Resilient Home
Regenerative Home
Zero Energy Home
Water Home
Renewable Home
Right-Size Home
Responsible Home
Adaptive Home
Long-Lasting Home
Safe Home
Urban Home
Grow Home
Expandable Home
Diversity Home
Innovation Home
Restorative Home
Ecological Home
Dream Home
My Home
OptiMN Home

Bassett Creek **ReGen Home**

Volume One

Team OptiMN

University of Minnesota

April 4, 2017

United States
Department of Energy
2017 Race to Zero Competition

optiMN
ReGen Homes

00

University of Minnesota OptiMN Team

Bassett Creek ReGen Homes

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University of Minnesota OptiMN

Qualifications

Team Profile

A passion for sustainable, equitable, and energy efficient homes has brought together a cross-disciplinary and talented group of University of Minnesota students to form Team Opti-MN.

This multi-disciplinary team brings together students from eight different programs including Building Science and Technology,Masters of Science in Sustainable Design, Masters of Architecture, Architecture, Construction Management, Business Marketing, Landscape Architecture, and Bioproducts and Biosystems Engineering. The challenge of building a zero net energy ready home in Minneapolis, MN necessitates a multi-pronged approach to create homes, that unite communities, regenerate the surrounding environment, and provide affordable and comfortable living to local families. The support of various departments of the University of Minnesota and the guidance of local housing and development professionals propels us to produce a socially-conscious design that can regenerate and inspire the surrounding environment.

Matt Dries, Team Leader

Matt is pursuing a Bachelor of Science degree in Building Science and Technology with a minor in Construction Management. Graduating in May 2017 and anticipate applying building science principles to residential and commercial construction.

I conducted energy and financial analysis for the proposed 6-unit attached housing.

I have experience with energy modeling and analysis developed through work with Residential Science Resources. Member of 2015 Grand Award winning Team Opti-MN.

Sorelle Chekam

Sorelle is a Bachelor of Science senior in the Sustainable Systems Management Major with an emphasis in Building Science and Technology. She will graduate in Spring 2017. My role in the Race to Zero competition is implementing the best system of indoor air quality and ventilation that is susceptible for green building housing while ensuring that the system fits for the surrounding environment.

Maria Fernanda Laguarda-Mallo

Maria is a graduate Research Fellow at the University of Minnesota; PhD Candidate in Bioproducts and Biosystems Engineering and Management; MSc. in Bioproducts and Biosystems Engineering and Management; MSc. in Timber Construction; Bachelor's degree in Architecture; and Associates degree in Interior Design.

I am a Professional Architect interested in sustainable and renewable materials used in energy efficient buildings; Member of 2015 Grand Award winning Team Opti-MN. My role in the Race to Zero Team is of Design Team Leader. I am interested in applying knowledge in architectural design and innovative wood-based structural systems in the design of Opti-MN's housing project.

Katerina Grengs

Katerina graduated with Bachelor of Design in Architecture and is completing a minor in Construction Management. Her internship at US Green Building Council first introduced her to sustainable design and how much creating a healthy, efficient space can improve a person's life.
My role in the Race to Zero Team is focusing on the interior design. I am interested in the way furniture and interior finishes can achieve a desired feeling for the space.

Aaron Hanson

Aaron is a Master of Science candidate in Science, Technology, & Environmental Policy with a minor in Law; Graduate Research Assistant for the National Science Foundation's Sustainability Research Network, and the Center for Urban and Regional Affairs' Kris Nelson Community-Based Research Program; UMN Energy Club Co-President; Bachelor of Science in Business & Marketing Education with a minor in Sustainability Studies; Associate of Arts in Accounting.

Nelson Hull

Nelson is pursuing a Bachelor of Applied Science in Construction Management.
My role in the Race to Zero Team is evaluating the constructibility of the design and creating a project delivery schedule. Additionally, I am completing a comprehensive financial analysis for building construction costs and for tenant affordability.

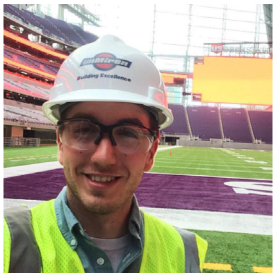
Parul Jain

Parul is a final year graduate student from Master of Science in Architecture - Sustainable Design. Bachelor's degree in Architecture. Pursuing research focusing on criteria development for natural water cycle site design.
My role in the Race to Zero Team is water design team leader, I contribute to managing the water aspects/features of the site and the building design through regenerative approach and creating nature-inspired solutions for the built environment. My emphasis for the team was on storm water control and utilization, and how the entire system can create a positive impact to the Bassett Creek development.

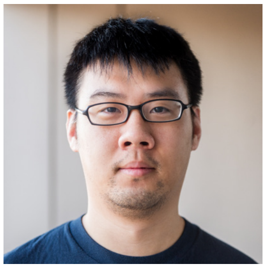
Lindsey Kieffaber

Lindsey earned a Bachelor's degree in "Growth & Structure of Cities" from Bryn Mawr College, and spent five years working in affordable housing as a Construction Project Manager. Lindsey worked with LHB Architects & Engineers integrating sustainable performance into architecture and researching city energy consumption and plug load reduction strategies. Currently pursuing a Master of Architecture with the University of Minnesota and expected to graduate in May 2017.
My role in the Race to Zero team is researching existing conditions towards the production of a master plan for sustainable development of the site at large; also to contribute to the architectural design of the proposed six units of attached housing. My interest lies in scalar thinking and looking at energy use and sustainability beyond a single unit.

Chris Laabs



Chris holds a Bachelor's degree in Architectural Studies from UW-Milwaukee and currently is pursuing a Masters of Architecture at the University of Minnesota where he will graduate in May 2017. Holds an interest in water, especially in non-potable water reuse in high-use or large-scale systems.
My role in the Race to Zero Team is generating the design of the 6 units of attached housing and the creation of a digital model of the design. Also worked on ensuring the design reflects the equity goals set by the team, especially in flexibility, privacy, and cultural needs.



George Liu
George graduated with a Master of Architecture and currently pursuing a Master of Science in Sustainable Design.
My role in the Race to Zero team is researching and implementing the domestic hot water system within the buildings and pursuing a more integrated whole building system with possibilities of combined system for small space constraint and energy efficiency.

Rodrigo Lozada
Rodrigo is pursuing a Master of Architecture degree at the University of Minnesota College of Design and graduated with a Bachelor of Science in Architecture at the University of Maryland.
My role in the Race to Zero Team is contributing to the architectural modeling and design development for the project. In addition, I have provided consultation with zoning requirements. Hope to integrate the architectural needs for the project with constraints and needs for a true net zero development.

Tim Markoe
Tim is pursuing a Master of Science in Architecture Sustainable Design, earned an Bachelor's degree in Environmental Science.
My role in the Race to Zero Team is researching and implementing efficient HVAC systems and renewable energy technologies. Having experience modeling and assessing energy efficient systems with buildings through my coursework in my master's program. Interested in providing the most energy efficient systems and best renewable technologies for our attached housing.

Luke Nichols
Luke is a Master of Landscape Architecture Candidate, Graduate Research Assistant with the Minneapolis Downtown Improvement District, Graduated with a Bachelor of Sciences in Environmental Sciences, Policy and Management.
My role in the Race to Zero Team is to contribute in the urban planning and landscape expertise to a sustainable, accessible, and integrated building design with the landscape and community. I collaborated with team members to design the landscape plan focusing on permeability between stream corridor, rainwater infiltration, and access to recreational resources.

Faculty Advisors

Pat Huelman
Pat is an Associate Professor in Residential Energy and Building Systems in BBE and serves as Coordinator of the Cold Climate Housing Program with the University of Minnesota Extension.

He is a lead faculty member for the Building Science and Technology undergraduate degree program and a principal investigator for hydrothermal 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 is currently Co-chair of the Criteria for Excellence in Building Science Education Task Group and received the NCHRC/DOE Excellence in Building Science Education Award in 2013. For two decades Pat has taught BBE 4415/5415 Advanced Building Science. This class serves as a capstone course for the SSM-BST program and is taken by many students in the M.S. in Sustainable Design program.

Jim Lutz

Jim is a registered architect and Lecturer in the School of Architecture where he teaches classes in building technology and sustainability. He holds a Master of Architecture degree from Syracuse University and a Bachelor of Arts in Architecture from the University of California, Berkeley.
He served as a faculty advisor for the University of Minnesota's entry in the 2009 Solar Decathlon and has led a graduate studio in Haiti, working with Architecture for Humanity. He has also taught at the University of Memphis where he was a faculty advisor for TERRA, an award-winning LEED-Platinum sustainable design demonstration house.

Peter Hilger

Faculty Director and Lecturer in the Construction and Facility Management program, Mr. Hilger is an architect by training, a builder by passion, and a teacher at heart, A graduate of Georgia Tech and the University of Oregon, he has served the Construction Management degree program since its inception in 1997, is the recipient of the CCE Distinguished Educator Award in 2009, was Faculty Advisor for the Solar Decathlon-2009 team, and received the University's Morse-Alumni Distinguished Teaching Award in 2015. He also maintains a private commercial architectural practice.

Team OptiMN would also like to acknowledge the support of Marilou Cheple, researcher at the Department of Bioproducts and Biosystems Engineering. Her input on construction and building science issues, as well as her help in reviewing and proofreading the final document is greatly appreciated.

Figure 1A: Team Roster

Name	Program	Building Science Training
Matt Dries (Team Leader)	BS. Building Science	2015, 2017, & BBE
Sorelle Chekam	BS. Building Science	2017 & BBE
Maria Fernanda Laguarda-Mallo	PhD. Bioproducts and Biosystems Engineering	2014, 2015, 2017, & BBE
Katerina Grengs	BD. Architecture	2017
Aaron Hanson	MS. Business Marketing	2015, 2017, & BBE
Nelson Hull	BAS. Construction Management	2017
Parul Jain	MS. Sustainable Design	2017
Lindsey Kieffaber	M. Architecture	2017
Chris Laabs	M. Architecture	2017
George Liu	MS. Sustainable Design*	2017 & BBE
Rodrigo Lozada	M. Architecture	2017
Tim Markoe	MS. Sustainable Design	2017 & BBE
Luke Nichols	M. Landscape Architecture	2017

2017: 2017 Race to Zero Building Science Training, 2015: 2015 Race to Zero Building Science Training
2014: 2014 Race to Zero Building Science Training
BBE: Equivalent Curriculum, BBE 4414 or BBE 5414
*Also holds a M. Architecture

Completed Building Science Education

I hereby certify that all of the above students have successfully completed the DOE Building Science Training for the 2017 Race to Zero Student Design Competition.

Signature

4/4/17
Date

University of Minnesota- Twin Cities

The University of Minnesota-Twin Cities is the flagship instutution of the University of Minnesota system. UMN has a strong reputation and history 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 the challenges of cold climate housing.

Department of Bioproducts and Biosystems Engineering

BBE'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 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.

Sustainable Systems Management - Building Science and Technology (SSM-BST)

SSM is a comprehensive systems approach to advancing solutions for processes and products, commercial and industrial businesses, buildings and energy systems that promote sustainability. Decisions in the private and public sectors are being made with greater consideration of their full range of economic, environmental and social impacts. Students work to incorporate cultures of energy efficiency and sustainability in the public and private sector. The students who specialize in Building Science and Technology are at the forefront of the transition to highly efficient, durable, and more environmentally compatible structures. Today's homes can be built to use much less energy and be healthier for its occupants. Program graduates have a range of career opportunities, working with builders, research institutions, product manufacturers, or consultants.

College of Design (CDes)

The College of Design at the University of Minnesota exposes students to the sociocultural, environmental, formal, and historical factors that shape the built environment. Students develop visual literacy by thinking through the design process in studios and workshops, by researching historical precedents, and by analyzing theoretical texts and the physical environment. The undergraduate programs at the UMN foster a sense of stewardship for the local and global built environment by providing opportunities for students to engage with faculty and research centers, enroll in service learning courses, and study abroad.

Master of Architecture (MArch)

The Master of Architecture Program at the University of Minnesota prepares students for the practice and discipline of architecture as a speculative, analytic, and investigative endeavor. Through rigorous methods of inquiry developed in the design studio, lectures and seminars, students acquire the breadth of knowledge required of the professional architect: the techniques and processes of representation, communication and analysis; the history and theory of making architecture and urban form for human use; and the technology, systems, processes and economics of construction and practice. This professional degree program is fully accredited by the National Architectural Accrediting Board (NAAB).

Master of Landscape Architecture (MLA)

The Department of Landscape Architecture at the University of Minnesota is one of the most engaged design colleges in the country. The focus is to design sustainable and artful solutions to the complex challenges of the 21st century. The program considers landscape architecture as an activist practice to create innovative approaches to the issues of our time. Students learn both inside and outside the classroom, taking advantage of our location in a vital design-rich urban region.

Masters of Sustainable Design (MS-SD)

The School of Architecture 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 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 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.

College of Continuing Education

For 100 years, University of Minnesota's College of Continuing Education (CCE) has been "opening doors" for those looking for distinctive learning opportunities for professional and personal growth. CCE offers degrees, advancement in your current profession, and opportunities to change careers. Flexible bachelor's, including the Bachelor's in Construction Management, along with professional master's degrees, carefully crafted certificates, and a myriad thought-provoking courses offered online and evenings (for academic credit, professional development, or personal enrichment) make it convenient for you to further your education.

Construction Management (CMGT)

Grounded in current industry practices and technologies, the Construction Management programs works to improve skills and knowledge of the construction process from the conceptual development stage through the final construction phase. Taught primarily by adjunct working professionals, students in the program range from working professionals to full-time students. Supportive, multidisciplinary approaches help students develop a broad base of knowledge demanded by today's industry. Management and leadership skills are extensively developed to prepare students to enhance the safety and desirability of the current construction industry.

University of Minnesota, Minneapolis Campus

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University of Minnesota OptiMN's

Industry Partners

Habitat for Humanity- Twin Cities
Contacts: John Hall, Chad Dipman, Noah Keller

Habitat for Humanity Twin Cities is a non-profit committed to building the quality of life, health and prosperity of the 7-county metro region through the production and preservation of homeownership. Habitat believes homes and families are the foundation of successful communities, and actively works to create energy efficient, affordable, and healthy homes for families.

Professional homebuilders from Habitat provided insights on designing and building slab on grade attached housing in Minneapolis that was critical to design development. Currently under construction by Habitat is an 8-unit slab on grade townhomes located within a mile of Team Opti-MN's proposed site. This related project, combined with Habitat's mission to make robust, affordable housing for occupants made them an ideal building partner selection for the Race to Zero.

Mississippi Watershed Management Organization
Contacts: Udai Singh, Doug Snyder

Mississippi Watershed Management Organization (MWMO) is a public organization that partners to protect and improve water and habitat in the urban watershed. They invest in people and infrastructure to support clean water, and provide knowledge, scientific data and expertise to help manage the Mississippi watershed. Their knowledge of the surrounding watershed and best practices helped us to reach a design and landscaping plan to best address the maintenance of water quality of Bassett Creek.

Designing to enhance the filtration of runoff water before reaching Bassett Creek and increasing infiltration will help the watershed stay healthy and sustainable. Early meetings and conversations with MWMO brought to our attention the need to address Bassett Creek preservation in the master plan.

Harrison Neighborhood Association
Contacts: David Colling and Eric Wilson

The Harrison Neighborhood Association (HNA) works to create a prosperous and peaceful community that equitably benefits all of Harrison neighborhood's diverse racial, cultural, and economic groups. They pride themselves on developing a realistic and community sensitive project; with this in mind, meeting with the HNA was of particular interest. The HNA provided information about the neighborhood character and how the community would like to see the neighborhood develop. Specific amenities such as a community garden were taken into account through conversations with the HNA.

Aeon
Contacts: Blake Hopkins, Senior Project Manager for The Rose Apartments

Aeon is a responsive non-profit developer, owner and manager of high-quality, affordable apartments and townhomes serving more than 4,500 people annually in the Twin Cities area. For 30 years, Aeon has been committed to helping people create a home in a safe, secure environment and connect to the community around them. Aeon believes that Home changes everything. As a developer who also owns and manages their buildings, they are committed to long-term investment of their properties. They were able to provide insight into materials, systems and maintenance items which they have found successful in their projects.

Meyer, Scherer & Rockcastle, Ltd. (MSR)
Contacts: Rhys MacPherson, Lead Architect for "The Rose"

MSR is an award-winning architecture and interior design firm committed to excellence. Their projects are diverse in type, size, and location, with specific depth of experience serving library, office, cultural, higher education, and residential clients. The firm has earned a national reputation for both designing exceptional new spaces and, through preservation, adaptive reuse, and renovation, designing innovative ways to reuse buildings.

MSR guided us through a tour of their Living Building Challenge Certified affordable housing project. Rhys explained the material choices and mechanical systems the pros and cons of the choices, and the balance between efficiency and cost. MSR has been a great partner in introducing us to systems and material thinking.

Residential Science Resources
Contacts: Mat Gates
Residential Science Resources (RSR) specializes in the implementation of utility, municipal, and government energy savings programs by providing home performance testing, certification, and consulting to home builders, rater and homeowners. They work to bridge the gap between building science theory and implementation of energy efficient construction. Insights and recommendations for modeling the performance of the proposed attached housing were provided to create energy usage estimates and a HERS score.

Simple Energy Testing
Contacts: Eric Boyd

Simple Energy Testing (SET) makes the process of getting homes approved for energy rebates as painless and easy as it can be. SET offers a simple and versatile range of services and is the rating industry leader in quality, innovation, and client experience. Among the services they offer are: blower door tests, RESNET ratings, IR scans, tax credit verification, site visit reports, and packages including Green Path. Simple Energy Testing helped our team with the energy analysis by calculating the REM/Rate energy model.

OptiMN's Bassett Creek ReGen Homes

Project Summary

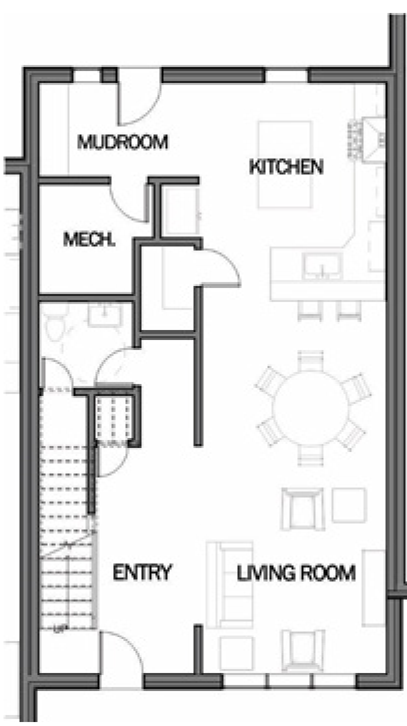
An urban infill site in the Harrison Neighborhood of Minneapolis was regenerated into highly efficient and affordable attached housing. Overlooking Bassett Creek, a 12-mile stream flowing directly from high-density areas to the Mississippi River, special attention to preserve the natural value and health of the local environment inspired our design. The goal of this development was to bring together people of diverse backgrounds, incomes, and family structures to a space that encourages healthy, social, and sustainable living at a low cost of ownership.

Relevance of Project to Competition Goals

A diverse and cross-dimensional team of thirteen students from eight different programs of the University of Minnesota have come together to solve the real-world challenge of providing sustainable, affordable, and attractive housing for those who need it most. The attached housing design follows the DOE Zero Energy Ready Home criteria. Other programs utilized include EPA's WaterSense, and incorporation of Energy Star appliances. Utilization of local industry partners, such as Habitat for Humanity and the Harrison Neighborhood Association, guides a market-ready design suitable for construction in Minneapolis. A high performance enclosure was developed through research and hygrothermal analysis. Effective HVAC systems work in tune with the surrounding environment and climate. Providing high indoor air quality and minimizing water usage were key goals for multi-family housing in this formerly industrial area.

Design Strategy and Key Points

- Connections to natural recreational assets guide site development and landscaping decisions
- Balance of privacy and visibility for each unit
- Orient each unit south for maximum solar energy
- Units oriented parallel to Bassett Creek's flow
- Optimize usable space within robust enclosure
- Integrated with Harrison Neighborhood desires



Project Data

- Location: Minneapolis, MN (IECC Climate Zone 6)
- Lot Size/Unit: 2980 sq. ft.
- Unit A: 1844 sq. ft. (+448), 2.5 stories; 5 units with 3 (+1) bedrooms, 1.5 bathrooms (+1); ADA visitable
- Unit B: 2182 sq. ft. (+408), 2.5 stories; 1 unit with 4 bedrooms, 2 bathrooms; ADA accessible
- HERS Score: 32 w/o PV; -1 w/ PV
- Est. Monthly Energy Cost: $66 w/o PV; $6.83 w/PV

Technical Specifications

- Hybrid "Perfect Wall" Approach: R-35
- Hybrid Compact Vented Roof: R-57
- Frost Protected Shallow Foundation: R-15 under slab/perimeter w/ R-25 wing
- Windows: South = U-factor 0.24 & SHGC 0.36 North = U-factor 0.20 & SHGC 0.21
- Heating/DHW Specifications: 96% CAE Cooling: 17 SEER
- Energy Recovery Ventilation: 80 cfm w/ 65% SRE

Site Analysis

The site selected for the proposed affordable attached housing and surrounding urban development is located two miles west of downtown Minneapolis, in the Harrison neighborhood. A targeted approach was made to select a meaningful area that would have a positive impact on the neighborhood and Minneapolis as a whole. The site selected overlooks Bassett Creek, which is an important water resource which runs through and under Minneapolis. Students on the Race to Zero team have researched the site, and have identified it as an important location for affordable, sustainable and higher-density living.

Historically the Bassett Creek Valley has been a largely industrial area because of it's proximity to the city, with Glenwood Avenue acting as a major road into Minneapolis. South of the site is Bryn Mawr Meadows, an extensive urban park with breathtaking views of downtown Minneapolis, and the International Market Square, a historic factory rehabilitated into successful mixed used complex with showrooms and apartments. Our proposed master plan development aims to transform and revitalize the outdated industrial landscape on a section of Bassett Creek. The master plan calls for mixed housing models. The neighborhood currently has mostly single family homes, but a development which is supposed to break ground in Spring 2017 would introduce a mixed use-multifamily housing on the northwest corner of the neighborhood. The proposed master plan would negotiate between the higher density and lower density by providing attached housing between two large mixed-use multi-family housing buildings. Perhaps most importantly, our development suggests the restoration of the long-neglected Bassett Creek.

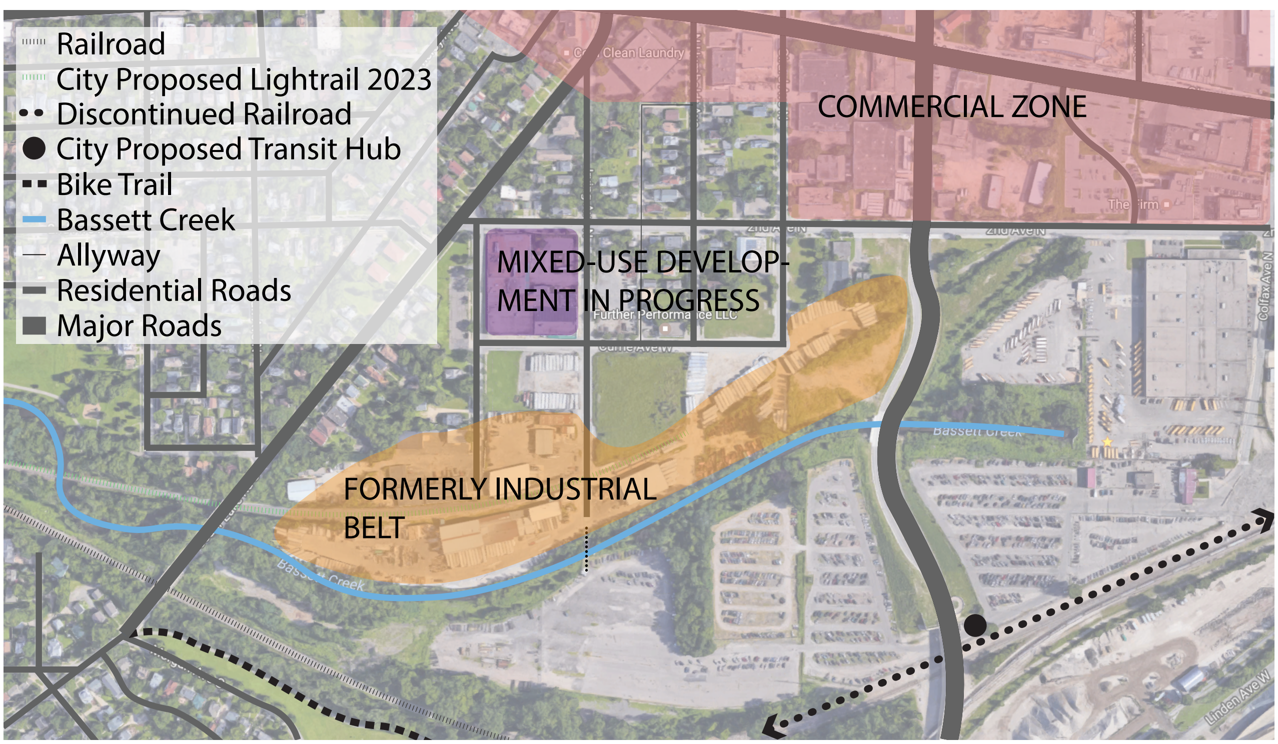


Figure 4A: Bassett Creek Valley- Analysis of Existing Conditions

Site Selection

The site selected for the proposed affordable attached housing and surrounding urban development are located between 1401 to 1499 Currie Avenue West, Minneapolis, Minnesota (Climate Zone 6). According to the Minneapolis Zoning Administration this area is part of the Resident District R5, which is categorized as a high-density, multi-family district, with 15ft. front and 5ft. rear setback requirements. Selection of the area was based on the area's potential to grow, the existing nearby amenities, businesses and public transportation, as well as the site's solar exposure, and proximity to Bassett Creek.

Figure 4B: Development Area

The area will be developed in two phases (I and II), as seen in Figure 4C, however for the purpose of this competition, only part of phase I (6 units of attached housing development circled with a dashed line in Figure 4C) will be analyzed. The housing units will be oriented with their long side perpendicular to the Creek (north-south). This decision was based on three main ideas: 1) Giving every attached housing unit a view towards the Creek and 2) Optimizing the building orientation to maximize southern photovoltaic potential 3) Allowing the shared green space to open up a view towards the downtown skyline.

Social Goals

Personal communication with some of our partners (Harrison Neighborhood Association and Habitat for Humanity) helped us determined the type of occupants for whom our project design would be tailored to. The Harrison neighborhood residents represents a wide range of ethnicities, races, religions, ages, and incomes. The area is also home to new and long-time metro renters and homeowners. The main priority of the Neighborhood Association is to prioritize mixed income housing opportunities that does not leave families costs burdened. In this context, Zero Energy Ready Houses could provide an opportunity to lower utility costs while guaranteeing comfortable living.

Based on the need identified by Habitat for Humanity and the Harrison Neighborhood Association our target market would benefit from the community to take advantage of this housing opportunity. The possibility of future expansion to a 5th bedroom was evaluated, as an option for even larger families with in-laws living in the same unit or that are willing to rent a room to help cover living costs. Multiple unit options will provide unique living types to cater to diverse family needs within the community. Therefore, creating a design that was affordable, flexible, efficient and maximized the use of the living space was one of our main objectives to be achieved with the design proposed for the competition.

Programs and Standards

Per competition guidelines, the proposed 6 unit attached housing project meets the DOE Zero Energy Ready Home criteria, showing that high-performance and efficient housing options can be affordable and attractive. Our project also meets ENERGY STAR Certification standards, through the selection of ENERGY STAR appliances, environmentally-friendly structural and siding materials, ENERGY STAR windows, low VOC interior finishes, highly efficient HVAC and air exchange systems, LED lights, high-efficiency water heating systems, as well as programmable thermostats.The window-to-wall ratio percentage also meets the Green Homes North Initiative requirement of 15%. To minimize the exposure of occupants to airborne pollutants, the team has been following the EPA Indoor AirPLUS recommendations.

Guidelines by EPA WaterSense Partnership Program were followed to guarantee the efficient use of water inside and outside the units. WaterSense labeled fixtures, ENERGY STAR washers and dryers, and an efficient water delivery system (that stores at most half of a gallon of water between the recirculation loop and the furthest fixture in the home) were designed as part of the project to meet these guidelines and ensure water conservation. Outside water was considered through the careful design of the units surrounding landscape with varied native drought resistant vegetation. Through consultation with the Mississippi Watershed Management Organization, optimized solutions to reduce stormwater runoff to Bassett Creek were implemented into the design.

Lastly, FORTIFIED Home buildings standards were referenced to reduce the chance of damage during a natural disaster event and guarantee resiliency. For this reason, a storm shelter area has been centrally located on the ground floor. The team agrees, paramount to the project's success as a model for an energy efficient home is it's ability to endure; to serve as a housing model for decades to come.

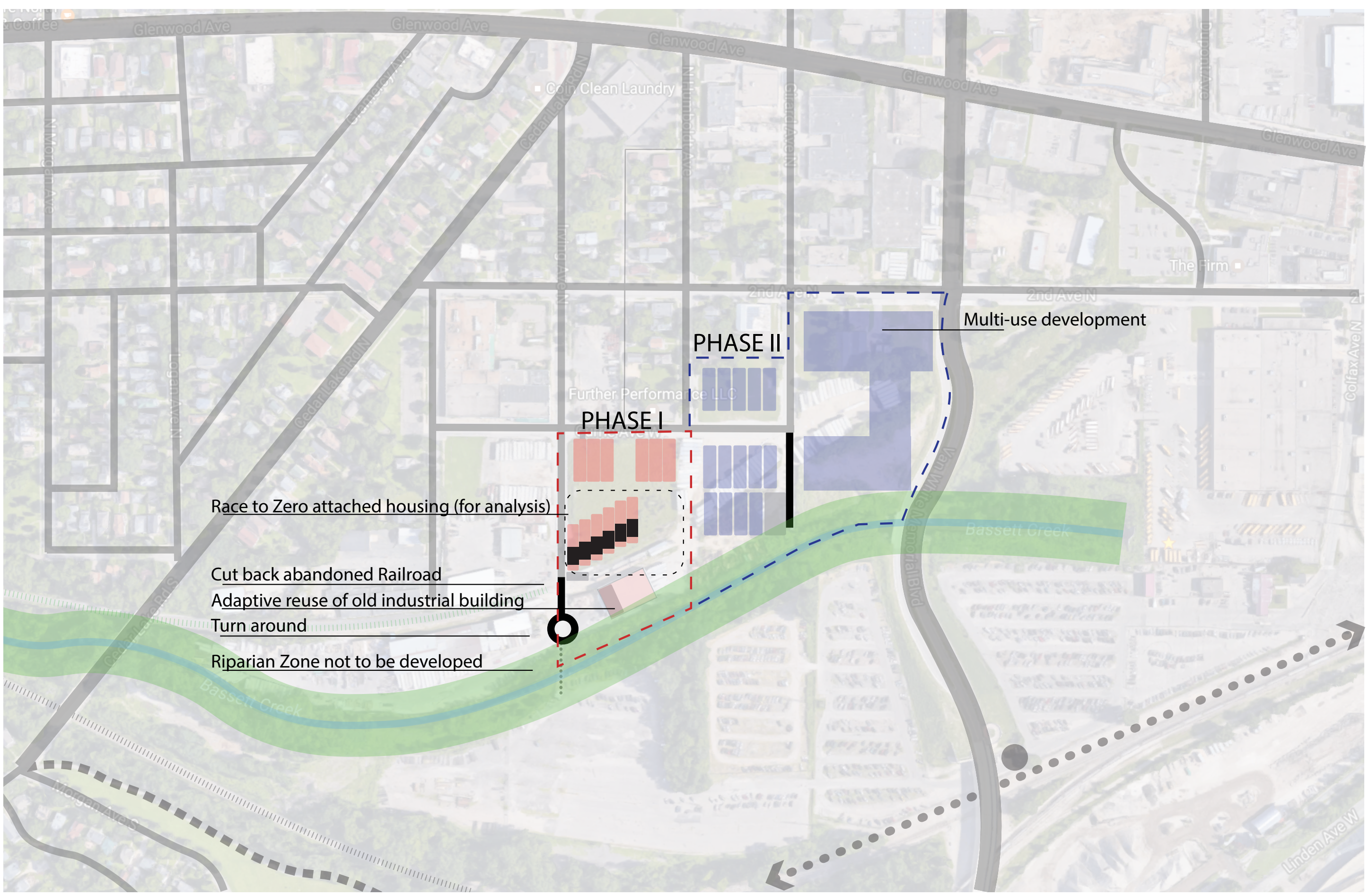


Figure 4C: Development Phasing & Location of Project

Architectural Design

Figure 5A: Phase 1 Landscape Plan

Landscape Goals

To reinforce the design goals to provide affordable housing and sustainable living to residents, our landscape strategy provides residents access to recreational areas and opportunities to grow food, a scalar approach to develop an urban agricultural neighborhood is included. At the scale of the Phase I development, we are retaining a warehouse immediately south of our project, that would be remodeled to provide facilities and amenities to the nearby Bassett Creek Park. farmers' market and artist studios. This community space will provide an important avenue for residents to market their produce and create a secondary line of income.

The site just north of the community warehouse houses a community garden and small scale orchard. Hardy pear trees (Golden Spice and Summercrisp varieties) developed by the University of Minnesota,will be planted in the communal orchard; they were selected based on their low-maintenance and disease resiliency.

Each property owner is provided with space to grow food (see Appendix 1 for planting plan). Two Serviceberry trees (Amelanchier laevis) that are native and produce berries will be planted on each property. Residents will have the opportunity to harvest the berries for jam, a local custom of Minnesotans. In the backyard, raised beds and a rain barrel are provided to give residents the opportunity to grow kitchen herbs for their daily needs. This wall will be composed of a steel beam from which steel wires will be connected to a concrete footing (see Appendix 1 for detail). Wild Grape (Vitis riparia) or Common Hops (Humulus lupulus 'Aureus') will grow up on the vines while also producing harvestable produce. This green wall will create a permeable fence that defines property boundaries without inhibiting a sense of community in our neighborhood. Whether the produce is wine from the wall, jam from the trees or produce from the garden, OptiMN Regen will be empowering residents from the ground up.

Another approach to sustainable living is through our stormwater plan (see Appendix 1 for stormwater plan). Our site plan includes a bioretention basin and bioswale that will collect rainwater from pervious and impervious surfaces within the primary subcatchment. This design not only reduces rainwater runoff into the creek but also connects the park's creek with our development.

The landscape design is also optimized to reduce the cost of living in this development. The interior communal space has a 300 yard, looped track for runners, but it also contains a swale and bioretention basin. This also allows the site to be divided.

into two easily distinguished areas. The outer area which spans from the property lots to the sidewalk is medium maintenance turf grass while the interior is composed of a light maintenance vegetated swale and bioretention pond (see Appendix 1).

Architectural Goals

The six unit attached housing project aims to optimize each unit's utilization of living space by limiting transition and circulation spaces, and creating a flexible and yet affordable unit that can respond to varied family programmatic requirements. Through meetings with the Harrison Neighborhood Association, the neighborhood family 3bedrooms per unit, with the option to expand to 4 need was identified. It was important to the team that the units demonstrate design equity, and as part of this goal, all of the units are ADA visitable and one of the six attached housing units is ADA accessible, with 1 bedroom and full bathroom on the ground floor.

A balance has been struck between maintaining the simple compact nature of the design (limiting corners and thermal bridging) and maintaining architectural interest (responding to site conditions, and ensuring the attached units maintain the neighborhood's human-scale). The decision to step back the units from one another was taken as a way to parallel the flow of Bassett Creek's while optimizing southern solar exposure. This allowed the homes to establish a private connection with nature, and to make the each attached unit feel unique and personal.

Unbasement (Flex Space)

Most homes in Minnesota have a basement. Many homes buyers expect to have a basement for storage, a place for the mechanical systems, and future expansion space. However, the reality is many Minnesota basements are cold, damp, moldy, and musty -- not a great place for the kids to play, a cozy family room, or future bedrooms.

Basements can be built to be efficient, durable and healthy, but at a much higher cost for excavation and concrete work than most builders and buyers care to spend. Team OptiMN chose to avoid those problems and costs by including a high quality "unbasement" on the third floor made possible with the hybrid compact roof. This space will serve the same functions as our traditional Minnesota basements without the Indoor Air Quality concerns. It will support the forced air heating, cooling, and filtration system for the house with easy access for ongoing maintenance. This unfinished space can be used as a comfortable kids play area, family room, an office, or a future owners suite for an expanding family. In addition the conditioned spaces beyond the knee walls will provide ample safe and readily accessible storage for the family.

Interior Design Goals

Interior design focused on bringing an outdoor feeling to the interior by using attractive and environmentally friendly materials. Materials with low volatile organic compounds (VOC) became an initial design goal to decrease indoor air pollutants, and increase occupant comfort.

Furniture was selected and spaced to create flexible and open spaces, giving homeowners the ability to optimize every inch of the living space. Materials used throughout the units aimed to generating a warm and welcoming atmosphere. The entire house will have interior walls made of 1/2" gypsum board with a class III vapor retarder primer/ finish interior white latex paint. This will slow the rate of vapor diffusion in the wall, but also allow for vapor drying to the inside of the house.

In the kitchen, soapstone countertops were selected. Soapstone is a non-porous material so it does not require the sealants that granite and sandstone require. Soapstone is a sustainable resource from quarry extraction to preparing it for the consumer, so there is a low lifecycle environmental impact. Additionally, it has a high resistance to bacteria. If the buyer chooses to switch it out for another material, Soapstone is 100% recyclable. The cabinets trade traditional upper cabinets for open shelving. This will allow the buyer to customize the home as they choose, but reduce unnecessary material on the front end. It also will allow the space to feel more open and airy. The lower cabinets will be traditional shaker cabinets made of MDF.

Example of OSB Flooring

Flooring throughout the entire first floor will be flex tile with a wood pattern, giving the house the warm feeling of wood floors and the durability of tile flooring. This selection responds to the radiant heating on the first floor. On the second floor there will be polished OSB as the final flooring (see image). The polished OSB will give a warm, finished look to the second floor. Overall, the interior finishes we have chosen reduce material use, and are environmentally friendly while maintaining a comfortable and beautiful interior.

Performance Goals

Building a sustainable, net-zero energy ready house must take into account both the operational energy use and embodied energy use of constructing the house. The design focuses on ensuring long-lasting high performance, structural integrity, and enclosure durability by carefully analyzing the moisture, thermal, air, and vapor interactions of the house using both the Glaser Method and WUFI simulation. Decisions are guided by energy analysis using system software such as BEopt, which produces cost and performance optimized solutions for our design. REM/Rate provides energy demand calculations given the enclosure strategy, orientation, and climate, and produces a HERS score to reflect energy performance compared to a baseline house. Enclosure design carefully accounted for site conditions, such as Minneapolis' cold climate, Harrison Neighborhood's historically lead-contaminated soil, and FEMA's designation of the site as a 100 year flood zone.

The roof and foundation systems were selected based on an early design decision that all space to be built will be usable and within the thermal envelope of heated space. A slab on grade foundation was selected in order to reduce the amount of excavation and use of concrete, thus decreasing the embodied energy of the house. A life cycle analysis of foundation systems conducted by the Minnesota Sustainable Housing Initiative (MNSHI) (See Appendix 1) informed us that a Frost Protected Shallow Foundation (FPSF) achieves the lowest amount of embodied energy, global warming potential, solid waste, air pollution index, and water pollution index. The Twin Cities Habitat for Humanity is currently building a series of slab-on-grade townhomes two miles from our proposed site, and has provided insights on how to ensure success in the installation of this approach. A vented-unvented hybrid roof assembly places the thermal, air, water, and vapor outside of the roof sheathing, allowing for conditioned and usable attic space. The selection again speaks to making all built conditioned space usable space, including the typically uninhabitable attic in cold climates. This choice necessitates control of the condensing surface of the roof sheathing with exterior rigid insulation and an air gap, which prevents critical roof failures such as ice dams and interior moisture issues. High performing and efficient HVAC and domestic hot water plant, distribution, and control systems have been analyzed and optimized to reduce upfront and operational costs, while ensuring high indoor air quality and comfort.

High performing and efficient HVAC and domestic hot water plant, distribution, and control systems have been analyzed and optimized to balance upfront cost with operational savings, while ensuring high indoor air quality and comfort.

Level 1 Interiors

OptiMN's Bassett Creek ReGen Home

Enclosure Durability

General Design Strategies

Long-term high performing enclosures rely on proper management of the four control layers: water, air, thermal, and vapor. A "Perfect Approach" (Building Science Corporation), which places the four control layers outside of the house was taken. Incorporating the "perfect approach" to affordable building practices, shallow slab on grade foundations and 2x4 studs, allows for construction and energy cost optimization. A continuous layer of peel and stick membrane on the wall and roof sheathing provides an air and water barrier without breach or discontinuities. A continuous layer of rigid insulation installed on the exterior of the roof wall and sheathing works to eliminate thermal bypass at the wall framing. The rigid insulation also allows achievement of high R-values over conventionally insulated 2x4 studs. This system is easily constructed by local builders such as Habitat for Humanity. U-values below 0.24 were identified as ideal for reducing energy consumption in both winter and summer. Southern windows were run through RESFEN analysis to determine the passive solar gain potential. SHGC coefficient was optimized to reducing energy consumption as a result of heating needs in the winter.

Enclosure Durability

Tight, highly insulated houses with only cavity insulation, are susceptible to condensation on the cold side of the exterior sheathing. Hygroscopic properties of wood sheathing, such as OSB, can experience mold issues and structural degradation with the accumulation of condensation without vapor drying. To prevent this, exterior rigid insulation is specified on the outside of the sheathing to keep the OSB and cavity warmer than the dew point, eliminating condensation potential. The OSB is continuously covered in a peel and stick membrane to prevent damage from liquid water and doubles as a continuous air barrier. Moisture that enters the siding through wind driven rain, or summer vapor drives will be able to drain through air gaps between vertical furring strips. Elimination of condensation in the walls and roof is confirmed through Glaser Method calculations and WUFI analysis.

Thermal bridges occur at rim joist to wall connections, along vertical lengths of studs, decks, and window frames. Three inches of exterior polyisocyanurate will greatly reduce the amount of thermal bridging that occurs over stud and rim joist framing. The mineral wool batt provides R15 to the insulation while also providing acoustical blocking and fire protection.

Frost-Protected Shallow Foundation

Slab on grade construction in cold climates typically involves building stem walls that extend below the frost line. In our design, a monolithic shallow foundation, which extends less than 2 feet below grade, eliminates the need for increased levels of excavation and concrete use. A Frost Protected Shallow Foundation (FPSF) is installed to prevent frost heaves, a large concern in colder climates, by extending a wing of insulation from the bottom of the footing outwards to a code specified distance according to the air-freezing index. The wing traps geothermal heat below the foundation to raise the frost

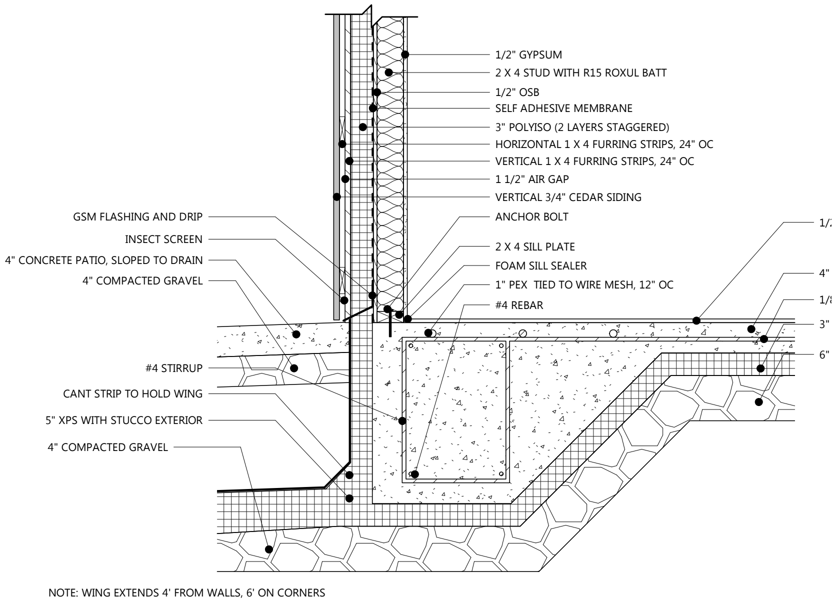


Figure 6A: Detail of the frost-protected shallow footing

line and protect the concrete from frost heave. In Minneapolis, an air-freezing index of 3500 calls for 3″ wing insulation extended 30″ from walls and 60″ from corners for heated buildings. Surrounding the entire slab with 3″ Extruded Polystyrene (XPS), including the below the footing, traps the heat totally within the building, essentially creating an unheated foundation design. For this reason, wing insulation values match those for unheated structures: 5″ XPS extending 4′ from walls, and 6′ from corners. The entire footing and insulation rests on 6″ of compacted gravel, which provides a continuous capillary break, negating the need for a polyethylene vapor retarder between the XPS and concrete. The gravel also allows for water drainage down and away from the foundation, further reducing capillary action into the concrete. A 4″ perforated drain tile is placed on the inside of the footing to transfer ground moisture to a sump pump.

Creating an innovative, yet constructible foundation design requires careful attention to current building practices. Through guidance from Habitat for Humanity and faculty advisers, preferred building practices and structural considerations were incorporated into schematics. A monolithic slab on top of rigid insulation is incredibly appealing to homebuilders. XPS as formwork is placed once for the entire building, and the entire attached housing footprint can be completed in a single pour. A low water to cement ratio (W/C) in the concrete mix will quicken curing times because less water will need to evaporate. A low W/C ratio requires plasticizers to make the concrete more workable. Minimal labor is required for concrete work, and the shallow nature of the footing requires minimal and simple excavation. The footing slopes to meet the slab at a 45 degree angle to allow for the gravel to easily settle on the earth. The XPS formwork follows the gravel installation, with the 5″ XPS wing attached to the vertical 3″ XPS by a cant skirt. Structural reinforcing is placed within the footing to distribute the load from the 2.5 floors above evenly through the footing and to the ground. Temperature steel and wire meshing are placed through the slab for support.

Above Grade Wall System

The exterior wall enclosure is designed using the perfect wall approach, in which the four control layers are placed outward of the OSB sheathing. The wall has an assembly R-value of 35, which exceeds 2015 MN State Building Code by R14 . The attached houses are designed with a continuous air barrier by placing a continuous peel & stick membrane over the OSB sheathing of the wall, which aligns with the roof air barrier as well. The wall and roof assembly contains 60% of insulation outboard of the sheathing and 40% inside the cavity, mitigating condensation potential for IECC Climate Zone 6 (Straube, High Performance Enclosures). Rim joists are similarly insulated to above grade walls with 3.5″ Roxul Comfortbatt insulation within the joist cavity. The typically under-insulated and poorly air sealed rim joists are easily sealed and insulated in the perfect wall approach.

The vertical wood siding requires both vertical furring for drainage and horizontal furring for siding installation be specified. This gap helps to back ventilate the cladding and reduces potential moisture problems, which can be prone to occur due to inward vapor drives in summer as well as wind driven rain. The cladding is drained using metal flashing at wall transitions and foundation to wall connection. All flashings around windows, doors, openings and transitions are integrated with the peel and stick membrane 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" Polyiso continuous exterior insulation. The foam insulation helps to minimize thermal bridging across the wall particularly from the stud members and rim joist. The R-15 Rock Wool insulation was chosen for the wall cavity because it is low cost but still provides adequate thermal resistance.

Wall- Insulation			Wall- Framing		
Material	Thickness	R value	Material	Thickness	R value
Interior Airfilm	-	0.68	Interior Airfilm	-	0.68
1/2" Gypsum Board w/ Latex	0.5	0.55	1/2" Gypsum Board w/ Latex	0.5	0.55
3.5" Rock Wool	3.5	15	2x4 Wood Stud	3.5	3.3
1/2" OSB Sheathing	0.5	0.62	1/2" OSB Sheathing	0.5	0.62
Peel and Stick Membrane	0.1	0.12	Peel and Stick Membrane	0.1	0.12
1" Air Gap	1	1.5	1" Furring Strips (Vert and Horiz)	1	0.94
3" Polyiso	3	18	3" Polyiso	3	18
Wood Siding	0.75	0.59	Wood Siding	0.75	0.59
Exterior Airfilm	-	0.17	Exterior Airfilm	-	0.17
Total:	9.35	37.2	Total:	9.35	24.97
Composite U-value		0.0269	**Composite U-value**		0.040
Percentage of Total		0.85	**Percentage of Total**		0.15
Wall Insulation U Component		0.0228	**Wall Framing U Component**		0.0060
Total U			***Total R***		
0.0288			35		

Figure 6B: Total U and R value calculations for OptiMN wall assembly

Partition Walls

Partition walls are framed 2x4 studs with R15 Roxul Batt insulation. Concerns at party walls mainly involve sound attenuation and fire control. Two layers of 5/8" Type X gypsum acts a fire barrier, which surround a 1" Coreboard, which acts a spacer between the walls. Electric outlet boxes between party walls are to be caulked and sealed to prevent air leakage between units. Sound travels well through small gaps such as plumbing and electrical boxes, so special attention to air sealing these gaps will assure high comfort and privacy levels between units. Ensuring that electrical boxes between units are not aligned will also help prevent sound transfer. The one hour fire rating on the party wall from foundation to roof is assured through the gypsum and coreboard, and extra ratings can be attributed to the Roxul Batt insulation.

Roof/Ceiling

Roof- Insulation			Roof- Framing		
Material	**Thickness**	**R value**	**Material**	**Thickness**	**R value**
Interior Airspace	-	0.68	Interior Airspace	-	0.68
1/2" Gypsum Board	0.5	0.55	1/2" Gypsum Board	0.5	0.55
2x6 Roxul ComfortBatt	5.5	15	2 x 12 Roof Joists	11.25	10.5
Air Gap in Rafter Cavity	5.75	1.82	1 1/18" OSB	1.125	1.45
1 1/18" OSB	1.125	1.45	Grace Perm-a-Barrier	0.01	0.06
Grace Perm-a-Barrier	0.01	0.06	6" Polyiso	6	36
6" Polyisocyurenate	6	36	1/2" OSB Sheathing	0.5	0.62
1/2" OSB Sheathing	0.5	0.62	Asphalt Paper	0.1	0.12
Asphalt Paper	0.1	0.12	1/2" Airspace (furring strip)	0.75	0.9
1/2" Airspace (furring strip)	0.75	0.9	Fiber cement Shingles	0.75	0.59
Fiber cement Shingles	0.75	0.44	Exterior Airspace	-	0.17
Exterior Airspace	-	0.17	Total:	20.985	51.64
Total:	20.985	57.8			
Composite U-value		0.0173	Composite U-value		0.019
Percentage of Total		0.85	Percentage of Total		0.15
Wall Insulation U Component		0.0147	Wall Framing U Component		0.0029
Total U			***Total R***		
0.0176			57		

Figure 6C: Total U and R value calculations for OptiMN roof assembly

The roof enclosure is modeled after a hybrid vented-unvented assembly where 60% of insulation is placed outwards of the roof sheathing and 40% in the roof cavity. The overall roof assembly has an R-value of 57, which can be seen in Figure 7B This system was selected based on the desire to create a comfortable living space in the attic, which is unusable in a typical vented roof assembly. The structural OSB is 1 1/8" sheathing and nailed to 2x12 I-joists. A water and air control layer is placed above this sheathing in the form of a peel and stick membrane. The thermal control layer of 6" polyiso provides R36 to the sheathing to keep it warmer than the dew point. Above the 6" polyiso is a 1x3 Furring Strip which provides 0.75" of an air gap. This air gap ventilates the shingles and roof sheathing to prevent snow melt on the roof reducing the potential for ice dams. The roof sheathing is protected from wind drive rain and snow melt by a layer of asphalt roofing paper.

Design of the roof carefully integrates a continuous fire wall between the two units from foundation to the roof connections. A small dormer protruding from the north roof allows for an egress window, required for a proposed bedroom in the unbasement. The dormer wall to roof connection necessitates flashing that is integrated with the peel and stick membrane. The south roof was pitched at 7/12, which is close to optimal for solar energy collection in MN but also allows for a greater surface for more solar panels. Eaves extending 1.5′ from the wall allows for summer shading of second floor windows, and gutters at the end of the eave drain water to rainwater collection systems.

Hygrothermal Analysis

Pen Test

A simple, qualitative way to assess the hygrothermal performance of the enclosure is to conduct a "Pen test." The air, water, and thermal control layers are simply traced around the section view of the house to represent continuities or discontinuities from below grade to above grade. Where there is discontinuity in tracing the control layers, there is thermal bridging, air leakage, or water infiltration. The continuity of control layers from foundation to roof in our assembly is accomplished by our innovative and simple enclosure design. Figure 6D shows the qualitative pen test for our enclosure and shows the clear continuity from slab to roof. The red line represents the thermal control layer of rigid insulation. The blue line represents the water control layer of the peel and stick membrane and below grade compacted gravel. Finally, the purple line represents the air control layer, which is also provided by the peel and stick membrane on the sheathing.

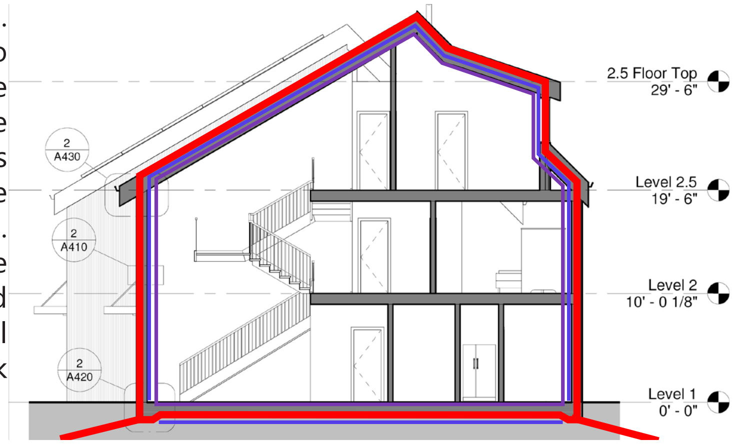


Figure 6D: "Pen Test"

Advanced Glaser Method

The Glaser method aims to calculate the steady state temperature and vapor profiles within each surface interface of the wall assembly. Comparing the saturation vapor pressure and the surface vapor pressure of each assembly interface will allow us to see if there is condensation potential on any wall surfaces. As long as the surface vapor pressure falls below the saturation vapor pressure, there is theoretically no condensation potential given the design temperatures and relative humidity (RH). The Glaser method neglects moisture movement through liquid water and air transport and also does not account for heat or moisture storage. To account for heat and moisture storage in building materials, the extreme average temperatures, and not the extreme design temperatures were used. The coldest average temperature in January, 16 degrees Fahrenheit, was used to represent winter conditions typical in our cold climate. An exterior RH of 30% is used, and an internal RH of 40% with the thermostat set to 70 degrees F represents preferred occupant conditions. Figure 7E shows the temperature and vapor profiles through the assembly layers in the winter, and reveals that surface vapor pressure levels of the wall assembly falls below the saturation vapor pressure, translating to no condensation potential. The hottest average temperature in July, 91 degrees F, was used to

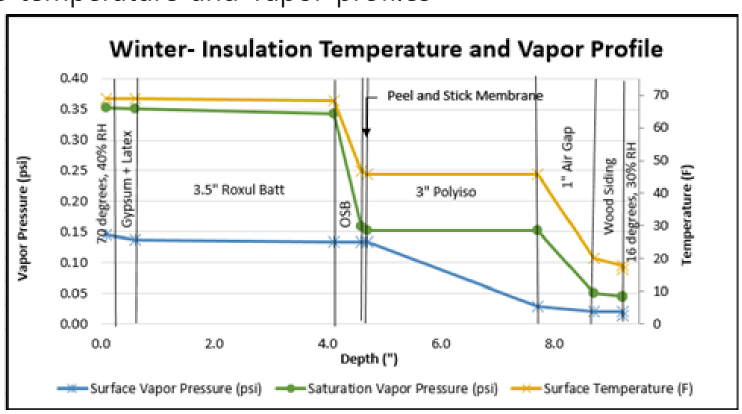


Figure 6E: Average Winter Conditions Glaser Method

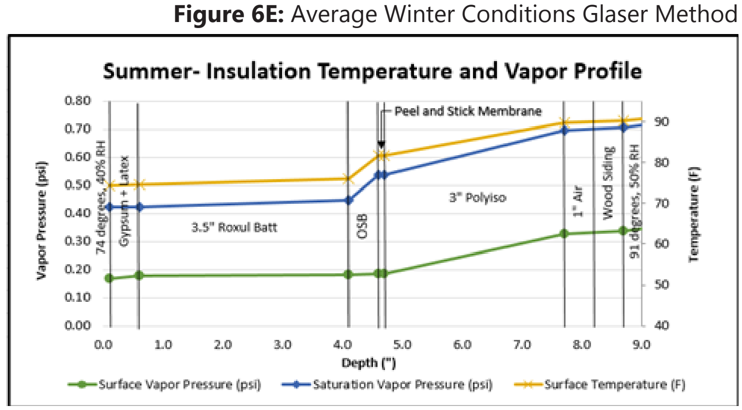


Figure 6F: Average Summer Conditions Glaser Method represent summer conditions. An exterior RH of 50%, and interior RH of 40% with the thermostat set to 74 degrees is used to represent realistic and comfortable summer conditions. Figure 7E shows the summer temperature and vapor pressure profiles of the wall assembly, and also shows no condensation potential. See Volume II for Glaser method calculations.

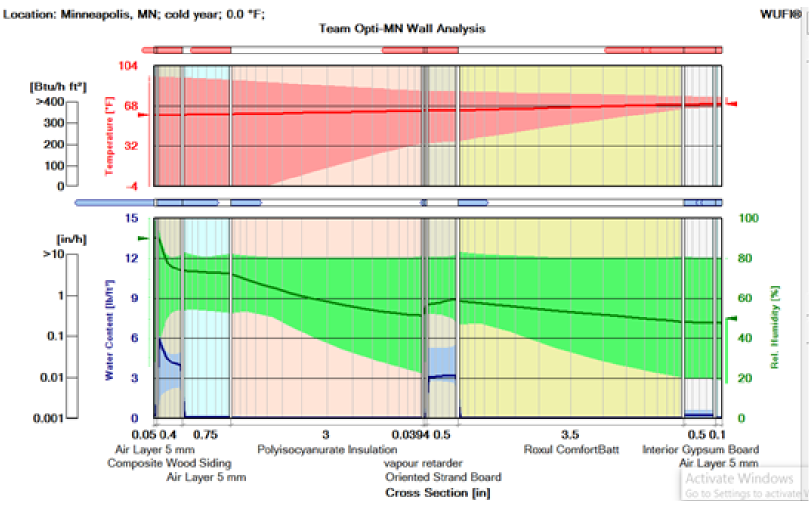


Figure 6G: WUFI Results

WUFI Analysis

Steady state analysis by the glaser method fails to account for rain events and frequent temperature and relative humidity changes throughout a day. WUFI allows for realistic simulation of heat and moisture movement in building assemblies and informs us of the drying potential of our wall, and potential condensation issues. It also accounts for moisture and heat storage in walls. Figure 6G shows the results of the WUFI analysis for the Opti-MN wall assembly. The critical layer of condensation is the OSB sheathing. The blue line traces the water content in the wall assembly throughout a five year span. Throughout the first year of analysis, the blue line at the OSB is significantly lowered, showing vapor drying in the wall assembly. This analysis was an important step in ensuring enclosure durability, because despite constantly changing temperature and moisture conditions, the wall assembly never accumulates condensation. It can be seen from Figure 6F that the interior temperature very minimally fluctuates which proves the low levels of space conditioning needed for this wall assembly. Also significant is the lack of any moisture on the interior gypsum wall which very airtight homes often experience and is a great indoor air quality concern. WUFI analysis was also conducted for the roof assembly which experiences similar amounts of vapor drying of the roof sheathing. Additional documentation is provided in Volume II.

Windows

It has been established that for a cold climate, a higher U-factor 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 and daylighting opportunities. There are no windows on the East and West, as these orientations fail to take advantage of passive solar heat gain. 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 poorly in terms of heat loss. Northern windows experience less beneficial solar heat gain and thus require lower U-factor values. A low U-factor, low SHGC is preferred for northern windows, while low U-factor, high SGHC is preferred in the southern windows.

Being a preferred local window manufacturer, especially for the Twin Cities Habitat for Humanity, Anderson A-Series windows and door have been chosen for this project. The windows selected for the southside facade will be double pane LowE, PassiveSun with Heatlock window with a U-value of 0.24 and a SHGC of 0.36. For the northside, Team OptiMN selected triple pane LowE4 Enhanced with Heatlock windows with an U-value of 0.20 and a SHGC of 0.21. This combination provided significantly optimized energy savings against 5 alternatives according to RESFEN analysis (See appendix XX). RESFEN allows us to compare window packages based on their annual window energy loss given inputs of window areas and orientation, U-factor, SHGC, and interior shading.

Indoor Air Quality

Providing exceptional indoor air quality is fundamental for residents' health. The quality of the air in the interior environment depends on providing fresh outside air, managing contaminant loads, and filtering particulates. Emphasizing indoor air quality minimizes the exposure to airborne pollutants and contaminants. Special care was taken in the design and specifications of equipment to reduce the potential for indoor pollutants and to mitigate them once they occur. The EPA Indoor Airplus requirements were followed and verified to assure the best possible indoor environmental quality for this high-performance DOE Zero Energy Ready Home. A solid IAQ plan involves four key approaches: pollutant avoidance, encapsulation, point-source control and general removal.

Pollutant Removal and Avoidance

Team Opti-MN has carefully designed these attached houses to reduce the pollutants that might be brought into the home though construction or during normal operation. Specific measures have been taken to reduce moisture entry, especially below-grade and with specific mitigation of radon, VOCs, and lead. If pollutants are generated in the units, source point removal is the most effective and efficient way to mitigate the impact on the indoor air quality in the rest of the unit. The ventilation design has been specifically chosen and designed to meet both the Minnesota Energy Code and ASHRAE 62.2-2010 (Section 6.4).

Combustion Pollutants
The potential for combustion pollutants can be virtually eliminated by using direct-vent, sealed- combustion equipment. The design for this project is a two-pipe boiler that will draw all combustion air from the outside atmosphere and discharge all flue gases directly to the outdoors. However, a carbon monoxide alarm will be installed in each unit per code to provide safety against a malfunction and to account for unexpected sources of combustion pollutants. The alarm will be hard-wired with a battery-backup function and placed according to NFPA 720 requirements and certified by either CSA 6.19-01 or UL 2034.

Radon Mitigation
Minneapolis is located in the EPA Radon Zone 1. For this reason, a passive sub-slab depressurization system will be installed to prevent accumulation of radon and other soil gases. A vertical ventilation pipe will run from under the first floor slab to the roof allowing soil gas to be vented by passive stack action. In addition, an inline fan will produce a slight negative pressure below the slab to create a suction point for soil gas removal. The frost-protected shallow foundation will be carefully sealed at edges, penetrations, and control/expansion joints with polyurethane caulk to impede radon flow into the house from the soil. A sealed sump basket will provide support for the 4″ gas-tight vent pipe that will exit through the upper roof.

VOCs and Lead

To further improve the indoor air quality, careful attention was given to material selection. All wood products and finishes will have low- to no-formaldehyde content. And all interior paints will be low-VOCs. Low-VOC and easy-to-clean hard surface flooring will be used throughout. Due to the prior industrial use of the area where our development is located, the soils may contain lead. Drop mats will be used to reduce soil entry by those entering the house. Airtight construction accompanied by high-efficiency MERV 12 filtration will also mitigate potential for lead dust entry.

Sealing and Encapsulating

For pollutants that can't be eliminated, special care will be taken to prevent them from off-gassing into the home environment. In particularly, for any composite materials the exposed edges will be sealed with a low-VOC sealants.

Point Source Removal

It is critical to control any point source pollutants before they escape that area and contaminate other portions of the home. Exhaust fans will be installed in the kitchen and bathrooms to remove excess moisture, odors, and pollutants associated with cooking and cleaning. All fans were selected to have low sone ratings, low power draw, and in some cases multiple speed settings for spot exhaust. Any openings for the fan or exhaust ducts will be properly air sealed and the exhaust duct will be sealed to the fan housing with mechanical fasteners and mastic for any flex duct.

General Household Ventilation and Filtration

While a point-source approach is preferred, it doesn't effectively capture all household pollutants and ensure high-quality fresh and filtered indoor air. For this design, a whole house ventilation system is built around an Energy Recovery Ventilator (ERV) that will provide point source pick-ups and fresh air supply back to all habitable room through the forced-air heating and cooling system. In addition, that system will employ a MERV 13 pleated media filter. This provides a high level of fine particulate capture for recirculated space-conditioning air and an additional level of filtration for the outside fresh air. Whole-house ventilation airflow and exhaust air flows would be measured by the Rater using RESNET Standard 380. Blower testing will be conducted to as part of the whole house level to ensure holes for exhaust fans in the exterior walls or ceilings hole cuts have been successfully sealed.

Ventilation

The ventilation system selected is an Energy Recovery Ventilator (ERV), that is able to recover between 70% to 80% of the energy from the existing conditioned air being exhausted and deliver that energy into the incoming air. It also transfers humidity keeping the interior more comfortably humid in the winter and pulling some of the water vapor out during the summer.

Ventilation Rates

A source point exhaust strategy maximizes the overall effectiveness and efficiency of the balanced energy recovery ventilation. Point source pickups for pollutant removal will be placed in all bathrooms, laundry, and kitchen. All exhausts will be directly vented to the outdoors through the ERV. Despite concerns for excessive negative pressure in this very tight house, a dedicated bath exhaust was added to the second floor tub/shower room. With three or more bedrooms this could be a major moisture generator; a quality bath fan that will run with the light is warranted. The home will be continually ventilated by the ERV. The specified ERV is designed to run at the required continuous ventilation rate of 80 cfm and can be switched the highest speed for 120 cfm. There are five pick-up grills that will be balanced as follows (under normal continuous operation):

Bathrooms*
- 1st Floor Half-Bath = 20 cfm
- 2nd Floor Bathroom (toilet room) = 20 cfm
- 3rd floor Bathroom(future) =20 cfm

Auxiliary Venting for Other Spaces
- 1st Floor Kitchen = 10 cfm
- 2nd Floor Laundry = 10 cfm

 * The bathrooms must be 20 cfm continuous to meet code.
 ** The 2nd floor bathroom (shower room) has a dedicated 50 cfm exhaust fan to meet code.

These ventilation rates are guided by the Minnesota Energy Code and ASHRAE Standard 62.2 (2010): Ventilation and Acceptable Indoor Air Quality. The minimal ASHRAE 62.2 ventilation rate for a 2298 square foot, 3-bedroom house will be: Minnesota Code = (0.02 cfm/sf x 2298 sf) + (15 cfm x (3+1) = 106 cfm*
* by code 1/2 of this must be continuous
For comparison the ASHRAE 62.2-2010 requirement would be = (0.01 cfm/sf x 2298 sf) + (7.5 cfm x (3 + 1)) = 52.98 cfm

The ERV will be designed and commissioned to exhaust a total of 80 cfm on low speed. This will provide continuous exhaust from 3 bathrooms, kitchen, and laundry area. The main upper level bathroom has a 50 cfm exhaust fan and the kitchen has a 135 cfm (in normal mode) range hood. With the ERV on high and main bath exhaust in operation the total ventilation rate will be approximately 170 cfm, well in excess of the code and DOE Zero Energy Ready Home requirements.

ERV EC15 ECM

The ERV is VENMAR model EC15 ECM ERV. It is an innovative system incorporating high performance motors equivalent in power to a compact fluorescent bulb (13.5 watts each) which will enable the EC15 ECM ERV to lower energy cost significantly without affecting its performance. The model meets the Energy STAR® requirements.

Exhaust Fans

Range Hood
Broan Elite

Cooking can be a significant source of pollutants, especially fine particulates. These units will use a high-quality range hood to remove potential pollutants directly at the source. This specific model, Broan Elite 290 CFM, RME50305SS is a 30"wide wall-mounted chimney hood in stainless steel. It is designed to detect excessive heat and adjusts the speed of the blower to high automatically to prolong the product's life. This model meets the Energy STAR® requirements.

The Panasonic WhisperGreen model FV-05-11VK1 rated at a flow speed of 50 CFM was chosen for the 2nd floor shower room because of its superior energy efficiency at achieving Indoor Air quality solutions. The model complies with ASHRAE 62.2, LEED , and Energy STAR.

Panasonic WhisperGreen
Ceiling Exhaust Bath Fan

Due to occupancy and heavy use, the second bath shower room will get a dedicated exhaust fan and light combination. The Panasonic WhisperGreen model FV-05-11VK1 rated at a flow speed of 50 CFM was chosen for the 2nd floor shower room because of its superior energy efficiency at achieving Indoor Air quality solutions. The model complies with ASHRAE 62.2, LEED, and Energy STAR.

Fresh Air Distribution

In high-performance airtight homes it is 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. The outdoor intake has been elevated off the ground, but still within reach for maintenance. The incoming outdoor air goes through the ERV to filter and temper (preheat and humidify in the winter and pre-cool 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 is distributed to all habitable rooms. The ECM air handler will cycle a minimum of 20 minutes each hour to meet Minnesota code and to ensure proper fresh air distribution.

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 Bassett Creek Valley area. High-efficiency air filters are recommended for all high performance homes.

Space Conditioning 09

Goals

High-performance, airtight, and low-load homes have special space conditioning requirements. Traditional oversized equipment can lead to short cycling, poor part-load performance, and ultimately occupant discomfort and complaints. Team OptiMN designed an integrated HVAC and DHW system that will:

- Provide high overall energy efficiency
- Be properly sized and provide 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.

Lenox XC21
Air Conditioner

Heating and Cooling System

For low-load homes space conditioning and ventilation requires properly sized equipment, high performance, and the most energy efficient HVAC equipment available to meet building and customer requirements. The compact combination system Energy Kinetics Accel EKOC1 was selected for this project. This system provides both domestic hot water and space heat from one system for our attached housing, adding to the energy efficiency of the project.

Enerzone Convertible
Air Handler

The Lennox XC21 air conditioner with the Enerzone air handler was chosen to provide both space heating using the hot water from the boiler system and a traditional split air conditioning system. This system is rated as one of the most energy efficient air conditions for 2017. It delivers exceptionally quiet performance, an important feature for attached housing. The designed airflow is 600 cfm. This lower design airflow rate contributes to reduced energy consumption by the air handler.

Radiant heat

Energy Kinetics Accel
CS EK1C90

Hydronic radiant floor is the most popular and cost-effective heating system according to U.S. Department of Energy. Radiant floor heating has numerous advantages. It is more efficient than forced air due to elimination of duct losses experienced with forced air heating. Because there is not forced air, the spread of allergens is greatly reduced in the house. Because hot air rises distributing the heat throughout the floor system, the heat will rise from the floor throughout the room providing a consistent comfortable temperature. In this closed loop system, the water recirculates throughout floor by PEX piping in a specific arrangement that returns to the boiler.

Incorporating radiant heat throughout the first floor and forced air throughout the top two floors brings yet another opportunity for reduced energy use. Radiant heat will provide uniform heating for the first floor and eliminating uncomfortable temperature swings. Installed under the floor, radiant heat provides a quiet and comfortable atmosphere and will reduce the need for use of the forced air system.

Honeywell Programmable Thermostat

Curb Energy Monitoring System

Automation - Control Strategies

With innovative energy efficient technology, management and control of this technology will add to reduced energy use.. A Curb energy monitoring system with a Wi-Fi Smart Thermostat from Honeywell will be installed. With the Curb energy monitoring system homeowners are able manage energy bills, review energy use trends, and monitor the solar system. The Curb is a great asset to add to this Net Zero energy home allowing residents to control and see first hand their energy use from their devices or on a web interface. The smart thermostat from Honeywell is easy to operate and program. Tablet, computer or the touch screen on the thermostat allows management of the thermostat to take advantages of savings and maintain comfort. With settings such as energy-saving mode, seven-day programming and indoor humidity sensor homeowners can control any aspect needed for comfort energy efficiency.

Lighting and Appliances

Light Selection and Design

LED lighting will be installed throughout the entire home. The lighting for this project is intentionally providing only the quality and quantity light necessary to perform the specific tasks of the space. The goal is to provide adequate lighting without unnecessarily overlighting a space, which would result in increased energy use. Recessed lighting will be installed in main living areas such as hallways, the kitchen, mud room, and laundry. Bathrooms will be served with hanging lights. For aesthetic reasons, a decorative light fixture will be placed in the dining area. The bedrooms and living room lighting will be served by lamps connected to outlets and switches.

Appliances

Appliances were selected based on performance, focusing where applicable on selecting Energy Star Certified appliances. The appliances selected include: refrigerator, dishwasher, clothes washer, and gas range. Whirlpool is a major donor for Habitat for Humanity, the project's proposed client, therefore the bulk of the appliances selected are Whirlpool products. A front loading washing machine was chosen for its reduced water consumption and because it spins faster thus removing more water and reducing dryer time. Ceiling fans will be installed in the bedrooms to reduce air conditioning demands.

	Appliance	Brand	Characteristics
	Washing Machine	Whirlpool	Energy Star 4.3-cu ft High- Efficiency Top Load Washer
	Drying Machine	Beko	Energy Star, Ventless, Electric 4.1 cu-ft Front Loader
	Refrigirator	Whirlpool	Energy Star, 20.5 cu- ft. Top-Freezer Refrigerator
	Stove	Whirlpool	Energy Star, 4-burner 5 cu-ft. Slide-in Gas Range
	Dish Washer	Whirlpool	Energy Star, Gold 51-Decibel Built-in Dishwasher

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OptiMN Bassett Creek ReGen Homes

Water Management

Kohler Refina
(K-5316-4-CP)
Bathroom Faucet

Kohler Mistos
(K-R72510-SD-VS)
Kitchen Faucet

Kohler Bancroft
(K-10548-CP)
Showerhead

Kohler Reach
(K-3983-S-0)
Toilet

Kohler Highline
(K-5481-0)
ADA Toilet

Hot Water System

The proposed hot water system reduces energy use and decreases utility costs. An efficient distribution system and fixtures reduce hot water delivery wait time as well as water usage and utility costs. Goals in designing an efficient system:

- High energy efficient water heater
- Proper sizing
- Efficient distributing system that delivers hot water within 30 seconds
- Watersense certified fixtures

An Energy Kinetics Model Accel CS EK1C 90 combination system was selected to provide both hot water for radiant heating and hot water for fixtures in the project. The Accel CS EK1C 90 has an AFUE of 96% and a storage tank capacity of 80 gallons. To insure proper delivery of the hot water a whole house manifold system will be used. This system shortens the distance for hot water to get from the storage tank to the fixture and keeping delivery time within 30 seconds. PEX has been selected for its durability, as well as its adaptability, ease of installation and because it requires fewer fittings, decreasing the risk of leaks.

Fixtures

All water fixtures are EPA WaterSense labeled, and the first floor fixtures are ADA compliant. WaterSense fixtures greatly reduce the water consumption of each unit. As an example, EPA states one toilet over the course of a year can save 13,000 gallons per year over a conventional toilet. Each unit has two bathroom faucets, one kitchen faucet, one showerhead, one regular toilet, and one ADA toilet for a total of six fixtures.

Exterior Water management

Water management goals
The water conservation approach for the site integrates best management practices (BMP) based on the Minnesota Stormwater Manual to reduce runoff volume, phosphorus content and total suspended solids (TSS) load on the Bassett Creek. Our primary goals are minimal rainwater runoff from the site and reduce municipal water usage for the site development. However grey water treatment and reuse are out of our project scope due to Minnesota Plumbing code ordinances.

Methods
In order to achieve these goals, the rainwater management plan includes four primary subcatchment areas or BMP's including bioswales, tree trenches, storage cistern and bioretention basin (Figure 11A). Also our system includes water efficient planting to minimize the irrigation usage.

Design includes rainwater harvesting which captures precipitation from the roof of north-western six units and stored into underground cistern (approx. 105,849 Ga) for the community garden and site irrigation purposes. Also each unit has a rain barrel on the northern side (approx. 40 Ga capacity) to collect rainwater for backyard irrigation usage. Rainwater coming from all the other sources including site impervious surfaces and other residential unit roofs are collecting into bioswale catchment area and bioretention basin which curtails the runoff, pollutants and holds water in case of extreme events.

Tree trench system without sewer underdrain is designed around three sides of the site boundary, approximately 150 Sq. ft. area and 5 ft. depth at each BMP along with porous concrete sidewalks. The system manages the runoff by infiltration or evapotranspiration and reduces the overall pollutant load.

The central area of the site has a multi-BMP system which combines a swale and bioretention basin. The swale side slope has a 7:1 ratio through which all the runoff flows to bioswale main channel of length 230 ft. by 3 ft. deep. This main channel connected to the bioretention basin with a sewer underdrain in case of overflow as per the regulatory barriers. The vegetated bioretention basin has a capacity of holding approximately 226,303.48 Ga and it helps to remove excess nutrients and eliminate water through evapotranspiration.

All the calculations (refer to Appendix 1) for BMP's are run under Minimal Impact Design Standards (MIDS) calculator to determine annual runoff volume reduction and annual pollutant load reduction for total phosphorus content and total suspended solids (TSS) for the entire site. "The MIDS goal is to retain 1.1 inches of rainfall whether it occurs in half an hour or over 12 hours.[2]"

Based on the BMP's and MIDS results summary as shown in Figure 11B, our design has achieved more than 95% runoff reduction and 100 % pollutant load reduction. We deliver overall water efficiency for our site and creates a positive impact on Bassett Creek by developing the holistic approach in our design.

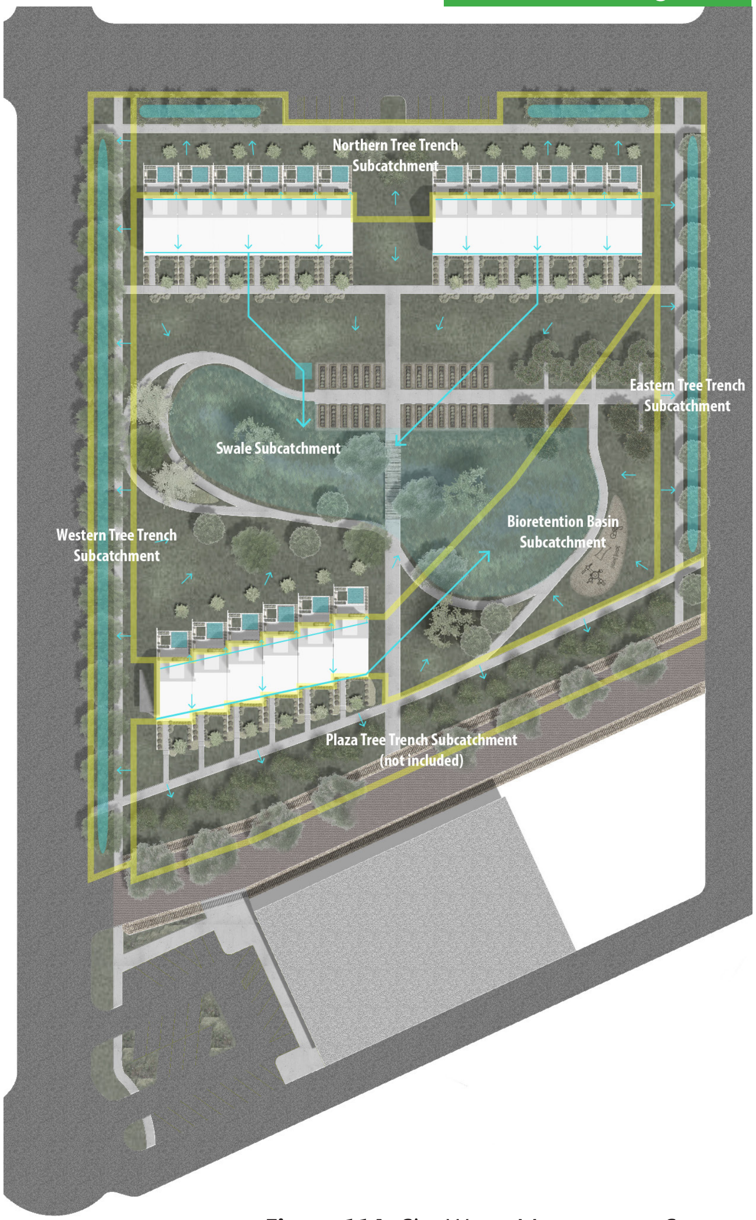

Figure 11A: Site Water Management Strategy

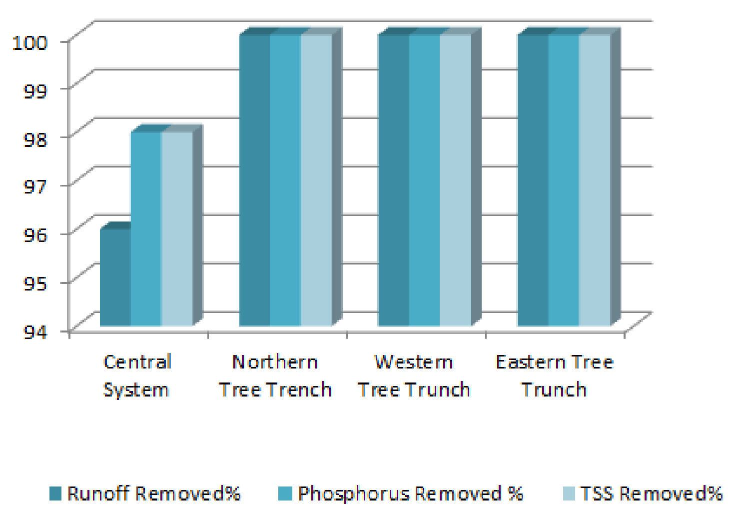

Figure 11B: Annual Volume and Pollutant Load Reductions Based on BMP's

[2]https://stormwater.pca.state.mn.us/index.php/MIDS_calculator

12

Bassett Creek ReGen Home

Energy Analysis

The energy analysis of the six attached housing units began with qualitative and quantitative comparison of multiple enclosure designs using BEopt. By entering multiple iterations of enclosure, mechanical, and human behaviors into BEopt, we were able to choose a path to cost and energy optimization. Analysis continued through the design stage by using REM Rate to provide heating and cooling loads based on enclosure and mechanical details. REM Rate provides a HERS score, which measures the performance of our design against a benchmark house of the same size. Heating and cooling loads were finalized using Manual J, which were compared to REM Rate values. Based on the loads calculated from these two methods, a solar array was chosen to allow us to achieve a Zero Energy Ready Home (ZERH) based on DOE criteria.

BEopt calculations

Energy efficiency designs derive from analysis of the house as a system. BEopt allows for evaluation of residential building designs based on cost and energy reductions compared to a B10 benchmark design. Data calculated for site energy consumption and utility costs allowed us to compare enclosure and mechanical decisions to find an optimized solution for a six unit attached housing building. A baseline design for the ReGen homes were compared to upgraded options, such as 2x6 cavities and R21 insulation, triple pane windows, slab perimeter insulation, and an electric water heater. From this analysis, we found that triple pane windows and increasing the slab perimeter insulation would decrease site energy use, while maintaining reasonable cost optimization. Figure 12A compares energy use of these design iterations that allowed us to choose triple pane windows on the North side, and R15 XPS around the entire slab.

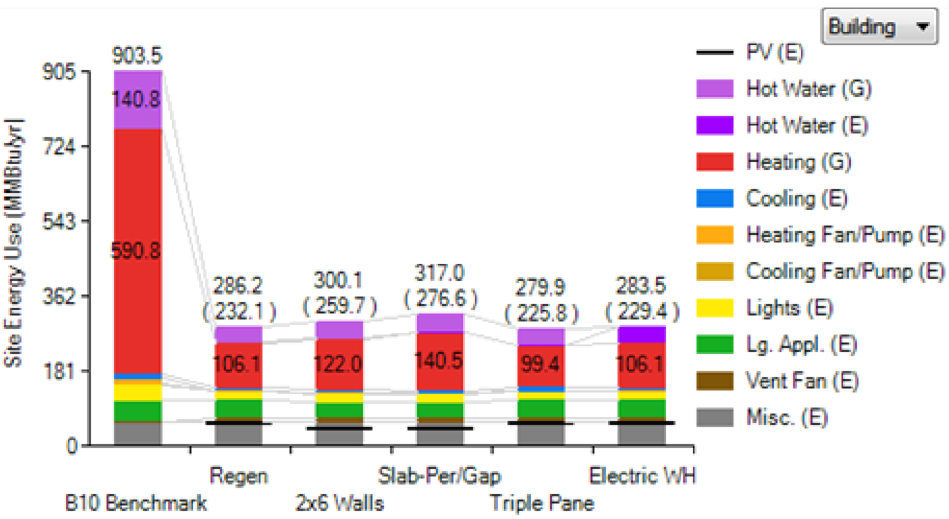

Figure 12A: BEopt analysis of ReGen homes compared to multiple design iterations

Heating and Cooling Loads

Heating and cooling loads were calculated by entering enclosure insulation and area values into both REM Rate and Manual J. Annual design loads allow for proper sizing of space conditioning equipment and renewable energy generation in order to achieve zero net energy. Figure XX summarizes the design loads from REM Rate and Manual J, which are very comparable.

Manual J calculates a heating load of 13.9 KBtu/HR and a cooling load of 8.87 KBtu/HR, for a total of 22.77 KBtu/Hr. REM Rate calculates a heating load of 13.0 KBtu/ Hr and a cooling load of 9.3 KBtu/Hr, for a total of 22.3 KBtu/Hr. These calculations relate very closely, and therefore confirm the heating and cooling loads fall below 23 KBtu/Hr total for a year. This is a very low total, signaling a robust enclosure, which allows for a simple solar array to offset energy costs and achieve zero net energy. A summary of Manual J and REM Rate calculations are provided in Volume II.

	Manual J	REM Rate
Heating Load (KBtu/Hr)	13.9	13
Cooling Load (KBtu/Hr)	7.5	9.3

Figure 12B: Heating and Cooling loads based on Manual J and REM Rate calculations

HERS Rating - REM/Rate

The Home Energy Rating System (HERS) is the standard at which home energy efficiency is evaluated compared to a typical reference home. A low HERS score signifies a reduction in lifetime energy bills for the homeowner, and therefore increases homeowner affordability and resale value. REM Rate is used to provide a HERS score, which serves as the basis for communicating the ReGen Home's superior energy performance. Attached housing units perform differently on end units and interior units due to the difference in ambient and party wall areas. For this reason, a HERS score was generated for three different units, and all achieve zero net energy with the same size photovoltaic system (PV). A summary of the HERS scores and associated utility costs with and without PV is provided by Figure 12C.

ReGen Homes HERS Score Summary				
	No PV	Utility Costs	PV	PV Utility Costs
ADA End Units	30	$69	0	$10
Interior Units	32	$66	-1	$7
East End Unit	31	$68	-1	$8

Figure 12C: HERS score summary for ReGen attached housing units

HERS scores ranging from 30-32 ensure new homeowners that their home consumes about a third of the energy costs of a house built to typical construction standards. With PV, homes achieve zero net energy, with the only utility costs coming from PV services charges.

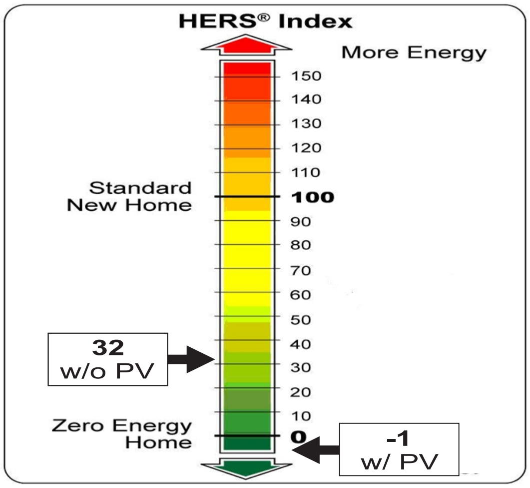

Figure 12D: HERS score

Solar Energy

Solar Photovoltaic (PV) panels provide the simplest and most recognizable form of renewable energy for residential homes. In order to optimize for solar energy collection, design choices such as a North-South orientation, increased southern roof area, and a 7/12 southern roof pitch were incorporated. A southern roof area of 701 square feet, an inclination of 30.3 degrees, and an azimuth angle of 180 degrees provide optimal conditions to achieve zero net energy. These design choices in turn affected how to support the structure of the house. Careful attention to structural plans from foundation to roof allow confidence that solar energy can easily be incorporated during construction.

Program Incentives

Currently PV systems enjoy specific federal and state (Minnesota) incentives to offset the cost of PV panels. In Minnesota the solar rebates are: the Residential Renewable Energy Tax Credit, and the Made in Minnesota (MiM). The available federal tax credits reduce the cost of solar arrays by 30%, and the MiM rebate rewards a certain cost per Kwh of energy produced for ten years if you buy a solar array produced in Minnesota.

Solar Capacity and Selection

The solar system selected is called the APEX 440W model produced by a Minnesota

PV company named TenK. Systems purchased from TenK can utilize the MiM rebate, and have a much higher energy production capacity than any other MN solar company. The MiM rebate equals $0.14 per KWh in a year. Higher energy production per panel derives from the system's utilization of parallel architecture to allow for multiple current pathways, which reduces inefficiencies such as shading, soiling, and others. The APEX 440W model has an efficiency rating of 16.8%. The system also incorporate a redundant inverter bus, which acts as the PV control module and is placed in the center of the array. This allows or less wiring and a 96% inverter efficiency. TenK also has a 500W model, however the 440W was selected because it still gets the houses to net zero at a lower cost than the 500W model. See Volume II for the specification sheet for this model.

The panels must be placed three feet from the edges of the roof, and each panel is specified at 6.62'x 4.26' for a total of 28.2 square feet per panel. A total of 18 panels can be placed on each southern roof, for a total solar array area of 507.6 square feet. A peak production of 7.92KW can be produced from this array. Costs for this array were simplified to be $5/Watt for a grand total of $39,600. This total is immediately reduced to $27,720 with the federal Residential Renewable Energy Tax Credit, and further reduced by the MiM rebate over the system's lifetime. Using the PVWatts calculator by NREL, an annual energy production of 11,260 KWh can be produced from this system given conditions in Minneapolis. Given Xcel energy rates of $0.11 per Kwh, this saves about $1,239 of energy costs in a year. This energy production equates to a MiM rebate of $1,576 in a single year. Given these conditions, a payback for the entire system can be achieved within 9 years (See Volume II).

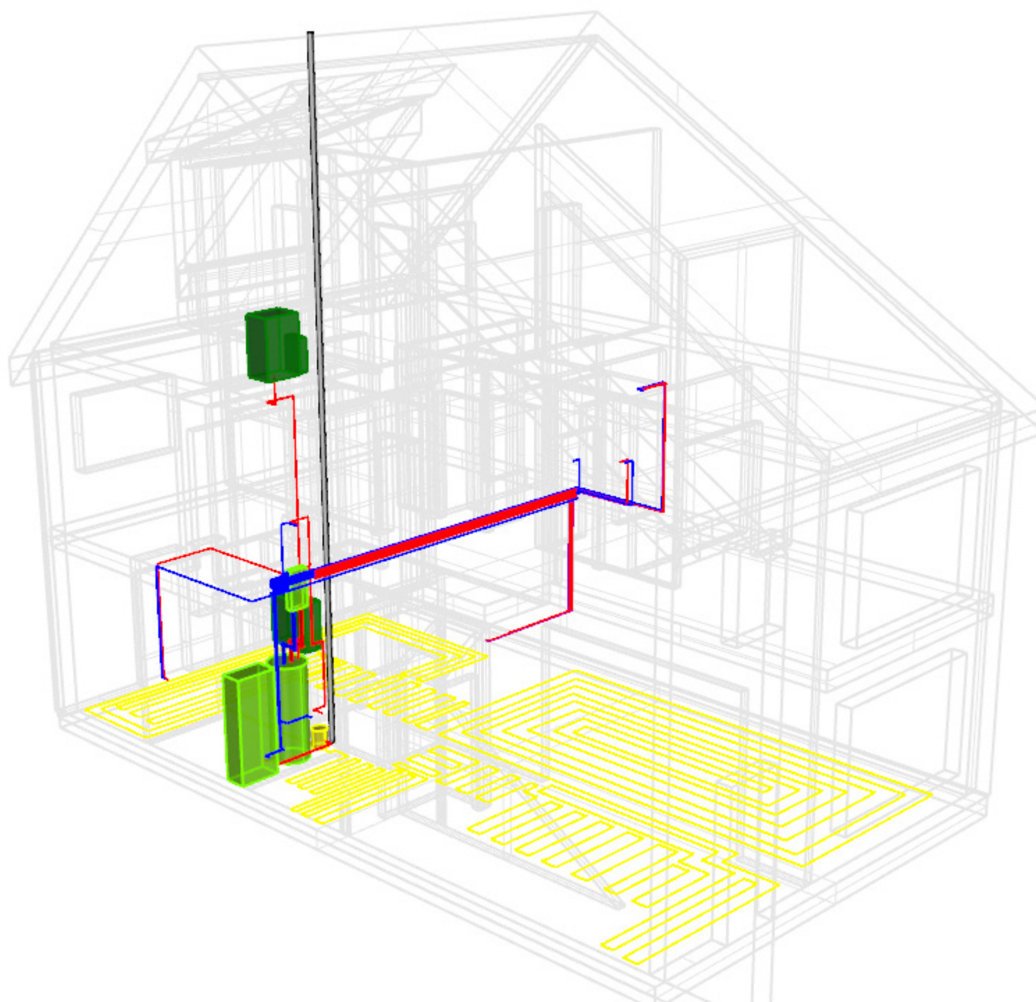

Figure 12E: Axonometric of Plumbing Plan

Construction Management Schedule

A construction schedule allows builders and construction managers to see the flow and logic of constructing ReGen attached housing. Quick construction is achieved using waterfall techniques, where one trade finishes a unit and moves to the next one, with the succeeding trades beginning immediately after they finish. A site logistics plan allows us to visualize our site through the eyes of a construction manager. The site proposed has spacious boundaries that allow for proper staging, quick and easy deliverables, and a logical flow of construction that is not impeded greatly by neighbors or existing conditions. The main concern for construction planning is to minimize harm to the surrounding landscape. Construction of the ReGen homes has potential to cause major silt runoff to Bassett creek, so construction and quality assurance of silt fencing, and stormwater control is important to the overall goal of regenerating the area. Construction of the bioswales and tree trenches preempt house construction to allow for rainwater collection from our site. A silt fence is to be placed around these bioswales to prevent suffocation of organic life.

Time, energy, and material are not to be wasted while constructing these homes. Efforts to mitigate construction waste begins at the planning and design stage. A frost protected shallow foundation, monolithic concrete pour allows for foundation construction that lasts no longer than 2 weeks from excavation to curing. A monolithic pour allows for high quality concrete work, as the concrete will cure at the same time. Constructing this foundation is mostly a matter of forming the rigid insulation, so errors are reduced by assuring proper formwork and reinforcing prior to pouring. Using a low Water to Cement ratio in the concrete allows for quick curing, which is crucial to slab on grade construction.

Framing and sheathing must be installed and inspected for air gaps. Using FSC certified wood allows for proper chain of custody and grading, so that wood used for construction is responsibly sourced and has adequate structural strength. Walls will be built on the slab of the left most unit and erected starting from the opposite end. This allows for work space away from main activities, and increases the tidiness of the site. Consult the construction quality assurance plan and the site logistics plan in Volume II.

Financial Analysis

From conversations with the representatives from the Harrison Neighborhood Association we determined that the Bassett Creek/Harrison area is home to a highly diverse neighborhood, with both renters and homeowners from the most varied economic, ethnic and cultural background. According to survey data obtained from ESRI Demographic, the average Median Family Income (MFI) is 48K, compared to the nationwide average of 62K, and the average age is 33 years old. The goal of our project was to provide affordable housing for the Bassett Creek/Harrison residents, meaning lower monthly bills than an average home. A detailed and thorough construction estimate can be found in Volume II and provides a realistic size of and costs of the project. Values from RSMeans were applied to the specific construction processes and area takeoff values for the entire building. Landscaping costs reflect the actual vegetation and design utilized in the front and back yard of each lot. The landscape of our master site plan was not assessed for costs, as it falls outside of the competition requirements for the financial analysis.

The final price for the total building was simply divided by 6 to get a per unit cost. An overall construction cost for the 6 attached units was determined to be $1.2 Million, with a per unit cost of $201,459. The units are constructed at $88/sq. ft., and the overall sales price per unit is $336,394 when adding overhead fees. This brings the cost up to $146/ sq. ft.

Solar panels were assessed for pricing by applying a $5/W of peak power. Rebates from the Renewable Energy Tax Credit were applied to determine a sales price of $27,780 for the solar array. The Made in Minnesota Rebate were applied to these costs, as well as energy savings provided by PVWatts by NREL, and a 9 year payback was determined. The cost analysis for the PV system can be found in Volume II. After this point, a homeowner can enjoy the cost benefits of the solar production and payback for many years to come.

Assumptions

- Electrical Rates- $0.11/KW,
- Electricity Inflation- 5%,
- Inflation rate- 3.2%
- Property Tax-1.345%
- Down Payment-30% of Mortgage
- 30 year fixed mortgage
- Annual Interest Rate- 4.5%
- MFI of 48K for a Harrison Neighborhood Fmaily
- $66 for monthly utilities as provided by REM Rate.
- Maintenance Costs of $120 based on Homeowner’s Association assistance.
- Includes basic home repairs as outlined in the Homeowner’s Guide in Volume II. Major appliance replacement would increase this cost, however this will be infrequent, and estimated to be every 25 years.
- Made in Minnesota Rebate of $0.14 for tenK solar as outlined in 2016 program guidelines.

ReGen Homes Affordability Compared to NAHB Costs

To provide a comparison to NAHB 2013 values of constructing single family residential homes, the per unit cost for each construction cost breakdown was utilized. The financial analysis required for the Race to Zero competition can be found in Volume II. Certain summary line items, such as framing, are significantly lower for attached housing because of the partition, also called party walls, characteristic in attached housing. Party walls are shared walls between units that require less insulation and material than ambient walls, and therefore provide a less expensive way to construct houses. Interior finishes are shown to be more costly by $10,000 dollars per unit, because of our choice to avoid carpeting and wood flooring, and instead use tile with a natural wooden color, flooring was much more costly. This is a cost that translates to less floor maintenance and higher indoor air quality, so was deemed necessary. A similar argument can be made to compare the exterior finishes, which are about $8,000 higher than the NAHB estimate because of exterior rigid insulation. Our use of polyisocyurenate on all exterior walls and the roof comes from BEopt and REM Rate energy analysis, in which the option for a higher R-value per inch was deemed necessary to reduce occupant utility bills and site energy usage. Exterior insulation can be expensive, but the building science justifies the cost by ensuring a durable, energy efficient house.

The construction costs and sales costs for one ReGen home is $16,000 below the NAHB average cost for a home of this size. Monthly costs calculated for the new homeowner include the mortgage, maintenance costs, property tax, insurance, and utility costs. Despite having higher property taxes than the national average, the ReGen homes provide a debt to income ratio of 52%. With Habitat Humanity financing of construction and financial resources for the homeowner, the total costs of construction and monthly costs will allow us to meet affordability targets of a 38% debt to income ratio. Habitat for Humanity is given XPS for free from DOW, which would greatly reduce the cost of the frost protected shallow foundation. They are given many other rebates for building materials which would directly benefit the homeowner. The total monthly payment after buying this house is only $2,018, with utility costs of only $66 without PV, and $6.83 with PV. This is $346 less than the NAHB default for our house.

Team Name: Team Opti-MN (University of Minnesota)
Contest Category: Attached Housing

Construction Cost Summary

	Baseline Design	Team Design
Site Work	$ 14,831	$ 14,831
Foundations	$ 20,627	$ 29,699
Framing	$ 41,461	$ 24,668
Exterior Finishes	$ 31,268	$ 31,034
Major Systems Rough-ins	$ 29,052	$ 23,147
Interior Finishes	$ 63,678	$ 73,073
Final Steps	$ 14,327	$ 5,009
Other	$ 1,997	$ -
Total Construction Costs	$ 217,243	$ 201,459

Sales Price Summary and Cost of Living

	Baseline Design	Team Design
Total Sales Price	$ 352,177	$ 336,394
Monthly Household Debt (0.5% MFI)	$ 261	$ 240
Operations and Maintenance Costs	$ 196	$ 120
Monthly Utility Costs	$ 160	$ 78
Property Tax	$ 332	$ 377
Insurance	$ 79	$ 79
Mortagage	$ 1,405	$ 1,193
Total	**$ 2,433**	**$ 2,087**
Estimated Target Family Income	$ 52,250	$ 48,000
Debt to Income Ratio	56%	52%

Figure 13A: Cost Summary