffit separating kitchen from dining room

Integration of Structural System:

- Slab on grade has been stamped and stained for use as first floor system
- 2x6 wood stud wall for structural support and deep cavity space for spray in closed cell insulation
- 14" wooden open web floor truss system to allow for running of HVAC ducting and plumbing

Integration of HVAC System:

- ERV unit was used to circulate air around the home, before the stale air is exhausted to the exterior
- Mini split pumps were utilized for their dehumidification mode, allows for dehumidification without over cooling
- ERV is integrated to maintain a positive house pressure and is interlocked with exhaust points throughout the home
- Chose a method of exhaust and intake that supplies in common areas and exhausts from the bedrooms drawing conditioned air into the bedrooms at night, correcting that short comings of the supply to bedroom model, which caused over-cooling in bedrooms during the night

Integration of Plumbing System:

- Utilized a stacking and proximity to provide centrally located plumbing
- Efficient length of piping
- Solar hot water system designed to provide 70% solar fraction

Integration of Lighting System:

- Convenient placement of lighting fixtures in locations where little to no daylighting penetration reaches allows for task lighting in areas such as closets and general night time lighting
- Focused on LED lighting
- Energy star lighting appliances

Furniture Placement:

- First floor is an open concept of better placement and flow around furniture
- Second floor bedrooms optimize floor area with door and closet placements for better furniture placement

Storage:

- Coat closet located to the inside of front door
- Pantry accessible from kitchen
- Centralized hallway storage closet on second floor
- Closets located in each bedroom

- Master bedroom features a walk in closet

Disaster Resistance:

- The truss system is designed to support the snow loads typical to the area. Howe truss system gable 6 panel 6:12 slope
- Area is not prone to natural disasters
- Able to resist strong winds that sometimes cause damage during summer storms.

Linkage to Outdoors:

- Southern front yard pushing the house back away from the street to match surrounding homes in the neighborhood
- House has a small footprint and allows for 12' of side yard to either side of the duplex
- Large shared backyard to the north of the duplex. Takes full advantage of site space and creates a larger than average usable lawn.

House Type:

- The Scott Home will be designed with Victorian Style to 50's gabled to fit the neighborhood. The home is made to be space and energy efficient to fit into the neighborhood.
- The two family detached dwelling (duplex) will be new construction on an open site. The Net Zero duplex will be designed for Greater Lycoming Habitat for Humanity.

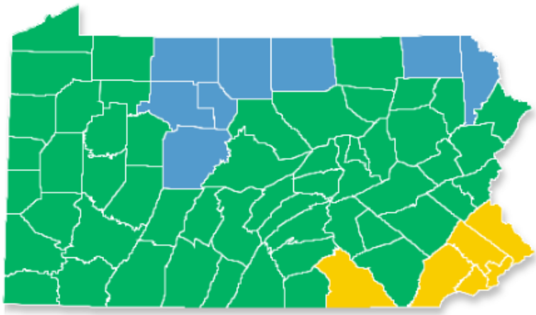
Location:

- The Scott home is located in the largest Lycoming County and North Central Pennsylvania.
- Our site is located on Lot # 4, 1608 Scott Street.

  This neighborhood is currently being redeveloped. Recently the City of Williamsport demolished a late 1800's abandoned warehouse that was a magnet for illegal activity. This made way for the *Brodart Neighborhood Improvement Project* - which includes a three story 40-unit apartment complex, two Habitat for Humanity projects (the Penn College designed duplex and a future single family home), plus several other duplexes for which the City has already secured designs.
- The site is surrounded by Victorian Style Duplex so the home will fit right in to the location.

Climate Zone:

- 2009 IECC: Zone 5 – Humid Continental



Lot Size and Configuration:

Climate Zone 5 & 4 Marine	
Ceiling R-value	38
Wood Frame Wall R-value	20 or 13+5[h]
Mass Wall R-value [i]	13/17
Floor R-value	30[g]
Basement Wall R-value [c]	10/13
Slab R-value [d], Depth	10, 2 ft
Crawlspace Wall R-value [c]	10/13
Fenestration U-Factor [b]	0.35
Skylight U-Factor [b]	0.60
Glazed fenestration SHGC [b, e]	NR

The selected site is located on Lot # 4, 1608 Scott Street, Williamsport, PA. The lot is 8508.8760 square feet.

House Orientation:

Neighborhood /Community Setting:

- The home design is a combination of the neighborhood Victorian style and Modern design.

- Residents are in walkable distance from stores and shops.
- Residents are able to get to work in minutes anywhere in town.
- The neighborhood is located near highways.
- The real estate in the neighborhood is a mix of both rented and owned homes.
- See Appendix B.1: Neighborhood Context and B.2: Precedent examples

Occupants:

- The occupants of the home will be able to suit a family of four in each unit.
- Scott home will be able to accommodate a family of four that qualifies for Lycoming Habitat of Humanity.
- The home will be ADA accessible.

Sustainability:

- Local & readily available materials that could be donated locally
- Easy to use products for quick and simple volunteer construction
- Low maintenance/ high durability
- Met passive efficiency requirements with a high performance : cost ratio
- Minimized finishes with off-gassing potential

Project Type:

- Reference Construction Schedule in Appendix B.3: Construction Schedule

Programs and Standards:

- PHIUS: See Appendix J.1: WUFI Report
  - Maximum of 4.75 kBTU/sf/yr heating demand
  - Maximum of .6 ACH @50 pascals
  - Maximum of 38 kBTU/sf/yr
- DOE Zero Energy Ready: See Appendix F.1 HERS Rating
  - HERS 50 or lower based on
  - Certified under Energy Star Qualified homes Version 3
  - Fenestration shall meet or exceed latest Energy Star requirements
  - Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels
  - Ducts located within the home's thermal and air barrier boundary
  - Hot water delivery systems shall meet efficient design requirements
  - All installed refrigerators, dishwashers, and clothes washers are Energy Star qualified
  - 80% of lighting fixtures are Energy Star qualified or Energy Star lamps (bulbs) in minimum 80% of sockets
  - All installed bathroom ventilation and ceiling fans are Energy Star qualified
  - Certified under EPA Indoor airPLUS
  - Consolidated Renewable Energy Ready Home Checklist
- Accessible Design

- Accessible route into and within building
- Accessible common use areas
- Usable doors
- Accessible light switches, outlets, and HVAC control

Building systems & design approach to meet sustainability, ENERGY STAR, and DOE Zero Energy Ready Home goals:

Passive house standards

- Super insulated – Wall: R45, Slab: R40, Ceiling: R75
- Super air tight- Continuous, unbroken air barrier. Caulking at all material intersections. Compact construction with minimum unbroken façade. Sprayed in closed cell insulation for easy sealing.
- ERV system and mini split heat pump
- Low U value windows and doors
- Minimal thermal bridging
- LED lighting and Energy Star appliances

DOE Zero Energy Ready

Designed with chase ways for future retrofitting of renewable resources such as PV and solar hot water

ADA Compliant

- Accessible building entrance on gently sloping concrete ramp poured on grade leading to both front and back porch doors
- Open floor plan with and 3' hallways
- Designed for future retrofit of residential elevator
- 32" clearance at all doors
- Accessible bathroom with nonslip floors and grab bars
- Light switches at 36" above FF, Electrical outlets at 18"-24" above FF

Design Integration, Regional Influences & Utility Incentives

Describe the integrated design process:

- Conducted a school wide interest meeting encouraging students from all majors to attend that explained the DOE competition, passive house design and integration principles, and our interest in collaborating with Habitat for Humanity.
- Weekly informative meetings and work sessions were held to discuss design goals and to collaborate between group members. We decided to pursue a PHIUS certification and incorporate universal design.
- Designated section leaders based on academic major. Major design decisions were made as a group with input from every specialty to implement thermal envelope, moisture management, IAQ, HVAC, and renewable-ready into the original design.

- "GroupMe" group messaging application was used for a continuous flow of information between all group members and advisors and allowed all design decisions to be discussed as they were being made.
- A central shared work file allowed group members to easily share and access project files and documentation.

Influential national, regional, and local programs:

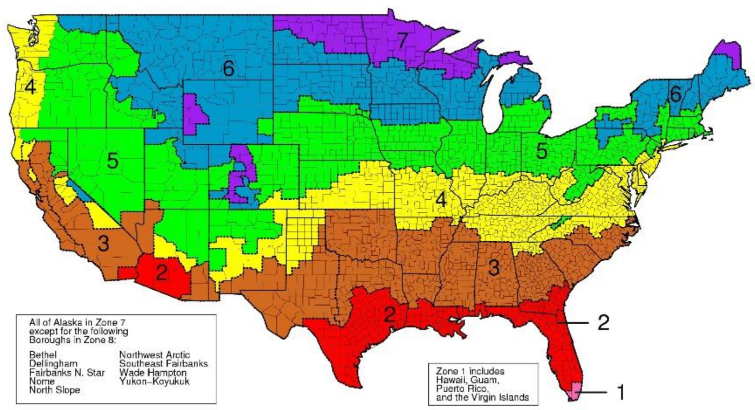
- Habitat for Humanity
    - Should fit into the rest of the neighborhood
    - Space and energy efficient
    - Designed to allow habitat for humanity families to succeed financially
    - Homeowners earn 30-80% less than median Williamsport income. 0% mortgage to be paid monthly. Unit cost $100,000 - $120,000
    - 2-3 bedrooms per unit
    - 1-1.5 baths per unit
    - Slab on grade, no basement
    - Washer, dryer, dishwasher to be included
    - Simple construction

Utility incentives and other Rebates:

- PPL Electric Utilities – residential energy efficiency rebate program
    - http://programs.dsireusa.org/system/program/detail/3854
- Solar Alternative energy credits
    - http://programs.dsireusa.org/system/program/detail/5682
- Residential renewable energy tax credit
    - http://programs.dsireusa.org/system/program/detail/1235
- High performance building incentives program
    - http://programs.dsireusa.org/system/program/detail/3354
- Habitat for Humanity Lowes grant
    - http://responsibility.lowes.com/apply-for-a-grant/

ENVELOPE DURABILITY

When designing the durability of the envelope of this building, many considerations had to be taken into account. Those considerations were; air transport, moisture management, and thermal performance based on our geological location in Williamsport, PA. To design and meet these considerations as well as local codes, this project is designed to a zone 5A climate and moisture territory based on our location in Williamsport, PA. Meaning that all our exterior wall assembly is using necessary insulation to reduce the amount of thermal bridging while also using best management practices and air barriers to reduce the amount of air infiltration into our envelope. That is why we choose to go with a closed cell spray insulation, to act as an air barrier, provide adequate R values, and to reduce thermal bridging between interior and exterior systems, while still fulfilling necessary requirements for a Zone 5A classification.



Next, when designing and preventing moisture and or condensation in our exterior walls, we designed our wall assembly to have expanded polystyrene ridged foam boards on the exterior of the walls. As well as a rain screen wall on top of the EPS, to prevent and allow any water that penetrates through our siding, to have a necessary path to stay on the exterior side of the wall, rather than on the interior side of the thermal envelope. This will ensure that our exterior walls are suitable and capable of repelling water and preventing condensation and or molding from occurring inside the wall cavity.

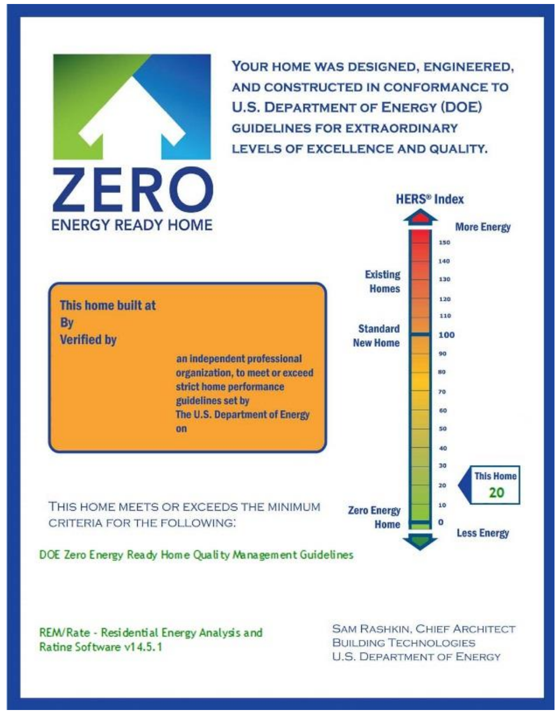
Climate Zone	Infiltration Rate, ACH50	≤ 50% Infiltration Rate, ACH50
1,2	6	≤ 3
3,4	5	≤ 2.5
5-7	4	≤ 2
8	3	≤ 1.5

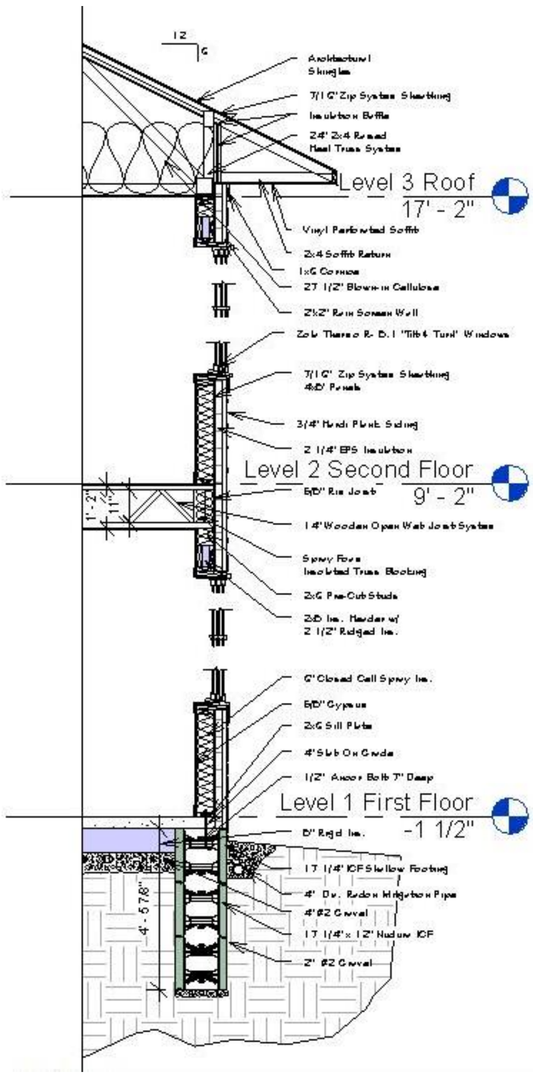
The other aspect of ensuring the durability, quality of construction of our building envelope, was to ensure that any materials that we specified were easy to install, durable, and to ensure that our building envelope is meeting DOE and ENERGY STAR ratings. While also being feasible for Habitat for Humanity volunteers to install. Since most of the labor comes from volunteer workers, we wanted to ensure whoever was installing the material would not compromise R Values, air infiltration changes and or the durability of the building envelope, due to the complexity and non-standard construction methods. That is why when building this building, we would highly recommend that the general contractor (Habitat for Humanity) would brief all vendors and or volunteers about the DOE Zero Energy Ready Home Quality Management Plan. This plan ensures that

Pennsylvania College of Technology
PENNSTATE

all construction installation regarding general construction, HVAC, insulation, air barriers, and any other trades necessary for construction follow and meet the ENERGY STAR Version 3 Requirements (See Appendix C.1: Energy Star v3 Checklist). This way as construction takes place, it will ensure that the project will meet all necessary requirements to be an ENERGY STAR / PHIUS rated home when completed.

Overall, since this is a Passive House, the DOE Zero Energy Ready Home Quality Management Plan will ensure that our building envelope exceeds the ENERGY STAR ratings, fulfills PHIUS requirements and is in fact durable and is resistant to moisture, air infiltration and thermal transfer. See Construction Documents in Appendix I for Scaled Section.





Pennsylvania College of Technology
PENNSTATE

INDOOR AIR QUALITY EVALUATION

Indoor Air Quality Approach

Scotts Home will be designed to provide excellent indoor air quality, we will exceed the EPA Indoor Air PLUS Checklist. Scott Home will also be provided with all Energy star appliances throughout the home.

Moisture Control

- The Scott Homes Site and foundation is exempt from moisture because it is slab on grade.
- Contact with slab as per (WMS 1.3) additional requirement through XPS insulation installed.
- Perimeter 4 inch perforated around the perimeter of the home.
- Installed 4 inch layer of ½ inch diameter or greater clean aggregate
- Used Class 1 vapor retarders on the interior side of vapor permeable insulation in exterior walls. (WMS 1.6 and 4.3)
- The home will be fully flashed: all windows and door openings, " kick-out flashing" at the low end of roof to wall penetration by using step flashing
- Direct all roof water away from the house using gutters and downspout system (WMS 3.2)

Pests

- Scott Home will be air tight sealed to keep out insects and pest.
- No crawl space
- Less than .5 air changers per hour which makes the home air tight.
- Screens on all doors and windows
- Seal all penetrations and joints between the foundation and exterior wall assemblies.
- Provide corrosion-proof rodent/bird screens for all building openings that cannot be fully sealed and caulked.

HVAC System

- Co2 Occupancy Sensor (ERV)
- Filtered Air Energy Recovered
- Air exchanger running 24/7
- The HVAC system is equipped with additional control to operate in dehumidification mode.
- Minimize room pressure for any bedroom that doesn't have a dedicated return (HVAC 2.8)
- The outdoor air inlets are located a minimum of 10ft. from contaminant sources (HVAC 7.1)
- The Scott home provides mechanical whole – house ventilation meeting all requirements of ASHRAE 62.2-2010 (HVAC-C 1)

Combustion Pollutants

- The home doesn't have any fuel burning appliances so it is exempt.
- The Scott Home has carbon monoxide detectors installed on each floor to ensure the safety of all occupants.

Building Materials

- In the design of the home we choose to go with Low VOC materials because of their indoor air quality concern, and negative toxic pollutants.
- Downstairs of the home is majorially concrete.
- The home was installed with moisture- resistant backing material behind tub and shower enclosures (WMS 4.2)

Home Commissioning

- The Scott home will inspect air – handling equipment and verify that heat exchangers/ coils are free of dust from construction debris.

Indoor Air Quality Design Approach

General performance goals

ASHRAE 90.1, 62.1, 62.2, 2010

- Calculated Req'd. CONSTANT ventilation by both methods
- Total Enclosed Floor Area
    - (Interior Space Area / 100) + 7.5 (# Bedroom + 1) = CFM Req'd
    - (1459.2 ft^2 / 100) + 7.5 (3+1) = 44.6 CFM
- Building Area Square Footage
    - (Building Area / 100) + 7.5 (# Bedroom + 1) = CFM Req'd
    - (1644 ft^2 / 100) + 7.5 (3 + 1) = 46.4 CFM

  Chose Method B for variable occupancy at constant load

  Available spare capacity with ERV (62.2 2013 higher ventilation rates)

Specific conditions

- Climate is mild and semi-humid, allowing selection of ERV or ERV
    - Chose ERV to minimize humidity loss during heating season.

Indoor Air Quality Environment Detail

Pollutants

- Two ERV system isolates problematic areas (Bath, Kitchen, Laundry) to exhaust undesirable air

Moisture Control

- VRV mini-split HP with Dehumidification mode
- Next best option to completely decoupled dehumidification

Use of/ Reliance on mechanic systems

- (2) Energy Recovery Ventilators (VENTILATION)
- (1) Dual-Circuit 19.5 SEER/ 9 HSPF Air-Source Mini Split Heat Pump Inverter Driven (Heat/Cool/Dehum)
- (2) 9,000 BTU Wall-Mount Cassette (Heat/Cool/Dehum)

References to Building Science supporting decisions

- ASHRAE standards
  - 90.1 IAQ
  - 62.2 Ventilation
- AirPLUS Evaluations Compliance Pathway

Moisture Control

- Site and Foundation
  - EXEMPT (Slab on Grade)
- Capillary Break installation
  - Polystyrene insulation beneath slab. Sheeting in direct contact with slab (WMS 1.3)
  - ADDITIONAL REQ
    - Under the polyethylene sheeting or extruded polystyrene (XPS) insulation installed to meet ENERGY STAR Water Management System Builder Checklist Item 1.3:
      - 4in. uniform layer of 1/2in. diameter or greater clean aggregate
- Damp-Proofing
  - Finish all wood framed walls with polyethylene and adhesive or equivalent waterproofing (WMS 1.5)
- Basement and Crawlspace insulation and conditioned air
  - EXEMPT (Slab on Grade)
- Drainage Plane and Drainage System
  - Continuous Drainage plane behind exterior wall cladding; overlaps flashing and is fully sealed at all penetrations (WMS 2.2)
  - Flashing or equivalent drainage system at bottom of exterior walls directs water away from drainage plane and foundation (WMS 2.1)
- Windows and door openings
  - Fully flash all windows, and door openings including: flashing over rough sill frames; side flashing that extends over pan flashing; and top flashing that extends over side flashing. (WMS 2.3)
- Gutters, downspout, site drainage
  - Direct roof water away from the house using gutters, downspouts that empty into lateral piping on a sloping finish grade (WMS 3.2)

- Roof to Wall Intersections and Roof Penetrations
  - Install “kick-out” flashing at the low end of the roof-to-wall intersections (WMS 3.1)

- Roof Valleys and Decking
    - Install a self-sealing bituminous membrane or equivalent at all valleys and roof decking penetrations for durability at potential failure points (WMS 3.3)
- Roof Eaves
    - Install ice flashing over the sheathing at eaves to provide protection from ice dams (WMS 3.4)
- Moisture-Resistant Materials and Moisture-Protective Systems
    - Install moisture-resistant backing material behind tub and shower enclosures (WMS 4.2)
    - Install a corrosion-resistant drain pain properly draining to a conspicuous point of disposal (HVAC-R 12.1)
    - Additional Requirements
        - Install only water-resistant hard-surface flooring in kitchens, bathrooms, entryways, laundry areas and utility rooms
        - Insulate water supply pipes in exterior walls with pipe wrap
- Class 1 Vapor Retarders
    - EXEMPT (Slab on Grade)

- Materials with Signs of Water Damage or Mold
    - Building materials with visible signs of water damage or mold are not to be installed or allowed to remain. If mold is present, effort should be made to remove all visible signs (e.g., by damp wipe with water and detergent). If removal methods are not effective then the material shall be replaced. However, stains that remain after damp wipe are acceptable. Lumber with "sap stain fungi" is except from this item as long as lumber is structurally intact. (WMS 4.4)
    - DO NOT enclose (e.g., with drywall) framing members and insulation products having high moisture content. (Note: Lumber should not exceed 18 percent moisture (WMS 4.5)
    - Wet application insulation, follow manufacturers drying recommendations (WMS 4.5)
- Radon Zones
    - Radon-Resistant Construction
    - Passive Slab Perimeter Vent
- Pest Control features
    - All penetrations and joints between the foundation and exterior wall assemblies (TES 5)
    - Provide corrosion-proof rodent/bird screens (e.g., copper or stainless steel mesh) for all building openings that cannot be fully sealed and caulked (e.g., ventilation system intake/exhaust outlets and attic vent openings). EXCLUDING: clothes dryer vents
    - NOTE: When sealing gaps that provide potential points for entry for rodents, copper or stainless steel wool is recommended in addition to sealant.

- HVAC Systems
  - HVAC Sizing and Design
    - Manual J8 Block Load @ Peak {7,400 BTUH Cooling; 8,800 BTUH heating}
    - Selection for non-ducted separate space conditioning
      *(100% capacity available at each conditioning location for seasonal offset. Upstairs unit runs the most during cooling, while the downstairs runs more during heating.)
  - Duct System Design and Installation
    - Room exhaust <= 700 FPM Velocity @ 100% ERV
    - Room Supplies <=700 FPM Velocity @ 100% ERV
  - Location of Air-Handling Equipment and Ductwork
    - ERV in mechanical closet under stairs
    - One apiece 9,000 BTU mini-split cassette head upstairs and downstairs
    - Duct runs in first floor ceiling (14" open web truss system) shortest path
  - Room Pressure Differentials
    - Bedrooms are vented to the hallway to maintain <3pa across doorways, bedrooms are kept in negative pressure, drawing conditioned first air
  - Mechanical Whole-House Ventilation
    - Hybrid constant ventilation.
    - Sized based on ASHRAE 62.2 @ 46 CFM constant ventilation (whole house ERV)
    - Waste ERV sized to deal with problem areas Activates on Occupancy/Use (Bathroom/Kitchen Vent)
    - Ventilation Controls for High-Occupancy (ASHRAE 90.1)
      - Independent CO_2 Demand Control (Hi-Lo offset)
        - Whole House ERV set at 850ppm CO_2
        - Waste ERV set at 800ppm CO_2
    - Economization Cooling
      - Economizer controller determines acceptable economization conditions (double air temperature, double enthalpy: (MAT AND OAT) AND (MAE AND OAE)). On acceptable conditions and Enable, make ECON contact on ERV.
      - BONUS: Over Ventilation of humid OA protection
  - Local Exhaust for Known Pollutant Sources
    - Kitchen hood exhaust makes Boost contact on Waste ERV, minimizing the impact on the whole-house ERV maintaining positive pressure
  - Filtration for Central Forced-Air HVAC Systems
    - Each mini-split indoor unit has cleanable filters
- Combustion Pollutant Control
  - Combustion Equipment Located in Conditioned Spaces
    - N/A
  - Carbon Monoxide Alarms
    - Specified 1 per floor

- Multi-Family Environmental Tobacco Smoke Protections
  - Air sealing between units
- Attached Garages
  - N/A

- Low-Emission Materials
  - Composite Wood
    - Specified high quality low VOC woods
  - Interior Paints and Finishes
    - Specified low VOC paints and finishes where applicable
  - Carpets and Carpet Adhesives
    - Specified all low VOC carpet and building adhesives
- Home Commissioning
  - HVAC and Ductwork Verification
    - Air leakage and operational checkout
  - Ventilation after Material Installation
    - Balance whole-house ERV to ventilation CFM
  - Buyer Information Kit
    - Homeowner House manual Operation and Maintenance

Pennsylvania College of Technology
PENNSTATE

SPACE CONDITIONING

Systems Approach & Performance Objectives

Relative to structure and climate

- Design principles
  - Latent design: 40-50% RH
  - Sensible design: 68/72°F Heat/Cool
  - ASHRAE 62.2 continuous ventilation calculated @ 46.44 CFM 2010 sub/80CFM 2013
  - Intermittent high pollution

Proposed operation and control

- Whole House ERV will run continuously at minimum airflow 47 CFM/80
  - Differential pressure accessory allows responsive control to changing static pressure conditions, to help maintain positive pressure in the house
  - CO_2 sensor maintains house below programmed CO_2 threshold (occupancy based ventilation modulation per ASHRAE 90.1)
  - Dehumidistat with OA lockout (HI OAH) maintain humidity levels in the home
  - Occupant fan speed control allows manual speed control and ON/OFF. EconoCool night cooling mode interlocks with the OA (HI OAH) lockout providing night cooling during acceptable conditions (Cool below heat pump night setback range)

- Waste ERV
  - Assists maintaining house pressure during depressurization events (Venting)
  - Replaces bathroom fans, which (during depressurization mock-ups exhaust CFM exceeded the ability of our ERV to maintain positive pressure. To mitigate this we decoupled the areas by using balanced exchange venting with a dedicated waste are ERV)
  - ERV operates on continuously in an exhaust zone
    - Upstairs bathroom (Occupancy + 10min) EXH 20 CFM
    - Downstairs bathroom (Occupancy + 10min) EXH 20 CFM
    - Kitchen (Exhaust Hood use) EXH 100 CFM
    - Kitchen (Programmable CO_2 sensor @ 800 PPM) (Occupancy based ventilation modulation per ASHRAE 90.1)
- Mini-Split Heat Pump (air-source) will run to maintain
  - Central Control
    - Heads are programmed for desired conditions
    - Optional central control center can control both heads simultaneously
  - Downstairs Heating (Programmed @ head)
    - 68°F Sensible Temperature
    - 40-50% Humidity
  - Upstairs Cooling (Programmed @ head)
    - 72°F Sensible temperature

        - 40-50% Humidity
        - Night set-back to facilitate nighttime economization via ERV
- Thermal conditioning by space type
    - The bedrooms through virtue of being the main exhaust points, are constantly pulling conditioned space air to them
    - The common areas are both supplied with first use outdoor air, and are also first use conditioned

Design Operation Goals

Equipment Selection

- Equipment was selected with limitations in small-sizing, a compromise was reached by specifying one unit for heat and one for cooling. The upstairs unit is set for cooling modes, while the downstairs unit is mainly heating. This selection has a few benefits
    - There is 100% redundancy between indoor units (if one fails, conditioning is achievable)
    - A head positioned at the top of the building is valorized by merit of expanded, humid air rises, making it the most appropriate point to condition the most appropriate air
    - A head positioned on the first floor in the open floor area is valorized by merit of cold dense air falling to the bottom of the structure, making it the most appropriate point to condition the most appropriate air

  WarmFlo1 1kW booster heater facilitates ERV usage below 10°F.

Integration

- The Waste ERV is integrated with the kitchen hood, making the ERV responsive to usage of the exhausting device
- The Waste ERV turns on with the Bathroom lights, and hold on ten minutes after the light is shut off

Operation/Control

- Maintain POS static pressure with Pressure Controller.
- Maintain comfort conditioning within 4°F (+/-2°F @ the thermostat)of desired as per ACCA occupant comfort with built in thermostats
- CO2 programmable sensor for occupancy based ventilation modulation.
- Occupancy relay in each bathroom is activated when the light is ON and is OFF-Delayed ten minutes past the light OFF
- Dehumidistat in the upstairs bathroom controls high humidity events in case the occupancy sensing
- Economizer controller to utilize comparative temperate and enthalpy between indoor and outdoor air, OK to economize if conditions met for night cooling with ERV

Evaluation of fuel selection option

- Electricity – 100% EFF
- Heat Pump – 300% EFF

System Design Supporting Documentation

Load calculation

- Our home has only ventilation duct work, room by room energy transfer is accomplished by pressurization. (appendix E ERV Ducting Strategy) Due to this, room by room heat/cooling loads are largely irrelevant. Non bridging continuous insulation creates extremely homogenous walls thermally.
- We chose a method of ducting with the ERV to pressurize the main areas and exhaust from the bedrooms. This is a transformation of the more classical example of exhausting from the polluting areas and supplying fresh air to the bedrooms. The classic model suffers from night-time conditioning issues in the bed rooms as the positive pressure from within prevents conditioned air from reaching the areas. This necessitates either room by room (heat) supply, or a redesign of the air flow in the house.

Commissioning Requirements

Initial Commission

- On envelope and window/door completion
  - Blower door testing @ 50 Pa for envelope air tightness verification
- At material installation of equipment
  - Whole-house ERV set to minimum continuous air flow
  - All accessories for each ERV are set and checked for installation/specification compliance
  - Function check of all accessory controls

Maintenance Requirement

Occupant responsibility

- Filter change of waste ERV exhausts (kitchen, both bathrooms)
- Check/clean ERV core every 6 mo.
- Check/clean mini-split cassette filters

Trade responsibility

  - Bi-annual system check-out on heat pump per manufacturer specifications
  - Annual check-out of ERVs per manufacturer specifications
  - Verify

Pennsylvania College of Technology

PENNSTATE

ENERGY ANALYSIS

Design Approach to Energy Efficiency

The house is composed of many energy efficient building techniques. Primarily we use the sun as the main source of heat for the building allowing for many windows facing the south side, while the building is well insulated to keep the heat gained in the house. The building is designed to also use an ERV to transfer heat from air leaving the house to air entering the house. There is also a large amount of energy conservation from the wall systems. Our super sealed super insulated walls keep the residents comfortable throughout both winter and summer.

Design/Construction Constraints & Challenges

The building occupancy is a challenge that we had to overcome because the building we are creating is to be home to two separate four person families. The size of the plot that we were given with, and the budget that we are confined to makes it so that the smallest squarest building is the most functional kind. The building was put together in a fashion that maximizes usable space while keeping favorable amenities to allow the building stay usable throughout the owners' entire life.

Photovoltaic HERS Ratings: For complete HERS Ratings see Appendix F.1: HERS Ratings

Home Energy Rating Certificate

1608 Scott Street
Williamsport , PA 17701

5 Stars Plus
HERS Index: 29

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

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	6%
Hot Water	11.0	$257	45%
Lights/Appliances	17.2	$404	71%
Photovoltaics	-9.4	$-221	-39%
Service Charges		$60	11%
Total	**21.6**	**$566**	**100%**

Criteria

This home meets or exceeds the minimum criteria for the following:

TITLE
Company
Address
City, State, Zip
Phone #
Fax #

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.

House Size Adjustment

Bench mark home 2 = 1,600 sq. ft.

Built home = 1,680 sq. ft.

Size factor = (1,600sq ft. /1,680sq ft.) .95

Complete HERS Rating: For complete HERS Ratings see Appendix F.1: HERS Ratings

Home Energy Rating Certificate

1608 Scott Street
Williamsport , PA 17701

5 Stars Plus
HERS Index: 20

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

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

Estimated Annual Energy Cost

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:

TITLE
Company
Address
City, State, Zip
Phone #
Fax #

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

The Home Energy Rating Standard Disclosure for this home is available from the rating provider.

Renewable Energy Systems Tradeoffs & Modifications

The way that we designed the Scott Free House to achieve a zero net energy use from all nonrenewable energy sources by installing passive systems including extra thick walls with an R value of SIP panels to keep in all the heat that is generated for our building. We have installed an ERV heat exchanger to pre heat the air before it enters the system. We have also inserted details to show a super sealed and insulated building.

Technology Options for Region and Climate

The Scott House uses passive systems to lower most of its energy use. Large south facing windows allow for maximum daylighting, while the first floor slab absorbs that light to help heat the home during the winter. Tilt & Turn windows allow for maximum sealing and airflow when opened. There is an ERV system that transfers both moisture and heat from the stale interior air into the fresh incoming air. The home is designed with high R value walls, roof, and slab. The surrounding buildings do not impede on any of the light coming to the house, making the roof a great place to put photovoltaics onto the home.

Renewable Energy Systems

The renewable systems we have added to our house sit on the south face of the roof allowing for maximum daylight collection and can be fit with the DWH on the same roof.

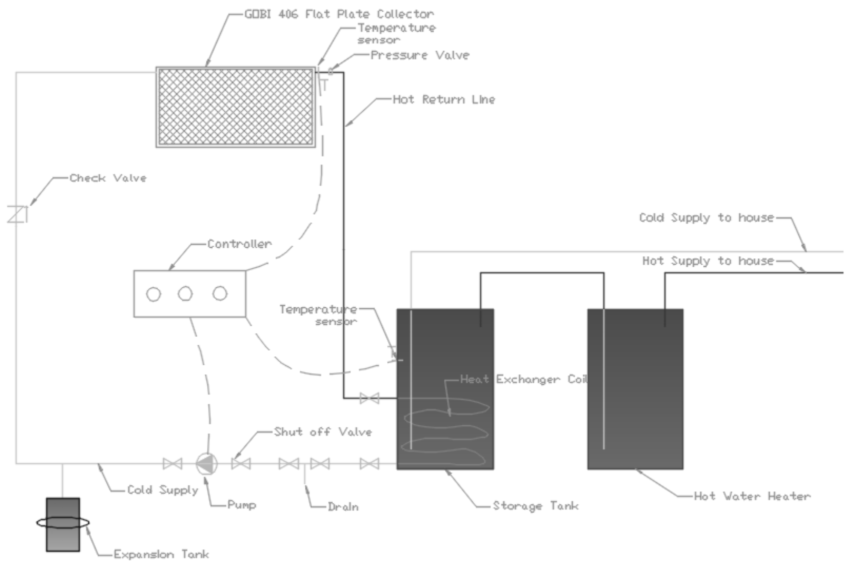
Renewable Design Considerations Details

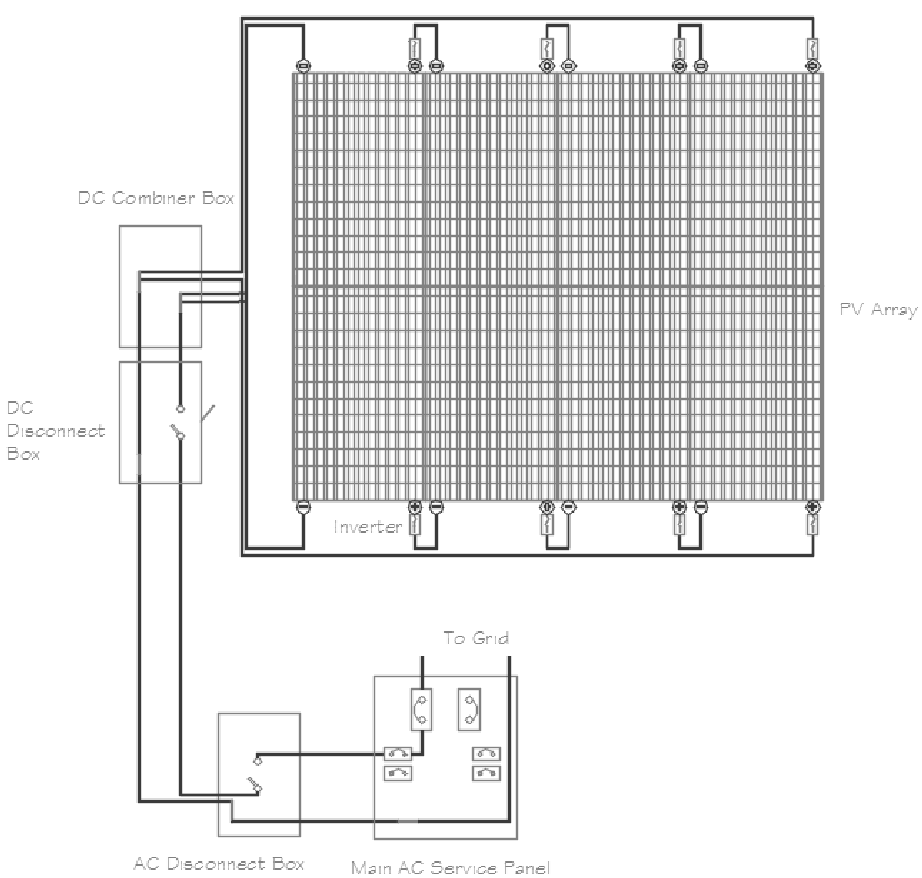
We have a roof truss system capable of holding all of our photovoltaics, and solar DWH panels. The house floor area is only 1,654 and there is an allowable roof area of 342sqft while keeping a 3ft walkway in case of emergencies, for all of our renewable systems. In total 128.7sqft is needed for the photovoltaics, while 48sqft is needed for the solar DWH system. This leaves more area for if the owner wishes to add any more photovoltaics to the home.

Renewable Ready Home Details

The Scott house will be built with a solar DWH system, the system can be a drain-back or closed-loop system and a photovoltaics system already setup. The photovoltaics system can have more panels added onto the system after construction to increase the savings for the family. All construction will meet the RERH standards and is ready for any photovoltaics added. There will be a 4" capped chase to the attic where the photovoltaics will be added, while 1" conduits will be added to the DC wire run. Mini micro inverters will be added with the solar panels canceling the need for a 4ft by 4ft plywood panel for the space.

Solar Thermal System (Top) & PV Systems (Bottom)





Active Renewable Energy Design & Component Analysis

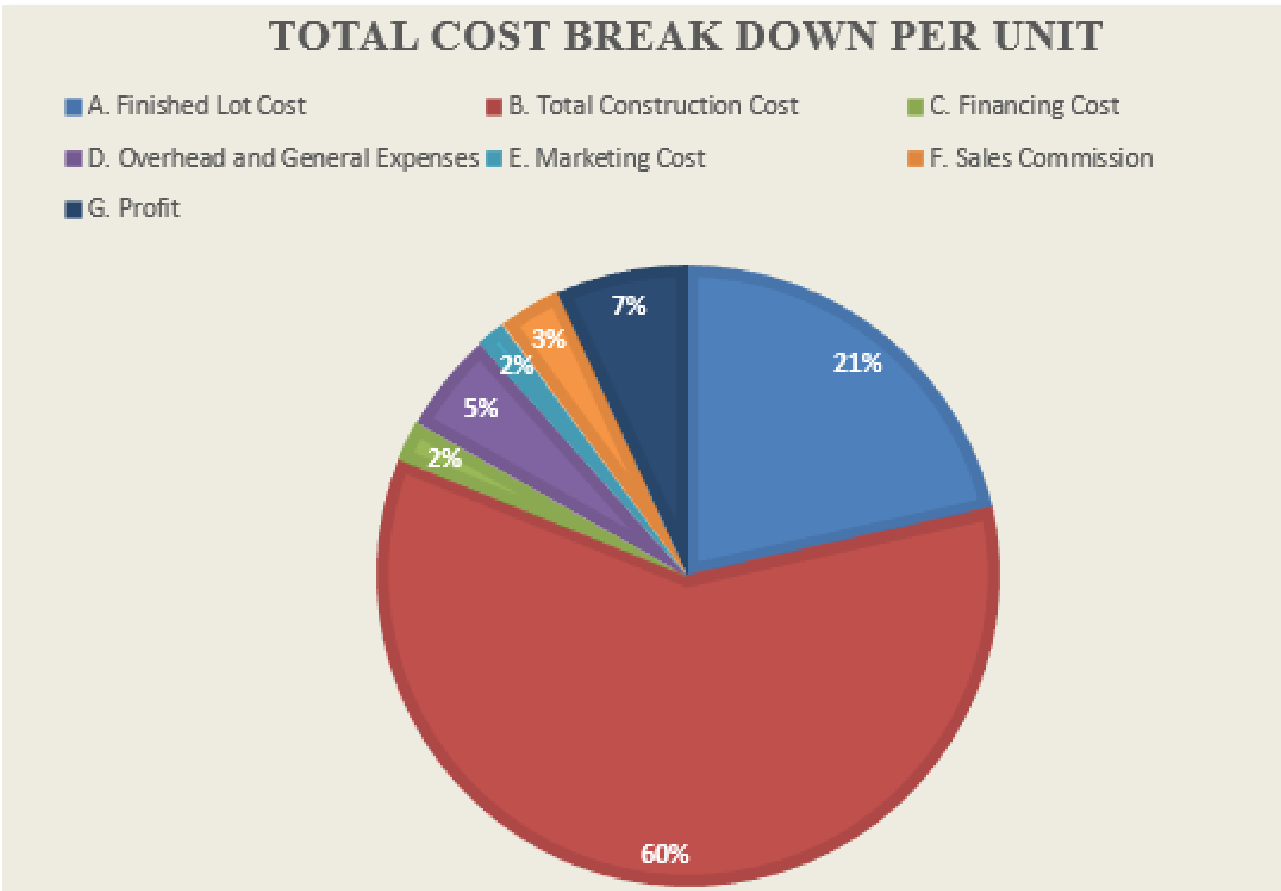
The Scott House is designed to use a Heliodyne Gobi 406, Blue Sputter, an indirect liquid solar hot water system on the roof that connects to our 80 gallon hot water heater. The roof is also designed to carry Astronergy 260 W PolyCrystaline each with their own Enphase Micro Inverter, allowing a low income family like the one we are working with to purchase their photovoltaics in smaller bunches, instead all at once in bulk. The use of micro inverters also make it easier to replace single older panels instead of the whole system.

Energy Production & Cost Estimates

The photovoltaic costs calculate the energy made and the money saved to show a payback period of about 9 years. The total costs for the system is $4,011.26 including labor. The total calculations can be seen in the Appendix G.3: Renewable Energies

FINANCIAL ANALYSIS

Financial Analysis of Siting & Constructing the DOE Zero Energy Ready Home: See Appendix G.1 Detailed Cost Breakdown



Financial Analysis of Cost and Affordability

At a first look, the D.O.E. Race to Zero Design Competition has a "Speculative design" approach with the house specified to a regional median family income rather than to a specific budget. However, our project was partnered with Habitat for Humanity with a 20%-50% decrease of the median family income. Since Habitat for Humanity is sponsoring this home to be built many of these costs such as labor and materials are reduced.

Items Deducted:

- All Labor costs except: HVAC, Insulation, and Excavation costs & installation
- Materials were reduced by 15% due to Lowes's Restore Program
- Lot costs were reduced to $1.00 via the Brodart Neighborhood Improvement Plan
- Financing costs are eliminated due to Habitat For Humanity using their in house payment options for selected clients
- Marketing and Sales costs are eliminated by having no need for real estate agent market and sell the home
- Profit is eliminated because Habitat For Humanity is a Non-Profit organization

This analysis shows a breakdown of total costs which satisfies a Williamsport "MFI," and meets the competition requirements. In addition, 3 optional cost breakdowns are provided for Habitat For Humanity costs.

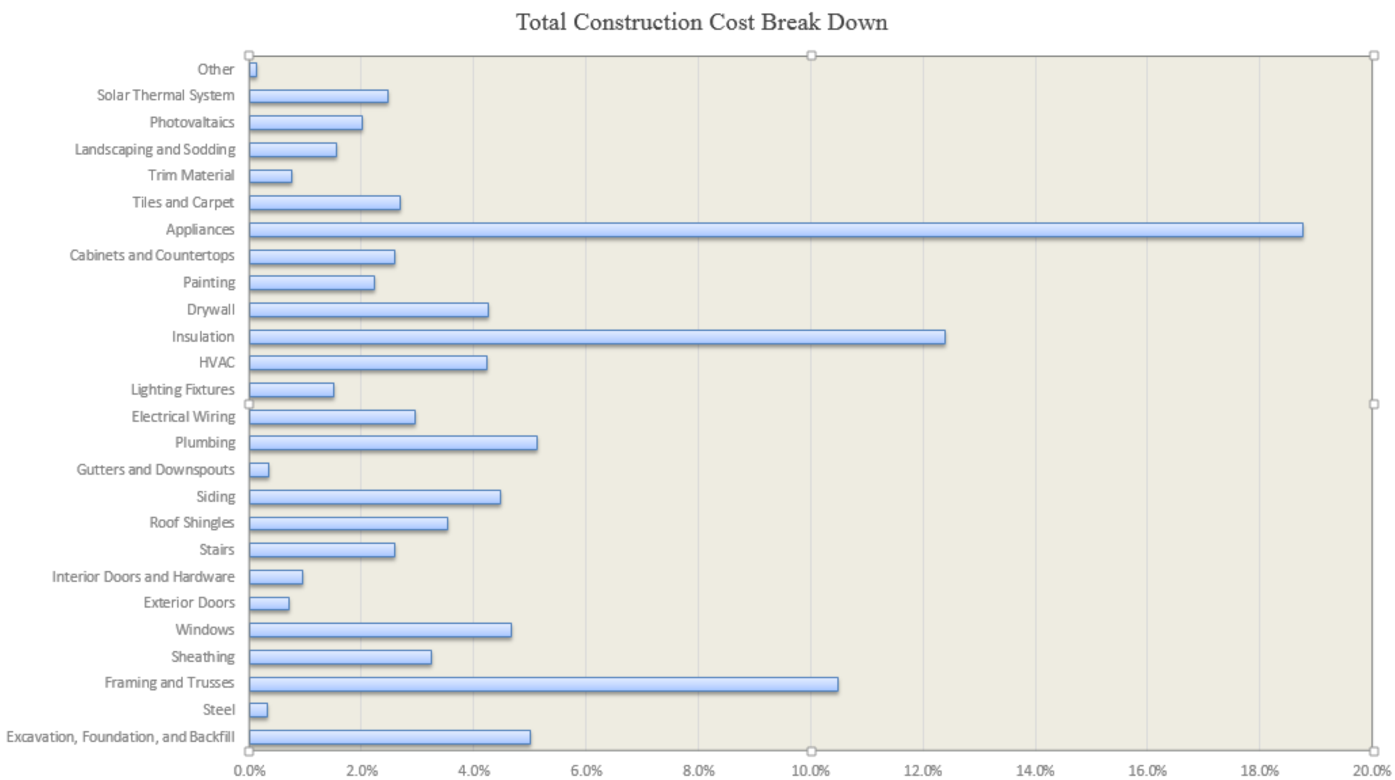
Final Cost of design Options Calculations:

- 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

Pennsylvania College of Technology
PENNSTATE

Construction Cost Break Down: See Appendix G.1 Detailed Cost Breakdown & Appendix G.2: Detailed Assembly Breakdown

Renewable Incentives



- Photovoltaic: See Appendix G.3: Renewable Energies
  - Federal Energy Tax Credit: 30% prepaid taxes of total cost of Photovoltaic system, which is 1203.38
  - Sustainable Renewable Energy Credit, a payback program, equaling $0.06 per kilowatt hour. The specified system is can save $17.93 per year on the maximum heating demand of a Passive House.
  - Payback period with Incentives is 9.2 years
- Solar Thermal Energy Savings: See Appendix G.3: Renewable Energies
  - $Saves 330.87 per year
  - Payback period is 14.6 years

Pennsylvania College of Technology
PENNSTATE

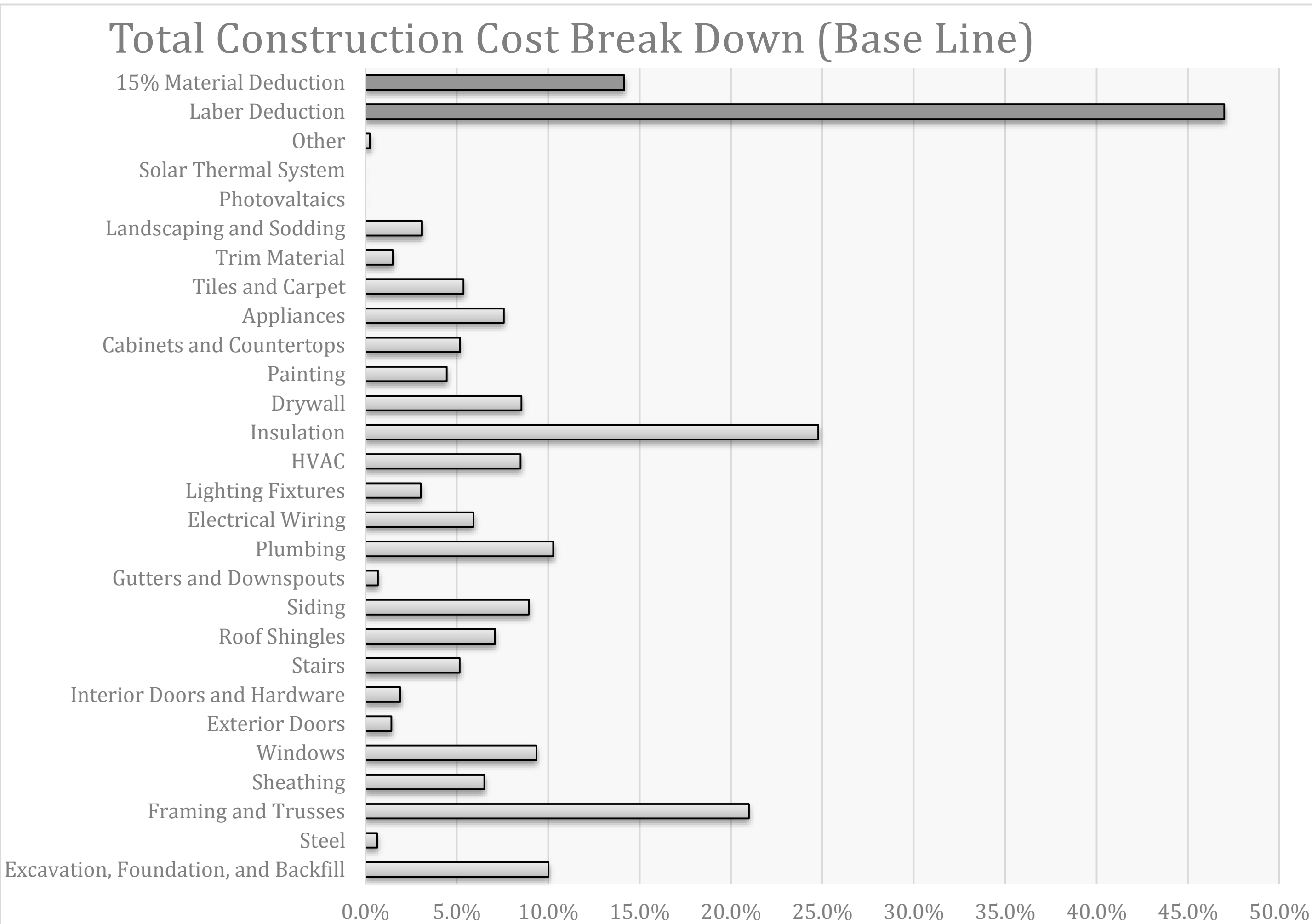
Market Value

See Appendix G.4: Market Value Breakdown & G.5: Utilities Cost

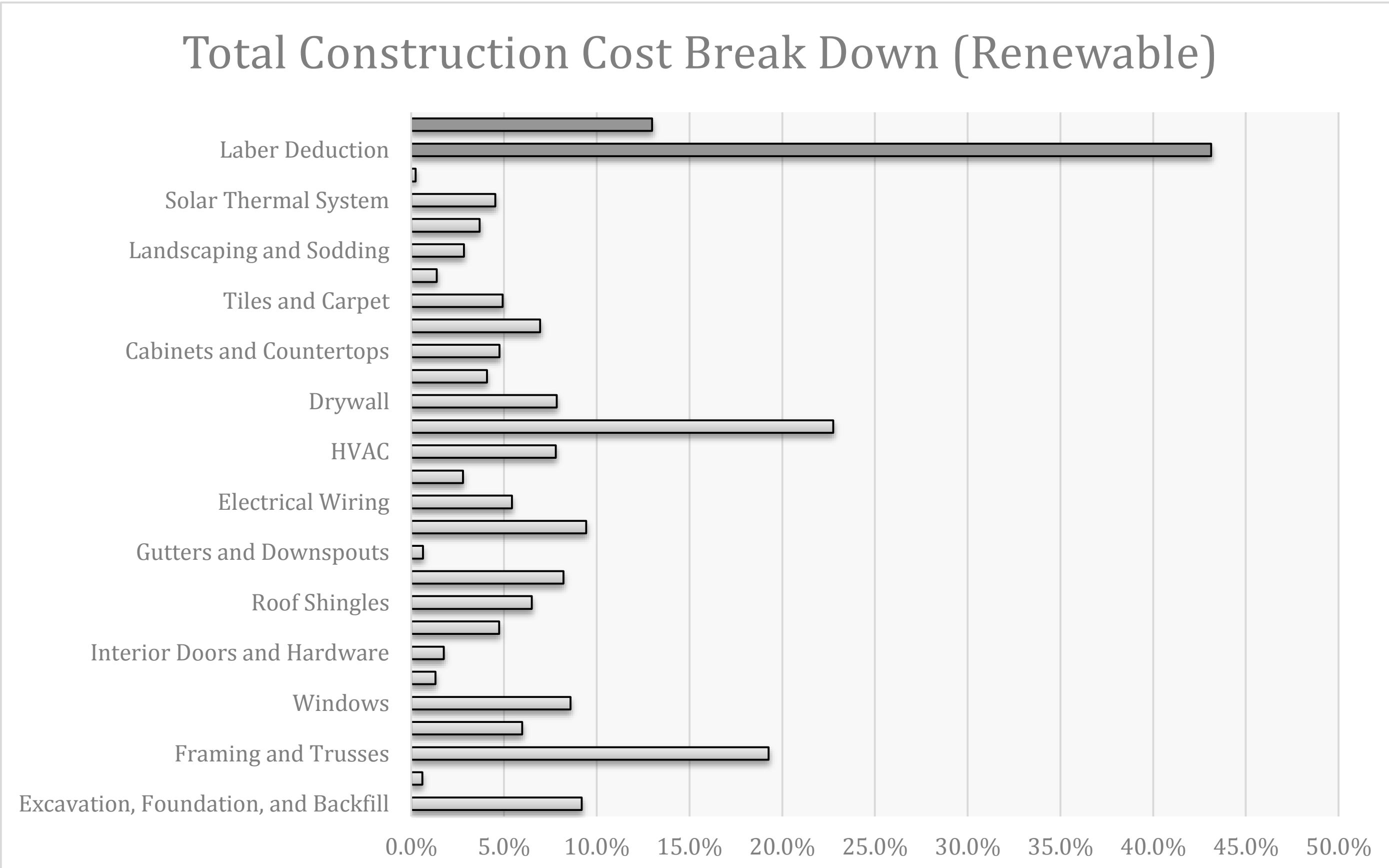
The calculated market value is $246,379.21. This cost includes direct costs, and non-construction cost. The projected annual household to income ratio base on the direct and non-construction cost is $43,703.25. This requirement is a 22.5% deduction of the Median Family Income for Williamsport, PA.

Habitat for Humanity Affordability Breakdown

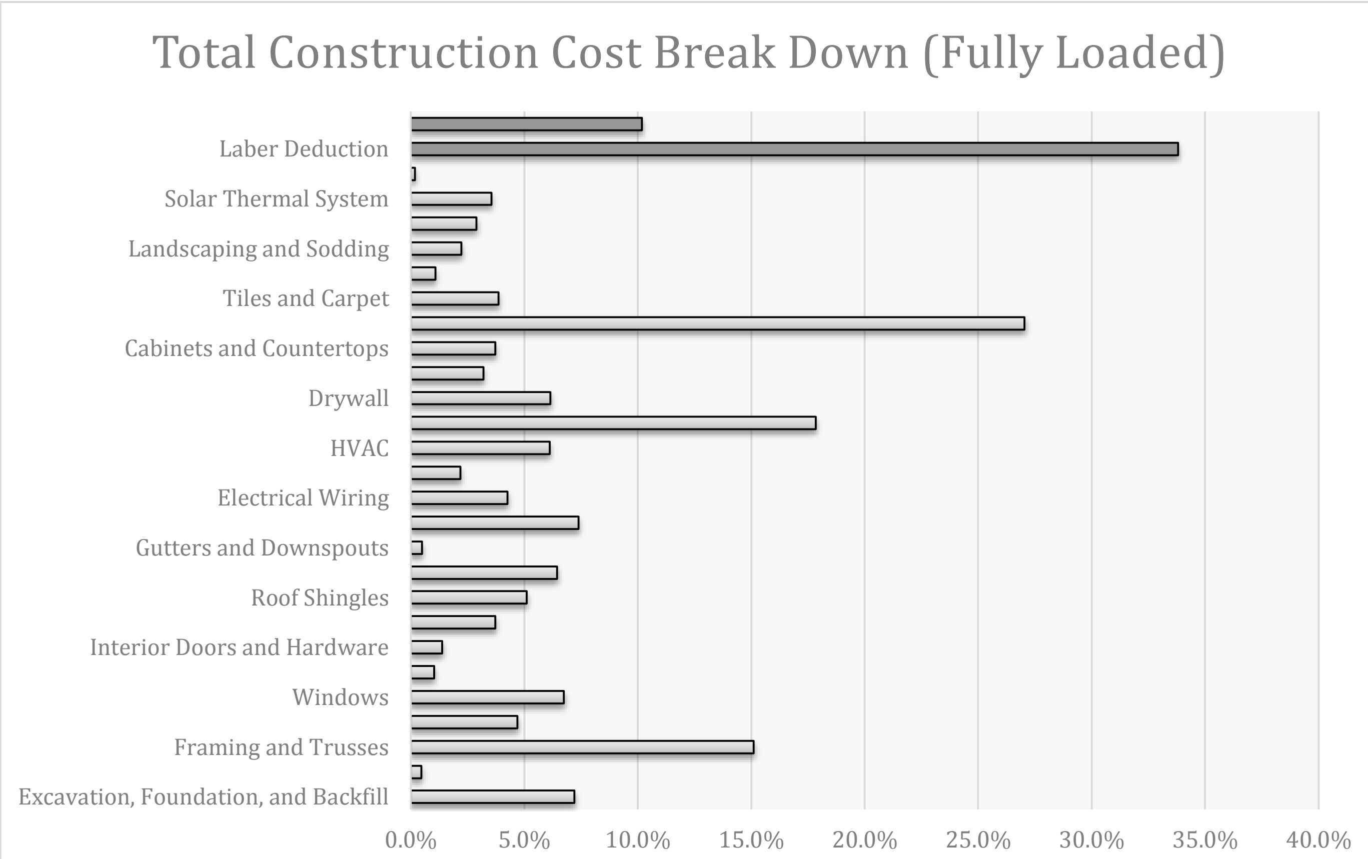
- Baseline Cost Breakdown: This breakdown is renewable ready and future ADA accessible. See Appendix G.6: Baseline Breakdown



- Renewable Cost Breakdown: This breakdown is with renewable and future ADA accessible. See Appendix G.7: Renewables Cost Breakdown



- Fully loaded Cost Breakdown: This breakdown is with renewable and ADA accessible. See Appendix G.8: Fully Loaded Breakdown



DHW, LIGHTING, APPLIANCES

DOMESTIC HOT WATER

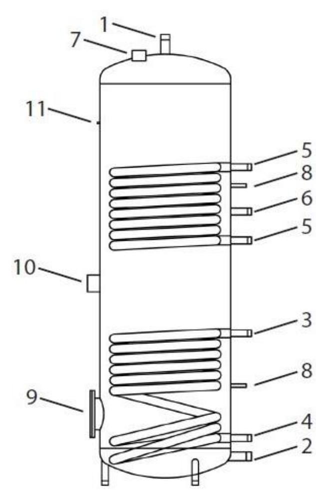
Domestic Hot Water Strategy

Our domestic hot water approach was to take advantage of the building's southern exposure by utilizing a solar hot water system. By using a solar hot water system we are lowering the amount of energy that would need to be used with a conventional hot water heater.

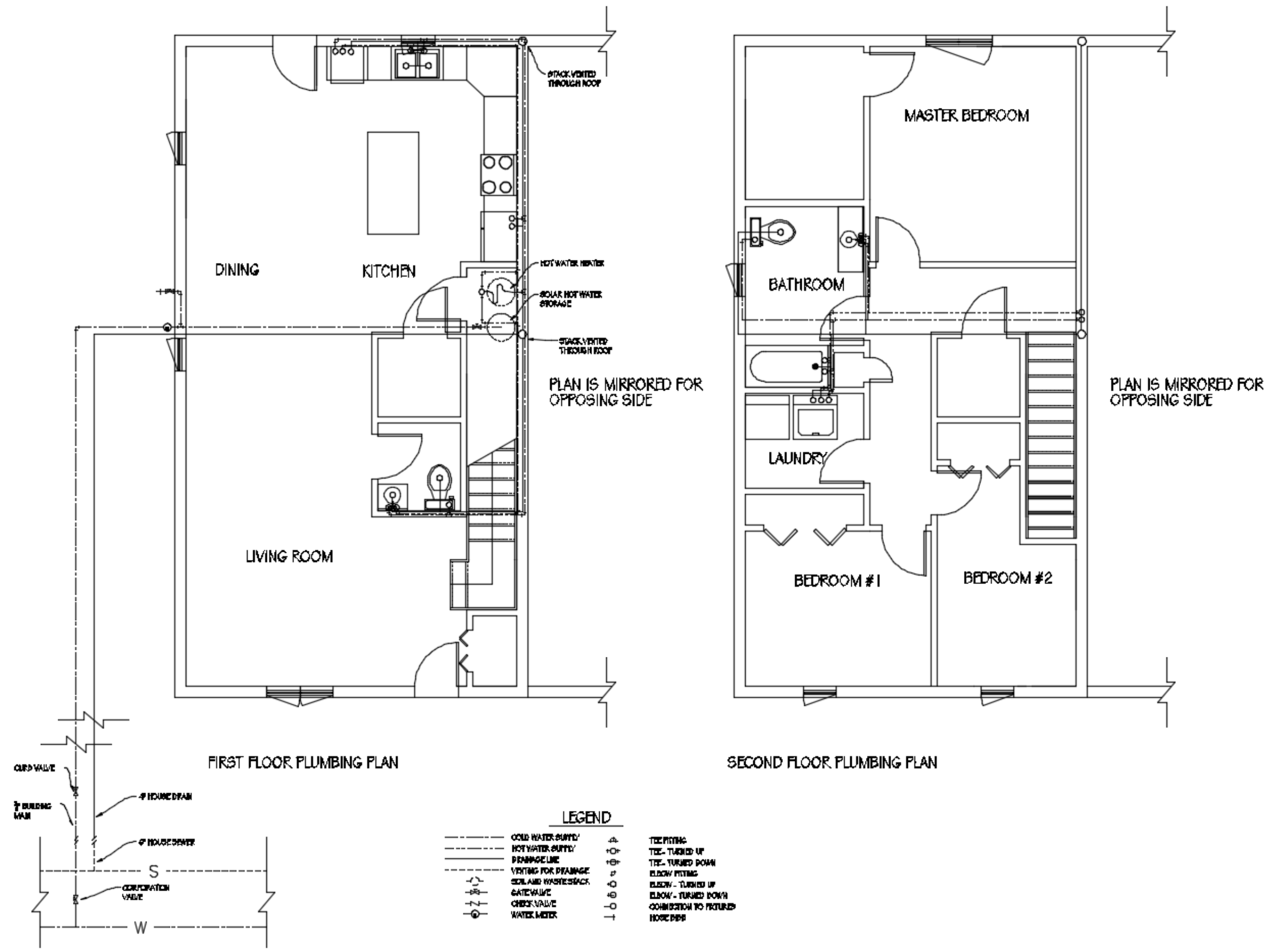
A flat plate solar collector will be placed at the center of the southern side of the duplex gable roof of each home. The piping will run from the solar collectors, north to the tip of the gable roof and then fed down through a chase that is inside the median wall of the two homes. The pipe will then go into the second floor system and come down through the mechanical room and into the hot water storage tank. The piping will run 30 feet straight down and will need an additional 15 feet to run to the most conveniently placed plumbing chase. In Appendix H.1 you can find the Closed Loop System and for the Plumbing Plan refer to Appendix I: Construction Documents.

System Features	Description
Flat Plate Collector	GOBI 406 001
Solar Storage Tank	Tank, Sun Earth W/1 Wall Heat Exchr 80 Gal Elec
Pump/Fill Station	Pump Grundfos UPS15-58FC/LC

1. Hot Water Outlet
2. Cold Water Inlet
3. Solar Supply
4. Solar Return
5. Auxiliary Coil Port
6. Recirculation Port
7. Magnesium Anode
8. Temp Sensor Well
9. Cleaning Flange
10. Electric Heating Elements
11. Thermometer (optional)



Plumbing Layout



Pennsylvania College of Technology
PENNSTATE

Water Demand

To find the water demand for one side of the duplex we first collected the number of total water fixtures that would be used in the home. Then we tallied the number of fixture units based on all the fixtures.

Total Water Supply Fixture Units	
Fixture:	W.S.F.U.
1 Bathtub (@ 2 W.S.F.U. each)	2
2 Lavatory Sinks (@ 1 W.S.F.U. each)	2
1 Shower Head	2
2 Water closets w/ Flush Tank (@ 3 W.S.F.U. each)	6
1 Kitchen Sink	2
1 Dishwasher	1
1 Hose Bibbs (@ 2.5 W.S.F.U. each)	2.5
1 Clothes Washer	2
Total	19.5

The total water supply fixture units tallied, we figured the gallons per minute (gpm) used throughout one side of the duplex. Using the algebraic equation below we found that the home would demand a 14 gallon per minute supply rate.

17/25(gpm) = x/19.5(gpm) I 25x = 331.5 I = 13.26
gallons per minute = 14

Hot Water Supply Fixture Units	
Fixture:	H.W.S.F.U.
1 Bathtub (@ 1.5 H.W.S.F.U. each)	1.5
2 Lavatory Sinks (@ .75 H.W.S.F.U. each)	1.5
1 Shower Head	1.5
1 Kitchen Sink	1.5
1 Dishwasher	1
1 Clothes Washer	1.5
Total	8.5

With the total hot water supply fixture units collected. Using the same algebraic equation, we found the hot water demand supply as 7 gallons per minute.

6.5/8(gpm) = x/8.5(gpm) I 8x = 55.25 I = 6.9
gallons per minute = 7

Water Usage and Cost Estimation of Williamsport Pa.

Average Family of Four Water Usage Per Quarter: 12,000 gallons

Average Quarterly Water Bill: $10.00

Cost per 1,000 gallons: $5.40

$5.40 x 12(gallons in thousands) x 3 (months) = $194.40

$194.40 + $10.00 = $204.40

The estimated quarterly cost for a family of four is $204.40

$204.40 / 3(months) = $68.13

The estimated monthly cost for a family of four is $69.00

DOE Mandatory Water Efficiency: 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

LIGHTING AND APPLIANCES

Lighting Strategy

Our lighting strategy involves practices of passive building orientation, strategic window placement, and the use of energy saving fixtures.

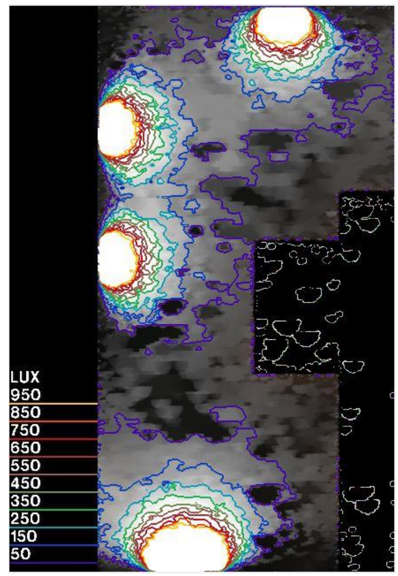
Our window placement follows rudimentary passive principles such as balancing the number of windows on an exterior wall as well as south facing windows to collect as much solar passive lighting as possible. The goal of this principle is to allow the occupants to save on lighting energy costs.

A challenge that we had to face with design was that with a duplex type home, the two houses share a median wall and this eliminates the ability to use natural lighting through the entire house. Another related issue we had to deal with was the fact that the home would have a longer orientation causing the inner parts of the home to depend on active lighting. Our team dealt with this concern by strategically placing the homes side windows farther toward the back of the home allowing as much natural light as possible deeper into interior sections. Due to the team's aim of passive design, we were limited to the number of window openings. To allow for balanced natural light and passive design requirements, we chose to focus the majority of our active lighting features in the inner parts of the interior of the home. This includes specific task lighting in the kitchen, as well as sufficient ceiling lighting in the second story corridor.

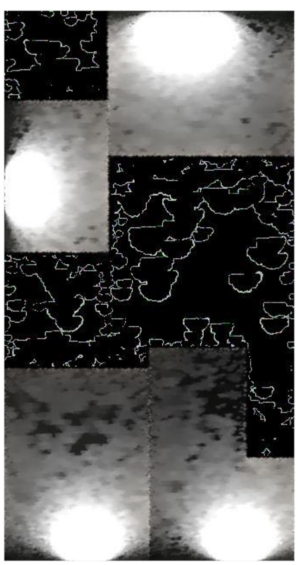
Daylighting Study

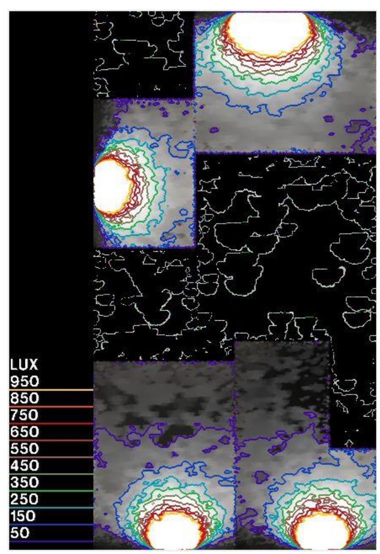
Our team was able to run a daylighting study in order to demonstrate our passive design. In the images we saw the amount of natural light the home receives, as well as which spaces will need active lighting. The study was run using the Williamsport location as well as the standard CIE overcast sky as if it were the 21st of September.

First Floor Daylighting



Second Floor Daylighting



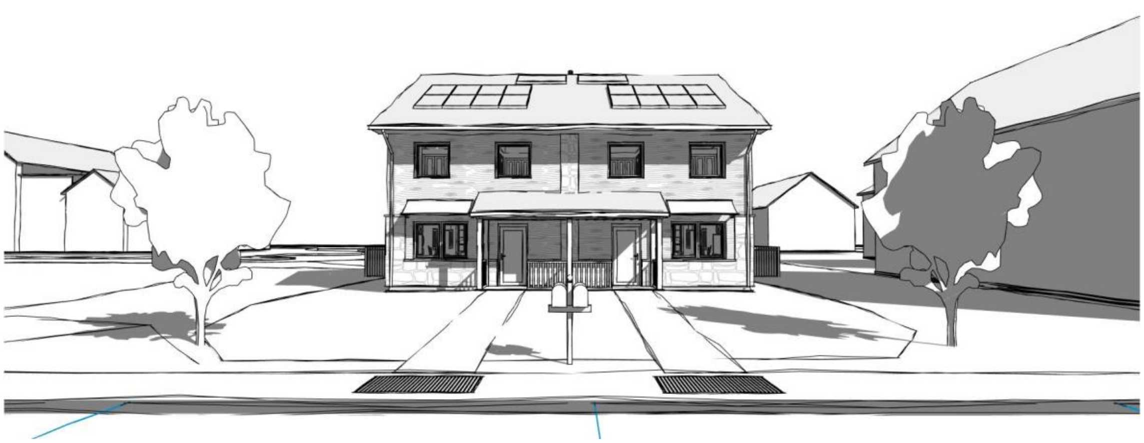


Lighting Comparison

Based on the information of the lighting comparison chart, we understand LED lighting to be the most suitable approach to have less environmental impact as well as overall cost effectiveness.

We have implemented all Energy Star LED fixtures and bulbs into our lighting design. By using LED lighting we will reduce the home's overall energy consumption, and make it more possible to reach Net-Zero due to a reducing the electrical load.

	LED	CFL	Incandescent
Light bulb projected lifespan	50,000 hours	10,000 hours	1,200 hours
Watts per bulb (equiv. 60 watts)	10	14	60
Cost per bulb	$35.95	$3.95	$1.25
KWh of electricity used over 50,000 hours	500	700	3000
Cost of electricity (@ 0.10per KWh)	$50	$70	$300
Bulbs needed for 50k hours of use	1	5	42
Equivalent 50k hours bulb expense	$35.95	$19.75	$52.50
Total cost for 50k hours	$85.75	$89.75	$352.50



Lighting Fixtures

Our lighting approach allows for the use of 90% ENERGY STAR fixtures as well as 100% ENERGY STAR approved LED bulbs.

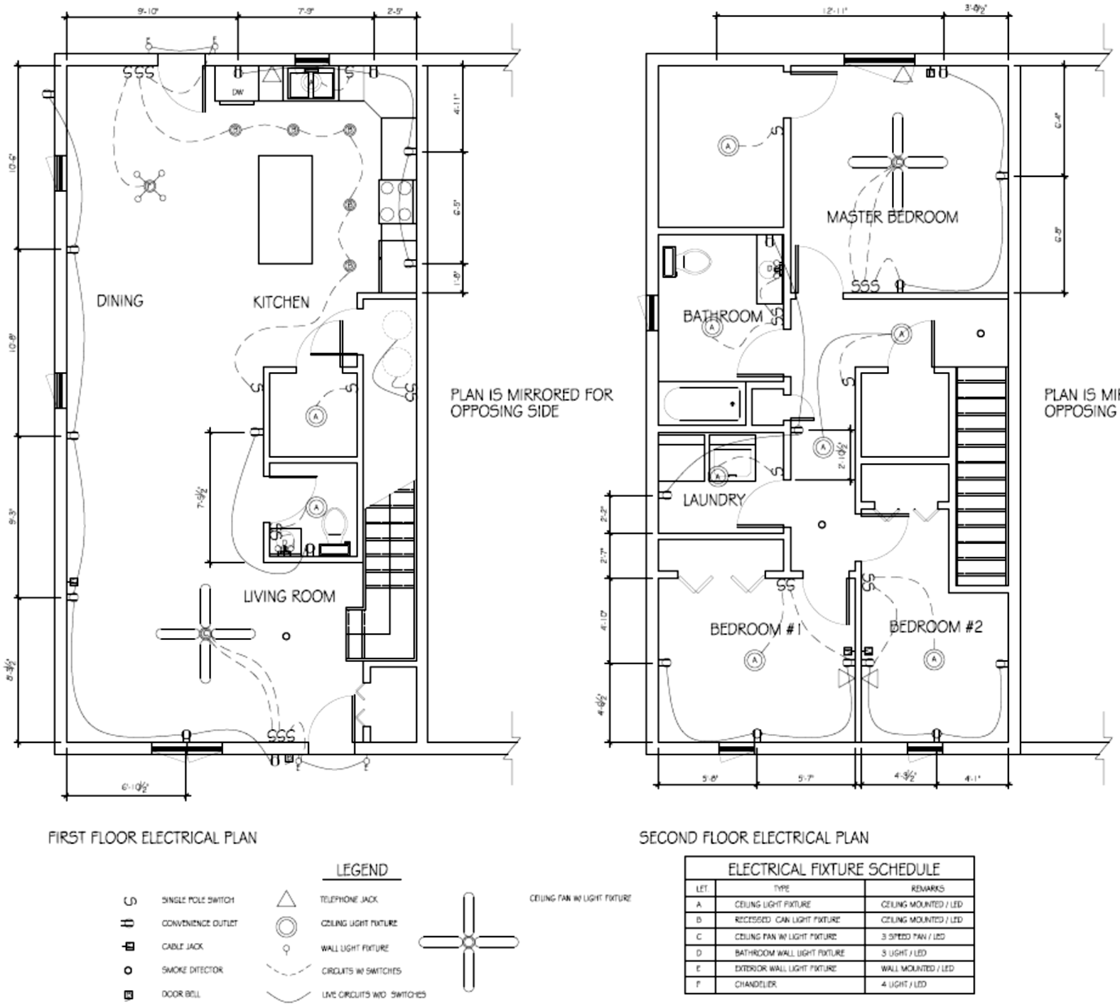
Fixtures	**Description**	**Model Number**	**ENERGY STAR**
Can Lights	Utilitech Pro 100-Watt Equivalent Matte White LED Recessed Retrofit Downlight	53164161	Yes
Ceiling Fan	Hunter Palermo™ Led 52-in Brushed Nickel Indoor Downrod or Flush Mount Ceiling Fan Integrated Led Included Remote Control Included 5 ENERGY STAR	59048	Yes
Flush Mount Ceiling Lights	Utilitech Pro 12.598-in W White LED Ceiling Flush Mount	MXL302-LED18K835	Yes
Bathroom Wall Lighting	allen + roth 3-Light Merington Brushed Nickel Bathroom Vanity Light	VBS271-3BNK	No
Dining Room Chandelier	Progress Lighting 5-Light Brushed Nickel Chandelier	P4217-09	Yes
Exterior Wall Lights	Kenroy Home Mesa 9-in H Textured Black Outdoor Wall Light ENERGY STAR	70000TB	Yes

Home Energy Monitoring System

We have chosen to utilize a home energy monitoring system to assist occupants in understanding and becoming involved with their energy use. The “EnviR” system, provides a battery operated interface that will track ten circuits as well as individual appliances’ energy consumption. The sensors are installed within the electrical box.

Electrical Layout

Our electrical plan strives for ADA requirements of receptacle outlet height of 18 inch from finish floor, as well as 12 foot maximum receptacle spacing. See Appendix I: Construction Documents



ELECTRICAL FIXTURE SCHEDULE

LET.	TYPE	REMARKS
A	CEILING LIGHT FIXTURE	CEILING MOUNTED / LED
B	RECESSED CAN LIGHT FIXTURE	CEILING MOUNTED / LED
C	CEILING FAN W/ LIGHT FIXTURE	3 SPEED FAN / LED
D	BATHROOM WALL LIGHT FIXTURE	3 LIGHT / LED
E	EXTERIOR WALL LIGHT FIXTURE	WALL MOUNTED / LED
F	CHANDELIER	4 LIGHT / LED

Electrical Appliances

Our electrical appliances include energy star kitchen appliances such as the dishwasher and refrigerator. Other energy star appliances would include the hot water heater and the clothes washer. We have chosen a highly efficient hot water heater that within two years will save more money than the initial cost. To maintain the tight building envelope and passive design we have chosen a vent-less dryer as well as a microwave oven with a minimal exhaust vent. See Appendix H.3: Appliances *for* examples.

Appliance	Manufacturer	Kilowatt hours	Model Number	Energy Star
Range	Frigidaire	-	FFEF3015LS	No
Dishwasher	Frigidaire	268	FGID2466QF	Yes
Washer	Samsung	95	WF42H5200AW	Yes
Vent-less Dryer	LG	-	DLEC855W	No
Refrigerator	Whirlpool	584	WRB322DMBM	Yes
Microwave Oven	Whilpool	-	WMH31017AS	No
Hot Water Heater	GE	1514	GEH50DFEJSR	Yes

User Manual

Plumbing

- Solar Hot Water Heater
    - Check around tanks for leaks.
    - Assure that the water temperature does not surpass 120 degree Fahrenheit.
    - Flush out sediments that build up from water supply.
    - Hire for an inspection every 3 to 5 years.
    - Hire for any desired additional water hot water appliance or fixture.
- Penetrations
    - Avoid any disturbances to building envelope and sealants.
    - Check for flashings and sealants for leaks or breaks.
- Piping
    - Check connection and fixture for and leaks

Electrical

- Fixtures
    - Utilize properly sized LED bulbs
- Outlets
    - Hire for and desired additional receptacles.

Pennsylvania College of Technology
PENNSTATE

Cost Estimation

Cost Estimation			
Electrical Appliances: Energy Star	**Amount**	**Cost**	**Total**
Manufacturer: Whirlpool			
Dishwasher	1	$ 539.00	$ 539.00
Refrigerator	1	$ 1,258.00	$ 1,258.00
Washer	1	$ 809.00	$ 809.00
Dryer	1	$ 999.99	$ 999.99
Range	1	$ 449.00	$ 449.00
Microwave Oven	1	$ 249.00	$ 249.00
Hot Water Heater	1	$ 999.00	$ 999.00
	Total Cost		**$ 5,302.99**

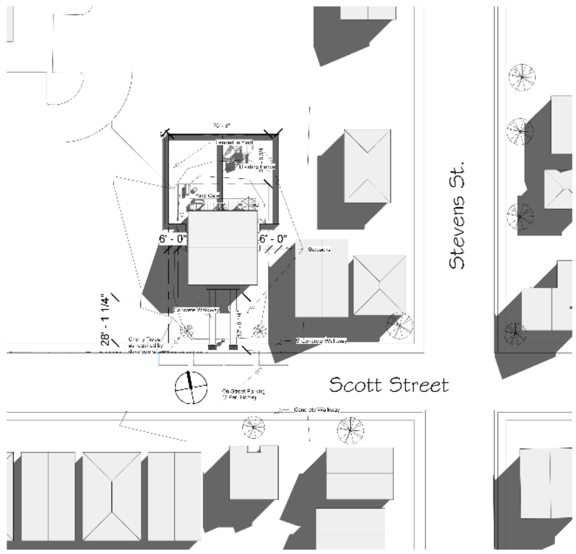
Lighting Fixtures			
Can Lights	5	$ 24.98	$ 124.90
Ceiling Fan	3	$ 175.00	$ 525.00
Flush Mount Ceiling Lights	10	$ 29.98	$ 299.80
Bathroom Wall Lights	2	$ 71.98	$ 143.96
Exterior Porch Lights	4	$ 49.97	$ 199.88
Dining Room Chandelier	1	$ 194.24	$ 194.24
LED Light Bulbs	22	$ 7.98	$ 175.56
LED Chandelier and Bathroom Fixture Bulbs	7	$ 23.98	$ 167.86
LED Exterior Light Bulbs	4	$ 26.00	$ 104.00
Energy Monitoring Systems	1	$ 129.00	$ 129.00
	Total Cost		**$ 2,064.20**

Total Fixture Cost	**$ 7,367.19**

CONSTRUCTION DOCUMENTS

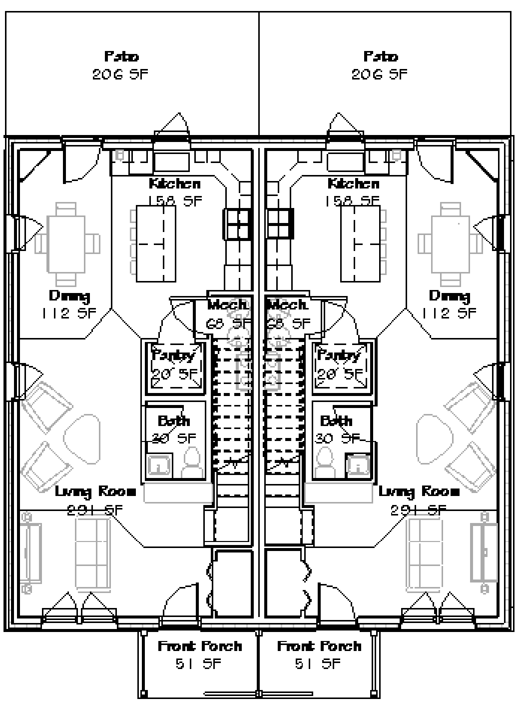
See Appendix I: Construction Documents for Scaled drawings.

Site Plan

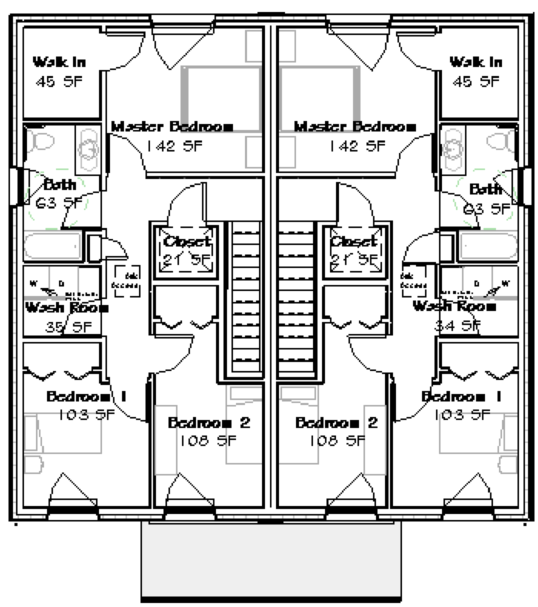


1 Site Plan
1" = 40'-0"

Floor Plans



1 First Floor Plan
1/8" = 1'-0"

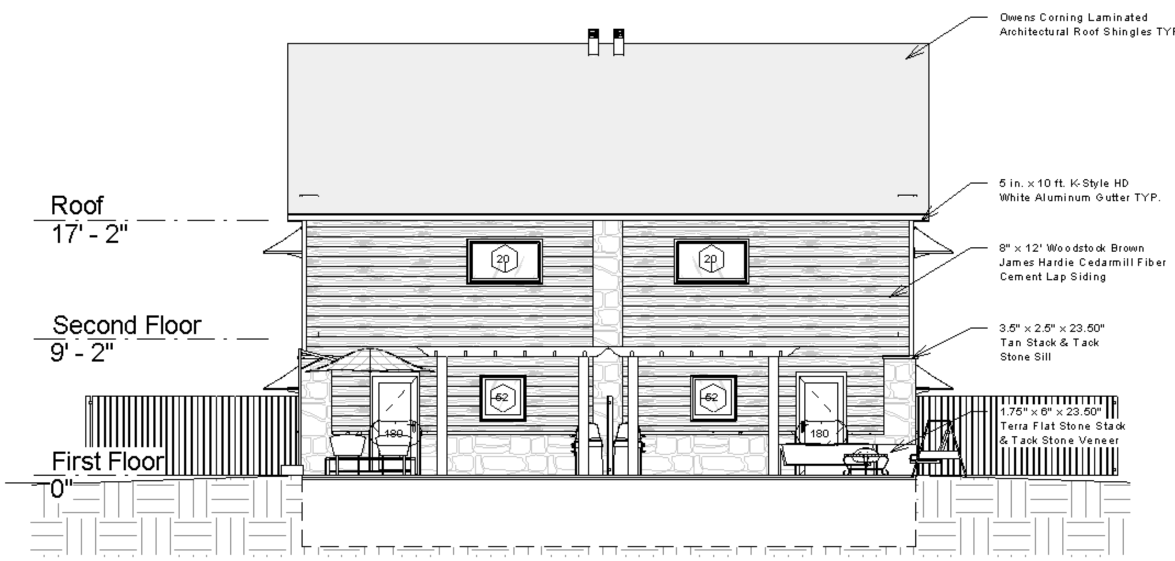


1 Second Floor Plan
1/8" = 1'-0"

Pennsylvania College of Technology
PENNSTATE

Elevations:

South (Top) & North (Bottom)

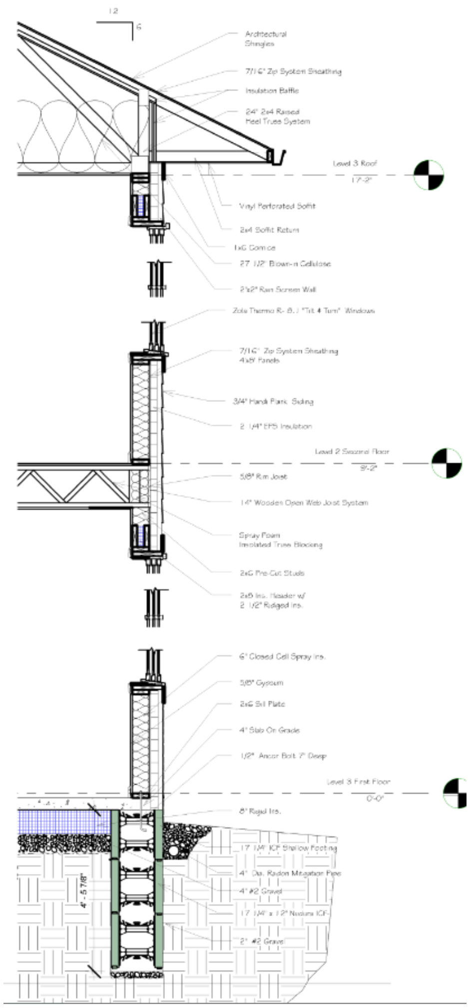


East (Top) & West (Bottom)

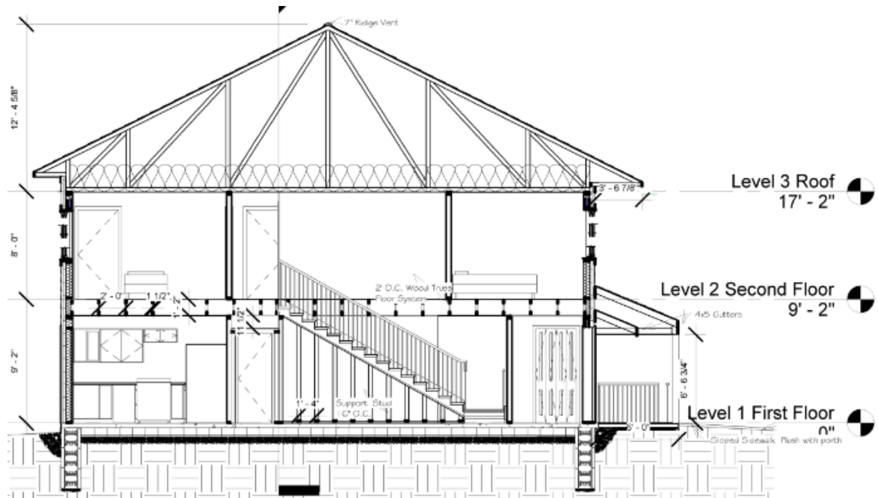
Pennsylvania College of Technology
PENNSTATE

Sections

Wall Section

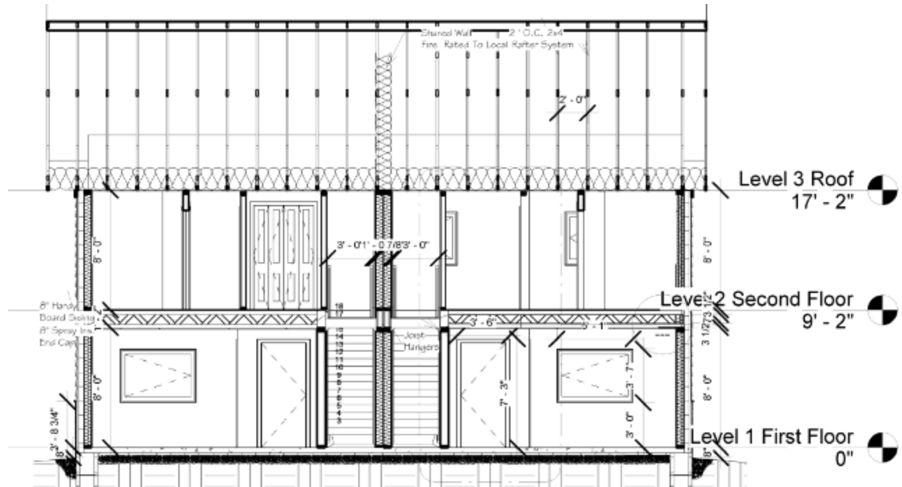


Longitudinal Section



Longitudinal Section
1/8" = 1'-0"

Transverse Section



Transverse Section
1/8" = 1'-0"

Door & Window Schedules

Window Schedule					
Family and Type	Level	Width	Height	Type Mark	Count
: 3' x 3'	First Floor	3' - 0"	3' - 0"	52	6
: 3' x 4'	First Floor	3' - 0"	4' - 2"	23	4
: 3' x 3'	Second Floor	3' - 0"	3' - 0"	52	2
: 4' x 4'	Second Floor	4' - 0"	4' - 0"	22	4
: 5' x 3'	Second Floor	5' - 0"	3' - 0"	20	2
louvres_window_-_1_Bay_6262: LW 1.2x1.6	Roof	2' - 0"	2' - 0"	24	2

Door Schedule					
Level	Family and Type	Width	Height	Type Mark	Count
First Floor	Bifold-4 Panel: 48" x 84"	4' - 0"	7' - 0"	13	2
First Floor	Residential_Exterior_Door_with_Optional_Storm_Door_15160: 3-0 x 6-8 x 5.75 x 4 Flush	3' - 0"	6' - 8"	36	4
First Floor	Single-Panel 2: 36" x 84"	3' - 0"	7' - 0"	49	6
Second Floor	Bifold-4 Panel: 48" x 84"	4' - 0"	7' - 0"	13	2
Second Floor	Bifold-4 Panel: 60" x 84"	5' - 0"	7' - 0"	14	2
Second Floor	Single-Panel 2: 20" x 84"	1' - 8"	7' - 0"	56	2
Second Floor	Single-Panel 2: 36" x 84"	3' - 0"	7' - 0"	49	14

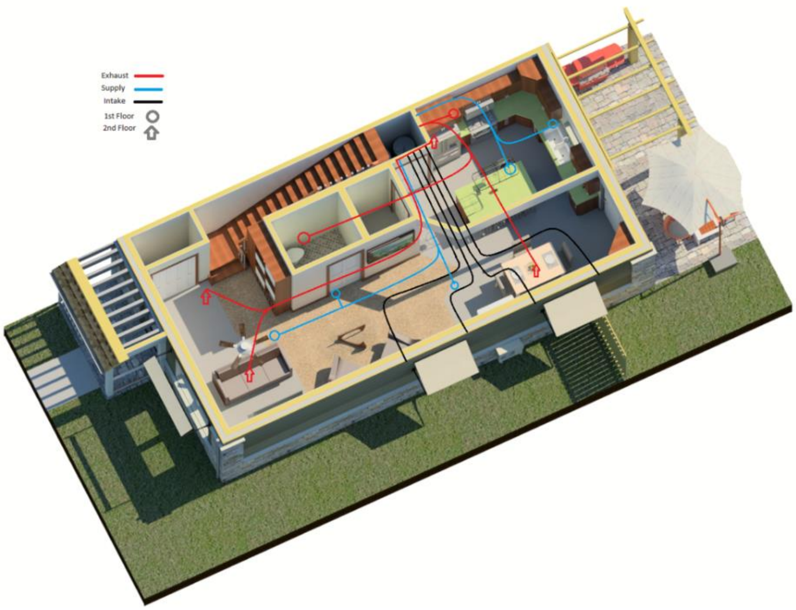
Electrical Plan

First & Second Floor

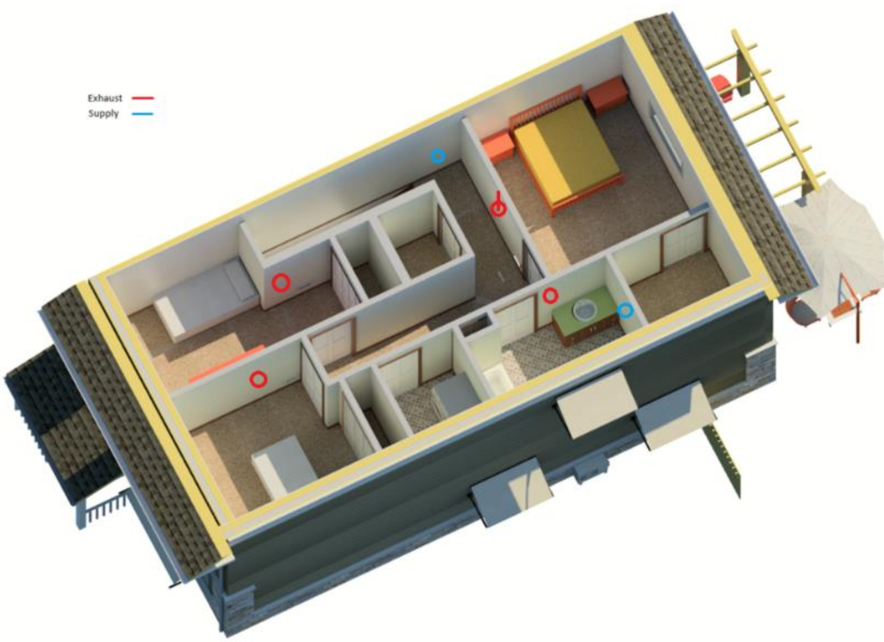
Pennsylvania College of Technology
PENNSTATE

Mechanical Plan

First Floor



Second Floor

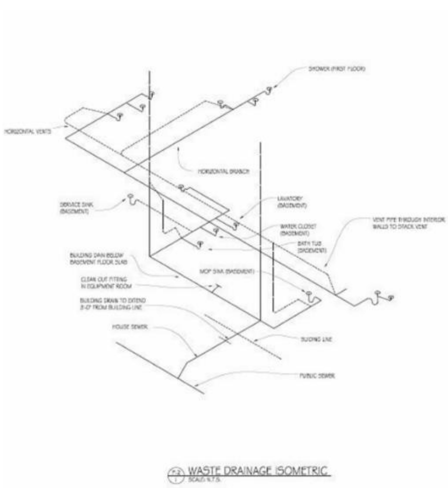


Pennsylvania College of Technology
PENNSTATE

Plumbing Plan

First & Second Floor

Isometric Plumbing Plan & Fixture Schedule



PLUMBING FIXTURE SCHEDULE

IDENT. SYMB.	TYPE OF FIXTURE	NO. REQ'D.	MANUFACTURER AND CATALOG NO.	PIPE CONNECTION SIZES CW	HW	S & W	VENT	TRAP	GAS	REMARKS
WC	WATER CLOSET	3	ELJER "SILETTE" NO. E 5002 TWO-PIECE	3/8"	-	3"	2"	-	-	VITREOUS CHINA WHITE
T	BATHTUB	2	ELJER "RIVIERA" NO. E 1130-60	1/2"	1/2"	2"	1 1/2"	2"	-	ENAMELED FIBERGLASS WHITE
SH	SHOWER	1	ELJER "FALLS" NO. E 2098 SPECIAL	1/2"	1/2"	2"	1 1/2"	2"	-	ENAMELED FIBERGLASS WHITE
L	LAVATORY	3	ELJER "BRENDA" NO. E 3328	1/2"	1/2"	2"	1 1/2"	1 1/2"	-	VITREOUS CHINA WHITE
S	KITCHEN SINK	1	ELJER "KENTON" NO. E 2325 DOUBLE	1/2"	1/2"	2"	2"	2"	-	STAINLESS STEEL
LS	LAUNDRY SINK	1	ELJER "BARROW" NO. E 6385 SINGLE	1/2"	1/2"	2"	2"	2"	-	PLASTIC WHITE
MS	MOP SINK	1	ELJER "LOWBOY" NO. E 5692 FLOOR	1/2"	1/2"	3"	1 1/2"	3"	-	ENAMELED CAST IRON WHITE
WH	WATER HEATER	1	RHEEM "SERIES 800" NO. RH80-71 1300	3/4"	3/4"	-	4"	-	1/2"	80 GAL. CAPACITY NATURAL GAS
CW	CLOTHES WASHER	1	MAYTAG "SUPER 8"	1/2"	1/2"	2"	1 1/2"	1 1/2"	-	8 POUND CAPACITY WHITE
DW	DISH WASHER	1	MAYTAG "SCRUB MASTER"	1/2"	1/2"	2"	1 1/2"	1 1/2"	-	WOOD PANEL FACE TO MATCH CABINETS
HB	HOSE BIBB	2	CRANE 8-106	3/4"	-	-	-	-	-	

INDUSTRY PARTNERS

Expert Organization(s):

National Sustainable Structures Center (NSSC), Williamsport, PA:

- John Manz - *Director (Manager of NSSC's infrastructure, training and technical assistance services, Assisted the US DOE to draft the National Resid. Energy Upgrade Guidelines)*
- Gerald Welshans - *Instructional Specialist, (PA-certified weatherization instructor, Level 1 Thermographer, BPI "Super Proctor", various BPI certifications)*
- John Wilson - *Consultant/Instructor (BPI certifications, PA-certified weatherization instructor)*

Students in BSD420 Renewable Energy used the NSSC facility for training on how to use a blower door to discover infiltration problems in buildings.

Industry Partners / Expert Advisors:

- 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.
- David Iman – *Partner, Creative Cabinetry, LLC*

  David provided costing estimates for cabinets and countertops in kitchen, bath and vanity. He also provided shop drawings for these items. The students worked with him and gave him the design.
- 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.