University of Minnesota

IMPACTHome

OptiMN

Urban Homeworks

U.S. Department of Energy Race to ZERO
2015 Student Design Competition
22 March 2015

TABLE OF CONTENTS

1 TEAM QUALIFICATIONS

Team Profile

Team OptiMN is a collection of students at the University of Minnesota who have passion for sustainable housing. Our team is made up from a collection of programs that make us qualified in sustainable housing practices and the DOE Zero Energy Ready Home competition. Team OptiMN from the University of Minnesota is composed of students in programs such as Residential Building Science and Technology (8) Construction Management (4), Marketing (1), and Design (1) which help create a versatile team that can effectively tackle the challenge of designing a zero energy ready home with optimum impact for the Minneapolis community.

Collin Coltman | Team Leader

- Residential Building Science and Technology & Construction Management – Residential Emphasis
- Having served on the University of Minnesota's first Team OptiMN, I joined up for the second year of the competition and served as the Team Leader for this year's University of Minnesota's Team OptiMN, focusing on the many different aspects of creating our team's Impact House. I dream of building the sustainable, high-performance homes of the future but today.

Jose Aaron Cruz-Salinas

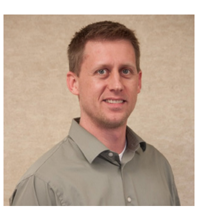
- Construction Management – Commercial Emphasis
- I dream in becoming a Construction Project Manager in a Construction Company and dream of incorporating LEED in projects to help develop more sustainable buildings.

Matthew Dries

- Residential Building Science and Technology
- I contributed primarily to the financial analysis as well as aspects of the documentation, such as the homeowner's user guide. I strive to spread and implement sustainable housing practices in the Midwest as well as develop new strategies for energy efficient houses of the future.

Maria Finsness

- Residential Building Science and Technology & French
- I serve as Team Organizer for this team and help make sure everything is on track. I would like to see cities grow into sustainable, healthy, inclusive and innovated communities, and I wish to be apart of that growth in city planning and sustainable construction.



Aaron Hanson

- Business and Marketing Education – Sustainability Studies and Housing Technologies Emphasis
- I have gained hands on experience as a framing carpenter before working as finance professional in the real estate market. I have extensive experience with building envelope products, and exterior home improvement renovations and his current work is focused on business sustainability and energy efficiency in residential buildings.

TEAM QUALIFICATIONS

Kyle Holmes

- Construction Management – Residential Emphasis
- I served on the financial analysis team as the construction cost estimator. I love the construction industry, and am looking forward to beginning a career, learning skills in construction management, as well as eventually beginning my own residential construction company.

Laurel Johnston | Design Leader

- Master of Science in Sustainable Design (Masters in Architecture from Kansas State University)
- I served as the Design Team Leader and focused on the design, construction drawings, and submission layout. I am inspired by an ancient Native American proverb: “We do not inherit the Earth from our ancestors, we borrow it from our children.”

Tyler Kitzerow

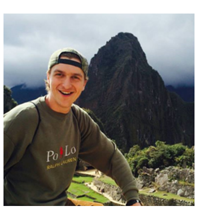
- Residential Building Science and Technology & Energy Efficiency Technical & Mid-State Technical College
- I focused on the indoor air quality and assisted in the mechanical portion of the project. In the future, I plan to be a consultant to builders and home owners on building performance related issues.

Maria Fernanda Laguarda Mallo

- Doctorates in Bioproducts and Biosystems Science Engineering and Management & Master’s in Bioproducts and Biosystems Science Engineering and Management & Master’s in Timber Construction & Bachelor’s in Architecture & Associate’s in Interior Design
- I helped the design team in the beginning and am looking forward to working on the development of sustainable and renewable materials used for energy efficient buildings.

Jackie Larson

- Construction Management
- I worked on the financial analysis side of the project for team OptiMN. I am currently interning at the Minnesota History Center in the Historic Sites division.



Frank Peeters

- Residential Building Science and Technology
- I was part of the IAQ and Enclosure Team. You’ll be able to find me funneling innovation, creativity, and efficiency into the complex of cold-climate residential homes.

Peter Schneider | Enclosure Leader

- Residential Building Science and Technology & Construction Management & Physics
- My area of expertise was in the enclosure details and the energy analysis. I enjoy working with homes and finding new ways to make homes beautiful and high performing. I believe we can, and should build homes

TEAM QUALIFICATIONS

Kristel Spiegelberg

- Residential Building Science and Technology & Spanish Studies
- I am a member of the Opti-MN team and contributed mainly to the financial and homeowner analysis.

Cavan Wagg | Systems Leader

- Residential Building Science and Technology
- My primary responsibility was designing, sizing, and implementing the heating, cooling and hot water systems. I've enjoyed the experience that the DOE Race to Zero competition has given me and I hope to put the knowledge to work in the field after graduation.

University of Minnesota

The University of MN has a strong history and reputation in building science, energy efficiency, high-performance buildings and sustainable design. Their academic, research and outreach programs for high-performance housing are nationally recognized, especially for their work addressing cold climate housing and the fenestration and foundation subsystems.

Bioproducts and Biosystems Engineering (BBE)

A bio-based revolution is underway, and it is fundamentally changing how the world produces and consumes food, feed, fiber, materials, chemicals, fuel and energy. The Department of Bioproducts and Biosystems Engineering's research and academic programs are at the forefront in the discovery, development and application of the renewable resources and sustainable technologies required to meet the global population's increasingly sophisticated needs, while at the same time enhancing and preserving the environment.

With a common unifying mission to integrate engineering, science, technology and management for sustainable use of renewable resources and enhancement of the environment, BBE faculty and graduates create solutions in all stages of design, development and manufacturing. BBE is jointly affiliated with the College of Science and Engineering (CSE) and the College of Food, Agricultural and Natural Resource Sciences (CFANS) and is the home of the Residential Building Science and Technology (RBST) undergraduate degree program. Officially the RBST degree is called a subplan, but it has a separate curriculum plan and students graduate with Residential Building Science and Technology on their diploma.

Cold Climate Housing Program (CCHP)

For almost three decades the Cold Climate Housing Program (CCH) has been part of the BBE department. The CCH is an information and education program that promotes the idea of the "house as a system." This means that the building structure, the mechanical systems in the house and the occupants are interactive and work simultaneously. A change in one part of the system will affect the others. By recognizing and respecting this system approach we can enhance the performance of our houses.

Residential Building Science and Technology Degree Program (RBST)

Residential Building Science and Technology graduates are interested in architecture, new technology and the building business and industry. Today's homes can be built to use one-half the energy and be healthier for the people who live in them. The materials used to build them can perform better and last longer with less environmental impact. In RBST, students are at the forefront of the transition to highly efficient, highly durable and more environmentallycompatible structures. Every day building scientists find new ways and new materials to make buildings better. Program graduates have a range of career possibilities; working with builders, research institutions, product manufacturers, or consultants.

Master of Science in Sustainable Design Program (MS-SD)

The School of Architecture within the College of Design has responded to the growing challenges of population growth in urban centers by developing the Master of Science in Architecture Sustainable Design (MS-SD.). The solutions to this and other environmental challenges hinge on sustainability: preserving the earth's resources, inhabitants, and environments for the benefit of present and future generations. Bringing together a rich group of multidisciplinary courses, projects and research opportunities, students can customize the program to meet their individual needs.

The school's unique dual-degree program allows students to combine professional architectural studies with a focus on sustainable design theory and practice. The curriculum provides designers and researchers with the knowledge and expertise to address issues including energy and resource efficiency, water, waste reduction, materials and technological innovations in sustainable design. The dual degree prepares students to integrate sustainable design practice and research in the design professions, government agencies, research institutes and business.

Construction Management

The B.A.S in Construction Management is designed to improve student's skills and knowledge of the construction process from the conceptual development through final construction. It is taught by a strategic blend of U of M faculty and industry experts, giving graduates tools they can apply immediately on the job. The construction management program uses a multidisciplinary approach to develop a broad base of knowledge needed by today's professionals and is grounded in current industry practices and technologies. The program has four tracks: Commercial, Residential, Highway/Civil, and Facilities Management.

Faculty Advisor

Pat Huelman | Associate Professor, Bioproducts and Biosystems Engineering

Pat Huelman is an Associate Professor in Residential Energy and Building Systems with the Department of Bioproducts and Biosystems Engineering and serves as Coordinator of the Cold Climate Housing Program with the University of Minnesota Extension. He is the lead faculty member for the RBST undergraduate degree program and a principal investigator for hygrothermal testing at the Cloquet Residential Research Facility. Currently, Pat is the Project Lead for NorthernSTAR, one of the Department of Energy's Building America Teams. He received the NCHRC and DOE Excellence in Building Science Education Award in 2013.

For two decades, Pat has taught BBE 4415/5415 Advanced Residential Building Science. This class has served as a capstone course for the RBST program and is taken by many students in the MS-SD program. Traditionally, this course has focused on the theoretical aspects of heat transfer, moisture transport, and air flows. It includes building science fundamentals, load calculations, hygrothermal analysis, as well as an introduction to mechanical systems. Last fall this course was reorganized to help prepare the students for the DOE Race to Zero Student Design Competition. This competition has provided an excellent opportunity for the students to apply these principles to an actual house design project.

TEAM QUALIFICATIONS

Industry Partners

1 | Urban Homeworks

Ben Post, Director of Real Estate Development

Ben has been with Urban Homeworks since 2005 and directs the Real Estate Development team. He oversees the real estate development pipeline, develops community and lender relationships, creates program financial proformas, and manages the construction and development teams. Ben is responsible for filling the real estate development pipeline via existing programs and also through exploring and developing new ventures. On the management side, Ben has developed processes for vetting, scoping, pricing and executing new projects and programs. Throughout his tenure at UHW, Ben's leadership skills have played a significant role in the organization's growth and development.

Les Olson, Field Superintendent

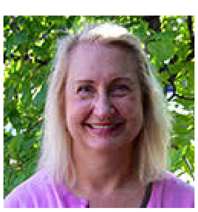
Les has been with Urban Homeworks since the summer of 2012, first as a volunteer and then as a full-time staff member beginning in 2013. Les brings his wealth of knowledge and experience in coordinating and scheduling residential home building and remodeling projects. Les also brings strong project management and supervision skills to his position of Field Superintendent with Urban Homeworks. Les is responsible for the strategy and leadership on Urban Homeworks' construction projects to ensure quality, timeliness and cost containment.

Mai Ka Lee, Project Coordinator

Mai Ka came from a mortgage origination background since graduating from St. Cloud State University in 2010 with a bachelor's degree in Finance and a minor in Economics. She is directly responsible for ensuring all funder and lender requirements are completed, and all compliance items submitted during the phases of acquisition, construction finance closing, construction, buyer-sale and close-out.

Pam Bookhout, Project Manager

Pam is responsible for planning, securing financing and executing single-family and multi-family projects, both rehabilitation and new construction. She brings extensive experience in real estate development, including multi-family new construction projects, historic rehabs, and recapitalization within existing portfolios. Her single family experience includes administration of both rehab and new construction programs under local and federal funding programs both in the non-profit sector and in local government.



Dianne Pikula, Project Manager

Dianne has been with Urban Homeworks since the winter of 2013. She has considerable experience in the design and project management of both new and rehab construction projects. Dianne is responsible for determining scopes of work, project budgets, schedules, contracts and reporting metrics.

TEAM QUALIFICATIONS

2 | Residential Science Resources (RSR)

This growing veteran owned company was founded in 2004 by one of the first graduates of the University of Minnesota's Residential Building Science and Technology program, Mat Gates. RSR specializes in the implementation of utility, municipal and government energy saving programs by providing home performance testing, certification and consulting to home builders, raters, and homeowners; bridging the gap between scientific theory and implementation of energy efficient construction.

Initially focused on energy rating and building science consulting in the Twin Cities and Greater Minnesota, RSR quickly became more than a "Rating Company." With a current staff of over 50 employees, RSR currently provides full rating, auditing, consulting, and program services to six national utility companies in four states, four hundred+ home builders and remodelers, and ten HERS rating companies...and various government and community entities.

In today's homebuilding market, educated home buyers demand better performance in the homes they purchase. As the demand for high quality, energy efficient homes grows, RSR is positioned to grow with the market and drive the high level of service and value its clients have come to expect. RSR assists in creating homes that outlast, outperform and outsell the competition.

Mat Gates | Owner and CEO

As Founder and CEO, Gates' is responsible for the strategic vision of RSR and leads the team that operationalizes and executes that vision. Initially, Gates was directly engaged in designing, launching, and directing energy efficiency programs for utilities, municipalities, and other clients. In addition, Gates created and developed HouseRater®, home energy software that assists in the management of energy efficiency programs for utility companies, builders and homeowners. As a Building Science Consultant and industry expert, Gates routinely educates professionals and homeowners on health, safety, comfort, durability, and of course energy efficiency. Gates has a B.S. in Residential Building Science & Technology from the University of Minnesota and is a certified RESNET Quality Assurance Trainer and Rater.

TEAM QUALIFICATIONS

University of Minnesota Team Opti-MN

It has been my honor and pleasure to guide this determined group of students through the 2015 Race to Zero Student Design Competition.

Participants	Program-Major	Building Science Education
Collin Coltman (TL)	BBE-RBST & CEE-CMgt	Completed: RTZ-BS for NZH
Jose Cruz-Salinas	CCE-CMgt	Completed: RTZ-BS for NZH
Matthew Dries	BBE-RBST	Completed: RTZ BS for NZH
Maria Finsness	BBE-RBST	Completed: RTZ-BS for NZH
Aaron Hanson	CEHD-BME	Completed: RTZ-BS for NZH & UMN-ARBS
Kyle Holmes	CCE-CMgt	Completed: RTZ-BS for NZH & UMN-ARBS
Laurel Johnston	Arch-MSSD	Completed: RTZ-BS for NZH & UMN-ARBS
Tyler Kitzerow	BBE-RBST	Completed: UMN-ARBS
Jackie Larson	CCE-CMgt	Completed: RTZ-BS for NZH
Maria Laguarda	BBE-BBSEM	Completed: RTZ-BS for NZH & UMN-ARBS
Frank Peeters	BBE-RBST	Completed: RTZ-BS for NZH & UMN-ARBS
Peter Schneider	BBE-RBST	Completed: RTZ-BS for NZH & UMN-ARBS
Kristel Spiegelberg	BBE-RBST	Completed: RTZ-BS for NZH
Cavan Wagg	BBE-RBST	Completed: RTZ-BS for NZH & UMN-ARBS

TL = Team Leader
RTZ-BS for NZH = Race to Zero – Building Science for Net Zero Housing
UMN ARBS = U of MN – BBE 4415/5415: Advanced Residential Building Science

I hereby certify that all of the above students have successfully completed the two Race to Zero Building Science for Net Zero Housing courses and/or my BBE Advanced Residential Building Science course.

______________________________ ____3/22/15_____
Signature Date

University of Minnesota
Team OptiMN
"OptiMN Impact Home"

Project Summary

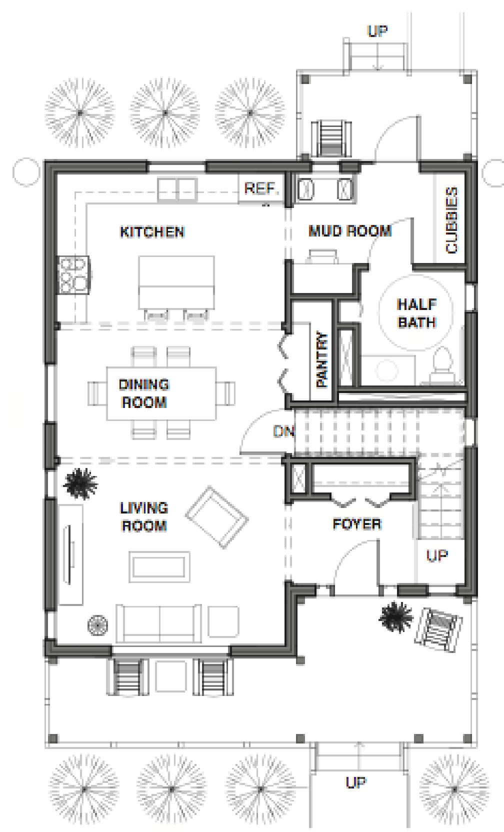
Designed to fit on the majority of North Minneapolis infill lots, the OptiMN Impact Home is a collaborative project between the University of Minnesota and Urban Homeworks. The overarching goal was a flexible, high-performance, energy-efficient, and affordable house that can be easily built by Urban Homeworks and purchased by eligible low-income residents of North Minneapolis through the Green Homes North program.

Relevance to the Goals of the Competition

The Impact Home meets both the DOE Zero Energy Ready Home criteria (per competition guidelines), as well as the Green Homes North program criteria established by the city of Minneapolis. It demonstrates that a high-performance, zero energy ready home can be attractive and affordable.

Design Strategy and Key Points

- **Enclosure**: Durable and robust building systems using a hybrid 2x4 wall with exterior insulation; cathedral truss roof with exterior insulation; high-performance windows; and exterior foundation insulation.
- **HVAC**: High-performance integrated space and water heating system with inverter heat pump for cooling/dehumidification, energy recovery ventilator, and high-efficiency filter – all delivered through a compact, small duct distribution system.
- **IAQ**: Design strategy focused on pollution avoidance, source-point exhaust, continuous ventilation, and consistent distribution of fresh and filtered air to all habitable rooms.



Project Data

- Location: Minneapolis, MN
- 2009 IECC Climate Zone: 6
- Square Feet: 2,544 (including unfinished lower level)
- Number of Stories: 2
- Number of Bedrooms: 3
- Number of Bathrooms: 1.5
- HERS Score: 32 w/o PV; 0 w/ PV
- Estimated Monthly Energy Costs: $93 w/o PV; $10 w/ PV

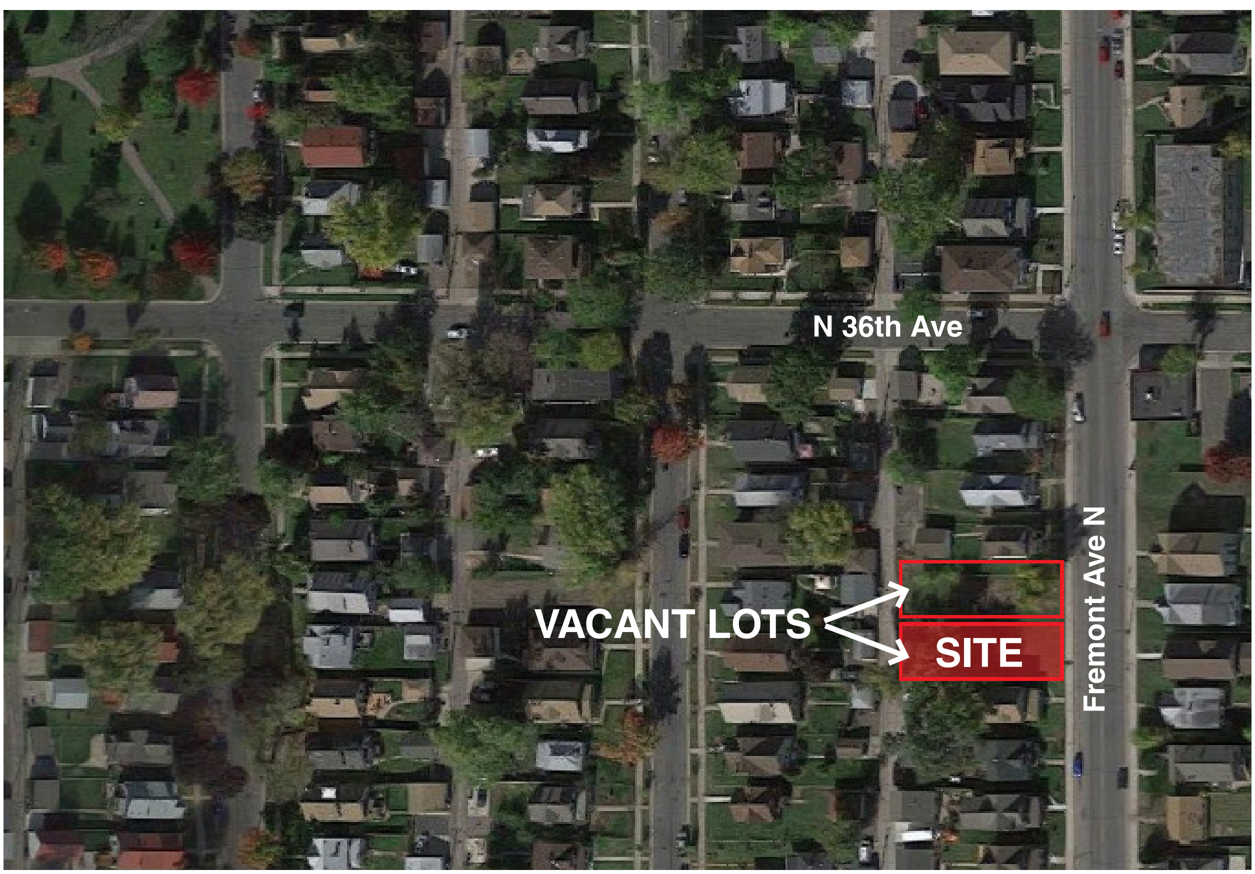
Technical Specifications

- Slab Insulation = R-10; Foundation Insulation = R-15
- Wall Insulation = R-30; Roof Insulation = R-50
- Windows = 0.27 U-Value; 0.20 SHGC
- Heating/Cooling/DHW Specifications = 95% CAE; 17 SEER
- Energy Recovery Ventilation = 60 to 120 cfm w/70% SRE

2 DESIGN GOALS

Social Goals & Site Selection

We wanted to choose a site that would be meaningful and have a positive impact on the community so we chose our site in North Minneapolis. This area was hit hard by the forclosure crisis followed by a series of tornadoes in 2011 that cut right through the heart of the neighborhood. Today, there are still a bunch of vacant lots including our site and the one next to it. The Green Homes North Initiative saw these empty spaces as an opportunity and plans on building 100 energy efficient homes over a five year span which began back in 2012. These homes will build market value, increase community pride, and offer an affordable housing alternative that will complement the older, classic homes in these neighborhoods. The Green Homes North program gives buyers another reason to discover the diverse neighborhoods of North Minneapolis. Advantage down payment and closing cost assistance is available to income eligible home buyers.



DESIGN GOALS

Design Goals

Department of Energy's CHALLENGE is to build a Zero Energy Ready Home.

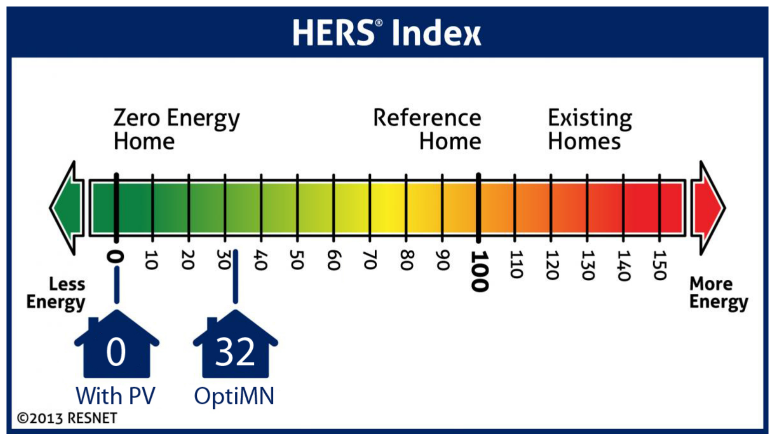
Urban Homeworks' MISSION is to produce equitable, dignified, communities.

Green Homes North INITIATIVE is to revitalize North Minneapolis neighborhoods with affordable, sustainable, and quality homes.

Therefor, team OptiMN's GOAL is to design a home that makes an **IMPACT** on the community and environment by achieving all of the above. Together, these helped form our design goals.

Performance Goals

Homes not only need to be designed well, they also need to preform well. The OptiMN Impact home, located in climate zone 6, is durable, meets the fortified home standards, achieves high indoor air quality, is zero energy ready, and fosters water stewardship. As you can see, we achieved a **HERS score of 32 and a score of 0 with photovoltaic panels.**



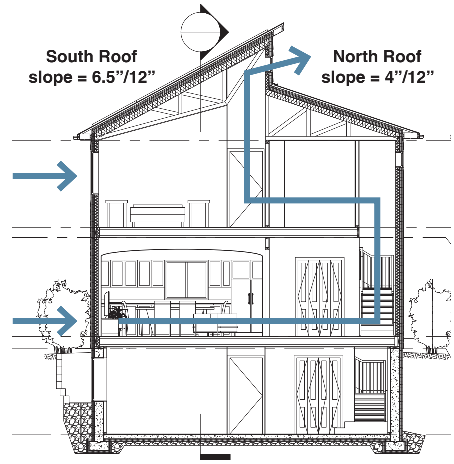
To achieve our performance goals we have included almost all of the green building options suggested by the Green Homes North initiative, such as: Energy Star appliances, Hardy Plank lap siding (engineered, environmental friendly wood siding), Energy Star windows, low VOC paints, Water Sense low flow plumbing fixtures, continuously active ventilation systems, engineered heating and cooling systems, whole house air exchanger systems, LED light bulbs, concrete that has a 40% fly ash content, 95% efficient sealed combustion furnace and water heater; programmable thermostat. Much more than 65% of construction waste from job sites gets recycled on Urban Homeworks' job sites. The property will be finished with native trees and landscaping with the additional objective of surface storm water management and water reuse.

In designing the OptiMN Impact house, we made a conscious effort to foster water-responsible design by meeting EPA WaterSense certification. To achieve EPA WaterSense certification, we designed the Impact house to use an efficient hot water delivery system that stores no more than a half of a gallon of water between the on-demand recirculation loop and the furthest fixture in the home. The hot water delivery system is described in detail in Section 8 of Volume I. In addition to EPA WaterSense certification, the house's landscaping is designed for the use of natural vegetation that requires less water to survive. Rainwater harvesting was also considered and is an option for the future homeowner to purchase to conserve water for landscaping.

DESIGN GOALS

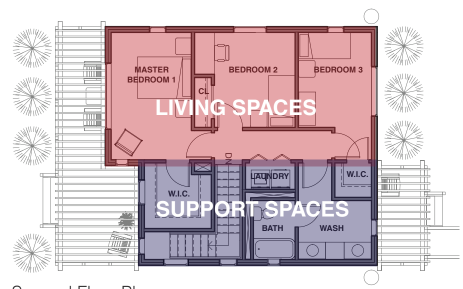
Architectural Goals

Familiar material and color selections balance the bold roof design. The clerestory windows were an early design decision made to bring natural daylight and ventilation into the spaces, create unique sectional qualities, and to increase the square footage of the southern roof to allow more photovoltaic panels to be installed.



Natural ventilation through operable clerestory windows

The overall footprint of the home was kept simple and compact to reduce the amount of building envelope exposed to the elements. One notch into the form was made to create an inviting entry at the front of the house. A large pergola covered porch and a higher percentage of window-to-wall ratio on the front façade increases street safety and fosters neighborly relations to create a better sense of place. The window-to-wall ratio percentage also meets the Green Homes North Initiative requirement of 15%. The longer side of the house is orientated south to take full advantage of the sun. Most sites in Minneapolis's residential neighborhoods work perfect with this design because they face either east or west.



Second Floor Plan

A compact, affordable home requires special attention to space planning to ensure no space is wasted or unused. The two finished floors total 1,696 square feet with the potential to finish off another 848 square feet in the lower level. The OptiMN impact home divides the house into two sections – living and support spaces. The support spaces include the foyer, mudroom, bathrooms, storage, pantry, laundry, and mechanical equipment while the living spaces include the living room, dining room, kitchen, and bedrooms. The support spaces are located on the northern side of the house to act as a buffer to the north.

First Floor Plan

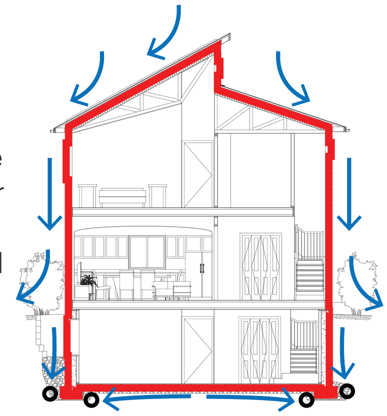
As one enters the house, a foyer creates a nice transition space for the occupants. The living room, dining room, and kitchen have an open floor plan to make the spaces feel larger yet arched openings still define each room. A mudroom off the kitchen has a desk area, seating, and cubbies for the children to keep their gear. These spaces along with the pantry, mechanical shaft, and storage fit together like a seamless jigsaw puzzle. Urban Homeworks typically works with larger families so an efficient mudroom is definitely a bonus. A handicap accessible bathroom is also located off the mudroom and is a straight shot from the back entry. A ramp leads up to the back porch making the home more visitable.

The second floor has three bedrooms with vaulted ceilings (an additional two more could be built in the lower level as well). The master bedroom has a large walk-in closet and two clerestory windows. Special care was taken to make sure the other two bedrooms were equally cool so kids wouldn't have to fight over who got the better room. The middle room is larger and has a built-in desk. The bedroom on the end may be smaller, but it has a walk-in closet and a clerestory window. The hallway has two clerestory windows and a closet with the washer and dryer. All the rooms share one bathroom; however, the bath and toilet are separated from the sink area so two people can be getting ready at the counter while another occupies the bath. All of the bathrooms are stacked and all the 'wet' elements are located in the same area of the house allowing an on-demand recirculating hot water distribution system to be installed.

3 ENVELOPE DURABILITY

General Design Strategies

The general design strategies were focused on ensuring long term performance and structural integrity of enclosure by improving moisture management, improving thermal performance through appropriate detailing and materials, and controlling vapor and air movement through the enclosure. We reevaluated the current way of managing air, moisture and heat flows and realized the need to move away from the current fragile way of building to a more robust design using high R- value assemblies.



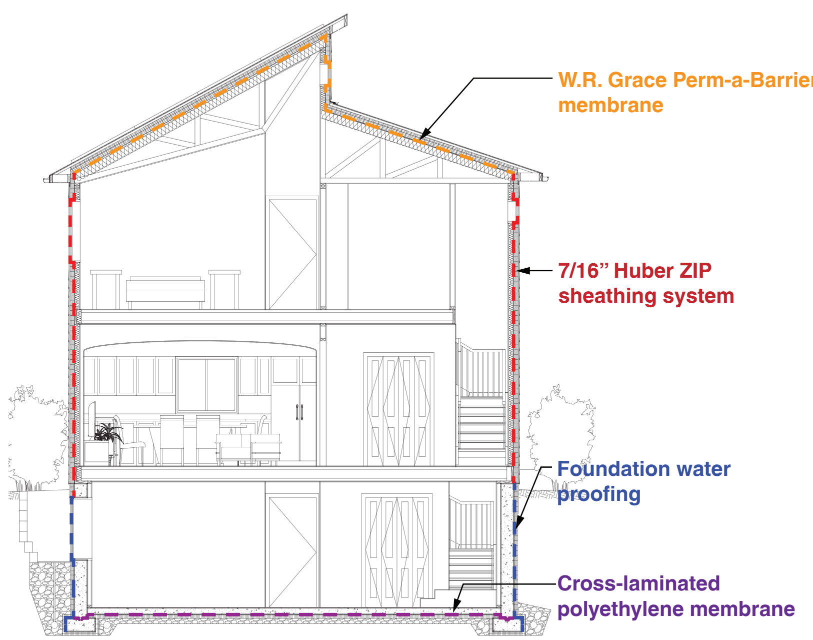
Enclosure Durability

In highly efficient walls with only cavity insulation, the back of the sheathing layer facing the cavity insulation may get cold. If sheathing is hygroscopic such as OSB, and the equilibrium moisture content goes up it may lead to mold problems and reduced performance. To counter this we have applied insulation to the outside of our wall system as well as the inside, to warm up the wall cavity and OSB layer. The exterior insulation not only helps to cut down on potential moisture problems from condensing vapor but also helps to eliminate thermal bridges. Thermal bridges occur at rim joist to wall connections, along vertical lengths of studs (if there is no continuous exterior insulation), cantilevers, decks and window frames. Our 3 inches of XPS will greatly cut down on the amount of thermal bridging that occurs. If moisture does get into our wall system we have designed our wall so that it can easily dry out and the moisture is not trapped inside the wall.

Above Grade Walls

Exterior walls are designed as 5/8" gypsum board, 2X4" @16" o.c stud walls with R-13 Fiberglass cavity insulation, ½" Zip Panel Sheathing and 3" layer of XPS exterior foam insulation with grooves cut on the back side. Hardieplank lap siding was used as cladding material on ¾" furring strips as a Rainscreen. The wall has an assembly R value of 32.55.

The house is designed with a Continuous Air Barrier on the exterior. The Zip Panel in the walls, Peel & Stick Membrane on the roof and 2" XPS foam under the basement slab act as a continuous air barrier for the house. The Zip Panel and Peel & Stick membrane which form the ice, water, vapor and air barrier are located on the inside of rigid insulation. This helps control the temperature and maintain it at a fairly stable temperature throughout the year consequently reducing the possibility of condensation and protects the structure. This strategy helps protect the OSB on the roof which is highly vulnerable to water from



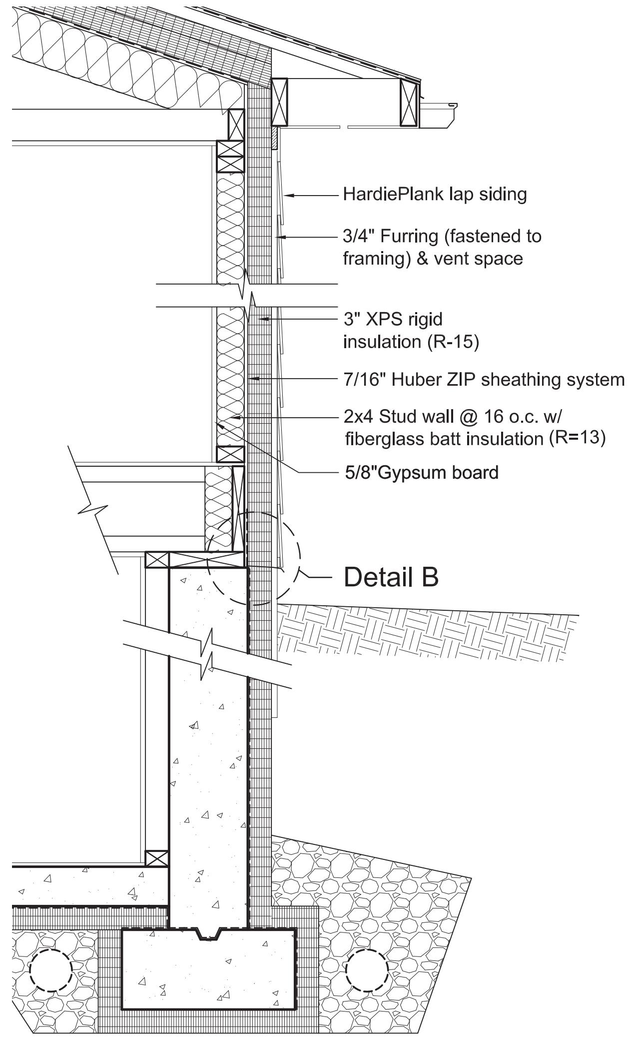
Control Layers

ENVELOPE DURABILITY

condensation problems arising from drops in temperature. All roof and wall assembly transitions are air sealed. In order for the Zip Panel to be most effective, the cladding is as detailed and grooves will be cut on the back side of the exterior XPS insulation to allow water to drain out from the paneling. ¾" furring strips @ 16"o.c is mounted to create a gap behind the HardiePlank lap siding. This gap helps to back ventilate the cladding and reduces moisture problems due to inward vapor drives in summer as well as wind driven rain. The cladding is drained using metal flashing at transitions and at the bottom of the wall. All flashings around windows, doors, openings and transitions are integrated with the Zip Panel to create a continuous 'drainage plane' that drains water 'down and out'.

The thermal performance of the wall is greatly enhanced by having a 3" XPS continuous exterior insulation. The foam insulation helps to minimize thermal bridging across the wall particularly from the stud members and rim joist. The R-13 Fiberglass batt insulation was chosen for the wall cavity because it is low cost but still provides adequate thermal resistance.

Deck & porch floor slabs are supported on sonotube piers that are independent of the wall above grade. This detail is designed so as to allow water to drain behind the deck/porch and minimize thermal bridging between house & deck.



Hybrid wall system & foundation

Foundation

Based on hygrothermal analysis in WUFI we have proposed 3" XPS exterior insulation over the foundation wall forming a continuous thermal barrier. This enhances the thermal performance due to increased R-value to R-22 and significantly reduces slab edge heat loss and thermal bridging. To help reduce the thermal bridging we are also installing XPS and High Density Foam around the footings. This is a low cost solution to help cut down on a thermal bridge that can be easily countered.

To help keep moisture out capillary breaks between the foundation wall and footings have been introduced to keep the basement drier by preventing capillary action, along with drain tiles and coarse aggregate to allow water to drain away. In addition to the capillary breaks, drain tiles, and coarse aggregate we will also install a sump pump.

The basement slab is insulated with 2" of XPS foam insulation (R-10) to prevent heat loss to the ground. The slab edge is responsible for approximately 62% of heat loss in the foundation (Pennsylvania Housing Research Center). 3" XPS exterior foam and air sealing the slab - foundation wall assembly helps to minimize slab edge heat loss.

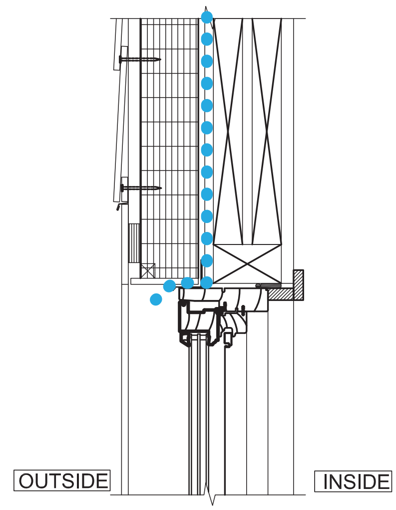
ENVELOPE DURABILITY

Roof/Ceiling

Our design proposes the use of two truss systems, a scissor trust for the south roof and a half truss for the north roof. With the two separate truss systems we will insulate the roof decking allowing for a conditioned attic space. To do this we will install 5/8" Gypsum board, 2X6" @ 24" o.c trusses with R-19 Fiberglass batts, OSB with Peel & Stick membrane on the outside, 5" polyisocyanurate, 5/4" furring stripes @ 24" o.c, roof decking shingles and roof paper on the north roof for a R-Value of 53.88. The south roof is nearly identical except the truss is a 4X6" @ 48" o.c with a 1 1/8" OSB board to support the extra span. This system allows the roof deck to stay at a uniform temperature and help prevent ice dams.

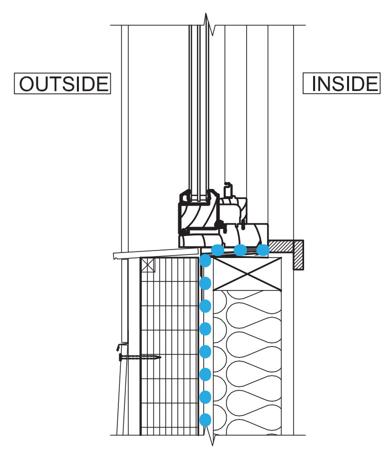
Window Fixing Detail

It has been established that for cold climates like Minnesota, a higher U-value would be beneficial to decrease the cooling costs and a higher SHGC and higher window area would be beneficial on the southern exposure to maximize the heat gains in winter. Hence, windows and patio doors have been positioned so that there is maximum southern exposure. Area of windows on the other orientations has been minimized to a reasonable extent. A balance has been achieved between the design and analysis so that the front elevation facing the north has a reasonable amount of windows and yet does not perform too bad in terms of heat loss. Being a preferred local window manufacturer, Anderson windows and doors have been chosen. The windows will have a U-value of 0.27 and a SHGC of 0.2. A Krypton/Argon filled cavity with LowE3 will achieve these U-values. (Refer to Window and Door Schedule in the Construction Document Set for their elevations).



Modified Glaser Method

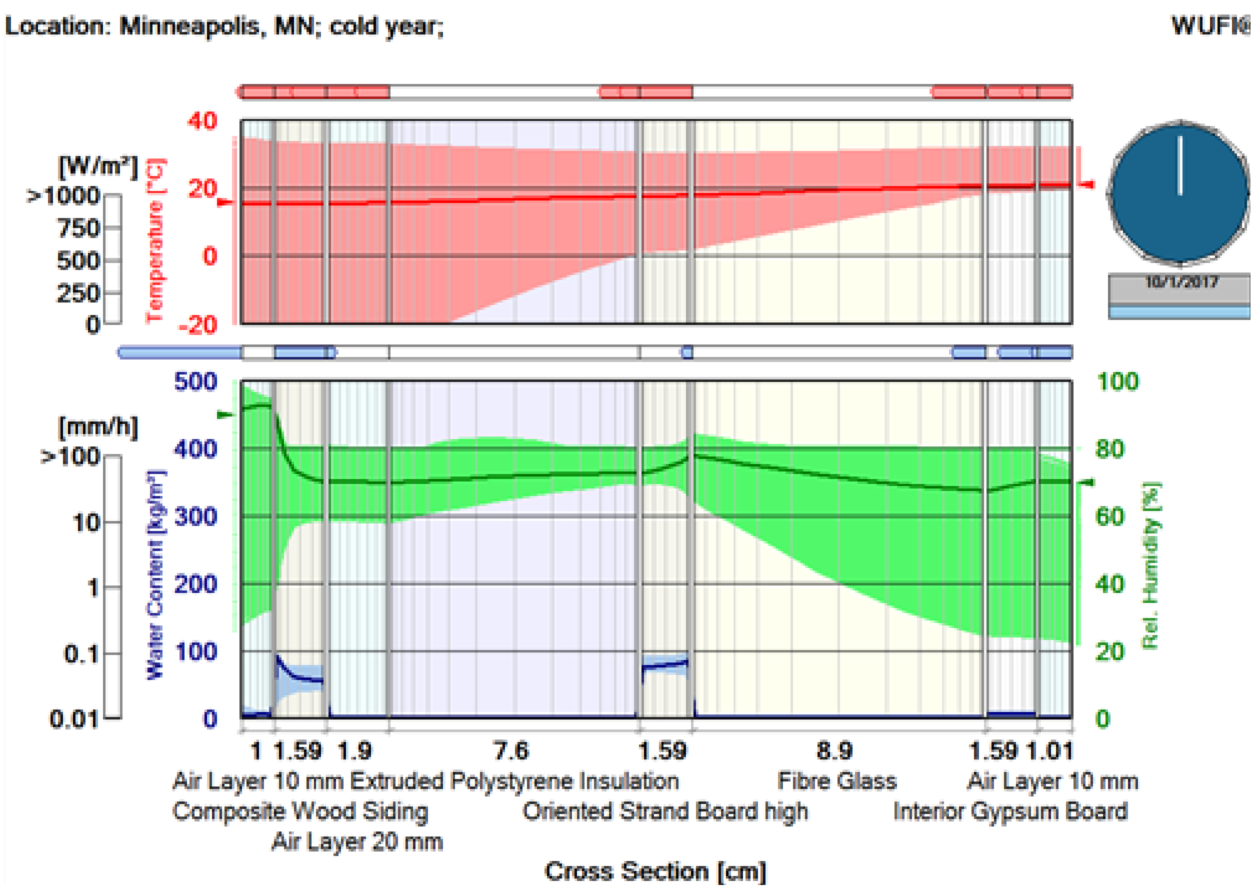
The Glaser or dew point analysis is a steady-state, one-dimensional, combined graphical and numerical method for assessing the moisture accumulation within exterior envelopes. With this tool, we are able to assess the hygrothermal performance of our wall system. However, the Glaser method has several weaknesses. It is simplified and steady-state; varying interior and exterior conditions are not accounted for. Also, thermal and moisture transport are independent and moisture transport is only accounted for by vapor diffusion; heat flow is exclusively by conduction. Neither liquid transport nor air transport is considered. Finally, both heat and moisture storage effects are not accounted for, therefore to account for storage, it is recommended to use monthly average conditions rather than extreme design conditions. For this reason, the vapor pressure profile for the coldest month (January) and hottest month (July) provide more realistic results. There are no condensation issues for the months of January and July (see appendix). This helps with confirming the robustness of our wall system.



ENVELOPE DURABILITY

Hygrothermal Analysis WUFI

To further confirm the superior hygrothermal performance of our wall system, we also performed an analysis using WUFI software. WUFI is a detailed, transient, and multi-dimensional tool than assesses the hygrothermal performance of exterior envelopes. The software accounts for varying interior and exterior conditions including wind-driven rain. It also accounts for heat storage, moisture storage, and liquid transport. There are many control parameters as well including: orientation, coatings, permeance of paint, interior moisture generation, climate data, etc. From the image from the WUFI analysis shown in Figure 3, the relative humidity (shown in green) never reaches 100% at any location throughout the wall system meaning no condensation issues. Also from this figure, the water content throughout the wall is shown in blue. At the siding and OSB layers, the water contents are higher than all other materials. This is due to the hygroscopic nature of the materials. It is likely that the moisture contents shown for these materials represent normal levels well below the fiber saturation point of the materials. In addition, the total water content and water contents of each material are lower at the end of the simulation when compared with the initial water contents. The high initial water content represents 'construction moisture'. From the lower water contents at the end of the simulation, we conclude that the wall system will dry out if there are periods of high wetting.



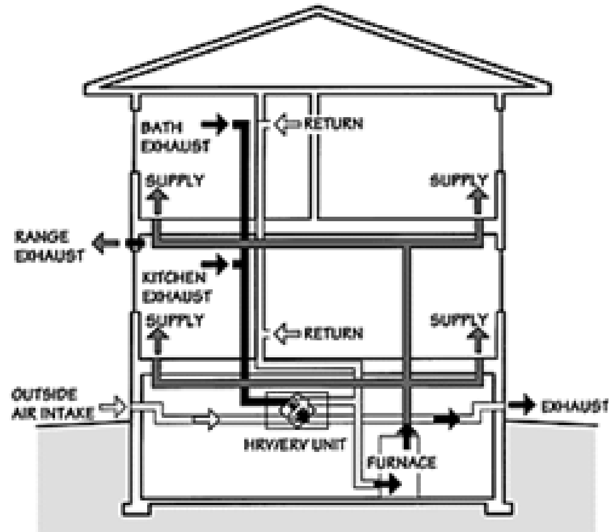
WUFI Simulation

4 INDOOR AIR QUALITY EVALUATION

General Approach to Indoor Air Quality

Providing exceptional indoor air quality is predicated on three key elements: a) pollutant avoidance, b) point source removal, and c) fresh air distribution. The team has exercised care in the design and specifications to reduce the potential for indoor pollutants and to mitigate them once they occur. The EPA Indoor Air Plus requirements will be followed and verified to assure the best possible indoor environmental quality for this high-performance, DOE Zero Energy Ready Home.

Our team implemented a balanced, source-point ventilation strategy. This strategy doesn't significantly affect the interior pressure of the space.



Balanced, source point ventilation strategy

IAQ Details

Below are the specific details that will be deployed to address healthy indoor air for our "Impact Home" design.

1 | Begin with Pollutant Avoidance

Team OptiMN has carefully designed this house to reduce the pollutants that might be brought into the home though construction or during operation. Specific measures have been taken to reduce moisture entry, especially below-grade, along with mitigation of radon, VOCs and garage pollutants.

Combustion Pollutants

First and foremost, the potential for combustion pollutants have been virtually eliminated by going to sealed-combustion equipment and a detached garage. Carbon monoxide alarms will still be used per code to provide safety against a malfunction or other sources.

Below-Grade Moisture Management

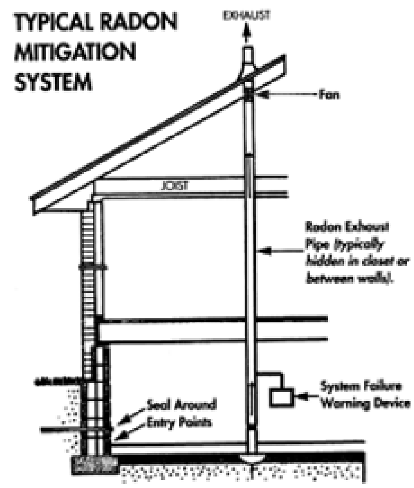
The below-grade components have been designed to address all four modes of moisture transport from the soil into the home. Bulk water is managed with proper surface grading, waterproofing with vertical drainage, and carefully designed and protected horizontal drainage on both sides of the footing. Combined with a 4" aggregate bed for horizontal drainage under the slab, water is directed to a sealed sump for discharge away from the home. Capillary concerns are addressed by the drainage layer under the slab, a capillary break on top of the footing, and exterior waterproofing on the foundation wall. Air transport is controlled by proper sealing of all below grade components and joints. Vapor transport has been addressed with the foundation waterproofing and an under slab membrane over the XPS foam insulation.

Radon Reduction Strategies

Minneapolis is located within EPA Radon Zone 1. For this reason, a passive sub-slab depressurization system is being proposed to mitigate radon and other soil gases. This system will produce a slight negative pressure below the slab, especially in winter months, to create a suction point for soil gas removal. The slab and foundation wall will be carefully sealed at

INDOOR AIR QUALITY EVALUATION

edges, penetrations, and control/expansion joints with polyurethane caulk to impede radon flow into the house from the soil. In addition, a sealed sump with a 4” gas-tight vent pipe will go through the house and exit through the upper roof. A radon fan won’t be installed at this time, but the attic design will provide an easy opportunity to install a continuous exhaust fan in the future.



VOCs, Lead, Etc

To further improve the indoor environment, careful attention was given to product selection. All wood products and finishes will have low formaldehyde content. And all interior paints will have low-VOC content. As standard practice, Urban Homeworks does not use carpeting in any part of the home. Low-VOC and easy to clean hard surface flooring will be used throughout. Due to extensive remodeling of its older housing stock and heavy car pollution before unleaded gas, the soils in North Minneapolis generally contain heavy levels of lead. Drop mats will be used to reduce soil entry by those entering the house. Airtight construction accompanied by high-efficiency MERV 12 filtration assists in capturing and containing fine particulates that may be contained within the soil.

Avoidance Pollutants at the Source

It is common for urban infill sites to have detached garages. That is a typical practice for our affordable housing partner, Urban Homeworks. This avoids any concern for garage gases including carbon monoxide, fuels, or stored chemicals from being drawn into the house by negative pressure in the winter or by exhaust fan operation.

2 | Remove Pollutants at the Source

If pollutants are generated in the home, source point removal is the most effective and efficient way to mitigate the impact on the indoor air quality in the rest of the home. The ventilation design has been specifically chosen and designed to meet the required ventilation rates both for the Minnesota Energy Code and ASHRAE 62.2-2010 & 2013

Source Point ERV

To maximize the overall effectiveness and efficiency of the balanced energy recovery ventilation, a source point exhaust strategy is being used. Point source pick-ups for pollutant removal will be placed in all bathrooms, laundry, and kitchen area. All exhausts will be directly vented to the outdoors through the ERV or a dedicated exhaust. The home will be continually ventilated by the ERV as it is designed to run at the required continuous ventilation rate of 60 cfm and can be switched to the highest speed of120 cfm. There are five pick-up grills that will be balanced as follows (under normal continuous operation):

- 2nd Floor Bathroom* = 10 cfm
- 2nd Floor Laundry = 10 cfm
- 1st Floor Half-Bath** = 20 cfm
- 1st Floor Kitchen = 10 cfm
- Lower Level = 10 cfm

* 2nd floor shower and toilet area has a dedicated exhaust fan
** 1st floor bath must be 20 cfm continuous to meet code

INDOOR AIR QUALITY EVALUATION

Dedicated Exhaust Fans

Do to the potential for high traffic in the 2nd floor bathroom, a dedicated, high-efficiency, exhaust fan is specified for 50 cfm. This can also be used to meet the intermittent ventilation requirement for the Minnesota code. Cooking can be a significant source of pollutants, especially fine particulates in homes. This house will use a high-quality range hood at 160 cfm to remove these potential pollutants directly at the source. It will be important for the residents to be educated and encouraged to use the range hood during cooking and to use rear burners whenever possible.

3 | Provide Fresh Air for People

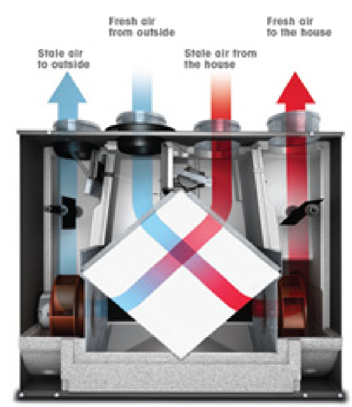
In high-performance, airtight homes it is especially critical to distribute fresh and filtered outdoor air to all habitable rooms. The team has developed a design to ensure fresh, filtered air is supplied throughout the house every hour.

Fresh Air Distribution

The outdoor intake has been elevated off the ground, but still with reach for maintenance. The incoming outdoor air goes through the ERV to filter and temper (preheat and humidify in the winter and precool and dehumidify in the summer) and then goes to the return side of the air handler where it goes through the MERV 12 filter and gets distributed to all habitable rooms. The ECM air handler will cycle a minimum of 15 minutes each hour to ensure proper fresh air distribution and to meet Minnesota code.

Filtration

The team has specified a MERV 12 air filter to increase the dust spot efficiency from the required 30-35% to 70-75%, as well as to decrease the size of particles that can be contained by the air filter from 3.0 pm to 1.0pm. This should assist in capturing and containing fine particulates from both indoor and outdoor sources, including lead particles that may be contained within the soil of other neighborhoods in the North Minneapolis area. Furthermore, high-efficiency air filters are recommended for all high-performance homes.



Indoor Humidity Management

To accommodate interior moisture issues the team has designed the ducting system to pull air from the ceiling by placing a return duct high on the second floor. This will also mitigate any condensation build up on the clerestory window. Point source pickups have been located in every bathroom to pull moist air directly from its source. The kitchen range hood is directly vented to the outdoors to remove excess moisture from cooking. Our robust building envelope mitigates condensation potential, but also allows moisture to dry to the indoors so that it does not become trapped in the wall cavity. The exterior insulation on walls and roof eliminates the ability for moisture to condense and freeze to the sheathing in the winter, also preventing mold and other biologicals from forming in the wall cavities in the warmer months.

INDOOR AIR QUALITY EVALUATION

Ventilation Rates

The ventilation rates are guided by the ASHRAE Standard 62.2 (2010): Ventilation and Acceptable Indoor Air Quality. The minimal ASHRAE 62.2 ventilation rate for a 2,544 square foot, 3 bedroom house will be:

ASHRAE 62.2-2010 = (0.01 cfm/sf x 2544 sf) + (7.5 cfm x (3 + 1) = 56 cfm

Minnesota Code = (0.02 cfm/sf x 2544 sf) + (15 cfm x (3+1) = 111 cfm*

* 1/2 of this must be continuous

So the ERV will be design and commissioned to exhaust a total of 60 cfm on low speed. This will provide continuous exhaust from two bathrooms, kitchen, and laundry area. The main upper level bathroom has a 50 cfm exhaust fan and the kitchen has a 150 cfm range hood. With the ERV on high and main bath exhaust in operation, the total ventilation rate will be approximately 150 cfm, well in excess of the code and DOE Zero Energy Ready Home requirements.

ASHRAE 62.2 2013		
# BR.	5	3
Sq. Ft.	2544	2544
Total Required Ventilation	121.32	106.32

ASHRAE 62.2 2010		
# BR.	5	3
Sq. Ft.	2544	2544
Total Required Ventilation	70.44	55.44

MN Energy Code 2015		
# BR.	5	3
Sq. Ft.	2544	2544
Total Required Ventilation	140.88	110.88
Total Cont. Required	70.44	55.44

MN Energy Code 2015	3 BR		5 BR	
	Cont.	Total	Cont.	Total
* From Table @ 2000-2500 sq ft.	55	100	70	140
* From Table @ 2500-30000 sq ft.	60	120	75	150

5 SPACE CONDITIONING & VENTILATION

Primary Goals

High-performance, airtight, and low-load homes have special conditioning requirements. Traditional oversized equipment can lead to poor part-load performance, short cycling, and ultimately cause occupant discomfort. Team OptiMn wanted to design an integrated system that would provide:

- High overall energy efficiency at a low cost
- Proper sizing and exceptional thermal comfort
- Properly distribute supply runs to accommodate load demand while minimizing duct length.
- Keep all ducts within thermal and air barrier boundary (conditioned space)
- Easily and efficiently distribute condition, filtered, and fresh air to all habitable rooms.

Manual J was used to size heating and cooling equipment and allowed us to determine where to place supply ducts to meet room loads. Table 1 shows that the whole house heating and cooling design loads are very similar for Manual J and REMRate. Complete Manual J calculations are located in the Space Conditioning Appendix.

Heating and Cooling Load Comparisons		
	REMRate	Manual J
Heating Load (Kbtu/hr)	20.2	22.8
Cooling Load (Kbtu/hr)	10.3	14.5

Combination space and water heating was used with a coil looped through the air handler. This is a simple and efficient option when using a high efficiency water heater. The system yields a combined appliance efficiency of 95%. A water temperature of 120°F and flow rate of 4gpm at 500 Cfm yields a heating output of 23,000 Btu/hr which meets our peak heating demand at a low operating temperature (See Table 3 in Space Conditioning Appendix).

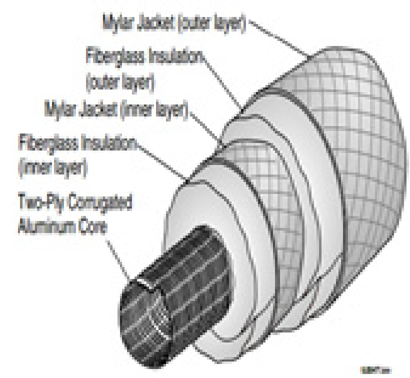
Combination Space & Water Heating w/ Unico M2430 2 Ton Hot Water Coil

The Unico iSeries Inverter heat pump was chosen as our cooling system. The inverter heat pump provides great dehumidification and reduces energy loss during the refrigeration cycle. It is also a good option to use for shoulder seasons when the heating demand isn't too high. This gives the owner added flexibility when deciding whether electricity or natural gas is the best fuel option. Heating and cooling is distributed through the Green Series Central Air Handler which contains an ECM motor for improved efficiency.

Green Series M2430 Compact Air Handler

iSeries IS24G065 Outdoor Inverter Heat Pump

SPACE CONDITIONING & VENTILATION



The desire for a convenient, properly-sized, flexible, and simple installation led our team to the compact and modular Unico System employing 2 ½ inch small, flexible ducting. This duct design helps reduce duct leakage and gave us extra freedom and ease to navigate ceiling and wall cavities. This approach allowed us to use I-joists, which are significantly cheaper than conventional truss floor systems. With proper duct design and outlet locations, the system can lead to less drafts and more even temperatures. Additionally, the nylon inner core with the insulation absorbs sound, delivering exceptionally quiet performance. All ducts were contained within conditioned space.

Our design airflow is 500 cfm. This relatively low airflow rate contributes to reduced energy consumption by the air handler. Supply duct data was determined using a pressure chart (@ 1.5 in. wc) taking into account equivalent lengths. Proper flow rates are critical to occupant comfort. Too high flow rates cause friction loss in the ducts and a perceived draft from the occupant, while too low flow rates leads to improper mixing.

A centralized return concept was utilized to minimize ducting with a dedicated pickup on each floor (Refer to Construction Documents B001 and B002). Our open floor plan allows for great air circulation, but for spaces with doors, through-the-wall transfer grilles were implemented to prevent over-pressurization and ensure greater comfort. Both high and low return pickups we placed in the 2nd floor hallway to account for the raised ceiling and overcome stratification.

All supply ducts run from the centrally located supply plenum, shortening the supply runs. Multiple supply runs were placed in larger more energy demanding zones.

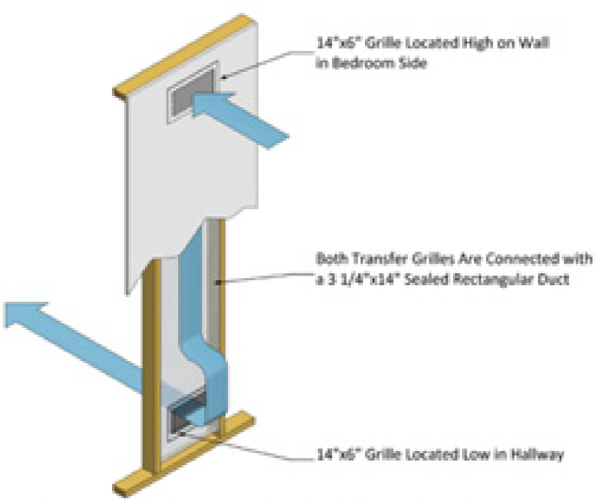
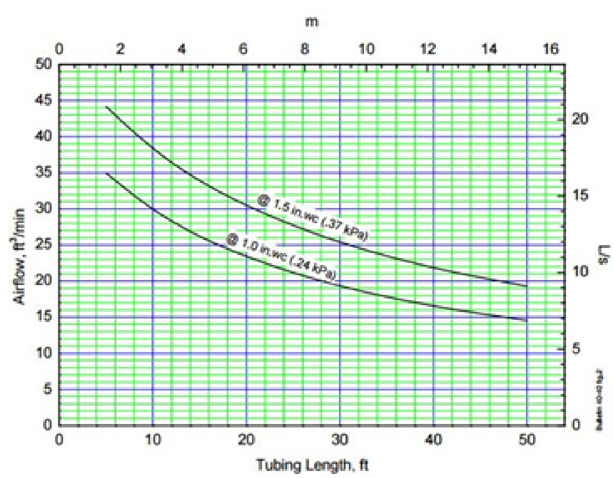


Figure 16. High/low through-the-wall transfer grille

Supply Tubing Airflow Capacity



SPACE CONDITIONING & VENTILATION

Room by Room Required Airflow @ 500 cfm				
	Energy Load (Btus/Hr)		Required Airflow (Cfm)	
Room	**Heating**	**Cooling**	**Heating**	**Cooling**
ML Mudroom	1250	802	30.9	36.9
ML Bathroom	431	155	10.7	7.1
ML Kitchen	1218	768	30.1	35.3
ML Dining	946	371	23.4	17.1
ML Family Room	2067	1525	51.1	70.2
UL Entrance & Stairwell	2339	1470	57.9	67.7
UL Bathroom	996	516	24.6	23.7
UL M Bedroom & Hallway	3095	2255	76.6	103.8
UL Bed #2	845	648	20.9	29.8
UL Bed #3	1619	1367	40	62.9
LL Bath	808	60	20	2.8
LL Mechanical	367	151	9.1	6.9
LL Lounge & Stairs	2283	259	56.5	11.9
LL Fut. Bedroom #4	829	259	20.5	11.9
LL Fut. Bedroom #5	1122	259	27.8	11.9
ML Mudroom	1250	802	30.9	36.9

Supply Duct Data @ 500 cfm			
Supply Duct Number	**Length from Plenum (ft)**	**Airflow Capacity (cfm) @ 1.5 in. wc**	**Room or Zone**
1	22	29	LL Lounge
2	16	33	LL stairs
3	11	38	LL Bedroom 1
4	21	30	LL Bedroom 2
5	16	33	LL Bathroom
6	13	35	LL Mechanical
7	17	33	Front Entrance & stairs
8	10	38	Front Entrance & Stairs
9	20	30	Living Room
10	19	31	Living Room
11	16	33	Kitchen
12	24	28	Mud Room
13	18	32	ML Bathroom
14	30	25	Master Bedroom
15	28	26	Master Bedroom
16	15	34	Hallway
17	18	32	Hallway
18	18	32	UL Bedroom 1
19	25	27	UL Bedroom 2
20	13	35	UL Bathroom
21	4	44	UL Bathroom

6 ENERGY ANALYSIS

Using REM/Rate, we analyzed the amount of energy our building will consume throughout the year. Our design loads are 20.2 kBtu/hr for heating and 10.3 kBtu/hr for cooling. According to REM our annual consumption is a total of 63.8 MMBtu/yr, in Minneapolis that equates to roughly $1121 per year as found in REM/Rate found in volume II. We found our house will have a HERS rating of 32 without PV.

REM/Rate: Without PV Performance Report (refer to Volume II)

REM/Rate: Home Energy Rating Certificate

After running REM with 590 square feet of PV panels on the south roof we got a HERS rating of 0. The PV will cut down on our yearly cost, bringing the approximant yearly energy bills of $124 as shown in REM/Rate found in volume II.

There are two major design challenges of incorporating PV paneling onto the roof, insuring the correct orientation and degree of the panels as well as ensuring the roof can support the load of the panels. In our design we had to install a thicker OSB layer on the south roof in order to accommodate the extra load from the panels, we also altered our first roof idea in order to increase the surface area available on the south roof for PV panels. We took these parameters into account to create a roof that was south facing with an appropriate pitch, visibly appealing, and structurally sound.

Planning for a zero energy ready home began with the site location. An empty site was chosen in North Minneapolis that had minimal southern shading, and sufficient tree coverage on the north. To provide for maximum area on the southern side of the house, a clerestory window design was utilized. The total area of the southern roof is 735 ft2. With the panels lying flush against the roof, they should have an inclination angle of 28.4 degrees, and an azimuth angle of 180 degrees.

The team decided to use solar panels from a Minnesotan solar company called tenK in order to be eligible for a Minnesota rebate program. The model chosen was the tenK XT-A 410 Wp module for a variety of energy efficient reasons. This system utilizes parallel architecture to allow for multiple pathways for current flow, which mitigates the impact of shading, soiling, and other solar reducing factors. This system also utilizes a redundant inverter bus, which acts as a PV control module. This can be placed in the center of the array and allows for less wiring and greater efficiency in converting produced DC to AC, which can be used in the home. This system is also helpful because it uses multiple inverters connected in parallel, which distributes the workload better, lowering the duty for each inverter by half. This control module also does not need emergency maintenance and has a 25-year warranty. The solar panel itself is composed of polycrystalline silicon, which can be as efficient as monocrystalline cells but typically costs less. Each panel has a power warranty of 92.2% for a maximum of 25 years. The area of each panel, as seen in figure 1, is 29.5 ft2.

Arranging the panels solely on the southern roof in a landscape format, the house can hold 20 panels. Thus, a maximum power of 8.2 KW can be produced by the solar panels. The total area on the southern roof utilized by the panels is 590 ft2. The installation costs were simplified to be $5/watt, so the total costs based on an array of 8200 Watts is $41,000. This cost can be reduced greatly by federal and state rebates. The Federal Residential Energy Tax Credit allows for a 30% discount on the installation, reducing the cost to $28,700. The state of Minnesota also provides a sales tax exemption on solar panel purchases. The Made in Minnesota rebate rewards Minnesota-made solar panel buyers for 10 years with an annual payment based on the amount of energy produced in each respective year. Using a PV wattage calculator produced by the National Renewable Energy Laboratory (NREL), the total energy and savings produced by the solar array was found. The total annual energy produced based on local

ENERGY ANALYSIS

North Minnesota solar radiation data was calculated to be 10,337 KWh. The Made in Minnesota rebate program rewards the homeowner using a tenK array $.25 per KWh, thus rewarding a total of $2,584 for one year. The annual energy saved based on Xcel energy rates in 2015, roughly 10 cents per KWh, was found by the NREL calculator to be $1,034. If these rates were to be kept consistent for the 10-year lifetime of the Made in Minnesota rebate, the payback period is estimated to be 8 years for the array. This estimation can be found in the financial analysis. The addition of the PV array would significantly reduce the HERS score from 32 to 0.

Specifications	
Power Output at STC (Pmax)	410W,
Power Tolerance	+/- 3%
Cell Type	Polycrystalline Silicon
Number of Cells	192 Half Cells
Glass	3.2 mm Tempered Glass
Max Current Output	7.5A
Rated DC Voltage	35V Minimum / 57V Maximum
Operating DC Voltage	51V – 55V
Ground Fault Detect	Integrated (Compatible w/Inverter GFDI)
Internal Ground Fault Limit	500 mA
Frame Size	77.40 in × 54.90 in *(196.60 cm × 139.50 cm)*
Frame / Background	Silver / White
Backsheet Material	PET Covered Aluminum
Bypass Diodes	None
Operating Temperature Range	-40°F to 185°F *(-40°C to 85°C)*
Module Nominal Operating Cell Temperature	109°F *(43°C)*
Temperature Coefficient	-0.46% / °C
Static Load Capacity	50 PSF / 2400 Pa
Hail Resistance	Direct 1" impact at 52 mph *(84 km/h)*
Weight	71 lbs *(32.2 kgs)*
Certifications	UL 1703/UL 1741 IEC 61215 EN 61730
Product Warranty	12-Year Limited
Power Warranty	3% First Year LID; 0.2% Linear Degradation per year after; 92.2% minimum at 25 years.

tenK XT-A 410 Wp Specifications

7 FINANCIAL ANALYSIS

Summary

The financial analysis section of this document explains the construction costs, energy costs, and cash flow analysis of the OptiMN Home based on the DOE Race to Zero Competition guidelines and the standards of the builders of Urban Homeworks. The home is also analyzed with the option of having a photovoltaic system. The Hard cost, or construction cost, of the OptiMN home was found to be $226,797. Given that the square footage of the house is 1696 ft2, the cost per square foot was found to be $131. The Soft Costs, or non-construction costs, was found to be $90,050. Thus the total cost, summing the hard and soft costs, is found to be $311,847.

Assumptions

- Direct construction costs include land acquisition, garage, and unfinished lower level.
- Utility costs are taken at $1121 based on the HERS rating.
- Maintenance includes only major appliance replacements, and not minor maintenance that will be found in the homeowner guide.
- inflation rates in Minnesota was found to be 3.2% based on a study by the Bureau of Labor Statistics and used for each component of the total monthly cost.
- 2015 utility cost increase was found to be 5.6% using a study by Excel energy in Minnesota. https://www.xcelenergy.com/staticfiles/xe/Regulatory/Rate-Case/MNRequest2014-15/faqs/index.html
- The Net Present Value was found for all costs and rebates with a discount rate of 7% based on typical average rate of returns in the stock market.
- PV data presented in table 7 was found using an Energy Calculator made by the NREL. It asked for details of the chosen PV system and used local solar radiance data to produce estimates for the Kilowatt hours produced by the PV system. This was used to find the annual savings based on local energy prices accounting for inflation and price increases.
- The Made in Minnesota (MiM) Rebate data found in table 7 was calculated using $.25/KWh that is listed in the program's details.

OptiMN Construction Cost

Due to our goal of being affordable for residents in north Minneapolis, we constrained our maximum budget for total project cost of $311,847. Based on feedback provided by Urban Homeworks, we decided to constrain our budget further to be similar to that Urban Homeworks works with: A budget of no more than $240,000 for direct-construction costs.

To meet this goal, we worked with Urban Homeworks to develop prices for each line item of the construction estimate, using cost data from previous homes built by Urban Homeworks and using cost data collected from retailers and data collected by Building America research. In the end, the Team OptiMN Impact team decided to leave the basement unfinished and use the funds to fund better HVAC equipment, ERV equipment, and to fund our innovative roof design.

In the end, the OptiMN Impact house would cost an estimated $226,797 for the direct-construction costs, and with a 5% contingency, the house falls below the $240,000 budget. When taking soft costs into consideration, figured using the 40.6% stated in the competition financial parameters, is $318,877 and is the final cost of the OptiMN Impact House.

We also analyzed the costs of incorporating a Photovoltaic system onto the roof of the Impact House. The direct-construction costs increased by $28,700 and including the soft costs specified within the financial parameters, the total cost of the PV, including the soft cost percentage of 40.6%, is $40,352. With PV panels, the total direct-construction cost is $255,497 and the total cost including soft costs is $359,510. The PV option is not affordable to the Urban Homeworks clientele, therefore is an option.

For the competition, we chose our OptiMN Impact House to be DOE Zero Energy Ready and not include the PV option.

OptiMN Home Following Competition Guidelines

Our target market were single-family first-generation homebuyers with a medium family income (MFI) of $63, 900 per year. This MFI is roughly 80% of that of Hennepin County, given to be $79,659 (HUD 2014). Below is a table of the cash flow analysis of this market.

Table 1: Cash Flow Analysis of Opti-MN with Competition Guidelines			
	Annual	**Monthly**	**Formula**
Medium Family Income (MFI)	$63, 900 (roughly 80% of Hennepin County's MFI)	$5, 325	$63, 900 Maximum Income
Home Ownership Affordability	$24, 282	$2, 023.50	MFI x 0.38
Utility Costs	$1, 121	$125	Calculated REM Value
Property Tax	$1, 917	$160	MFI x 0.03
Insurance	$780	$65	Standard $780 Value
Mortgage Insurance	$1, 598	$133.13	MFI x 0.025
Down Payment	$62,369	$5, 833.33	House Value x 0.2
Monthly Household Debt	$320	$26.63	MFI x 0.005
Amount Available for Mortgage Payments	$18, 547	$1, 514	Amount Left Over

Table 1: These values were calculated per competition guidelines using the formulas given by the table above.

With the cash flow in mind, we can calculate the monthly payment for the homebuyer.

Table 2: Home Financing Information Following Competition Guidelines	
House Value	$319,000
Principle Amount	$226,800
Interest Rate	3.75%
Number of Payments (Over 30 Years)	360
Monthly Payment	$1,264.00

Table 2: These values were calculated per competition guidelines.

FINANCIAL ANALYSIS

OptiMN Home Serving Urban Homeworks

We have focused our market to align with our sponsor Urban Homeworks, whose goal is affordable housing. Urban Homeworks focuses on lower income single families in northern Minneapolis and first generation homebuyers. They offer subsidies to help the affordability of the homes and give opportunities to the potential homebuyers.

For the Urban Homeworks market, the medium family income is approximately $63,900. Using this information, a table of the cash flow can be created, as shown below.

Table 3: Cash Flow Analysis of Opti-MN Home with Urban Homeworks Guidelines			
	Annual ($)	**Monthly ($)**	**Fomula**
Medium Family Income (Hennepin County)	$64,000	$5,333.33	$82,300 Bracket
Home Ownership Affordability	$31,274	$2,606.17	MFI x 0.38
Utility Costs	$1,121	$93	Calculated REM Value
Property Tax	$1,296	$108	MFI x 0.03
Insurance	$780	$65	Standard $780 Value
Down Payment	$7,600		House Value x 0.2
Mortgage Insurance	$1,600	$133.33	MFI x 0.025
Monthly Household Debt	$320	$26.67	MFI x 0.005
Income Available for Financing (Principle and Interest)	$14,894	$1,241.17	Money left over for Financing

Table 3: According to Urban Homeworks guidelines, the formulas given by the table were found. The MFI was found by taking 80% of the MFI of Hennepin County.

The information provided in Table 3 can also be used to determine the monthly payment for the home, as shown in Table 4 below.

Table 4: Home Financing Information without PV	
House Value	$152,000
Principle amount	$144,400
Interest rate	3.75%
number of payments	360
Monthly Payment	$731

Table 4: The House value was found with soft and hard costs followed by competition guidelines. The subsidized principle amount was found by subtracting the down payment found in table 3 from the house market value ($152,000). The monthly payment of the mortgage was found using the principle amount and was $731, which is well below of what the family of four can afford.

Table 5: Cost of Living for Opti-MN House Without Photovoltaic					
Year	**Mortgage**	**NPV Utility Cost**	**Property Tax**	**Insurance**	**Total**
0	$77,537	$1,121	$1,917	$2,378	$82,953
1	$15,168	$1,087	$1,873	$2,324	$20,452
2	$14,364	$1,054	$1,831	$2,271	$19,520
3	$13,602	$1,022	$1,789	$2,220	$18,633
4	$12,881	$991	$1,749	$2,169	$17,789
5	$12,198	$961	$1,709	$2,120	$16,987
6	$11,551	$932	$1,670	$2,072	$16,224
7	$10,938	$904	$1,632	$2,025	$15,499
8	$10,358	$876	$1,595	$1,979	$14,808
9	$9,809	$850	$1,559	$1,934	$14,151
10	$9,289	$824	$1,523	$1,890	$13,526
11	$8,796	$799	$1,489	$1,847	$12,930
12	$8,330	$775	$1,455	$1,805	$12,364
13	$7,888	$751	$1,422	$1,764	$11,825
14	$7,470	$729	$1,389	$1,724	$11,311
15	$7,073	$707	$1,358	$1,684	$10,822
16	$6,698	$685	$1,327	$1,646	$10,357
17	$6,343	$664	$1,297	$1,609	$9,913
18	$6,007	$644	$1,267	$1,572	$9,491
19	$5,688	$625	$1,239	$1,536	$9,088
20	$5,387	$606	$1,210	$1,502	$8,704
21	$5,101	$587	$1,183	$1,467	$8,339
22	$4,830	$570	$1,156	$1,434	$7,990
23	$4,574	$552	$1,130	$1,401	$7,658
24	$4,332	$536	$1,104	$1,370	$7,341
25	$4,102	$519	$1,079	$1,338	$7,039
26	$3,884	$504	$1,054	$1,308	$6,751
27	$3,678	$488	$1,031	$1,278	$6,476
28	$3,483	$474	$1,007	$1,249	$6,213
29	$3,299	$459	$984	$1,221	$5,963

Table 5: Gives a yearly break down of the total costs of the mortgage, the utility cost, property tax, mortgage and home insurance. These values are all discounted to find the future value for each year with a discount rate of 7%. All of these costs are added for a total value, which gives the cost of operation for the home in that given year.

FINANCIAL ANALYSIS

Table 6: Energy Saving Data with PV Implementation					
Year	**KWh Produced**	**MiM Rebate**	**Annual PV savings**	**Total Annual Savings**	**Annual Payback ($)**
0	11086	$2,772	$1,033	$3,805	24896
1	11086	$2,590	$1,138	$3,728	21168
2	11086	$2,421	$1,140	$3,560	17607
3	11086	$2,262	$1,142	$3,404	14203
4	11086	$2,114	$1,144	$3,258	10945
5	11086	$1,976	$1,145	$3,121	7824
6	11086	$1,847	$1,147	$2,994	4830
7	11086	$1,726	$1,149	$2,875	1955
8	11086	$1,613	$1,150	$2,763	-808
9	11086	$1,508	$1,151	$2,659	-3466
10	11086	$1,409	$1,153	$2,562	-6028
11	11086	$1,317	$1,154	$2,471	-8499
12	11086	$1,231	$1,155	$2,386	-10884
13	11086	$1,150	$1,156	$2,306	-13190
14	11086	$1,075	$1,157	$2,232	-15422
15	11086	$1,005	$1,158	$2,162	-17584
16	11086	$939	$1,159	$2,097	-19682
17	11086	$877	$1,159	$2,037	-21719
18	11086	$820	$1,160	$1,980	-23699
19	11086	$766	$1,161	$1,927	-25626
20	11086	$716	$1,162	$1,878	-27504
21	11086	$669	$1,162	$1,831	-29335
22	11086	$626	$1,163	$1,788	-31123
23	11086	$585	$1,163	$1,748	-32871
24	11086	$546	$1,164	$1,710	-34581
25	11086	$511	$1,164	$1,675	-36256
26	11086	$477	$1,165	$1,642	-37898
27	11086	$446	$1,165	$1,611	-39509
28	11086	$417	$1,165	$1,582	-41091
29	11086	$390	$1,166	$1,555	-42646

Table 6: Gives data produced by the NREL calculator (more info about the calculator can be found in the Energy Analysis). The KWh produced in the first year is assumed to be consistent despite an expected decrease in solar panel efficiency. The annual payback is found by subtracting the annual payback from the produced energy from the total cost of the solar array. The system begins to payback by the eighth year.

Table 7: Annual Cash Flow for Opti-MN House with PV Competition Guidelines			
	Annual ($)	**Monthly ($)**	**Formula**
Medium Family Income (Hennepin County)	$63,900	$5,325.00	$82,300 Bracket
Home Ownership Affordability	$24,282	$2,023.50	MFI x 0.38
Utility Costs	$88	$7	Calculated REM Value
Property Tax	$1,917	$160	MFI x 0.03
Insurance	$780	$65	Standard $780 Value
Down Payment	$71,847	x	House Value x 0.2
Mortgage Insurance	$1,598	$133.13	MFI x 0.025
Monthly Household Debt	$320	$26.63	MFI x 0.005
Income Available for Financing (Principle and Interest	$19,580	$1,631.67	Money left over for Financing

Table 7: According to competition guidelines, the formulas given by the table were found. The MFI was found by taking 80% of the MFI of Hennepin County.

FINANCIAL ANALYSIS

Table 8: Home Financing Information with PV	
House Value	$359,234
Principle amount	$287,388
interest rate	3.75%
number of payments	360
Monthly Payment	$1,456

Table 8: The house value found in table 4 was increased by the amount of the solar panel array, which was found to be $28,700 in the energy analysis.

Table 9: Cost of Living of Opti-MN House With Photovoltaic					
Year	**Mortgage**	**NPV Utility Cost**	**Property Tax**	**Mortgage and Home Insurance**	**Total**
0	$103,465	$114.90	$1,917	$2,378	$107,875
1	$11,585	$67	$1,849	$2,294	$15,661
2	$10,827	$115	$1,783	$2,212	$14,707
3	$10,119	$161	$1,720	$2,134	$13,811
4	$9,457	$205	$1,659	$2,058	$12,968
5	$8,838	$247	$1,600	$1,985	$12,176
6	$8,260	$287	$1,543	$1,914	$11,430
7	$7,720	$326	$1,488	$1,846	$10,728
8	$7,215	$363	$1,435	$1,781	$10,068
9	$6,743	$398	$1,384	$1,717	$9,447
10	$6,301	$431	$1,335	$1,656	$8,862
11	$5,889	$464	$1,288	$1,598	$8,311
12	$5,504	$494	$1,242	$1,541	$7,793
13	$5,144	$524	$1,198	$1,486	$7,304
14	$4,807	$552	$1,155	$1,433	$6,844
15	$4,493	$579	$1,114	$1,382	$6,411
16	$4,199	$605	$1,075	$1,333	$6,003
17	$3,924	$629	$1,037	$1,286	$5,618
18	$3,668	$653	$1,000	$1,240	$5,255
19	$3,428	$675	$964	$1,196	$4,913
20	$3,203	$697	$930	$1,154	$4,591
21	$2,994	$717	$897	$1,113	$4,287
22	$2,798	$737	$865	$1,073	$4,000
23	$2,615	$756	$835	$1,035	$3,729
24	$2,444	$774	$805	$998	$3,473
25	$2,284	$791	$776	$963	$3,232
26	$2,135	$807	$749	$929	$3,005
27	$1,995	$823	$722	$896	$2,790
28	$1,864	$838	$696	$864	$2,587
29	$1,742	$853	$672	$833	$2,395

Table 9: This table gives the new values of the mortgage and utility cost with the addition of the solar array on the southern roof. The initial cost of the system was included in the first year of the mortgage. The Made in Minnesota rebate was also subtracted from the mortgage for each year for 30 years as listed in table 6. The utility cost for each year was found by subtracting the utility costs found in table 5 by the PV annual savings found in Table 6.

FINANCIAL ANALYSIS

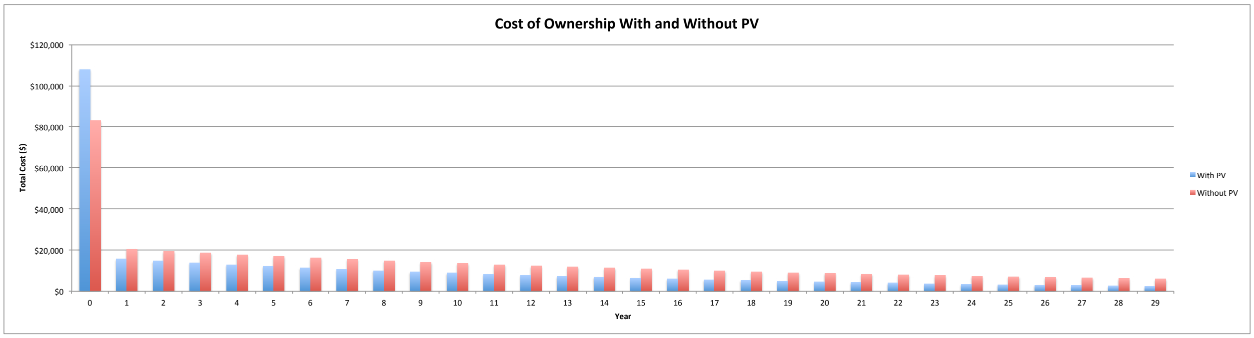


Chart 1: Graphically displays the difference in price between the Opti-MN model with PV and without. The “With PV” values can be found in the total section in table 9, and the “Without PV” can be found in the total section in table 5. The “With PV” is found to be substantially less than the “Without PV” model for every year after its upfront cost.

Through this analysis, the total amount saved over the 30-year lifetime of the mortgage, including the utility savings and rebates, is $59,083.

Maintenance Info

Maintenance is an important financial consideration for a homeowner, but will not be considered in the financial analysis because it ultimately depends on the user and their usage of the appliances. The appliances will have to be replaced in the long term, but the model of the replacement that the homeowner chooses cannot be determined at this point.

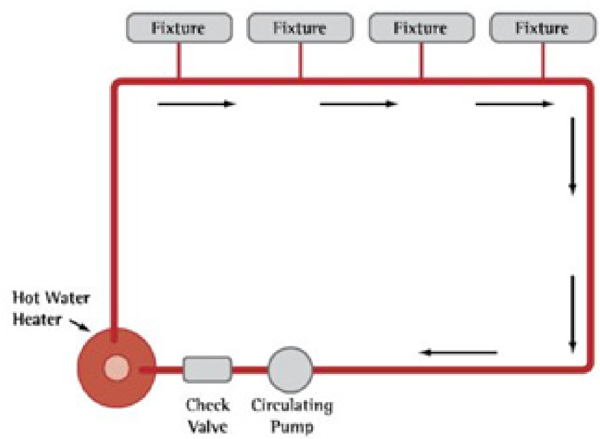
8 DOMESTIC HOT WATER, LIGHTING, APPLIANCE

Domestic Hot Water

The primary goal for hot water delivery system design was minimizing the cold water that is wasted waiting for hot water to arrive and to limit the hot water that remains in the pipes unused. To achieve this goal, we wanted to design our plumbing to use the shortest runs possible. Additionally, we aligned our design to comply with EPA's WaterSense specifications. With the design in place the next step was selecting and sizing a high-efficiency water heater. Today there are more choices for high-efficiency, sealed-combustion, condensing water heaters; however, the affordable housing community has found the conventional, storage-type water heaters to be more acceptable and durable than the tankless models. Additionally, standard storage tank models show less waste energy in start-up and require less maintenance when compared to tank-less models. With this information in mind, we selected the Polaris high-efficiency storage water heater model: PG10 34-100-2NV. It has a 34 gallon capacity, with a 96% thermal efficiency, and low standby heat losses of 1%.

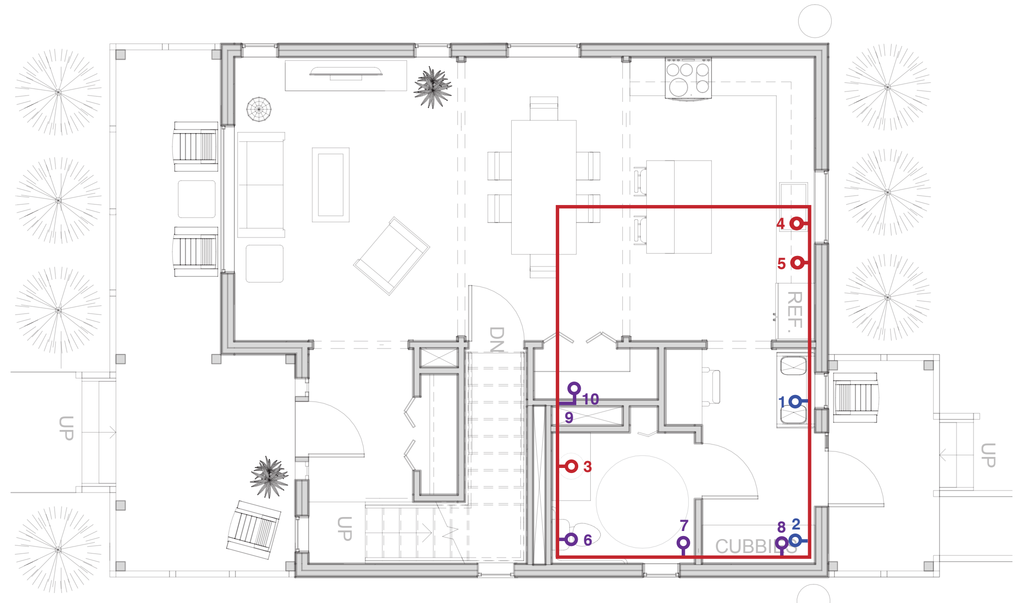
Polaris High Efficiency Water Heater

Demand Recirculation Pump and Loop



For the delivery system, we selected a Demand Recirculation pump system. Recirculation systems consist of a single continuous hot water supply loop capable of recirculating water throughout the home. A circulating pump draws heated water through the loop and returns any ambient temperature water remaining in the loop to the water heater. Additionally, the pump may return this water to the cold water line while drawing hot water from the water heater. Recirculation systems save water in two ways; reducing the wait time for hot water and returning ambient temperature water in the pipes back to the water heater. The process decreases the work that a water heater must do in order to achieve an acceptable temperature. Although energy is required to operate the pump, the energy saved by the reduced amount of heated water far outweighs the pump operation. Demand-initiated recirculation has been shown to be the most water-efficient hot water delivery system when designed and operated appropriately. We believe this efficiency justifies the added cost of the recirculation loop, pumps, and switches or sensors.

DOMESTIC HOT WATER, LIGHTING, APPLIANCE



(2) First Floor Plan
1/8" = 1'-0"

BASEMENT FLOOR PIPE SEGMENTS
1st FLOOR PIPE SEGMENTS
2nd FLOOR PIPE SEGMENTS

Hot water calculations were conducted with the EPA tool using the WaterSense flow rates. With our design, the worst fixtures (highlighted in yellow) have volumes of .207 and .221 gallons (well under the WaterSense total hot water volume limit of .5 gallons) and have a wait times of 8.3 seconds (below ASPE acceptable performance of 10 seconds). To reach these numbers our water fixtures were specifically designed to be in close proximity to each other, providing us with a smaller recirculation loop (See image below).

Hot Water Delivery System Calculations

Fixture	Pipe Segment	Pipe Diameter [in]	Water Capacity [oz/ft]	Pipe Length [ft]	Water Volume [gal]
basement bathroom	Drop from Loop	1/2	1.89	6.5	0.096
	1	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.118
				Hot Water Wait Time [sec]	4.7
basement bathtub	Drop from Loop	1/2	1.89	6	0.089
	2	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.111
				Hot Water Wait Time [sec]	3.0
1st Floor half	Drop from Loop	1/2	1.89	3.5	0.052
	3	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.074
				Hot Water Wait Time [sec]	3.0
1st Floor kitchen sink	Drop from Loop	1/2	1.89	3.5	0.052
	4	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.074
				Hot Water Wait Time [sec]	2.0
1st floor dishwasher	Drop from Loop	1/2	1.89	3.5	0.052
	5	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.074
2nd floor tub and shower	Drop from Loop	1/2	1.89	12.5	0.185
	6	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.207
				Hot Water Wait Time [sec]	6.2

Fixture	Pipe Segment	Pipe Diameter [in]	Water Capacity [oz/ft]	Pipe Length [ft]	Water Volume [gal]
2nd Floor Bath Sink 1	Drop from Loop	1/2	1.89	12.5	0.185
	7	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.207
				Hot Water Wait Time [sec]	8.3
2nd Floor Bath Sink 2	Drop from Loop	1/2	1.89	12.5	0.185
	8	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.207
				Hot Water Wait Time [sec]	8.3
2nd Floor Clothes Washer	Drop from Loop	1/2	1.89	12.5	0.185
	9	1/2	1.89	1	0.015
	10	1/2	1.89	1.5	0.022
				Total Hot Water Volume [gal]	0.221

1. Assumes a bathroom sink faucet flow rate of 1.5 gpm: the maximum flow rate for WaterSense labeled bathroom sink faucets
2. Assumes a kitchen facuet flow rate of 2.2 gpm: the maximum flow rate for WaterSense labeled kitchen sink faucets
3. Assumes a showerhead flow rate of 2.0 gpm: the maximum flow rate for WaterSense labeled showerheads.

Lighting Design Strategies

The lighting and appliances consumption is 50% of total residential electricity consumption according to the REM model used. This makes its very critical to make good lighting and appliances choices from the design stage.

The design of the house provides good daylighting with a Clerestory roof that allow natural day light to illuminate the 2nd level.

The process of the lighting design was to identify the optimal lighting levels for the different interior areas. The lighting design team studied the required lighting levels for the various interior spaces. This was essential in creating the optimal lighting plan.

Understanding the lighting use behavior of the homeowners

The lighting layout is planned with the user behavior pattern in a typical residence. The users would like to have easy access to light switches closer to doors. The office space, family room, kitchen space will have additional telephone, cable and additional plug points for any future uses. There would be no need for toilet exhaust fans other than the master bath as they are already integrated into the ERV unit. All toilets would have vanity and central ceiling lights with GFCI plug points. Two way switches with dimmers would be very useful control in the bedrooms and common areas.

Identifying the optimal locations to balance the optimal lighting levels and user behavior in interior spaces

All switch boards are arranged to be close to the corresponding entry door to ensure easy access. The staircase spine is lit by two set of two way switches to balance energy and efficiency. Two-way switches and dimmers are placed in common areas like the Great room, kitchen and family room along with the bedrooms. It is typical that two or three fixtures in one room are linked together to one switch for better usability. A ceiling fan with light fixtures is used in the family room and they can also be placed in each of the bedrooms. The use of two bulb ceiling fixtures and one bulb ceiling fixtures are designed to cater to the respective light levels in spaces. The location for exterior light fixtures is designed with lighting levels for outdoors.

The team's mission for lighting inside the Opti-MN Impact home is integrating the designed spaces with the natural features to fit the practical needs of the homeowner. The two most distinctive natural features the Impact home offers are the clerestory windows and second story sloped ceiling. The average amount of time spent inside each room was estimated determining the average light usage. Using the clerestory natural lighting lowers the lighting usage of the master bedroom, hallway and third bedroom. Because the clerestory windows are located on the north side, a clean and delicate light pours through into the Impact home through the clerestory windows. This type of natural light offers a more comfortable feel for the resident. Table 8.1, shown above,

Living Space	Lumens/M^2	Lumens/ft^2
Kitchen	300-400	27.88-3.17
Living	400-500	37.17-46.47
Hallway	300	27.88
Bedroom	300-400	27.88-3.17
Bedroom (task)	700-800	65.05-74.35
Bath	500-600	46.47-55.76
Bath (task)	700-800	65.05-74.35
Reading	400	31.17

Figure 8.1: Lumens needed

displays the amount of lumens per square foot of living space for each room. The Impact team determined the amount of lumens for each space and chose the correct light fixtures and bulbs that would provide the desired lumens.

Each light fixture uses an LED (light-emitting diode) lightbulb for best energy efficiency. Even though the initial cost is higher than CFL and Incandescent lightbulbs, the LED leads the lightbulbs in longevity, durability, and reliability. However, the electricity cost over the span of a year is significantly less. Table 8.2 shows the difference in yearly electric cost between the LED and incandescent bulbs. The initial cost of incandescent is much less than LED, but the lifetime of LED is roughly 30 times longer. For each LED bulb, 30 incandescent bulbs need to be purchased. This data does not take into account the amount of money needed to do so. We did however calculate the cost of operation to saving approximately $270 annually over using incandescent bulbs

We have gathered specifications of lighting fixtures that are energy star rated and balanced the cost considerations with the financial analysis team, as listed in figure 8.3. All lighting fixtures used in design are energy star rated with all units being LED lighting.

Fixture	Units	Watts/Unit	Hours/Day	Tot Watt/Day	Total kWh/year
Track Lighting	1	16	8	128	46.72
Island Lighting	1	60	8	480	175.2
Ceiling Lights					
(Bed 1)	1	16.92	3	50.76	18.5274
(Bed2)	1	16.92	5	84.6	30.879
(Bed3)	1	16.92	3	50.76	18.5274
(Closets)	4	16.92	2	135.36	49.4064
(Foyer)	2	16.92	5	169.2	61.758
(Hall)	1	16.92	5	84.6	30.879
(Bath)	3	16.92	4	203.04	74.1096
(Living/Dining)	2	16.92	8	270.72	98.8128
Sconce Fixture	2	13	12	312	113.88
Vanity Fixtures	3	13	4	156	56.94
Wall-Mounts	2	11.6	12	278.4	101.616
				Total	877.2556
				Cost ($/kWh)	0.10
				Total ($/yr)	$ 87.73

Figure 8.2: Lighting usage costs

Others

The smoke detectors are located central in the first floor living area and in the second floor corridor close to the laundry room. The carbon monoxide detectors are placed in the mechanical equipment room, main floor, and the upstairs hallway. The electrical panel is positioned in the mechanical room. The electrical cut off box for the future solar PV panel is located beside the electrical meter for easy access. Urban Homeworks is an energy conscious builder and uses energy star rated appliances in kitchen and laundry areas. In the DoE challenge home, the team insisted on using the same energy star appliances by the builder to respect the style and clientele expectations. We have however upgraded the list by incorporating a range hood that meets energy star criteria.

DOMESTIC HOT WATER, LIGHTING, APPLIANCE

The various fixtures are listed as follows.

Indoor						
First Floor						
Light Fixture Type	Light Fixture Specification	Model	Energy (W)	Cost/Unit	Units	Cost
Fan Light Kit	Hampton Bay Ceiling Fan w/ 4-light LED Brushed Nickel	KERF4200LEDSN3K	16W	$ 119.00	1	$ 119.00
Island Light Kit	Cassiopeia 2-light Nickel Ceiling Island Light	CLI-WDK279982	60W	$ 109.90	1	$ 109.90
Ceiling Light	Commercial Electric Brushed Nickel LED Energy Star Flush	HUI8011L-2/BN	16.92W	$ 24.97	7	$ 174.79
Sconce Fixture	Green Matters 1-Light Brushed Nickel Wall Sconce	HD-3204	13W	$ 35.99	1	$ 35.99
Vanity Fixture	Green Matters 3-light Brushed Nickel Vanity Fixture	HD-3319	13W	$ 95.99	1	$ 95.99
					Total	$ 535.67
Second Floor						
Ceiling Light	Commercial Electric Brushed Nickel LED Energy Star Flush	HUI8011L-2/BN	16.92W	$ 24.97	8	$ 199.76
Vanity Fixture	Green Matters 3-light Brushed Nickel Vanity Fixture	HD-3319	13W	$ 95.99	2	$ 191.98
Sconce Fixture	Green Matters 1-Light Brushed Nickel Wall Sconce	HD-3204	13W	$ 35.99	2	$ 71.98
					Total	$ 463.72
Outdoor						
Wall-Mount	Hampton Bay Basilica Collection Wall-Mount Outdoor LED	HB703LEDP-293	11.6W	$ 64.97	2	$ 129.94
					Total	$ 129.94
Basement						
Ceiling Light	Commercial Electric Brushed Nickel LED Energy Star Flush	HUI8011L-2/BN	16.92W	$ 24.97	6	$ 149.82
Sconce Fixture	Green Matters 1-Light Brushed Nickel Wall Sconce	HD-3204	13W	$ 35.99	2	$ 71.98
					Total	$ 221.80
					Total	$1,351.13

Figure 8.3: Light fixture costs

We have gathered specifications of appliances that are energy star rated and balanced the cost considerations with the financial analysis team.

The various appliances are listed as follows:

Appliances	Specifications	Baseline	Rating	Design	Price
Kitchen					
Range hood	Whirlpool Gold 30" (GXW7330DXS) Vented Wall- Stainless Steel - CFM 150/300	Energy Star	CFM/W 4.8	150 cfm	$ 345.00
Range	Whirlpool 4.8 cu. ft. (WFE510S0AS) Self-Cleaning Electric Range - Stainless Steel - 40 amp - 220/240V				$ 300.00
Dishwasher	Whirlpool 24" Dishwasher (WDF510PAYS) - Stainless Steel - 258 kWh/yr - 3.47 gallon/cycle	Energy Star	EF .85 Gal/C 3.47		$ 250.00
Refridgerator	Whirlpool 17.6 cu. ft. (W8RXEGMWS) Top Freezer Refrigerator - Stainless Steel - 378 kWh/yr	Energy Star	AEU 378		$ 500.00
				Total	$1,395.00
Laundry					
Washer / Dryer Combo	LG 4.3 cu.ft. (WM3997HWA) Ultra Large Capacity Front Load Washer / Dryer Combo - Stainless Steel - 125 kWh/yr		MEF 3.3 IWF 3.2		$1,250.00
				Total	$1,250.00
				Total	$2,645.00

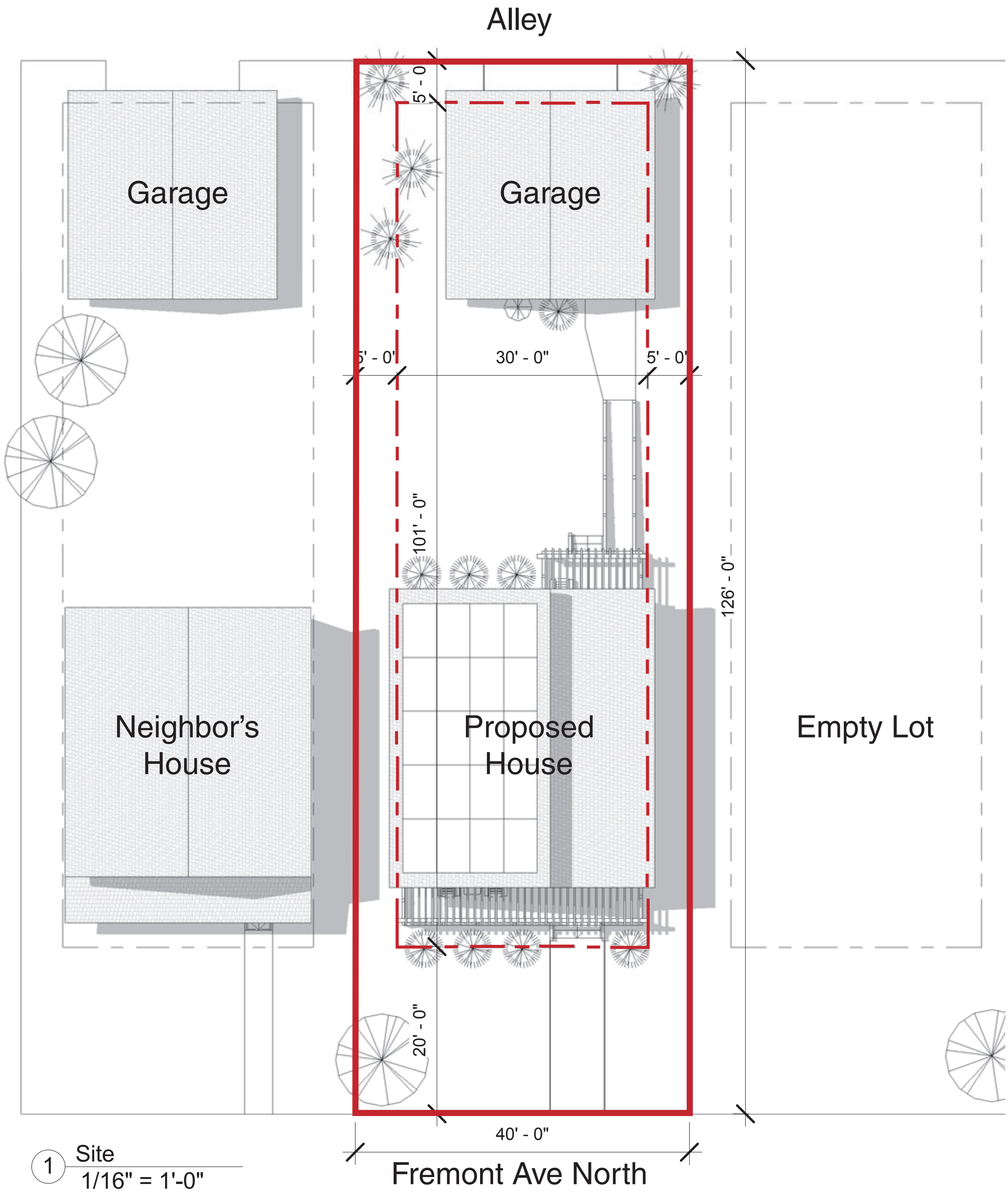
Figure 8.4: Appliance costs

DoE Zero Energy Ready - Design Build	
Lighting & Appliance Annual End-Usage	
Therms	64
kWh w/ plug loads	5559
Cost/year	$ 500.00

Figure 8.5: Annual End-Usage

9 CONSTRUCTION DOCUMENTS

DRAWING LIST	
A000	Title Sheet
A001	Site Plan
A002	Basement & First Floor Plan
A003	Second Floor & Roof Plan
A004	Elevations - East & West
A005	Elevations - North & South
A006	Sections
B001	Mech Duct Layout
B002	Mech Duct Layout & Demand Recirculation w/ Hot Water Distribution
B003	Electrical Layout
B004	Electrical Layout
C001	Enclosure Details
C002	Enclosure Details
C003	Enclosure Details
C004	Enclosure Details
C005	Enclosure Details
C006	Enclosure Details
C007	Enclosure Details
C008	Enclosure Details
C009	Enclosure Details



1 Site
1/16" = 1'-0"

3539 Fremont Ave N Minneapolis

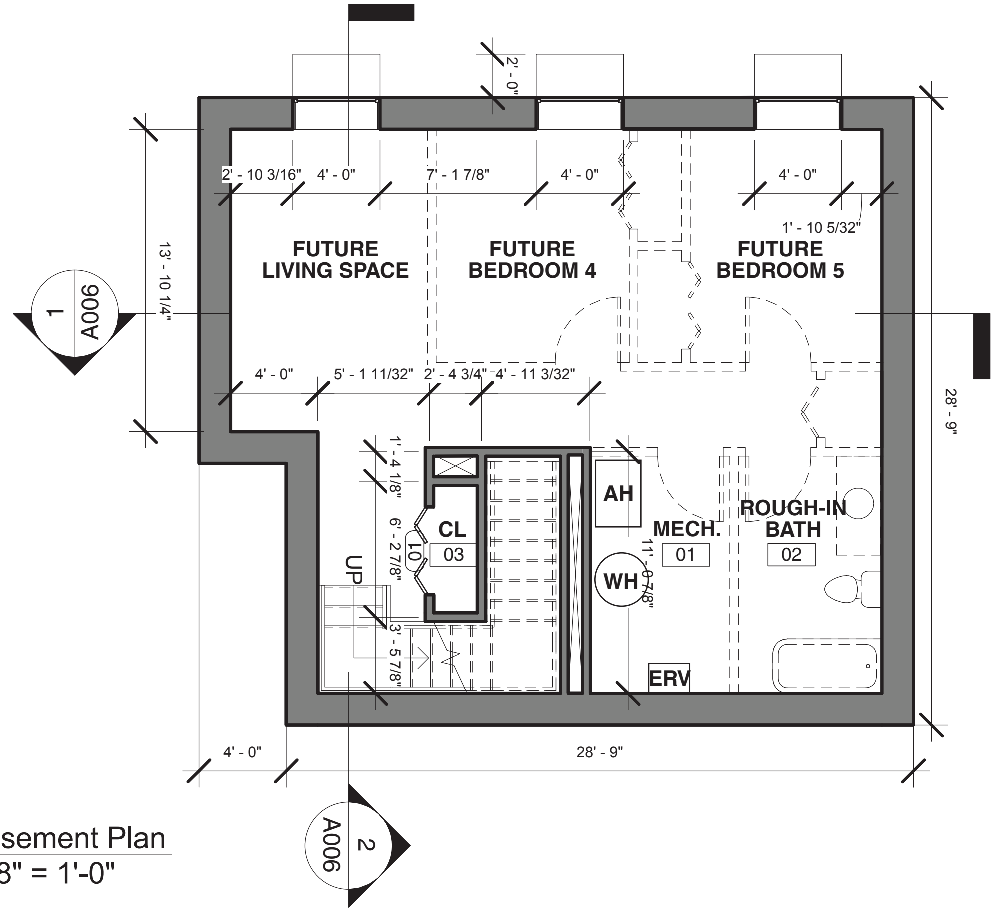
Currently an Empty Lot

N

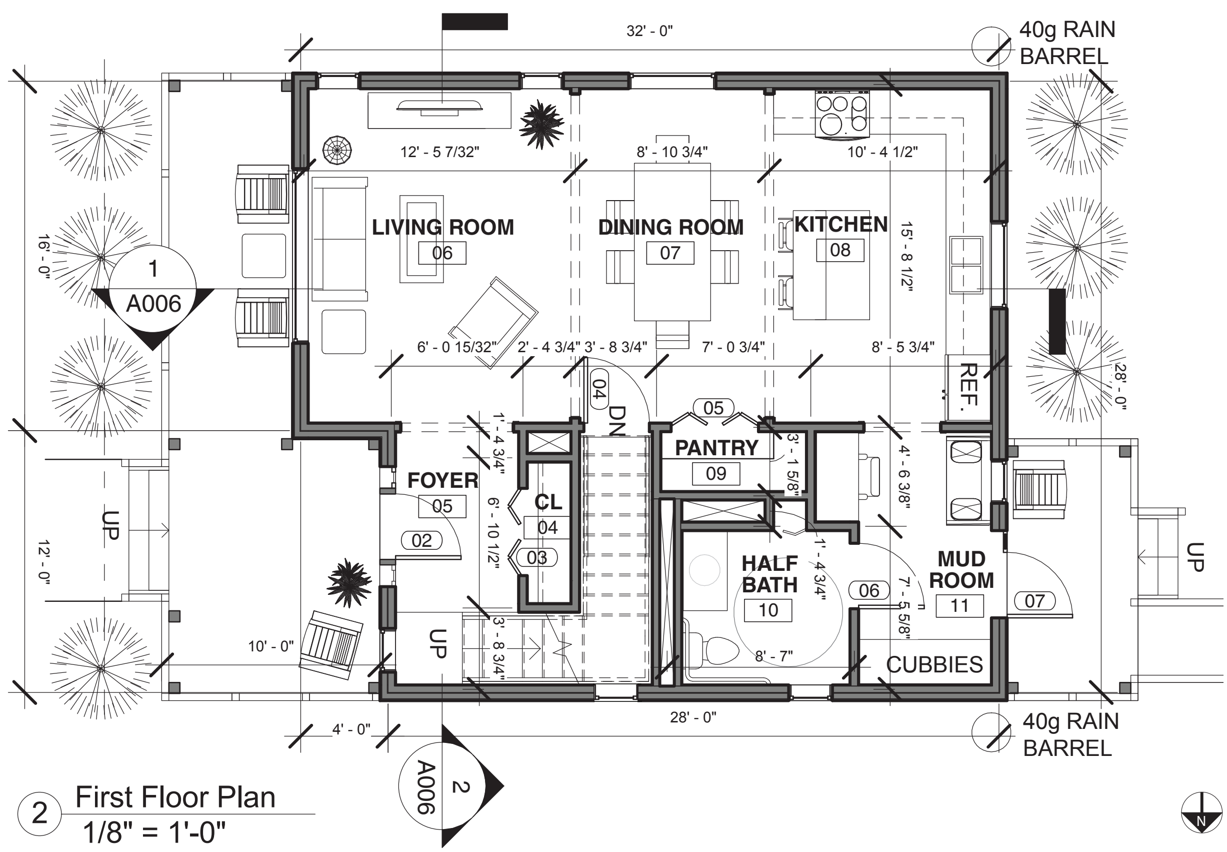
Sheet Title: Site Plan	Project Name:
Sheet Number: A001	DOE Race to ZERO 3539 Fremont Ave N Minneapolis, MN

OptiMN

RACE TO ZERO U.S. DEPARTMENT OF ENERGY STUDENT DESIGN COMPETITION



1 Basement Plan
1/8" = 1'-0"

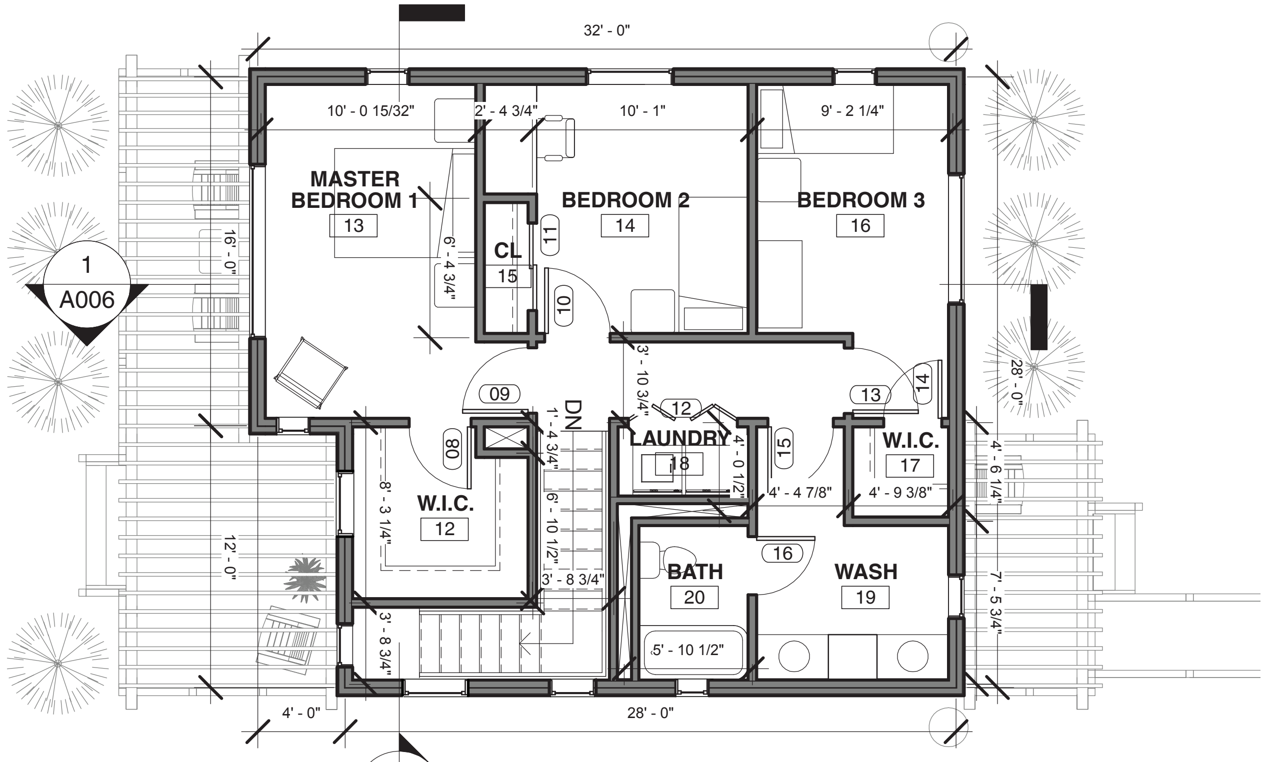


2 First Floor Plan
1/8" = 1'-0"

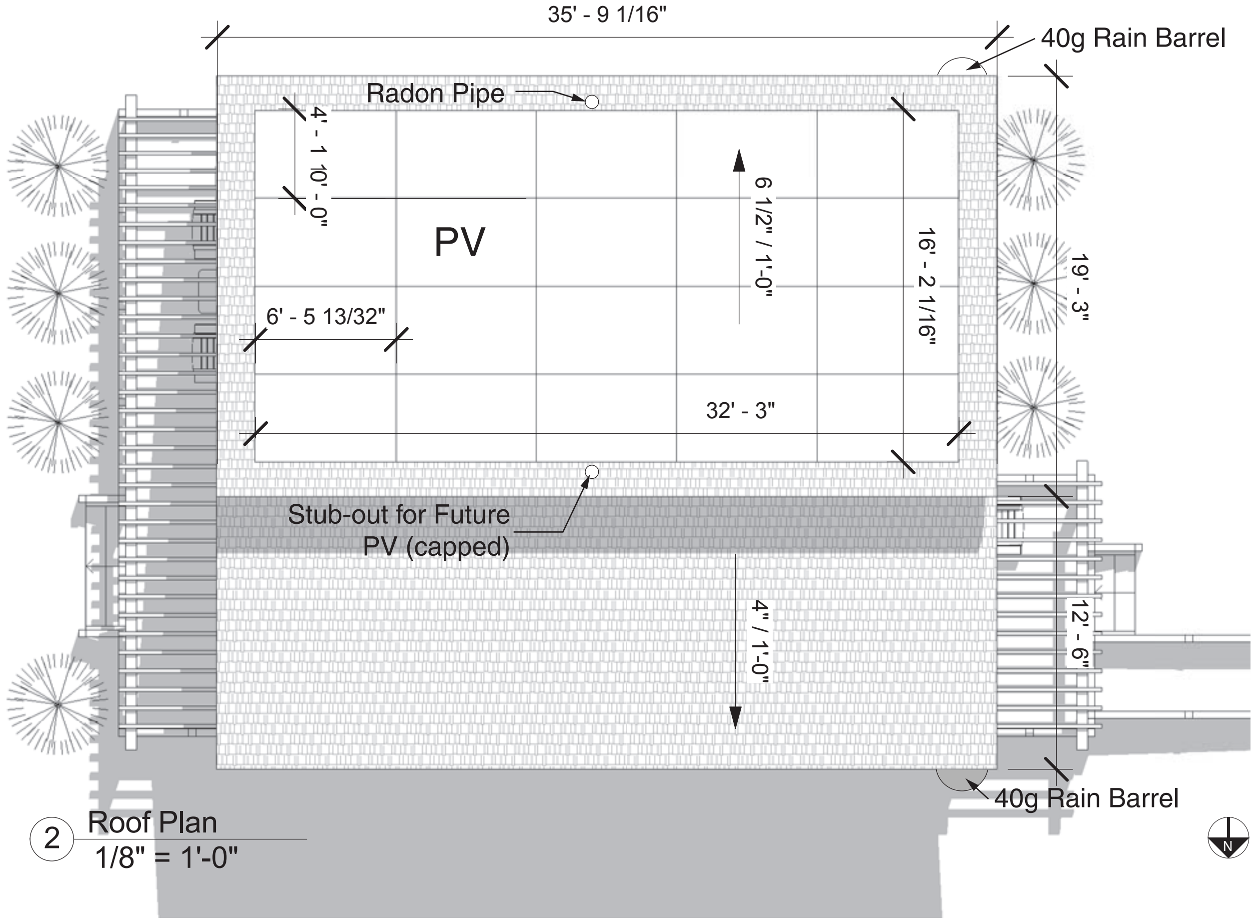
Sheet Title:
Basement & First Floor Plan
Sheet Number:
A002

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN

OptiMN



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



2 Roof Plan
1/8" = 1'-0"

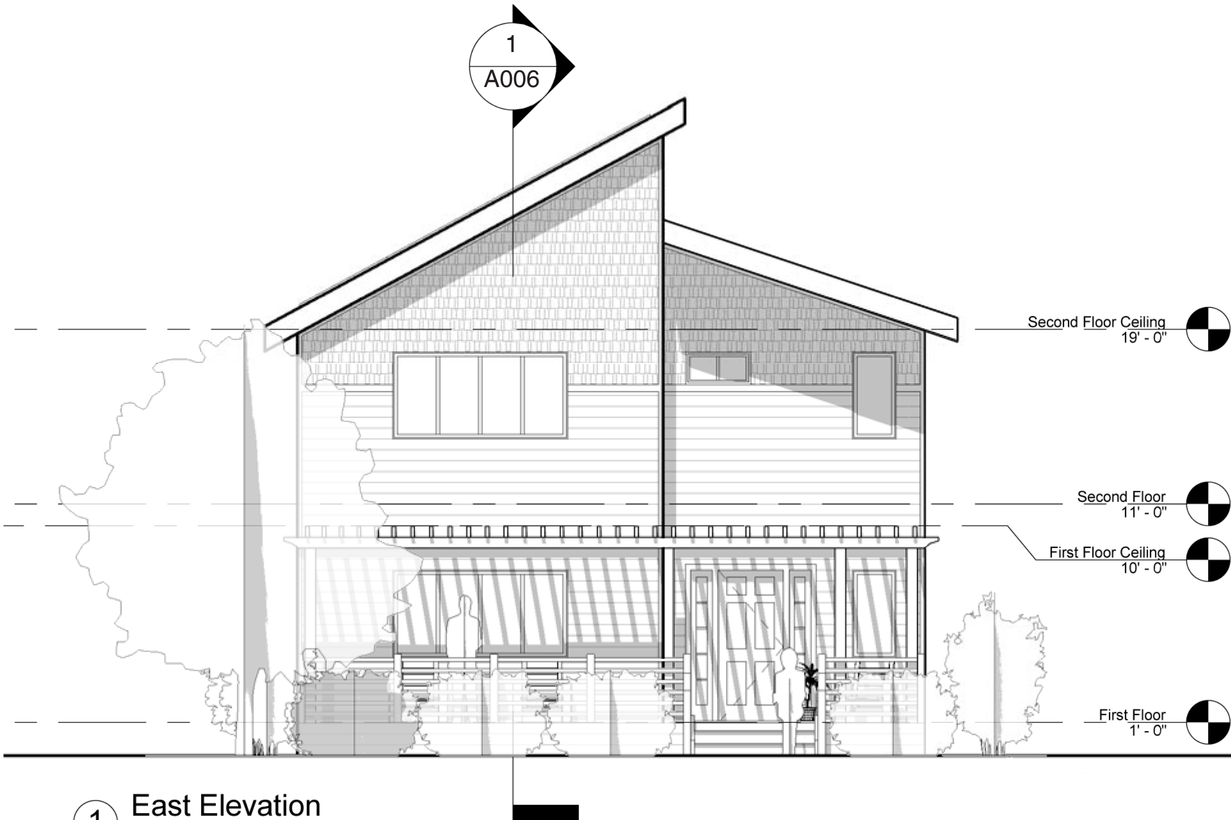
Sheet Title:
Second Floor Plan & Roof Plan

A003

Project Name:

DOE Race to ZERO

3539 Fremont Ave N Minneapolis, MN

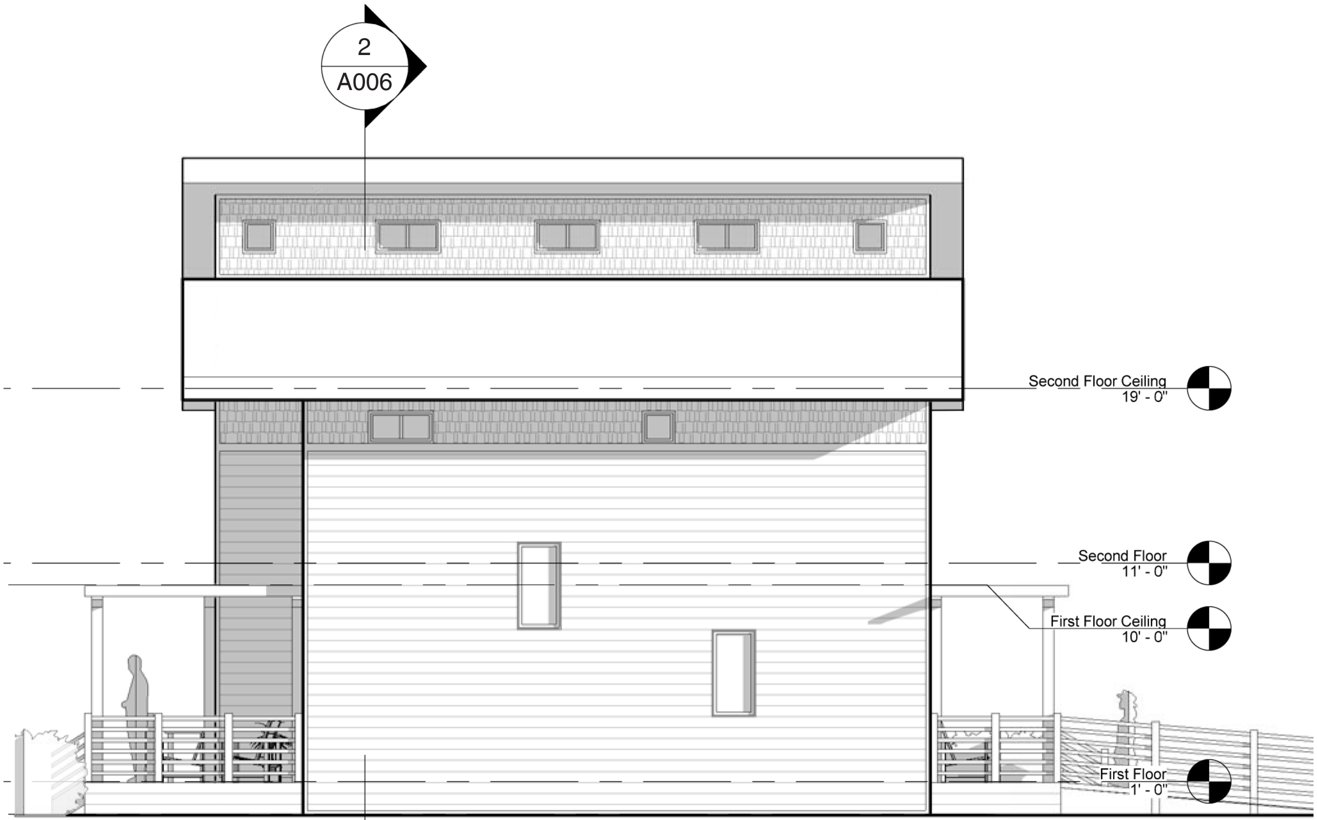


1 East Elevation
1/8" = 1'-0"

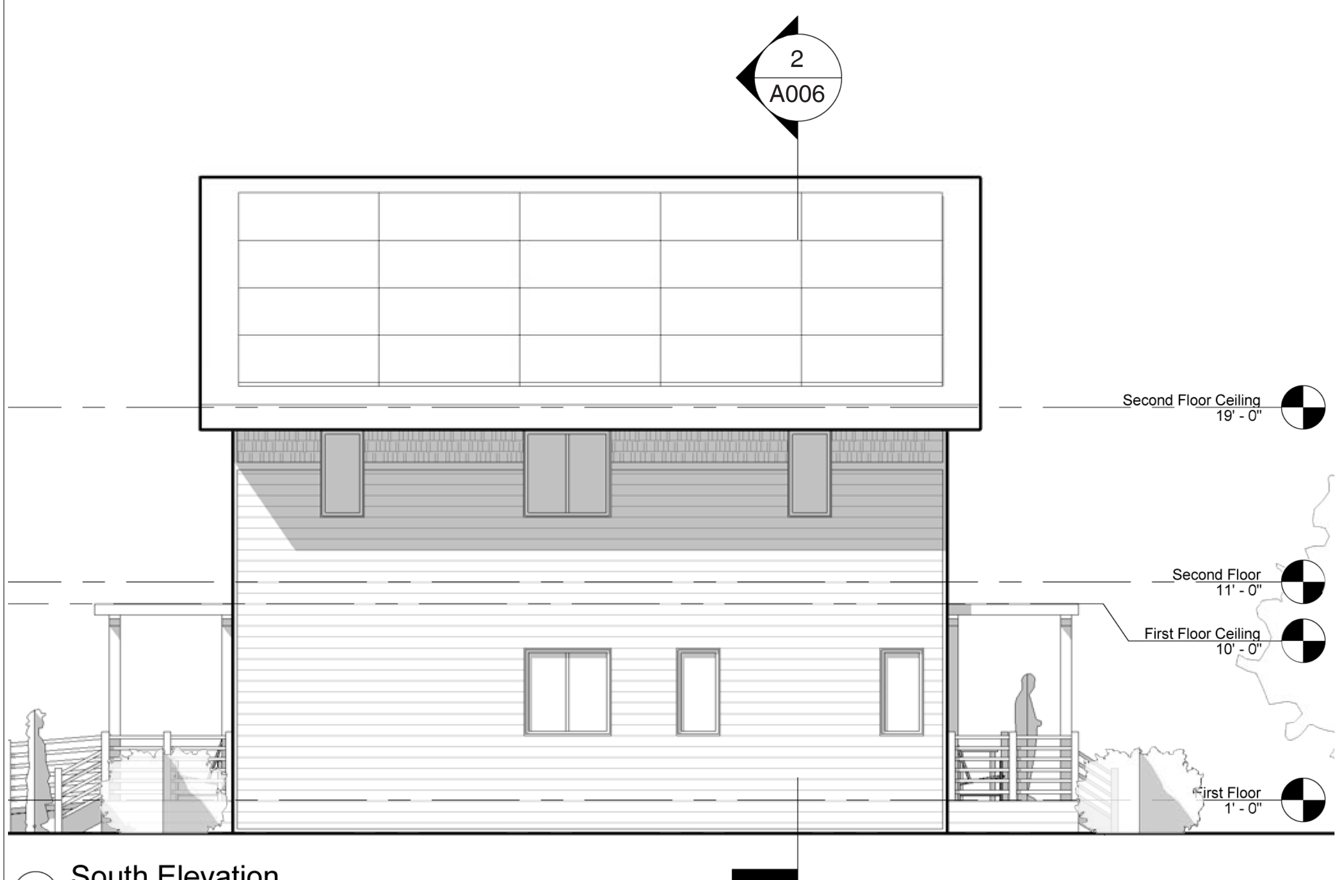
2 West Elevation
1/8" = 1'-0"

Sheet Title:
Elevations - East & West
A004

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN



1 North Elevation
1/8" = 1'-0"



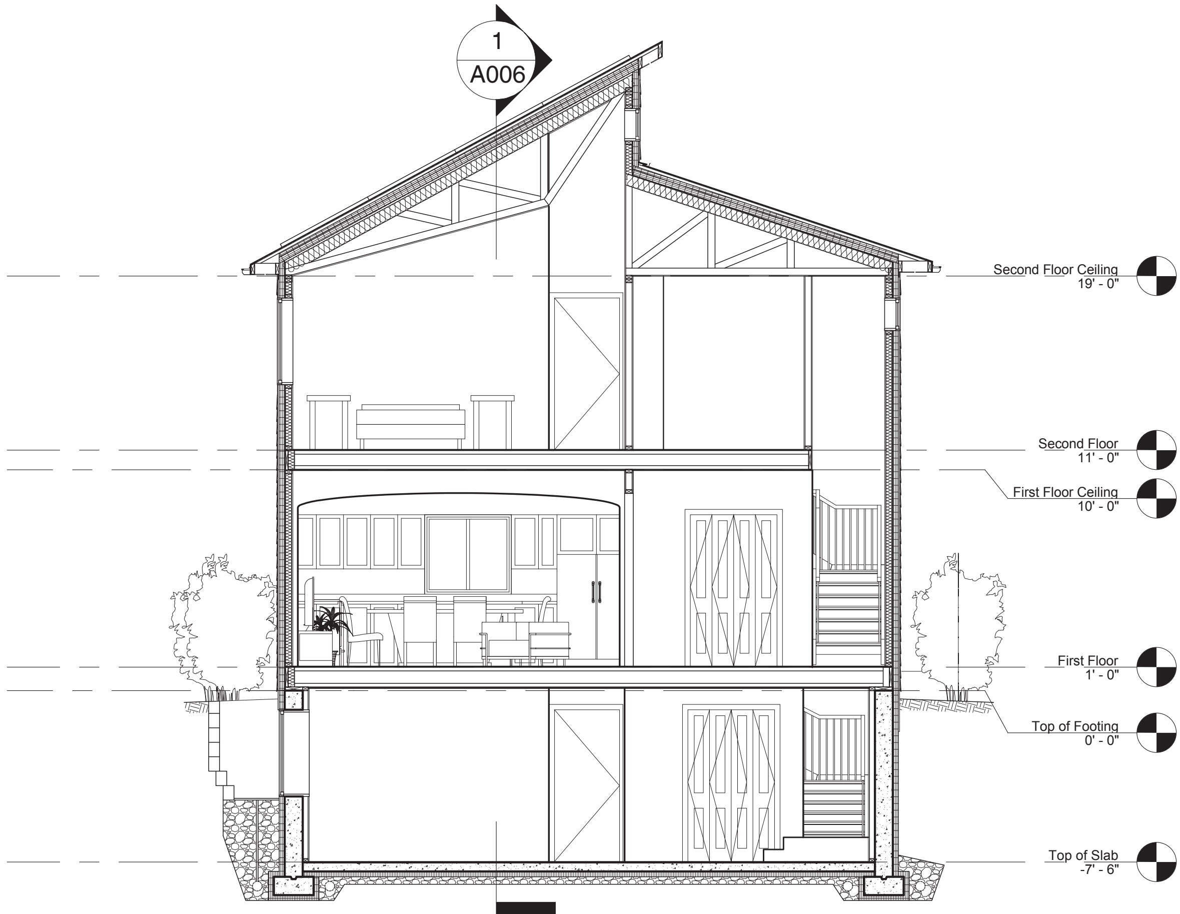
2 South Elevation
1/8" = 1'-0"

Sheet Title:
Elevations - North & South

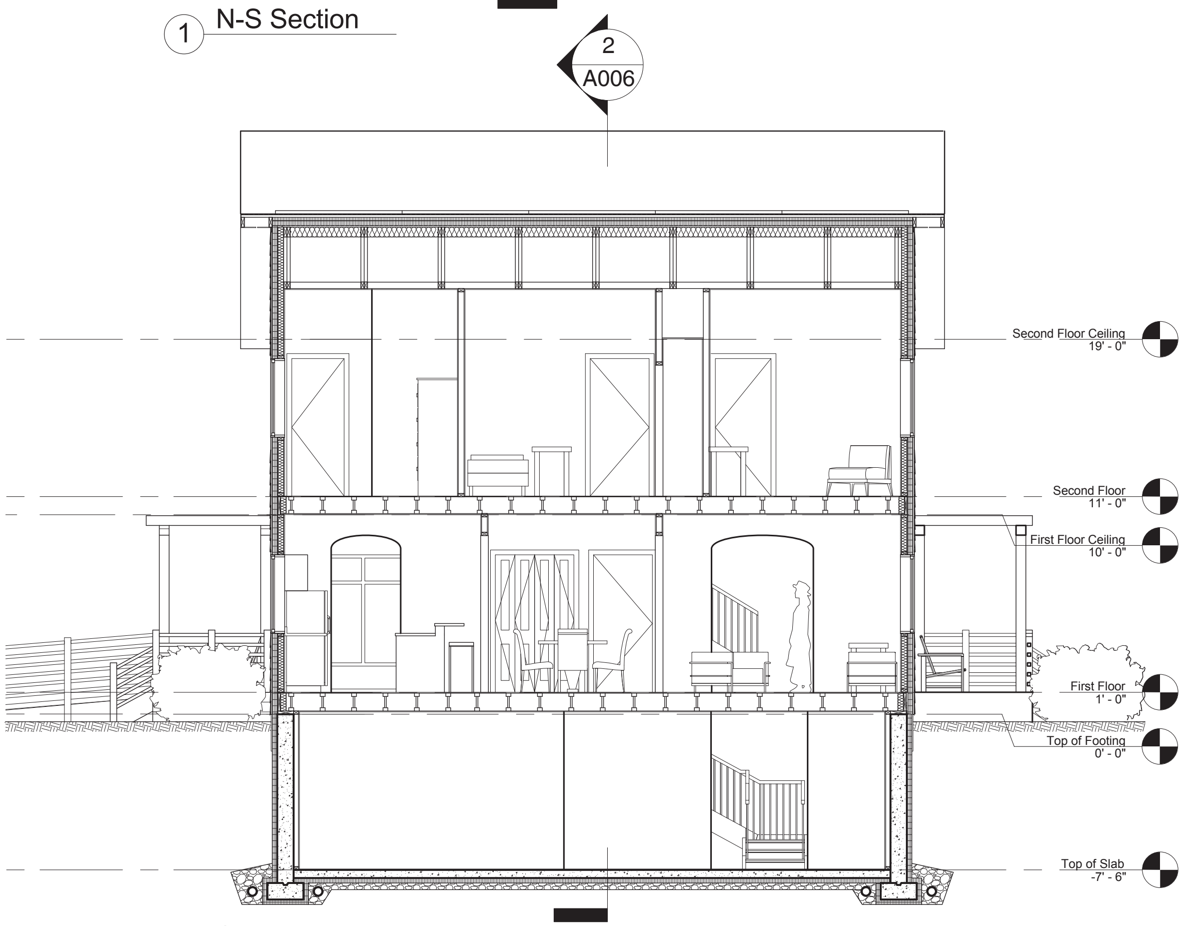
A005

Project Name:

DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN



1 N-S Section



2 E-W Section

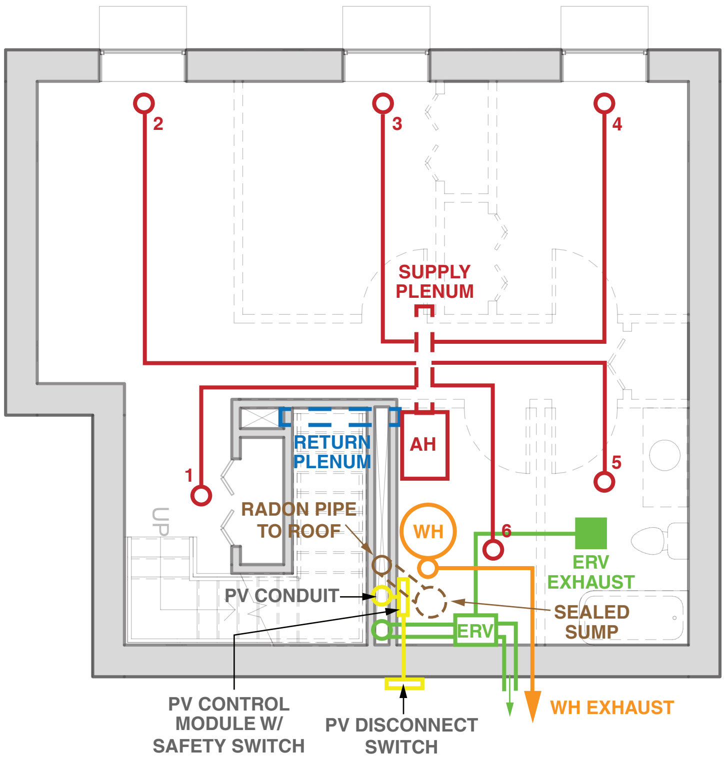
Sheet Title:
Sections

A006

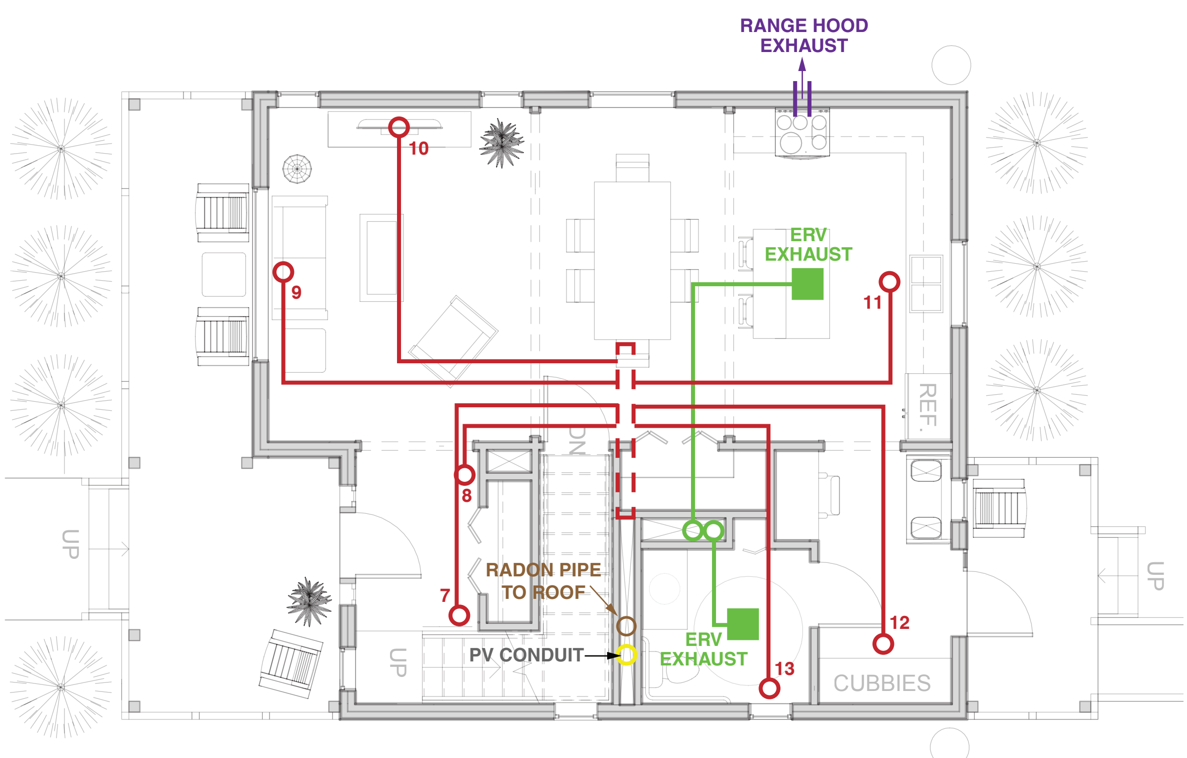
Project Name:

DOE Race to ZERO

3539 Fremont Ave N Minneapolis, MN



1 Basement Mechanical Plan
1/8" = 1'-0"



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

Sheet Title:
Mech Ducting Layout

B001

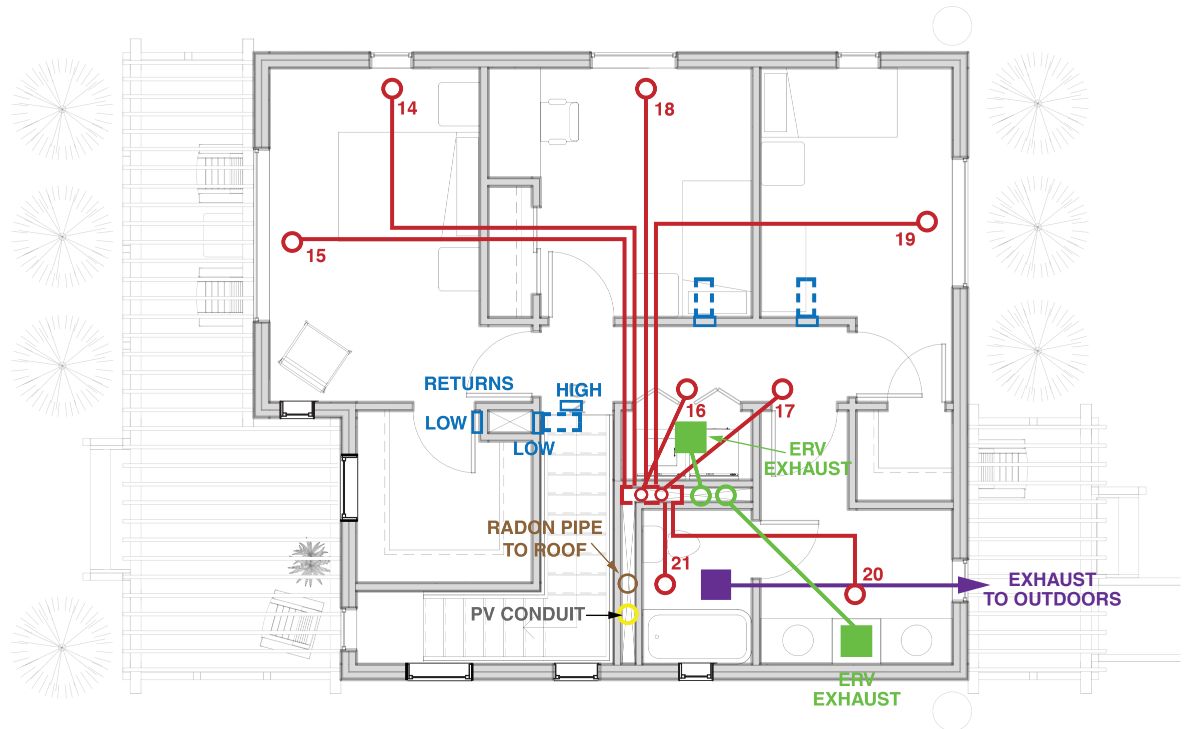
Project Name:

DOE Race to ZERO

3539 Fremont Ave N Minneapolis, MN

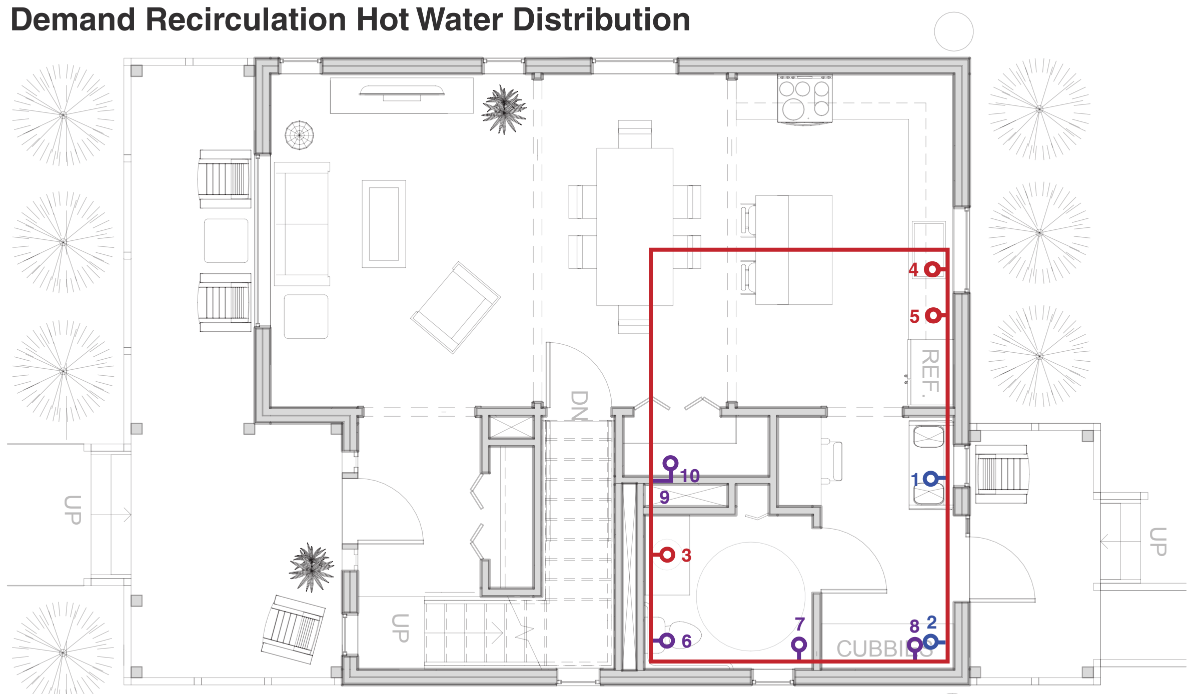
OptiMN

RACE TO ZERO U.S. DEPARTMENT OF ENERGY STUDENT DESIGN COMPETITION



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

Demand Recirculation Hot Water Distribution



BASEMENT FLOOR PIPE SEGMENTS
1st FLOOR PIPE SEGMENTS
2nd FLOOR PIPE SEGMENTS

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

Sheet Title:
Mech Ducting Layout & Demand Recirculation Hot Water Distribution

B002

Project Name:

DOE Race to ZERO

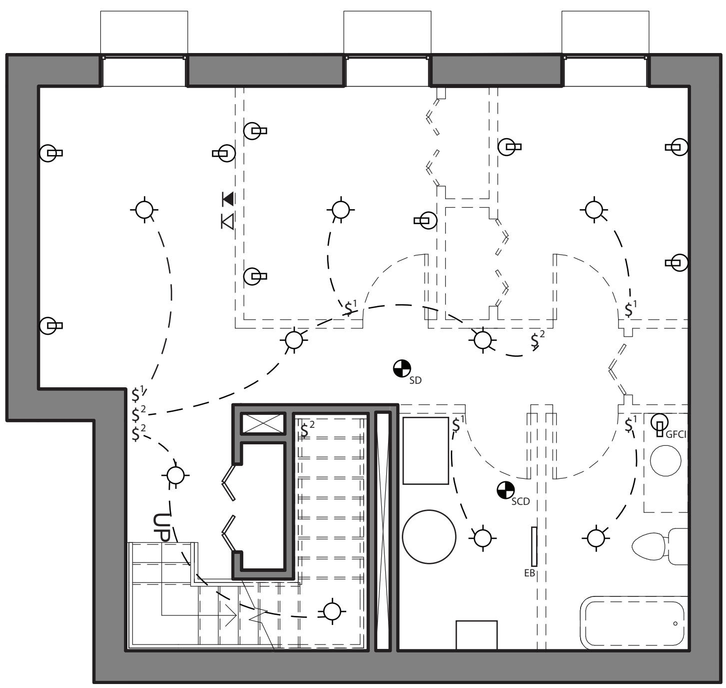
3539 Fremont Ave N Minneapolis, MN

ELECTRICAL EQUIPMENT LIST

Light Fixture Type	Light Fixture Specification	Model	Energy (W)	Cost/Unit	Units	Cost
Basement						
Ceiling Light	Commercial Electric Brushed Nickel LED Energy Star Flushmount	HUI8011L-2/BN	16.92W	$ 24.97	6	$ 149.82
Sconce Fixture	Green Matters 1-Light Brushed Nickel Wall Sconce	HD-3204	13W	$ 35.99	2	$ 71.98
					Total	**$ 221.80**
First Floor						
Track Light Kit	Hampton Bay Kelsp 3ft 4-light LED Brushed Nickel Track Lighting	KERF4200LEDSN3K	16W	$ 119.00	1	$ 119.00
Island Light Kit	Cassiopeia 2-light Nickel Ceiling Island Light	CLI-WDK279982	60W	$ 109.90	1	$ 109.90
Ceiling Light	Commercial Electric Brushed Nickel LED Energy Star Flushmount	HUI8011L-2/BN	16.92W	$ 24.97	7	$ 174.79
Sconce Fixture	Green Matters 1-Light Brushed Nickel Wall Sconce	HD-3204	13W	$ 35.99	1	$ 35.99
Vanity Fixture	Green Matters 3-light Brushed Nickel Vanity Fixture	HD-3319	13W	$ 95.99	1	$ 95.99
					Total	**$ 535.67**
Second Floor						
Ceiling Light	Commercial Electric Brushed Nickel LED Energy Star Flushmount	HUI8011L-2/BN	16.92W	$ 24.97	8	$ 199.76
Vanity Fixture	Green Matters 3-light Brushed Nickel Vanity Fixture	HD-3319	13W	$ 95.99	2	$ 191.98
Sconce Fixture	Green Matters 1-Light Brushed Nickel Wall Sconce	HD-3204	13W	$ 35.99	2	$ 71.98
					Total	**$ 463.72**
Outdoor						
Wall-Mount	Hampton Bay Basilica Collection Wall-Mount Outdoor LED Lantern	HB703LEDP-293	11.6W	$ 64.97	2	$ 129.94
					Total	**$ 129.94**
					Total	**$ 1,351.13**

LEGEND:

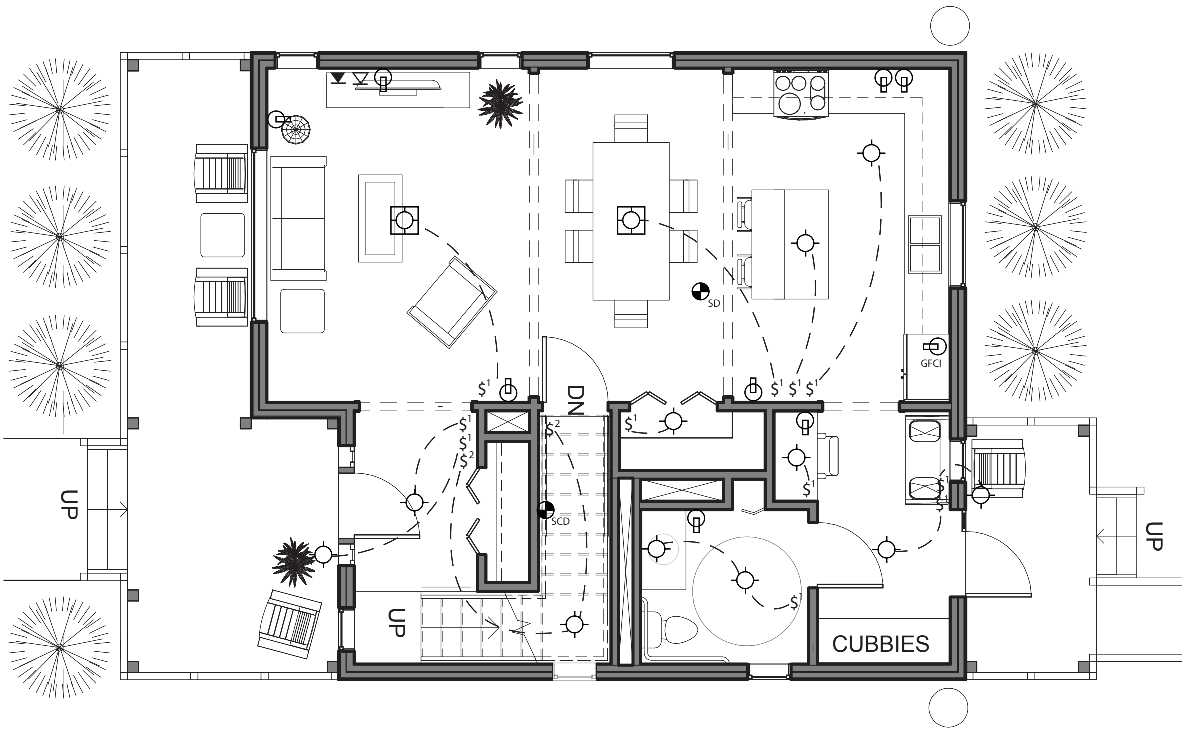
- Interior light fixture with elec. box rated for future ceiling fan
- Light fixture
- SD Smoke detector
- SCD Smoke/carbon detector
- Duplex receptor
- GFCI GFCI duplex receptor
- EB Electric box
- Computer jack
- Phone jack
- $1 Single pole switch
- $2 Two-way switch



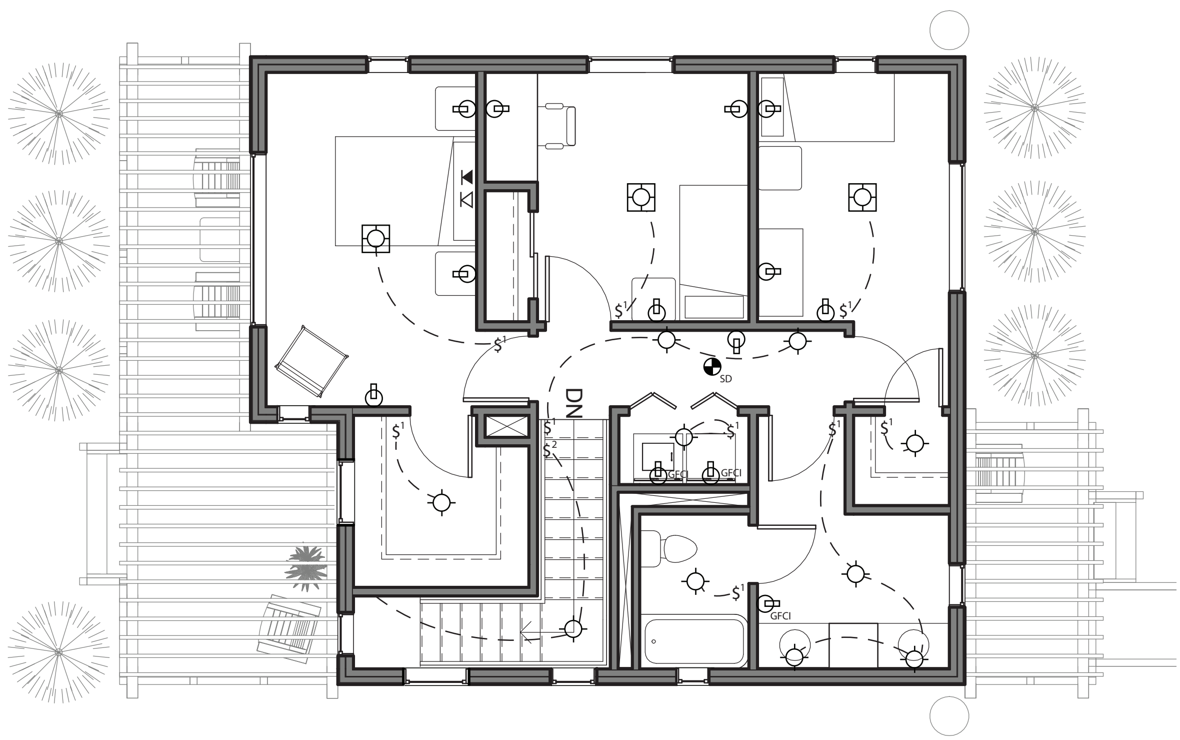
1 Basement Lighting Plan
1/8" = 1'-0"

Sheet Title:
Electrical Layout
B003

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN



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



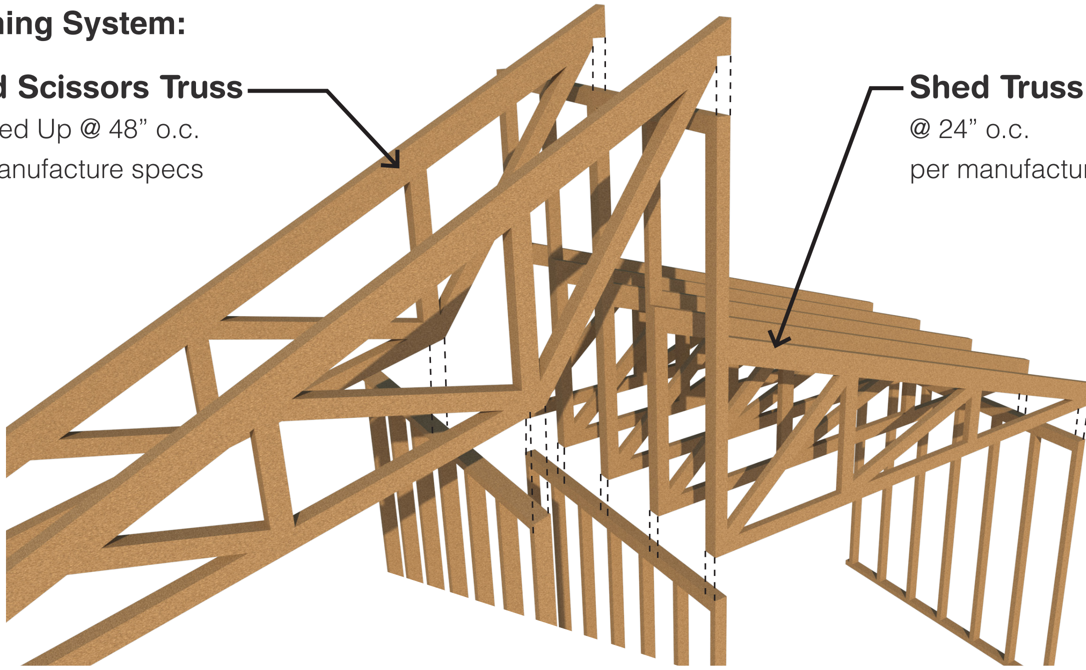
1 Second Floor Lighting Plan
1/8" = 1'-0"

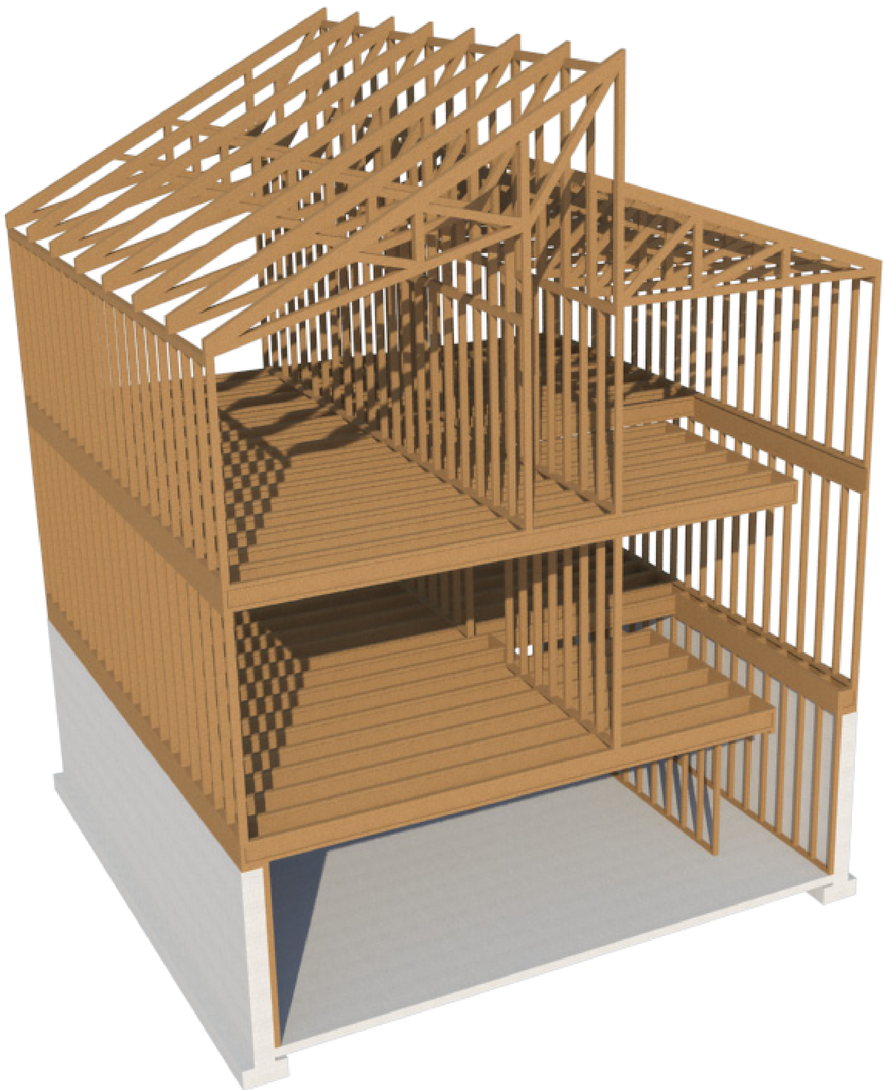
Sheet Title:	Project Name:
Electrical Layout	DOE Race to ZERO
B004	3539 Fremont Ave N Minneapolis, MN

Framing System:

Shed Scissors Truss
Doubled Up @ 48” o.c.
per manufacture specs

Shed Truss
@ 24” o.c.
per manufacture specs





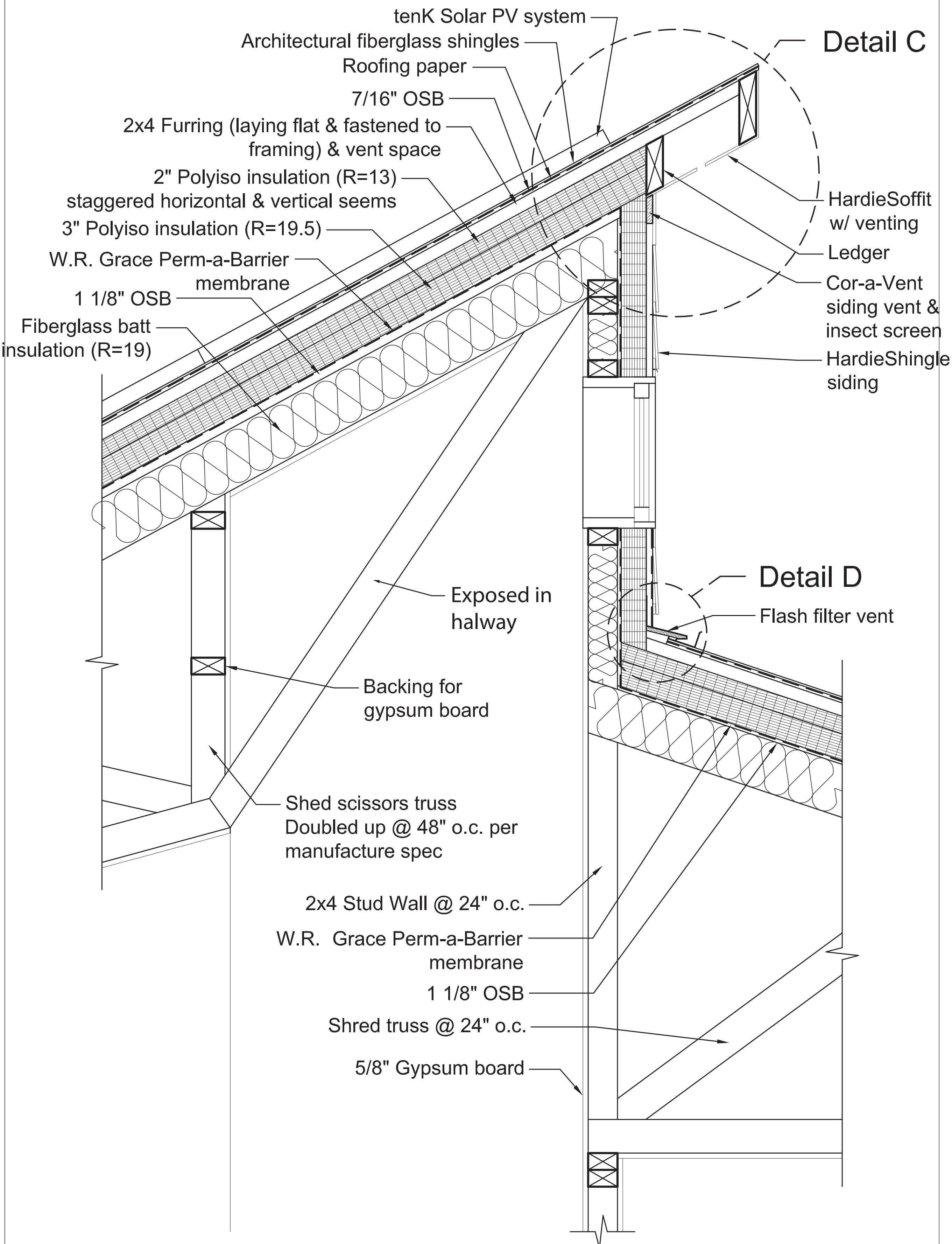
Sheet Title:
Enclosure Details

C001

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN

OptiMN

RACE TO ZERO
U.S. DEPARTMENT OF ENERGY
STUDENT DESIGN COMPETITION



Clerestory Wall DETAIL SCALE 3/4" :1'-00

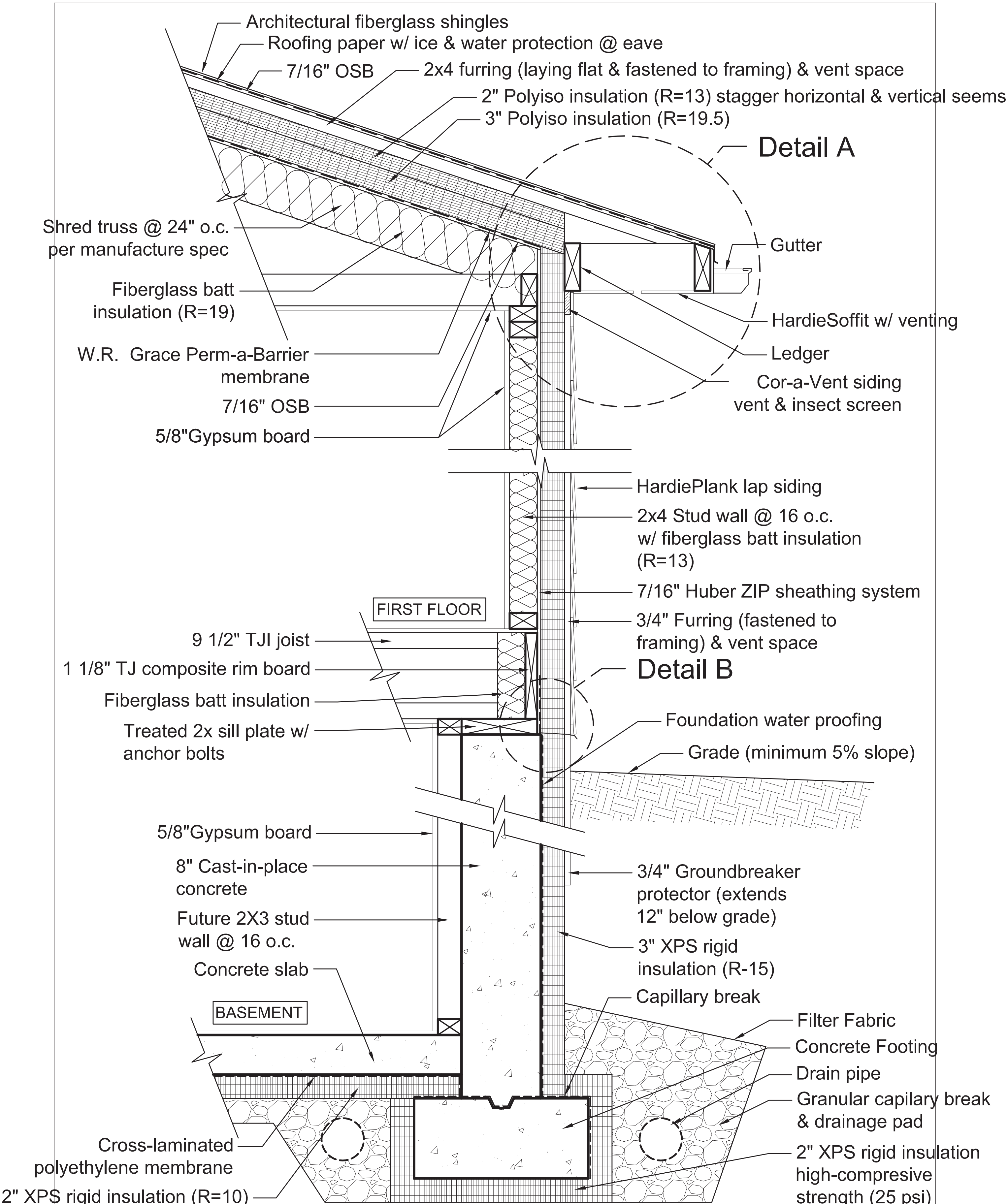
Sheet Title:
Enclosure Details

C002

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN

OptiMN

RACE TO ZERO U.S. DEPARTMENT OF ENERGY STUDENT DESIGN COMPETITION

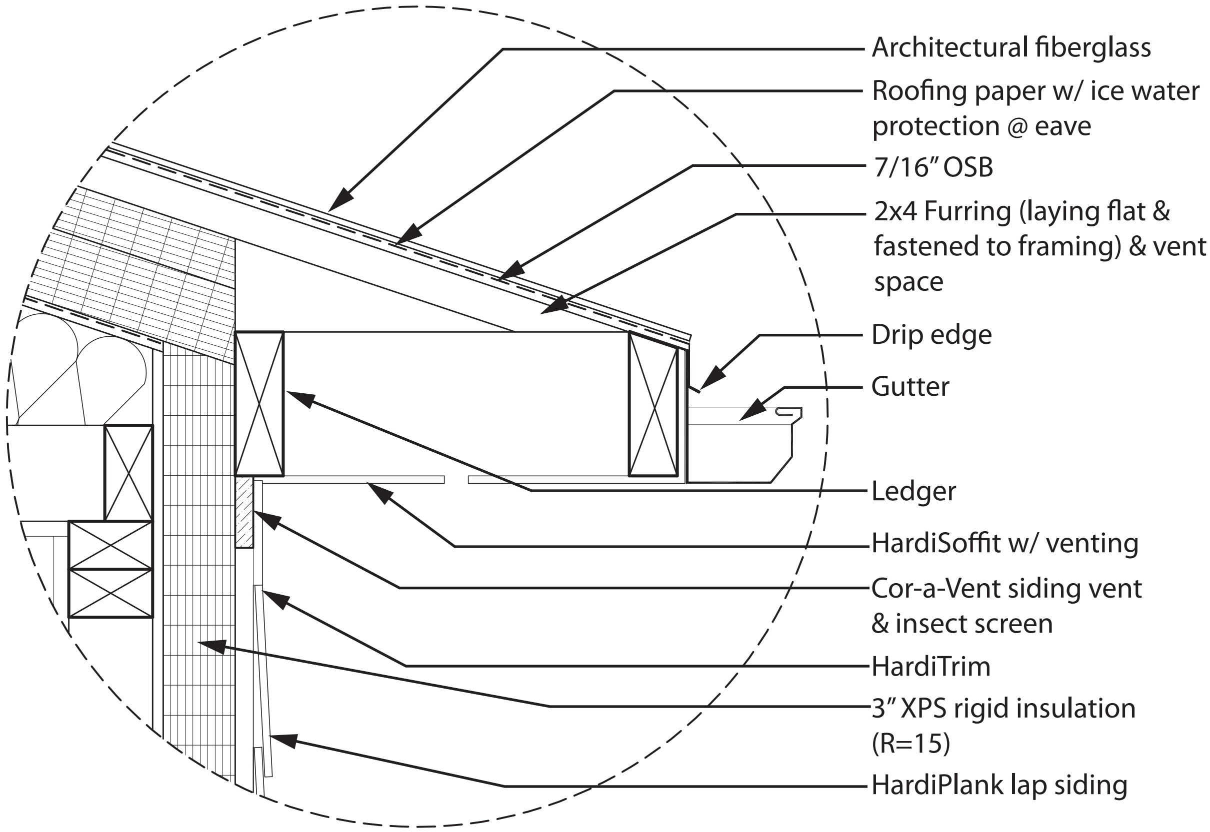


ROOF-WALL-FOUNDATION DETAIL SCALE 3/4" :1'-00

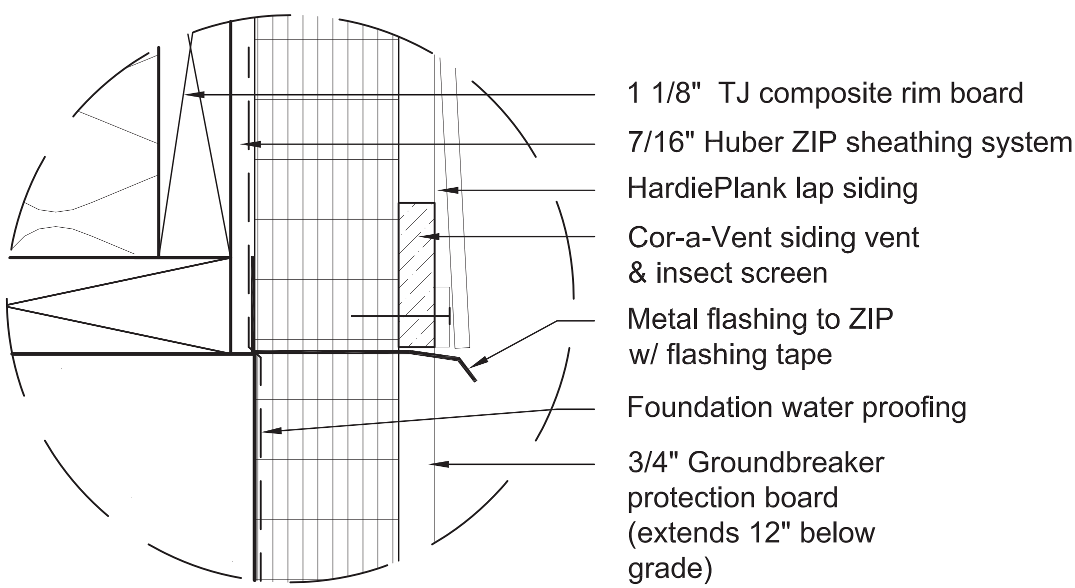
Sheet Title:
Enclosure Details

C003

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN

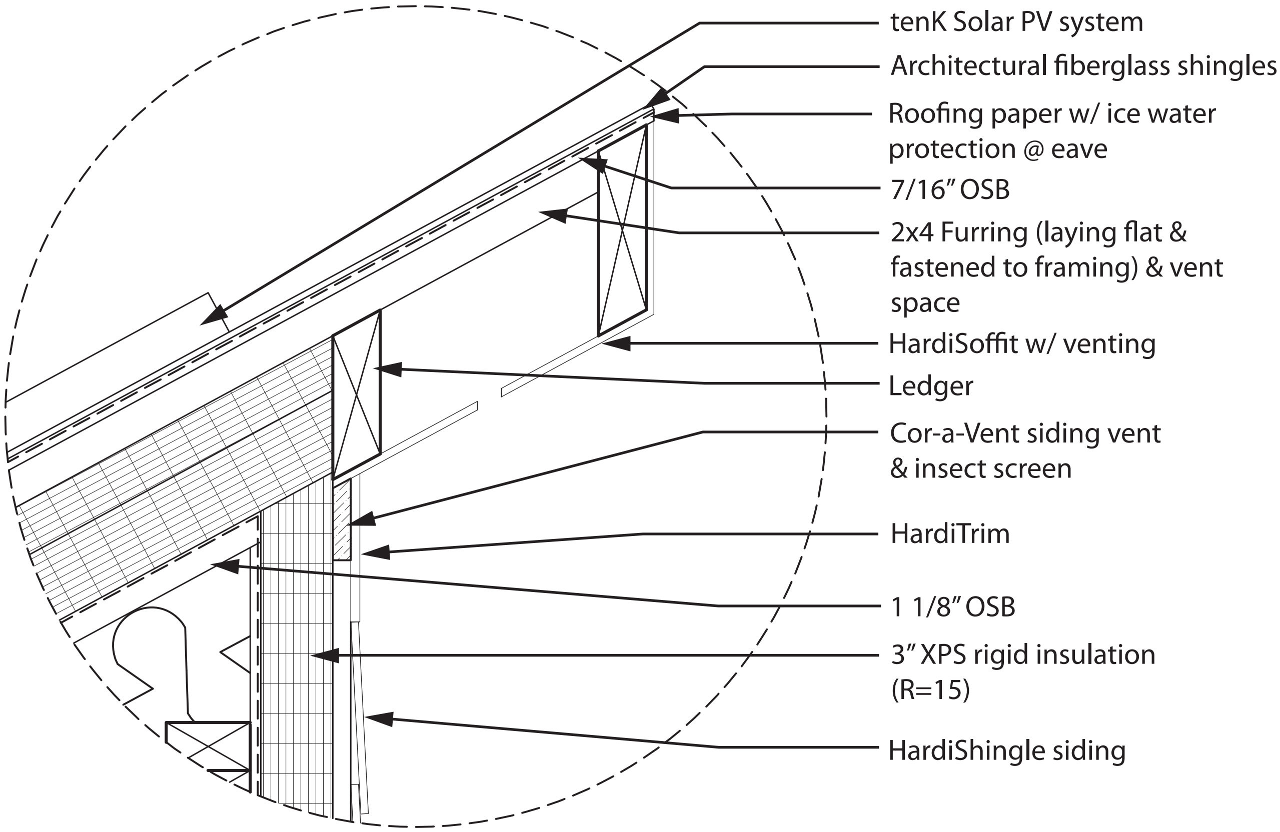


DETAIL A: North Overhang | Scale 1 1/2" = 1'-0"

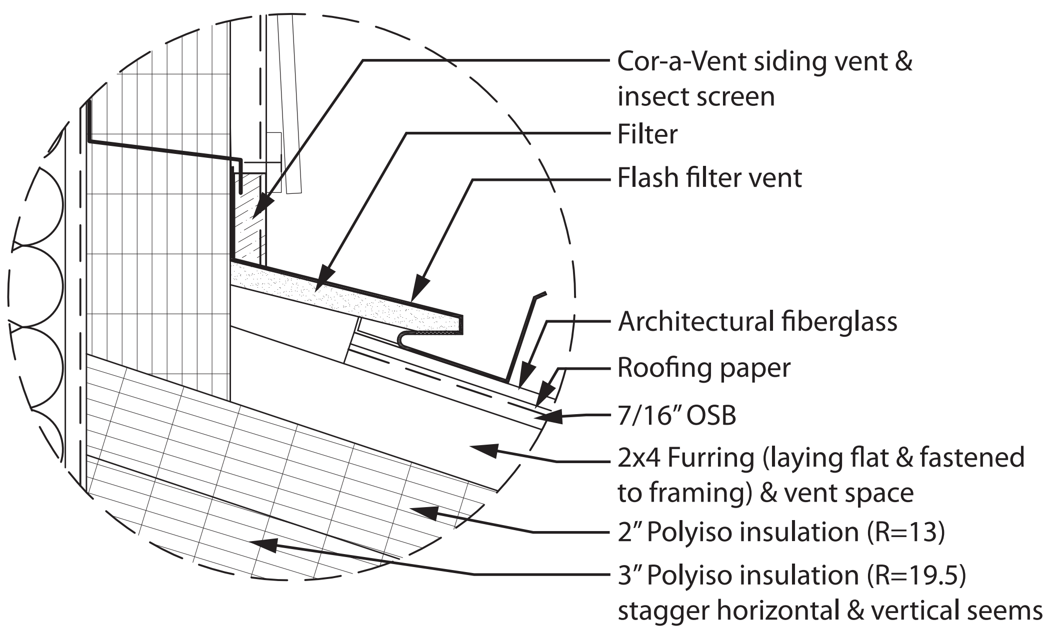


DETAIL B: Flashing Detail | Scale 3" = 1'-0"

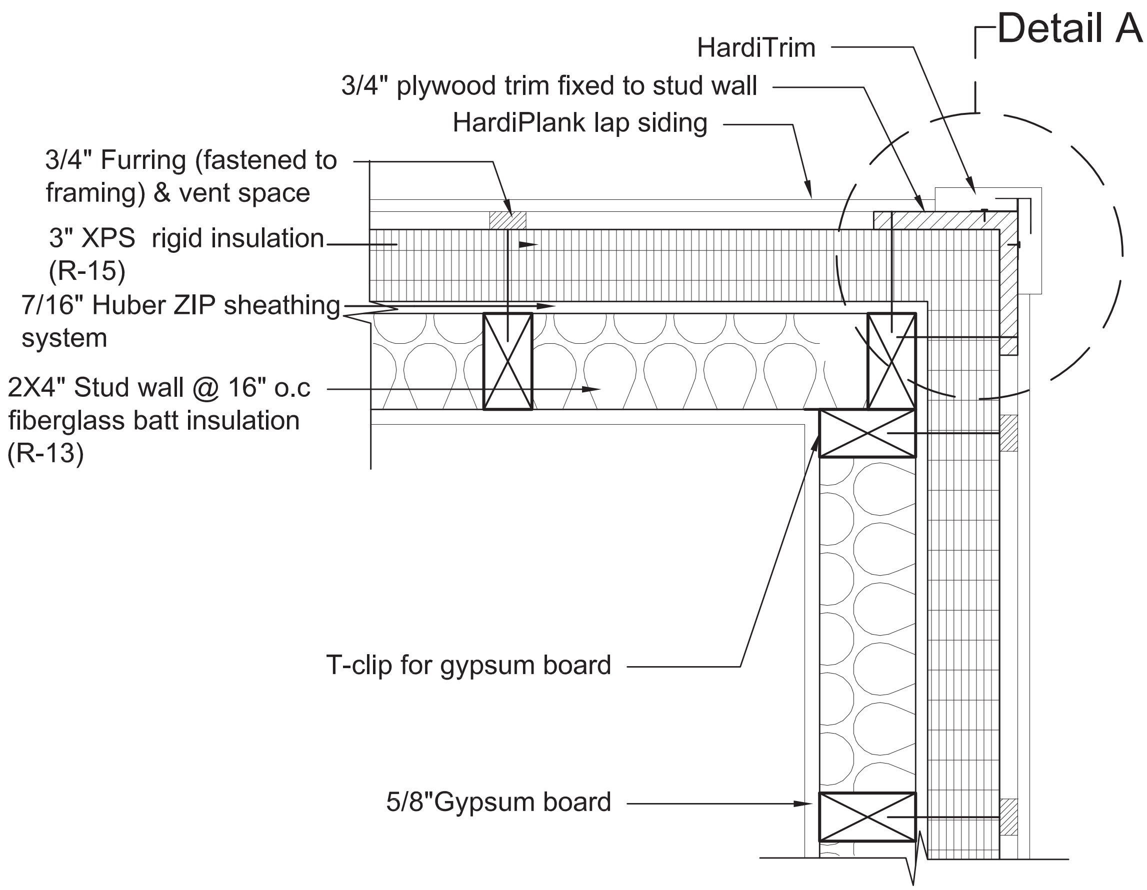
Sheet Title: Enclosure Details C004	Project Name: DOE Race to ZERO 3539 Fremont Ave N Minneapolis, MN



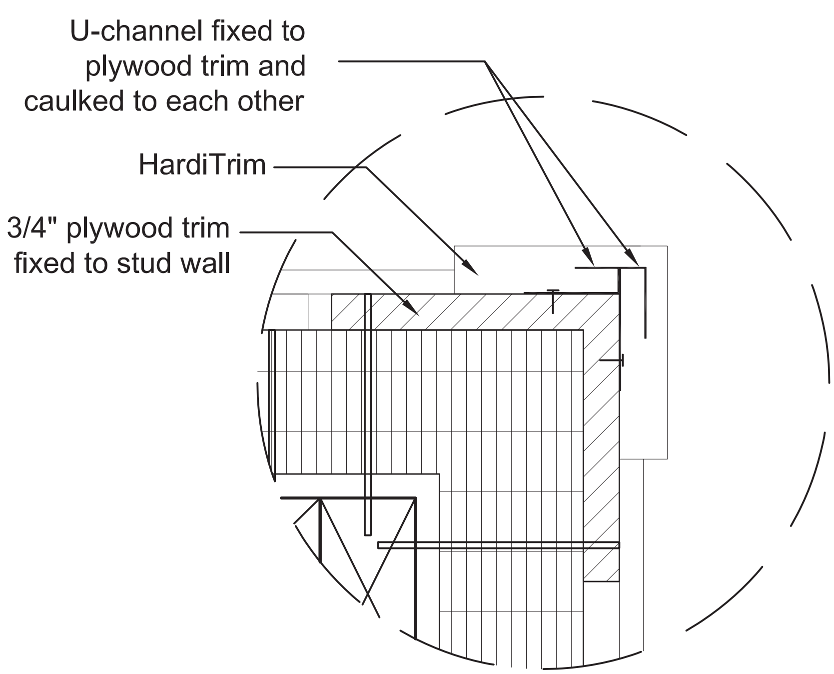
DETAIL C: Overhang Over Clerestory | Scale 1 1/2" = 1'-0"



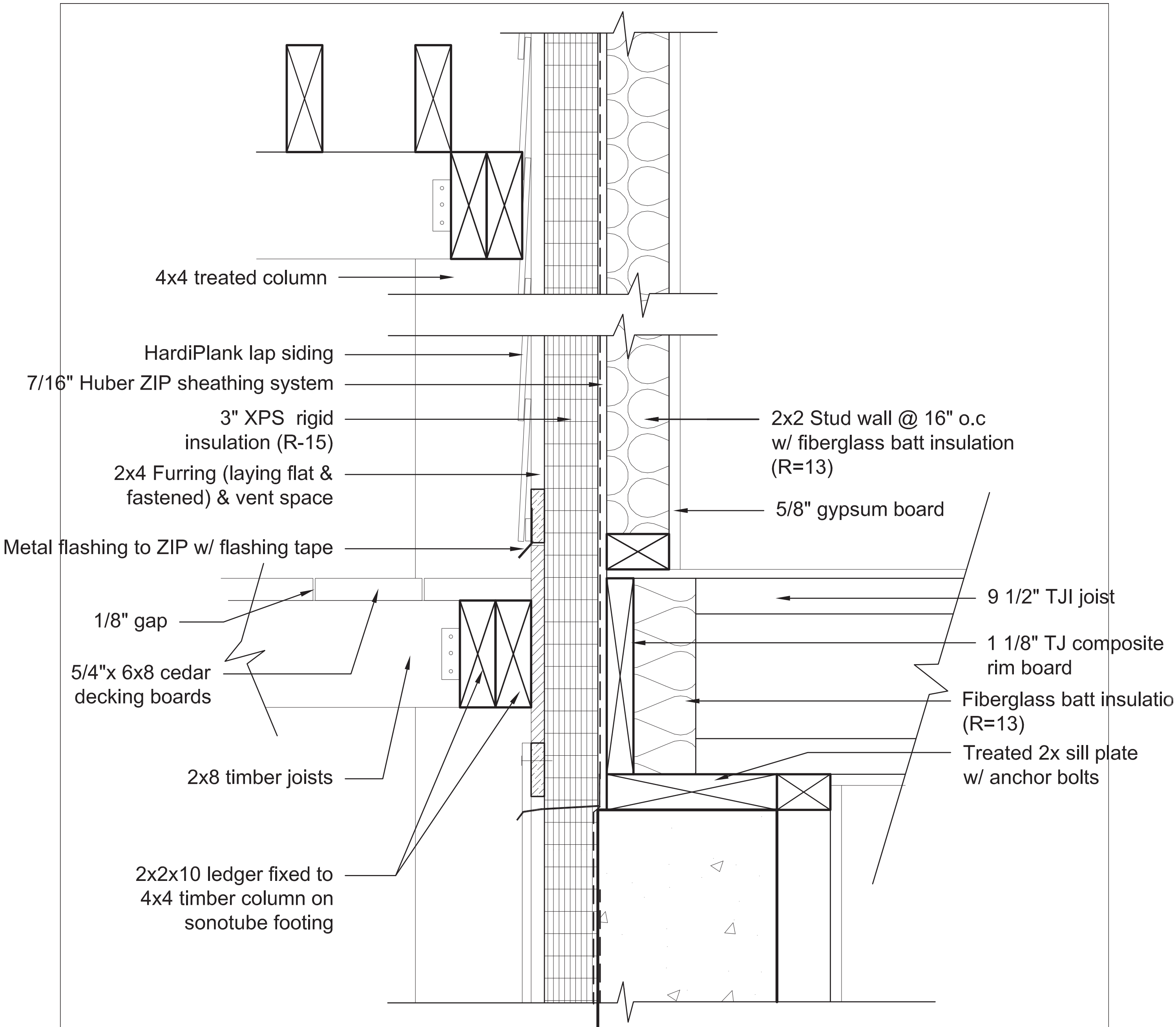
DETAIL D: Clerestory Roof Connection | Scale 3" = 1'-0"



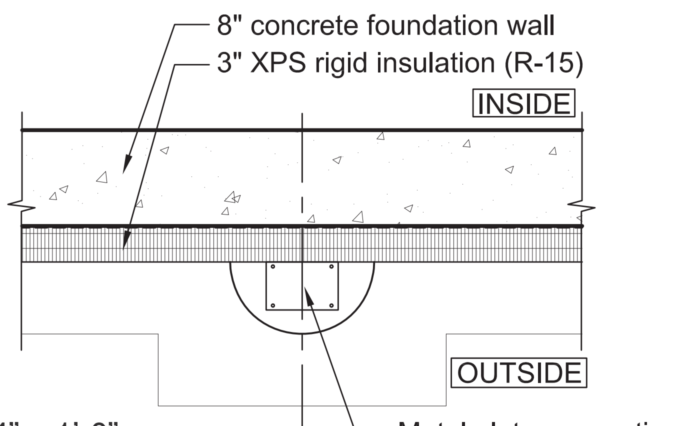
DETAIL C: Wall Corner Detail | Scale 1 1/2" = 1'-0"



DETAIL A: Corner Trim & U-Channel Detail | Scale 3" = 1'-0"



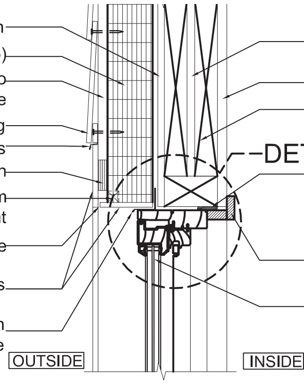
WALL TO DECK CONNECTION DETAIL | Scale 1-1/2” = 1’-0”



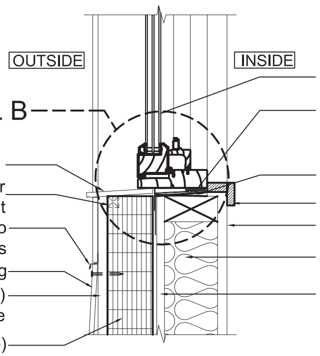
PIER DETAIL | Scale 3/4” = 1’-0”

Sheet Title:
Enclosure Details
C007

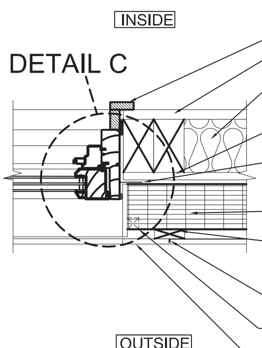
Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN



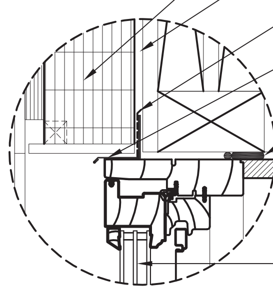
1 **Window Head Detail**
1-1/2" = 1'-0"



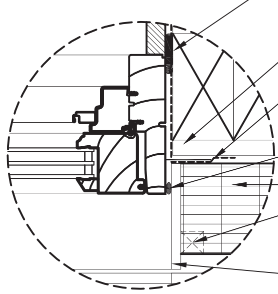
2 **Window Sill Detail**
1-1/2" = 1'-0"



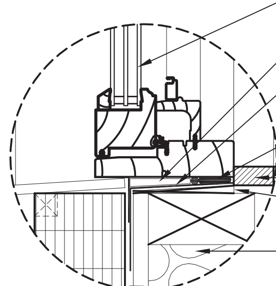
3 **Plan Detail**
1-1/2" = 1'-0"



4 **Detail A**
3" = 1'-0"



5 **Detail C (Plan)**
3" = 1'-0"

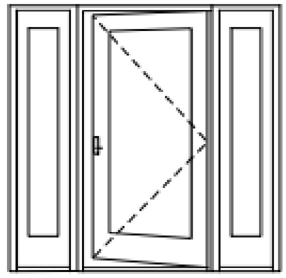
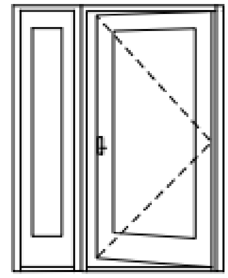
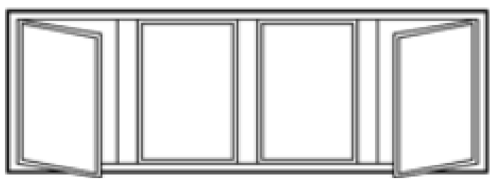
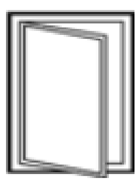
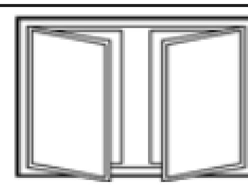
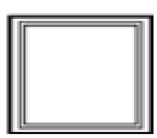
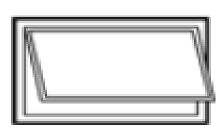


6 **Detail B**
3" = 1'-0"

Sheet Title:
Enclosure Details

C008

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN

Anderson Rectangular Doors		
Masonry Opening Rough Opening Frame Size Glass Size	4'-1 5/8" 3'-11" 3'-10" 19 5/8"	3'-4 5/8" 3'-2" 3' 9 15/16"
6'-11 9/16" 6'-10 1/2" 6'-10" 82"	 AESLI4068AP U - 0.17 SHGC - 0.27	 AESLO4068PA U - 0.17 SHGC - 0.27
Silverline by Anderson 70 Series		
Masonry Opening Rough Opening Frame Size	98 1/2" 97 3/8" 96 7/8"	
49 5/8" 48 1/2" 48"		70NCW4 U - 0.27 SHGC - 0.27
Masonry Opening Rough Opening Frame Size	25 3/4" 24 5/8" 24 1/8"	49 5/8" 48 1/2" 48"
49 5/8" 48 1/2" 48"	 70NCW1 U - 0.27 SHGC - 0.27	 7070NCW2 U - 0.27 SHGC - 0.27
Masonry Opening Rough Opening Frame Size	19 5/8" 18 1/2" 18"	37 9/16" 36 7/16" 35 15/16"
19 5/8" 18 1/2" 18"	 70NAW2 U - 0.27 SHGC - 0.27	 70NAW1 U - 0.27 SHGC - 0.27

Project Name:
DOE Race to ZERO
3539 Fremont Ave N Minneapolis, MN

10 INDUSTRY PARTNERS

Designing a “market ready” house for the affordable housing community was a primary objective in the Team OptiMN collaboration with Urban Homeworks for the Race to Zero Student Design Competition. Multiple meetings were arranged where students and Urban Homeworks project managers could meet, discuss the team’s progress, and receive feedback in its “market appropriateness” for the OptiMN Impact House. In addition, Urban Homeworks helped immensely by allowing the OptiMN team access to their bank of knowledge and construction experience.

In addition, Residential Science Resources stepped up to be the team’s Energy Rater partner. Residential Science Resources provided resources, technical assistance, and REMRate support. The team is grateful for RSR’s sponsorship of our team and their financial support of the presentation team’s travel to the Race to Zero competition at the National Renewable Energy Laboratory.