# EMPOWERING THE ARCHITECT TO ACHIEVE SUSTAINABILITY

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# Empowering the Architect to Achieve Sustainability

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**ABSTRACT**

On their current trajectory, the paths of sustainability and economics are set to collide. An architect needs to be the salesperson, rather than an advocate, of net-positive design. In order for sustainability to succeed, designers must push beyond certification program requirements. Sustainability must become affordable, and the world is relying on architects to solve the equation. However, the traditional client-architect relationship does not allow for an architect to implement the necessary freedom of design to take on this challenge. Through the study of developer-architects, who have complete and total control of all aspects of design and construction, I seek the meaning and empowerment brought about by the removal of the client from the architectural relationship.

Once architects are trained in sustainability, the opportunities to create a solution to environmental issues will increase. In this paper, case studies are investigated that have employed this new identity and its methods for creating elegant and affordable, net-positive housing. An analysis of waste-elimination theories, such as William McDonough and Michael Braungart's Cradle to Cradle theory of the never-ending cycle of technical nutrition, serves as a basis for designing with best practices in mind. Currently practicing developer-architects, for example Jonathan Segal, have provided insight into the advantages of expanding the role of an architect to include development and contracting. The resulting conclusions highlight the avenue by which architects shall be empowered to take on an active and expanding role in implementing sustainable design.

**Keywords**: Development, Sustainability, Economy, Net-positive

## THE GOAL

Empowerment for architecture lies within sustainability. And conversely, the success of sustainability lies within the empowerment of the architect. No longer can architects merely advocate for sustainable building practices, but rather must become common sense business practice. Terms such as 'sustainability' and 'green' currently serve mostly as marketing tools. In Yung Yau's *Economizing subsidies for green housing features: A stated preference approach,* Yau found that minimally acceptable house rating systems are generally perceived as "effective in promoting green buildings", but may cause "market inefficiency and rent-seeking problems." Furthermore, Yao goes on to state that energy efficient buildings that become Energy Star or LEED certified seek an increase of selling price of 5.76% and 9.94% respectively.[1] What's the real motivation here? Architects must find an avenue by which 'green' can mean more to the average consumer than simply specifying the most popular recycled materials or slapping a solar panel on the roof. When sustainable practice results in a strategic economic advantage to owners and tenants, only then will sustainability truly prosper. Hunting for a few creative ways by which to earn LEED points in a building doesn't solve the energy crisis. Sustainability must become the core principle by which a design centers. This thesis will dive into a topic that demands an open discussion: the intersection of sustainability, economics, and quality design.

[1] Yung Yau, Shuk Man Chiu, and Wai Kin Lau, Economizing subsidies for green housing features: A stated preference approach. Urbani izziv, volume 25, no. 2, 2014. 107-109.

Needed is a business model that could make housing consumers incentivized to seek sustainable systems. The byproduct of such a model could make the architecture profession thrive more than the current model allows. An emerging profession of developer-architects is proving that the removal of clients can prove beneficial based on productivity levels. Questions surrounding this new avenue of design include: how does a developer-architect acquire startup capital? How was the conclusion reached that the eradication of client will do the profession a service? Most importantly, should the developer-architect business model yield power, how can that power be harnessed to produce a more affordable model of sustainability?

Over the course of the research phase, the study of sustainability and the architect/developer process will occur simultaneously so that one side doesn't weigh too heavily over the other. The first step has been – and will continue to be – researching the current and past history of sustainability, developers, clients, LEED, etc. Case studies will have the utmost importance in my research as well. Each will be broken down to fit into categories such as affordability, sustainability, and developer-architect studies. Through the lens of other architects who have created successful net positive buildings, I will conclude which practices could become more marketable. The same will occur in studying developer-architects who have economically feasible business models. I plan to gain first hand research by directly contacting known developer-architects such as Peter Gluck and Jonathan Segal. By the end of my research, I plan to have in place a practical business plan reviewed by professors from Miami University's Farmer School of Business.

**ROLE EXPANSION**

For sustainability in the construction of buildings to flourish, the role and value of an architect must evolve. Sustainability needs a salesman someone to advocate in public realm, and San Diego's Jonathan Segal is doing just that. Segal works not only as an architect, but also as a developer and builder. "With the advent of the architect working for the contractor and developer, the architect has been regulated to just a messenger"[2]. Over the course of his working career, Segal has saved the equivalent of two and a half years by not traveling on the interstate by simply working within an urban landscape. Segal found that his adopted city of San Diego had issues in addressing the need for apartment spaces large enough for families, so he used his power as a developer to make the changes he thought necessary.

Figure 1. Jonathan Segal's first project as a developer was 7 on Kettner, a three-bed two-bath apartment that he and his family lived in.

[2] Jonathan Segal Documentary. Directed by Bread Truck Films. Performed by Jonathan Segal. San Diego, 2009. Documentary.

His first project as a developer/architect was 7 on Kettner, which served not only as a profit-driving startup investment, but also a three bedroom, two-bath apartment for himself and his family. Sustainability is the next issue that Segal is attempting to conquer in his apartment developments. “The q”, which rents studio apartments at a rate of over $1,200, features passive design that filters cross ventilation through exterior fins. More importantly to the owner (Segal) and the tenants, is the source of mechanical power. The building features enough solar power to run elevator, stair lights, exterior lights, common lights, garage mechanical systems, garage entry, exterior doors, etc. While the systems are not using energy from a power plant, they are also not prying money from the owner’s pocket. Instead of leaving the tenant to decide when to turn lights off and running up energy bills, all utilities are subrogated to individual tenants. More expense at the onset of the development to do so, but saving the owner over the course of time while also incentivizing tenants to conserve energy.

Figure 2. The q features mix use programming and implements sustainable design to increase profit margins while also encouraging tenants to conserve energy.

The struggle of positioning oneself to work in a similar fashion to Segal is the initial investment. The demeanor of a businessperson is needed, along with the attention to detail of an architect. Instead of designing, architects typically divide their talents into slivers of career fields: psychologist, attorney, theorist, researcher, advocate, salesperson, engineer, and others. Quickly lost in the shuffle are the two most important traits for advancing the practice – architect & businessperson. The cause of such disunion is the traditional client-architect relationship, which hinders the spirit of free design. Once the hurdle is removed, architects will have greater control of not only what gets built, but how and why. More of Segal's time is spent designing, effectively positioning himself to use his education and training at a greater capacity than many architects. The AIA sponsored a study titled *Managing Uncertainty and Expectations in Building Design and Construction* based on interviews of 200 architects, contractors, and clients. The study found that while 86% of owners were satisfied with the building quality of their project, only about 63% reported satisfaction regarding cost and schedule.[3] The effort to design a structurally sound building, while doing so at the variable satisfaction levels of a client, clearly is a strenuous task. Removing the traditional relationship could dramatically impact the career of practicing architects. Segal stated: "The dilemma most architects have is they need to get their first commission…and they have to start from the bottom and work their way up. It takes 20-30 years before you become a real architect and get a real commission. We basically just circumvented that. We shortcut it by doing our own projects and not having a client."

[3] Davis, Clark S., FAIA, and R. Craig Williams, AIA. "Managing Uncertainty." THE JOURNAL OF THE AMERICAN INSTITUTE OF ARCHITECTS, January 29, 2016.

Imagine our profession and the implications of a young, vibrant workforce harnessing the power to forge positive change in our built environment.

Peter Gluck of the Manhattan based firm GLUCK+ echoes Segal's thoughts in Lisa Delgado's *The DIY Approach to Housing.*[4] Gluck says that architects "sit in their office waiting for someone to call them to do a development- and they wait a long time." Gluck's firm has opted to take the developer-architect role as well, focusing on multi-story residential spaces (similar to Segal). The TroutHouse features a contemporary façade and open floor plan, while also incorporating a number of sustainable features. A roof deck features a 5.5 Kw solar panel array, which even in the humid continental climate New York was able to produce more energy than the 6000 square-foot building consumes. Gluck reaps the benefits of TroutHouse's LEED Gold and Energy Star certifications. GLUCK+ principal Mark Mancuso expressed that working from a development standpoint also shortens the design and construction time and is more efficient. "Normally, we design something and then go to the developer-client, and then the design changes to tailor it to the way they want". Cutting the client from the process reduces design time and overall effort. Loadingdock5, a Brooklyn developer-architecture firm currently is in the process of building their own self-funded project similar in scale to TroutHouse. Their project incorporates inexpensive building materials such as corrugated steel roofing. Budget constraints usually equate to *less* design

[4] Delgado, Lisa. "The DIY Approach to Housing." Oculus, 2015, 40-41.

experimentation, but when the architect becomes in control of the process, architectural quality is not lost (Delgado, 41).

GLUCK+'s Urban Townhouse in Manhattan highlights the promise of adding freedom to an architect's repertoire. This project was one in which Gluck served a client, but the architect gained control of contracting responsibilities.[5] The house sought to reinvent the spacing sequence of a typical urban row house. Most urban housing units feature a centrally located elevator (both longitude and latitude), with staircases along the sides.

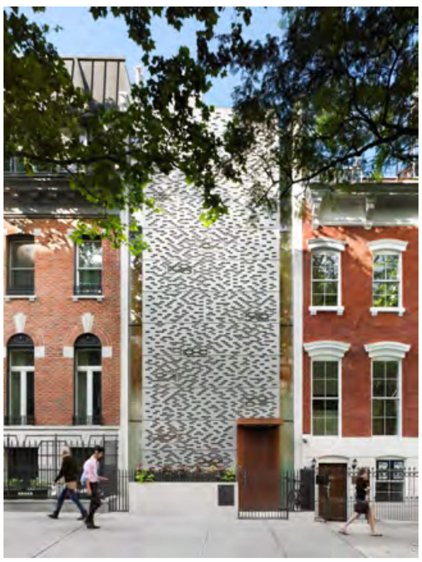

Figure 3. GLUCK+'s Urban Townhouse experimented with patterned façade studies, ultimately referencing the typical brick typology of the neighboring buildings.

Shifting the entry sequence to the front of the building allowed the building to maximize an open plan. The occupant engages the architecture from sidewalk approach throughout circulation to the floor of choice via a spiraling staircase around the elevator

[5] Koch, R., & Freeland, E. (2016, May 13). Urban Townhouse / GLUCK. Retrieved May 13, 2016, from http://www.archdaily.com/348932/urban-townhouse-gluck

shaft. Brick typology is referenced through apertures in a veil at the property line. A structural concrete wall then stores a vertical library, while also allowing light to enter the space through additional punched openings. The maximized space in such a tight site condition created highly valuable space. Architects, as Segal says, need to experiment and make mistakes. The freedom gained by owning the building or, in this case, constructing the building, lends itself to thorough and quality design.

**AFFORDABLE FOR MOST**

Without affordability, there will be no sustainability. Joseph Eichler was an early pioneer of building architecturally pleasant residences at or below market rate. Eichler benefited from the suburbanization of California in the 1950's and 60's. In Gwendolyn Wright's *Performance Standards,* Wright emphasizes that Eichler had a "keen awareness of the needs and opportunities of his time and milieu." Post WWII brought about the advents of new inexpensive building materials, such as plywood and foam insulation.[6] Eichler found that he could design with materiality as the base, and fit the consumer's need based upon budget. The American modernism approach involved a sweeping, mass-market single-family housing movement. 65 years later, America could lead the sustainability movement by launching affordable alternatives.

[6] Wright, Gwendolyn. "Performance Standards." Places 14, no. 2 (2001): 46-47. Wilson Web.

Figure 6 & 7. The plans for the house shown can be purchased online at a modest $4,500. Assuming the Eichler estate receives a generous 10% commission for his work, this house is only $45,000, affordable to a large portion of the middle class.

Like Eichler, Frank Lloyd Wright used his talents to address concern of rising construction prices in the early 1900's. He performed a study and wrote an article for *Ladies Home Journal* in April of 1907, in which he sought a design for a single-family house for under $5000. Wright removed all but the essentials, stating his design featured "No attic, no butler's pantry, no back stairway have been planned; they would be unnecessarily cumbersome in this scheme, which is trimmed to the last ounce of the superfluous."[7] The 30'x30' plan was developed so that concrete forms could be used for each foundation wall. The United States Department of Labor provides an inflation calculator, which goes back to 1913, six years after Wright wrote that construction costs had risen 40% over the previous six years. The four-bedroom one bath's $5000 price tag

[7] Wright, Frank Lloyd. "A Fireproof House for $5000 ESTIMATED TO COST THAT AMOUNT IN CHICAGO, AND DESIGNED ESPECIALLY FOR THE JOURNAL." Ladies Home Journal, April 1907.

inflated to 2016 rates is the equivalent of $119,654.55.[8] An incredibly modest price for a custom home by a world-renowned architect.

More current models show that sustainably driven design can also prove affordable. Llano Exit Strategy, designed by Matt Garcia, was constructed as four separate livable spaces with a budget of only $40,000 each. A fifth space was built as a communal cooking, dining, and entertaining space. Resting on a plot of land adjacent to the Llano River, the group of friends were moved by the 'tiny house' movement, and created their vacation homes with inexpensive materials-notably corrugated sheet metal, concrete, and plywood interiors.[9] Garcia formed the roofs to crease at the rear third, leading to metal trenches that connect the complex formally while collecting rainwater functionally. The small square footage of these living spaces show that comfortable living can exist without massive amounts of room. Downsizing allows for low budget constraints to not mitigate design quality.

The use of shipping containers as an architectural element is nothing groundbreaking. However, in the search for an economic, environmental sustainable model of development prove relevant. One such large-scale undertaking is 27boxes in Melville, South Africa. True to the name, the open-air mall employs 27 freight-shipping

[8] "CPI Inflation Calculator." Bls.com. Accessed March 15, 2016. http://www.bls.gov/data/inflation_calculator.htm.

[9] McLaughlin, Kelly. "Tiny Houses by Matt Garcia – Llano Exit Strategy." Humble Homes. Accessed March 15, 2016.

containers available for rent by merchants. Developer Arthur Blake said of the mall, "building with containers takes two thirds of the building time compared to conventional building and the costs are 80% of bricks and mortar." His statement is a testament to the economic and sustainable potential of the industrial reuse nature of shipping containers. They certainly come with their own new set of issues: need for cranes to place them, torches are needed to cut through the steel, new construction methods, and new engineering practices. The biggest issue at hand becomes the ability to efficiently heat and cool a container space. Warm climates like the one 27boxes is built in are capable of taking on a material that doesn't lend itself to being heated very well. However, if the containers were to be used in a climate near Cincinnati, the harsh winters and lingering cold of late fall and early spring would prove as a challenge. Still, the cycles of reuse as well as no need for new products are a William McDonough style Cradle-to-Cradle material use.

## REMOVING THE GIMMICK FROM SUSTAINABILITY

The architecture needs to take a hard look at the way we are addressing sustainability. The accreditation system currently in place is not serving in a capacity to save the Earth, but rather as an unregulated gimmick. Take Las Vegas' Palazzo Hotel & Casino as an example. The casino's designers were able to cash in on the tax abatements accompany a LEED Silver rating. The building racked up points enough to receive a $27,000,000 tax abatement over the span of 10 years. Here's the issue: many of the points the casino was able to earn do little to nothing in terms of sustainability. One point for being located in an urban environment. One point for being near public transit. Two points for using recyclable materials such as ***steel and concrete.*** One point for cards on hotel beds that informed when towels would be replaced (green design education program).[10] Other buildings receive points for having parking spaces dedicated to hybrid cars, or posting signs indicating the building's rating. Besides tax credits, developers are rewarded with allowance to build taller than zoning codes typically allow. The system is a money grab that needs revamped. But architects don't need to wait for them to do so.

The aforementioned William McDonough is the co-author of Cradle to Cradle, which describes the need for better design of products to feature never-ending lifecycles. He has formed a theory that designers of all things (products, cars, buildings, etc.) should do so with sustainability at the forefront of their process. McDonough describes the friction that currently exists preventing sustainability from achieving:

> *"…Industrialists often view environmentalism as an obstacle to production and growth. For the environment to be healthy, the conventional attitude goes, industries must be regulated and restrained. For industries to fatten, nature cannot take precedence. It appears that these two systems cannot thrive in the same world."*

[10] Schnaars, C., & Morgan, H. (2013, June 13). In U.S. building industry, is it too easy to be green? USA Today. Retrieved May 13, 2016.

McDonough goes on to describe his work for a Holocaust Memorial proposal in New York. He visited Auschwitz and Birkenau to feel the power of the 'giant machines designed to eliminate human life'. There, he "realized that design is a signal of intention". He brought that perspective back to the states and felt that he had to stop working to be 'less bad', and ultimately create buildings and products with completely positive intentions. These designs would be "loved by all children, of all species, for all time". The pair coauthored *"The Hannover Principles",* which spoke to the idea to "Eliminate the concept of a waste - not reduce, minimize, or avoid waste, as environmentalists were then propounding, but eliminate the very concept, by design. This prospect is one that might seem tough to stomach, but then the authors point to another industrial species that has had only positive effects on the environment.

> "*Consider this: all the ants on the planet, taken together, have a biomass greater than that of humans. Ants have been incredibly industrious for millions of years. Yet, their productiveness nourished plants, animals, and soil. Human industry has been in full swing for little over a century, yet it has brought about a decline in almost every ecosystem on the planet. Nature doesn't have a design problem. People do."* (McDonough & Braungart, 16).[11]

The issue with McDonough's work is that, per most problems, begins with money. McDonough works for the Chinese government designing entire city concepts. Sustainability must become more accessible to the user and architect than working directly for a global superpower.

[11] McDonough, W., & Braungart, M. (2002). Cradle to cradle: Remaking the way we make things. New York: North Point Press.

ZEB House in Oslo, Norway is one residential design that begins to use sustainability as the driver. The entire roof surface is comprised of solar collectors at an optimum 19-degree slope. The net positive house uses the panels to power all utilities in the house and even use excess energy to power their electric car. What's left is then sold back to the energy company. This house exemplifies what architects should be striving for: the elimination of energy bills. Take my own home instance. If my $52,000 house had the same mechanical systems as ZEB, the energy savings over the course of the escrow (30 years) would be over $92,000. Almost double the value of the home! No need to slap a sign on the outside boasting of a LEED accreditation when the house's design is paying for itself.

## EMPOWERING THE ARCHITECT

Simple supply and demand points to increased value of the architect should a portion of the community take on ownership and development. Studies show that the economic climate currently, and historically, lends itself to allowing architects to do so. Jonathan Segal shoots for an average of only one project per year, in his case multi-family apartment units. Should more architects be willing to take on their own developments and not be required, from an economic standpoint, to seek several or even dozens of projects (per year), supply of architectural services will drop. Thus, the cost of such services will increase. Housing trends show that apartment units are in extremely high demand. "The State of the Nation's Housing 2015", conducted by Harvard University's Joint Center for Housing Studies, found that homeownership continues to fall, with a First Quarter rate of only 63.7%, which is the lowest in over two decades.[12] Cincinnati and Dayton, in particular, have seen a -3.6% and -3.8% change in homeownership from 2006-2013.[13]

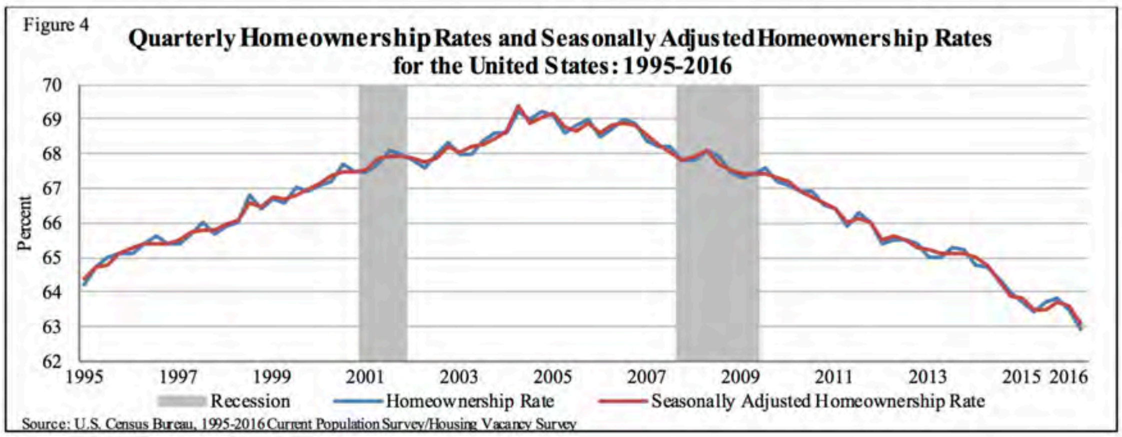


Figure 12. The US Census Bureau reports record low homeownership.

However, rental vacancy rates are at all-time lows. The Harvard report shows that since 2004, renter household growth has averaged 770,000 annually. The age of this group may come as a surprise. Not only are millennials opting to rent at booming numbers, but also middle and retirement aged folk, which doubled the rental growth over the past decade of renters 35 and under. Millennials, however, provide the future of economic stability of multi-family housing units. Homeownership amongst 18-34 year-olds has dropped to an all-time low of 13.2%.[14] Aside from a generation-combined trillion dollars in student loan debt, would-be homeowners are finding that their economic standing, as well as love for amenities and community, pushes them toward renting rather than owning. The burden of dropping anchor on a 30-year mortgage is one millennials are quick to pass on.

[12] Donahue, Kerry. The State of the Nation's Housing 2015. Report. Joint Center for Housing Studies, Harvard University. 1-8.
[13] "Homeownership Statistics for Metro Areas." Governing.com. Accessed August 2, 2016.
[14] Truly. "Why Millennials Love Renting." Forbes.com. October 7, 2014. Accessed August 2, 2016.

Cincinnati based 49Hundred Apartments have tapped into the growing pool of renters, of which are seeking high-end units. Notably, DINKS (dual income, no kids) and empty nesters are prominent tenants. These are not the type of renters that hunt for roommates and low cost apartment space. As Chris Oole stated in a recent Cincinnati Enquirer article, "I've owned a house before. I'm at a stage of my life where I want to acquire experiences, not things. The apartment setting is good for creating social opportunities to meet other people."[15] Rental rates at 49Hundred range from $1,200 to $1,900 per month for one to two bedrooms. While rental rates have increased an average of 3.5% every year since 2010 that still hasn't stopped apartment occupancy rates from reaching 96.5% occupancy over those same years. 49Hundred's Blue Ash complex of over 250 units was 100% leased prior to construction completion.

Architects entering the world of development will require a low-risk investment to maintain cash flow to provide for their own families. Multi-family units are a trend that won't be dying off anytime soon, if ever. Freedom of design allows architects to manipulate sites as they choose. Jonathan Segal's 'Charmer' was built on a 30,000 square foot lot, fully capable of housing 40+ units. Typically, a traditional developer would max out the lot. Segal, however, chose to only supply 21 units on the entire property, with two of those being live-work studios and three being commercial units.[16] The result was an architectural piece that sits light on its' footprint, straying far from the typical blocky, heavy units. Creating multi-family units allows the architect to have a voice in what gets built, not just how. Better communities are established by finally being capable of implementing the design skills architects spent

[15] Prevish, Val. "High-end Driving Growth in Region's Rental Market." Cincinnati Enquirer, July 15, 2016. Accessed July 16, 2016.
[16] The Charmer / 7mns. Performed by Jonathan Segal. Vimeo.com. 2012. Accessed August 2, 2016.

years harnessing. All the while, increasing their own value in society as well as those in the practice who choose to stay client-based.

## CONCLUSION

The architectural community needs to take a look at their role in society and ask ourselves if we truly are contributing to our full potential. If the answer is no, or not fully, the second question needs to be: are we willing to take on the business side of the industry to enhance our overall stake? Architects could take ownership; literally, of the social issues they truly want to address. My agenda is a desire to make the world a better place via net positive residential construction. Another architect might choose to go after impoverished communities in Haiti. Whatever the case may be, we have already established an ability to design. Our next task should be finding a way to make our art become reality. That can’t happen without addressing the financial aspect of building. I look forward to furthering my research by conducting interviews and exploring designs with my research as the backbone.

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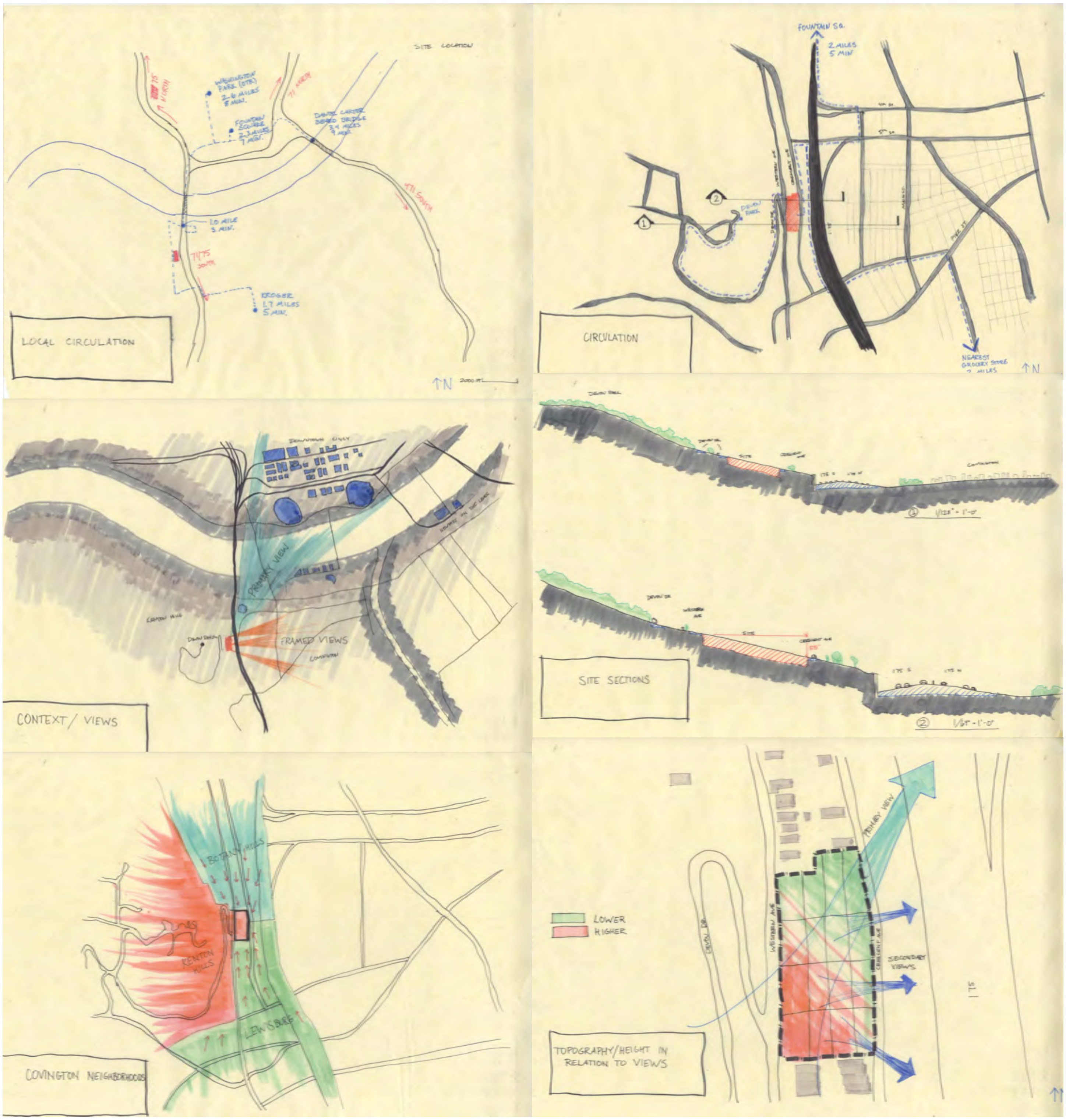
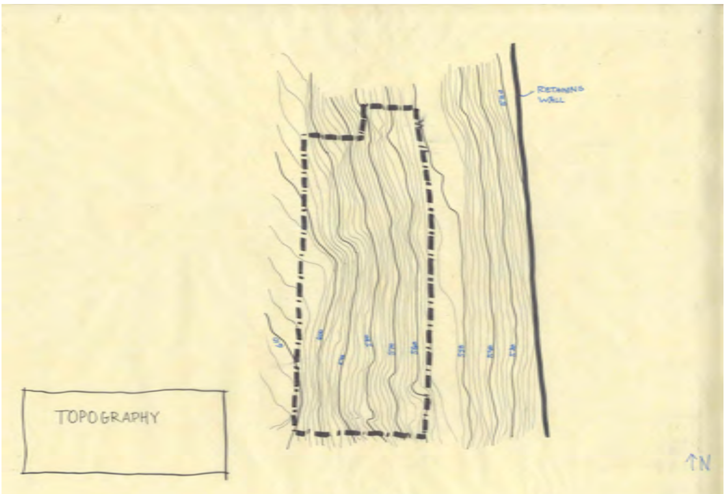
[16] The Charmer / 7mns. Performed by Jonathan Segal. Vimeo.com. 2012. Accessed August 2, 2016.

# SITE ANALYSIS

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MAX DEVELOPMENT STUDY
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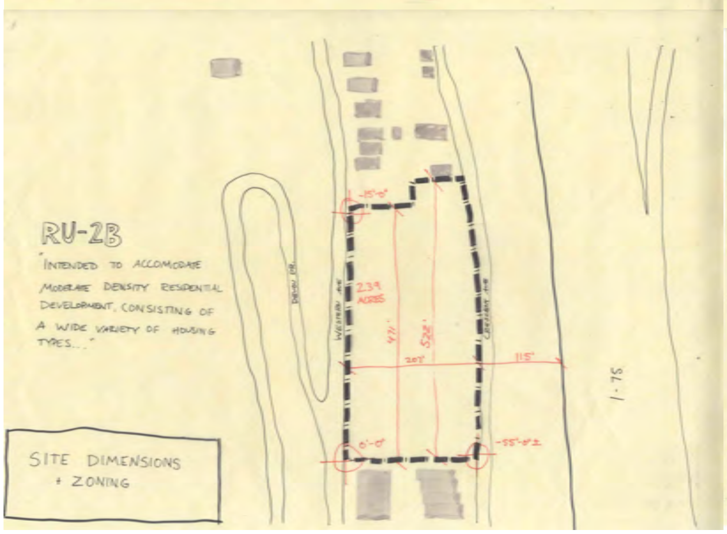
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EXISTING TREE CANOPY
I-75

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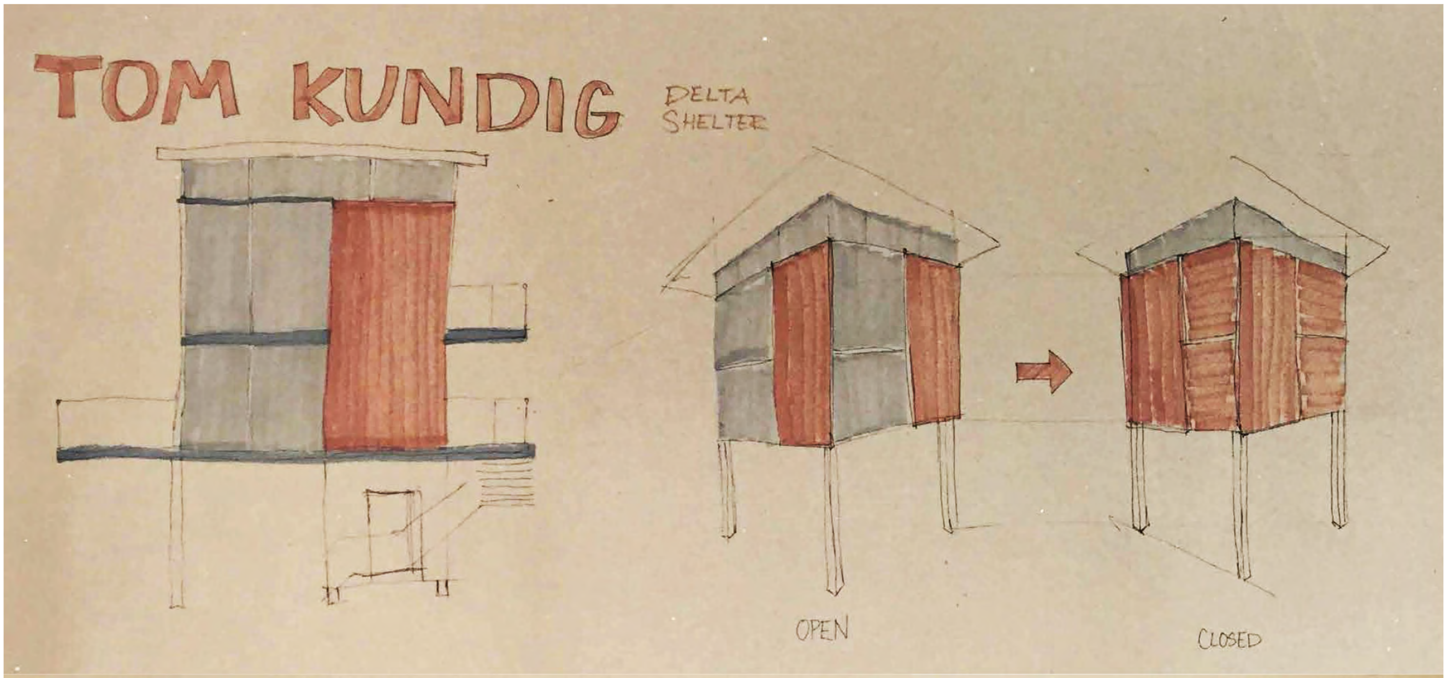
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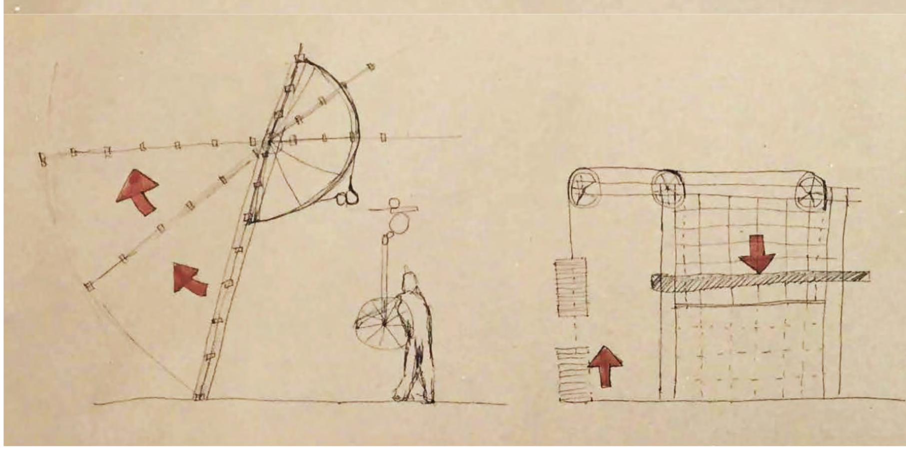

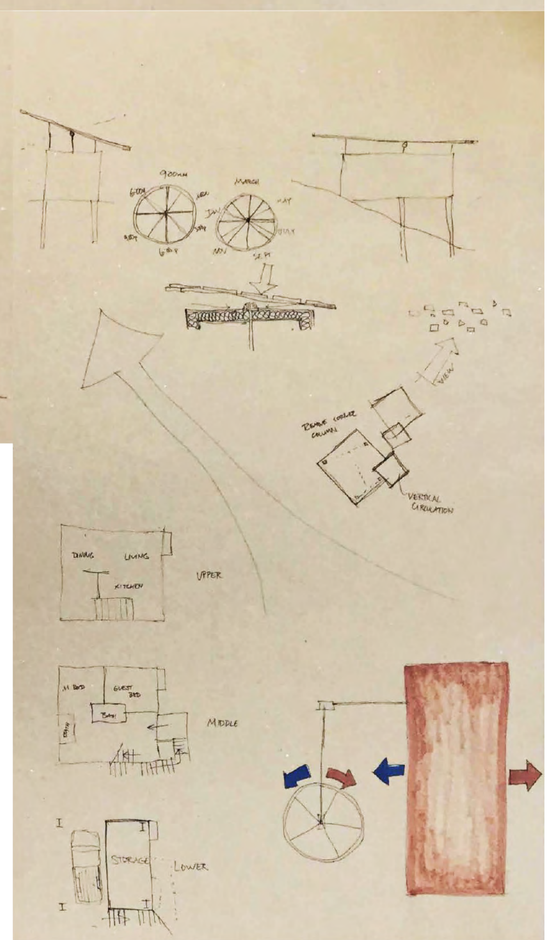
UPPER
MIDDLE
STORAGE
LOWER

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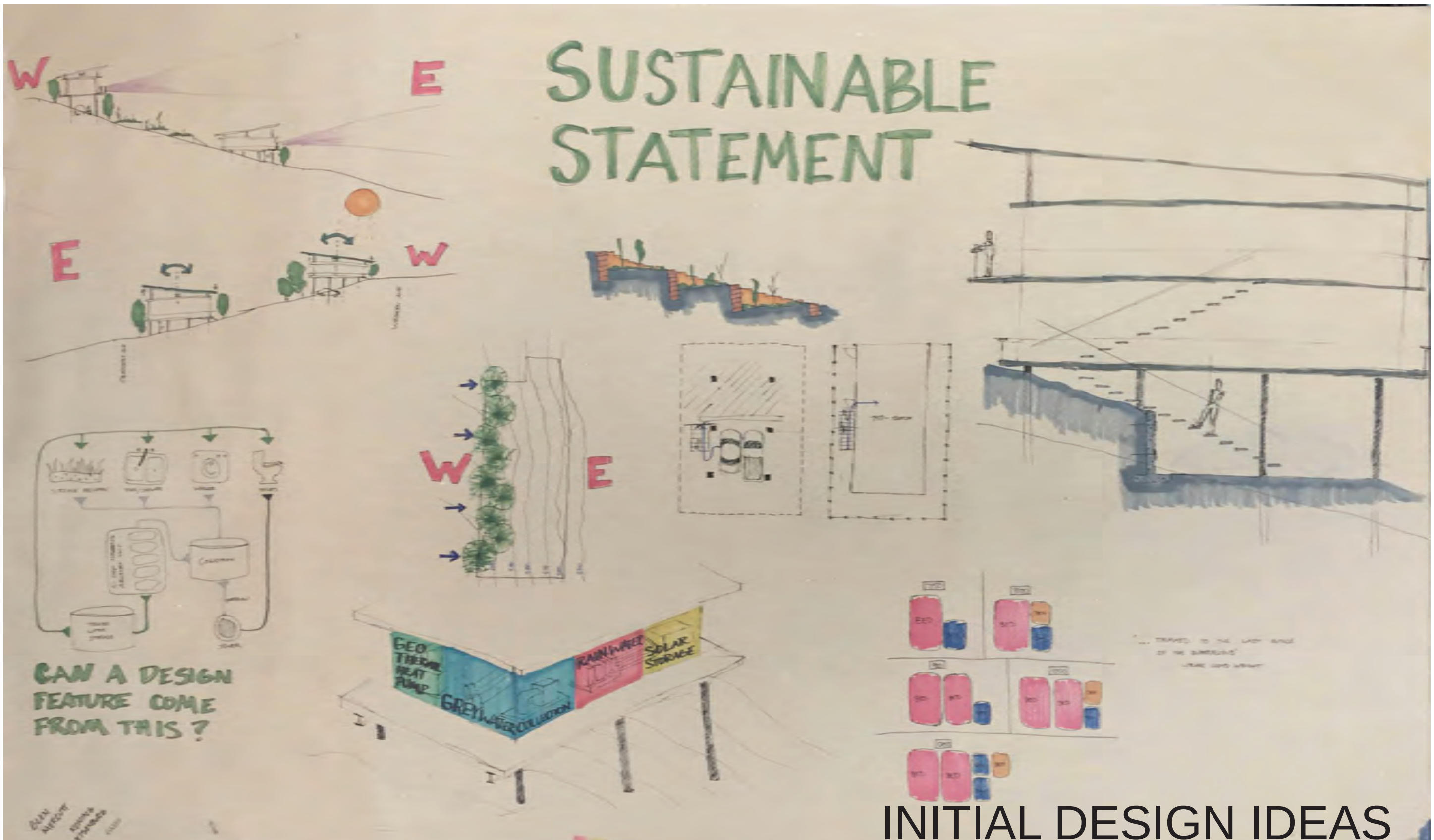
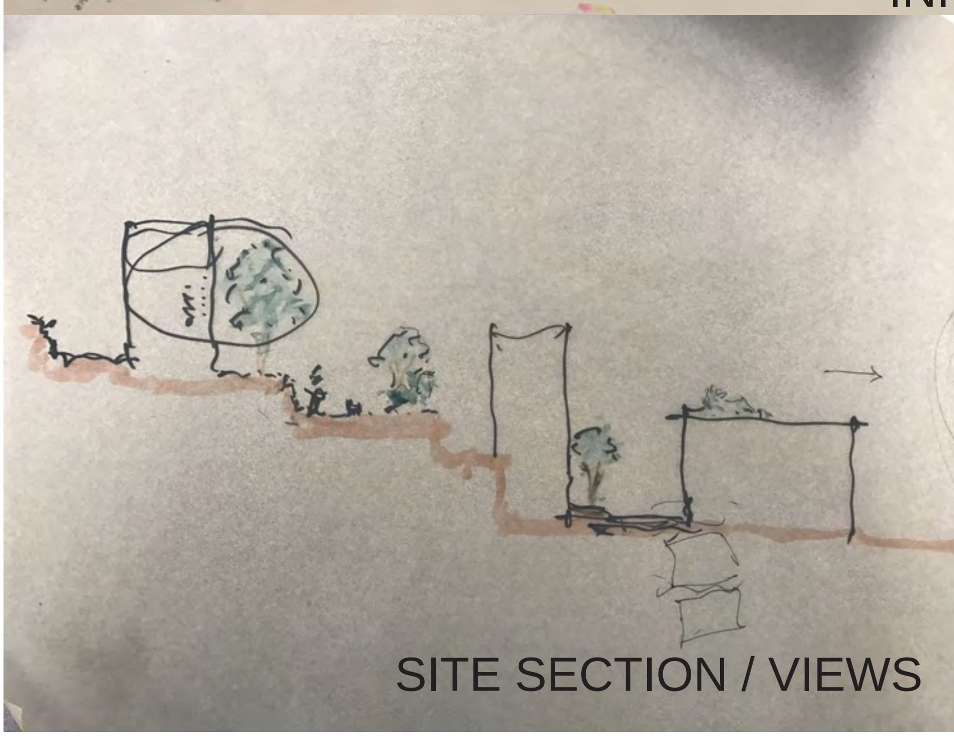
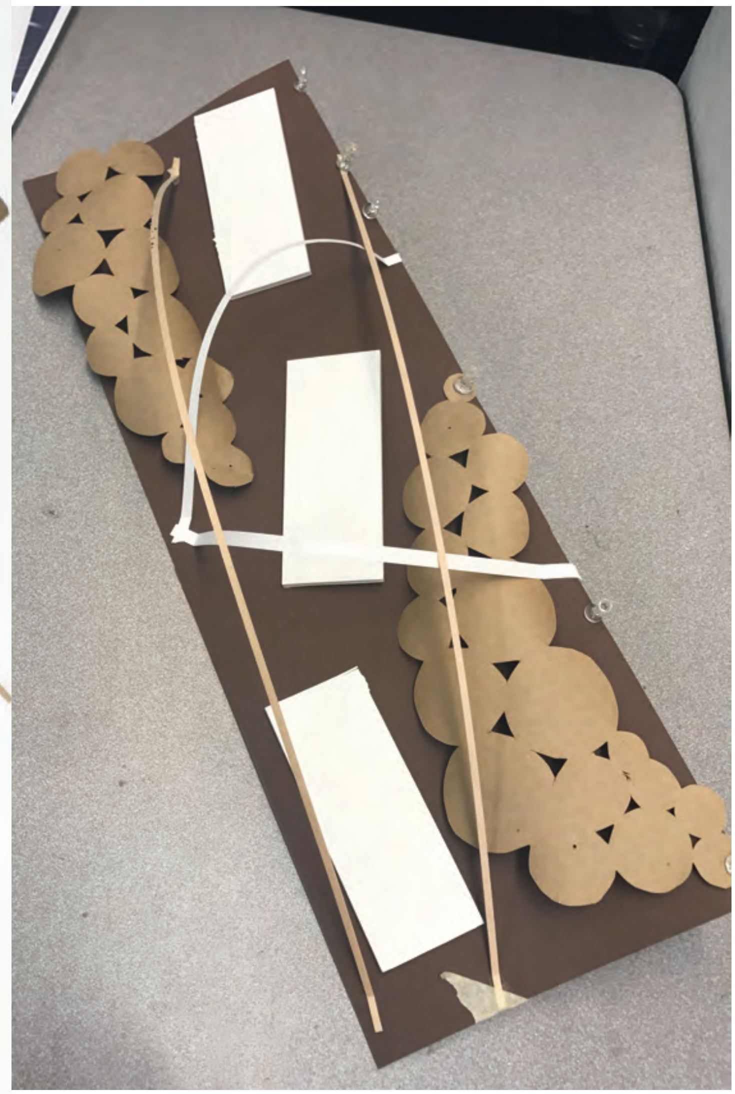


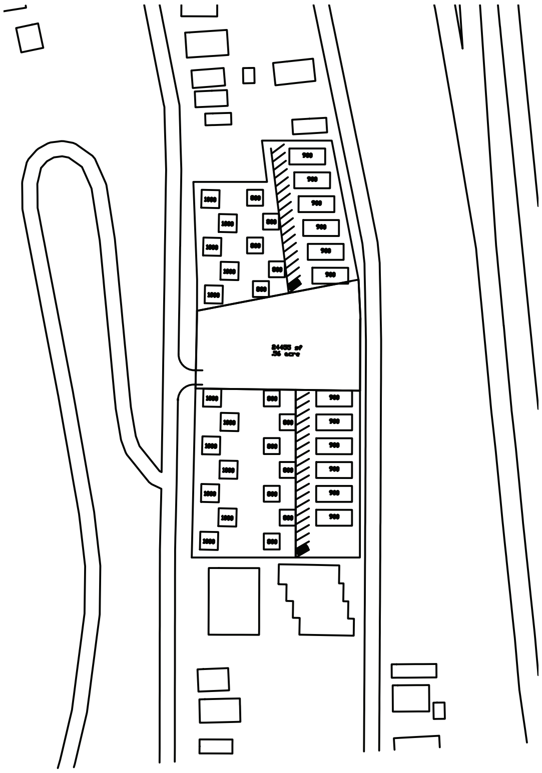

INITIAL DESIGN IDEAS



SITE SECTION / VIEWS

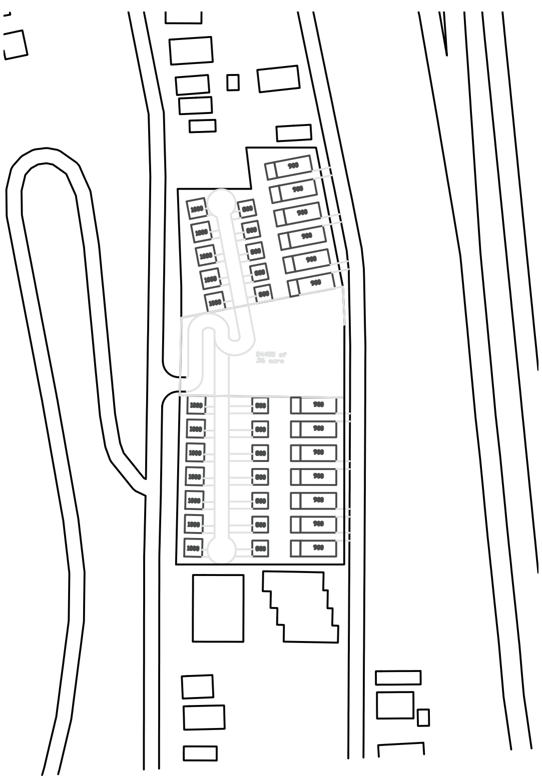

LIGHTLY TOUCH THE EARTH



48

# UNIT ARRANGEMENTS



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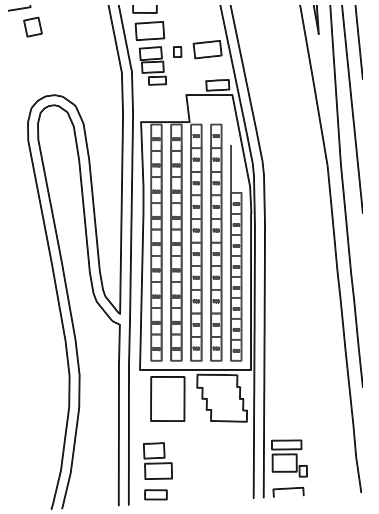

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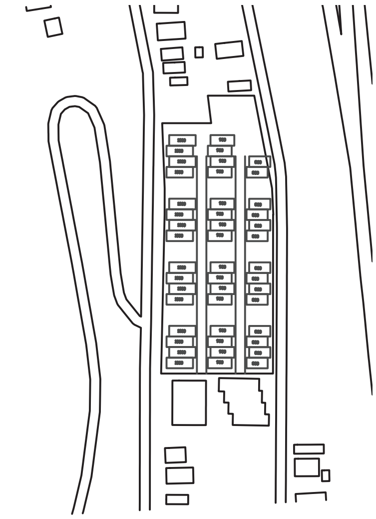

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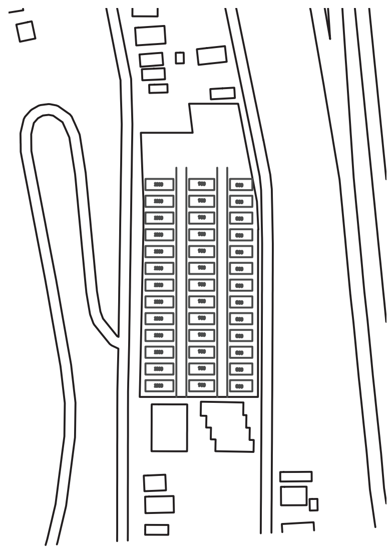

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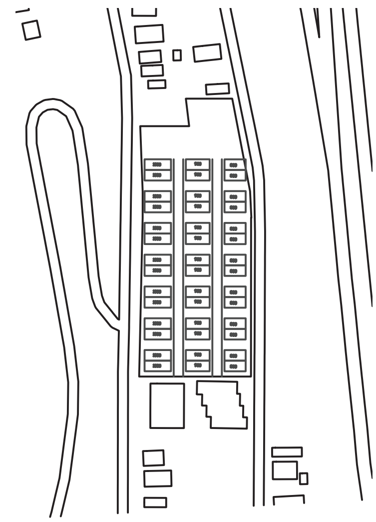

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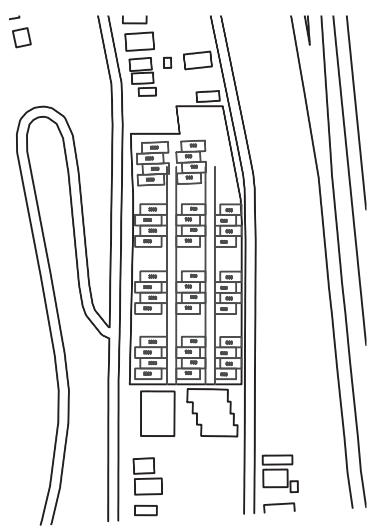

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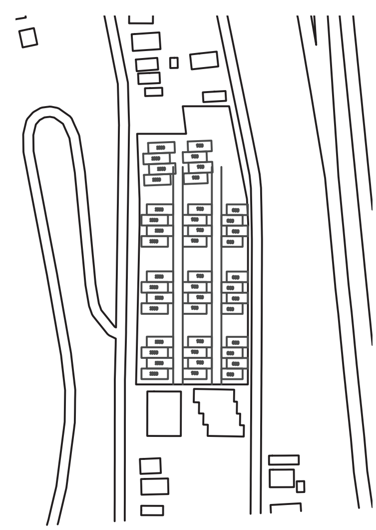
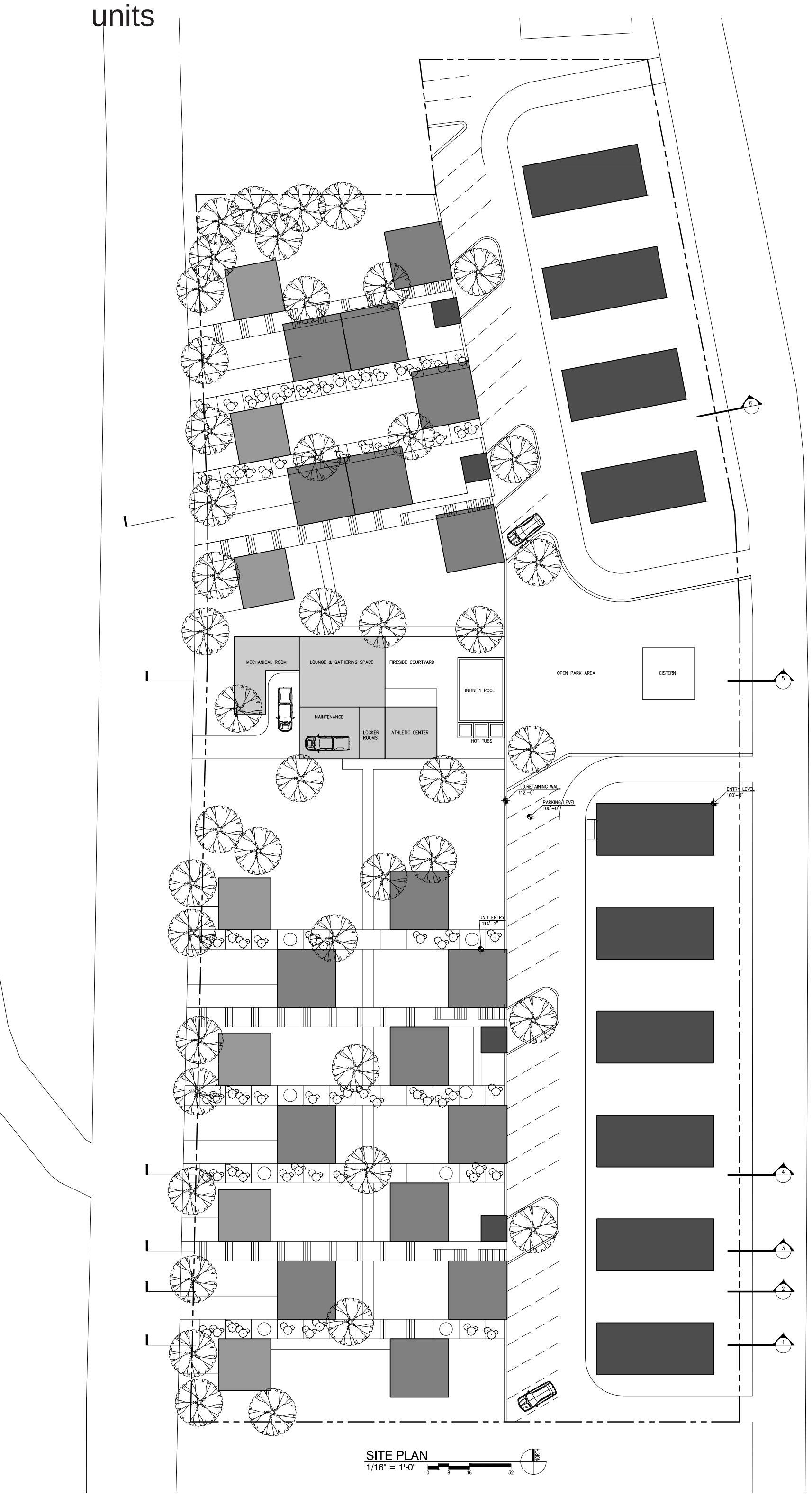


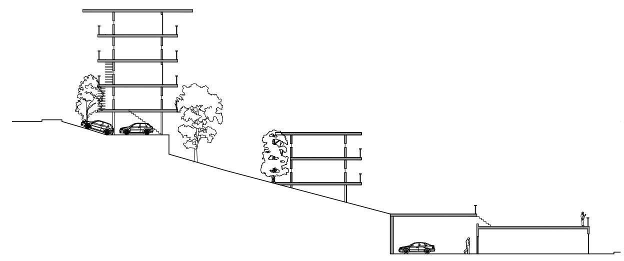
44

# END OF FALL SEMESTER DESIGN | At this point, site layout was completed and I focused on detailing individual units

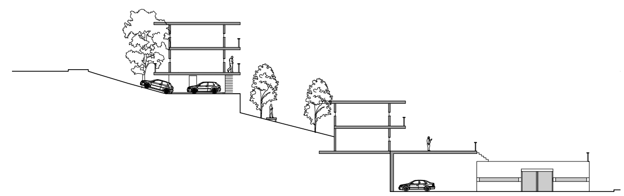



SITE PLAN
1/16" = 1'-0"

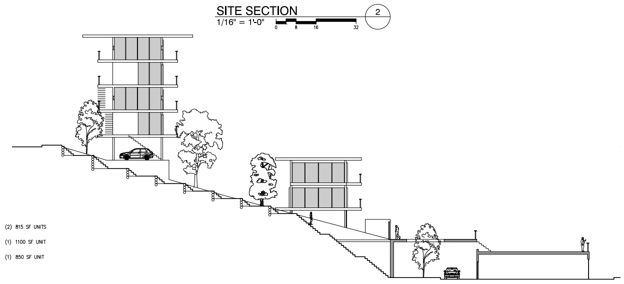
(2) 815 SF UNITS
(1) 1100 SF UNIT
(1) 850 SF UNIT



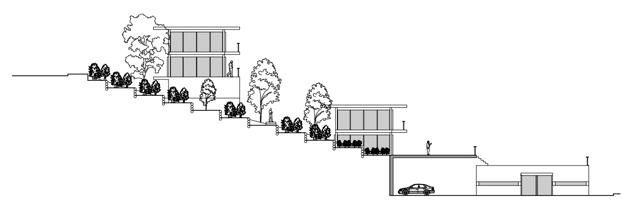
SITE SECTION 1
1/16" = 1'-0"



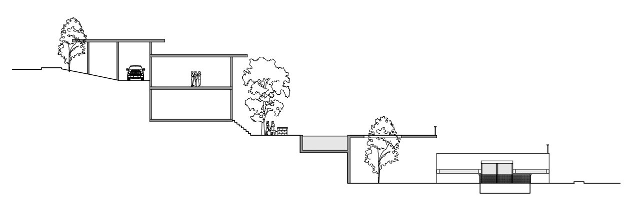
SITE SECTION 2
1/16" = 1'-0"



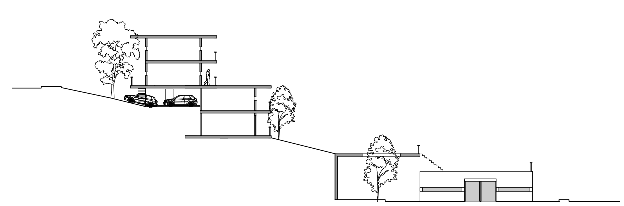
SITE SECTION 3
1/16" = 1'-0"



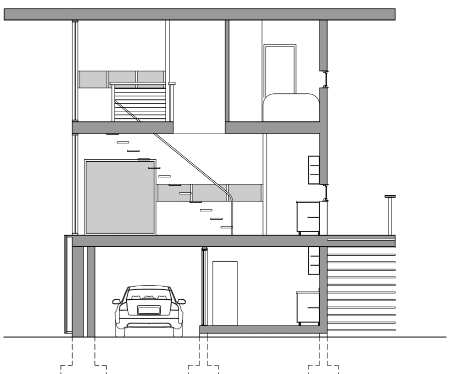
SITE SECTION 4
1/16" = 1'-0"



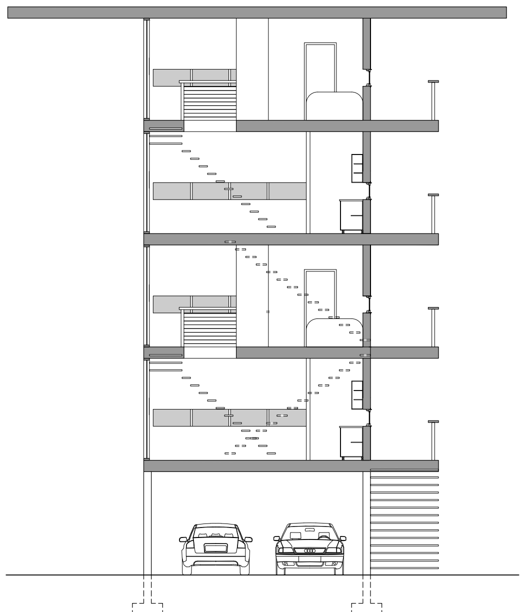
SITE SECTION 5
1/16" = 1'-0"



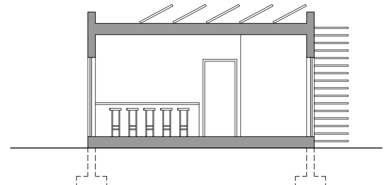
SITE SECTION 6
1/16" = 1'-0"



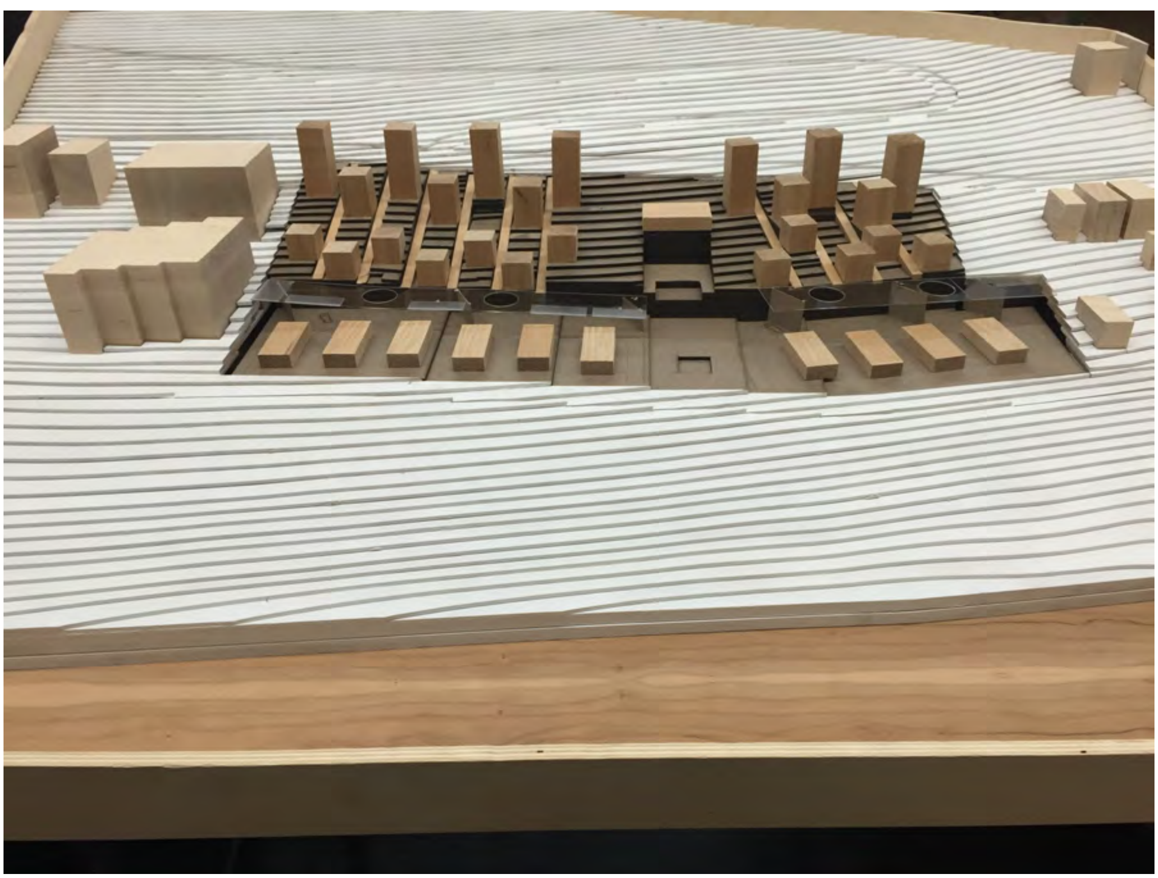
UNIT SECTION (A)
1/4" = 1'-0"



UNIT SECTION (B)
1/4" = 1'-0"

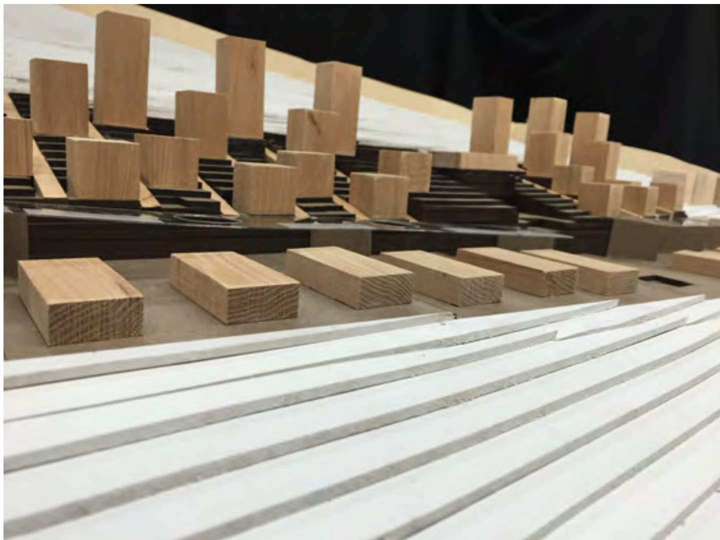


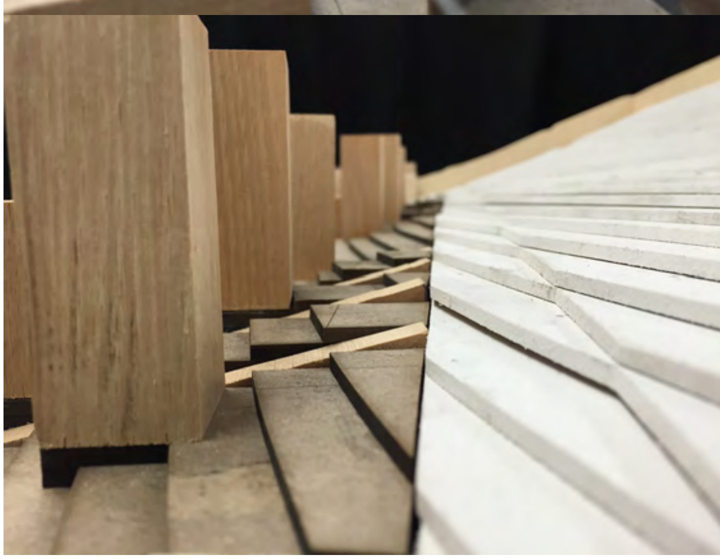
UNIT SECTION (C)
1/4" = 1'-0"

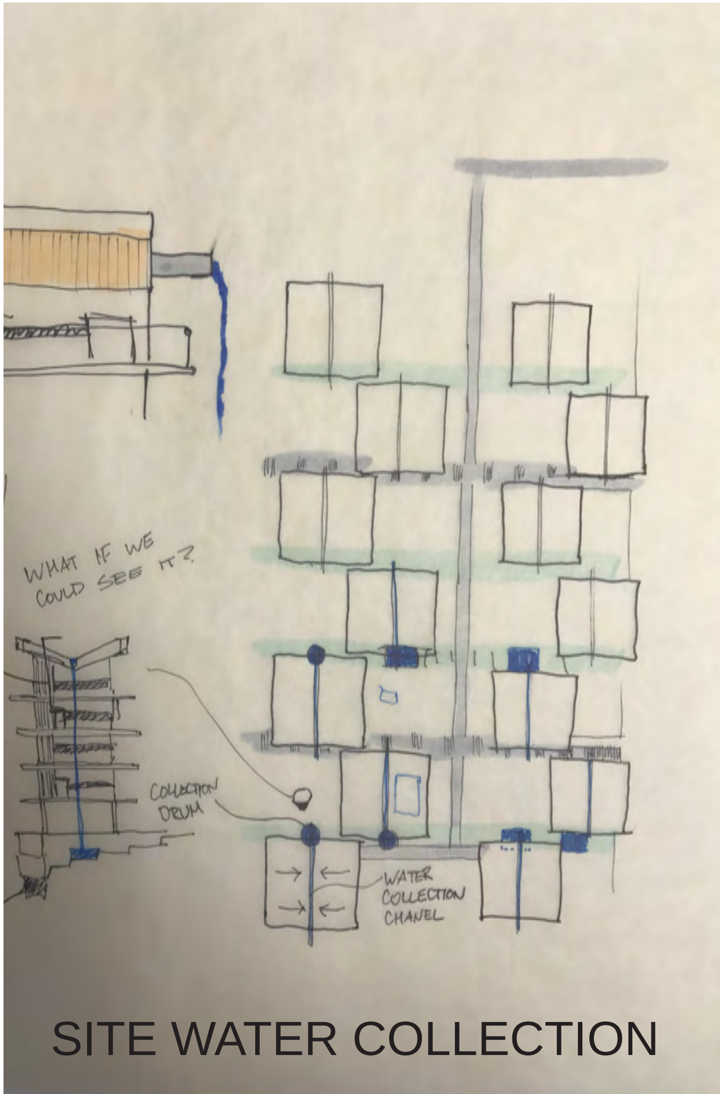


## FALL SEMESTER MASSING MODEL

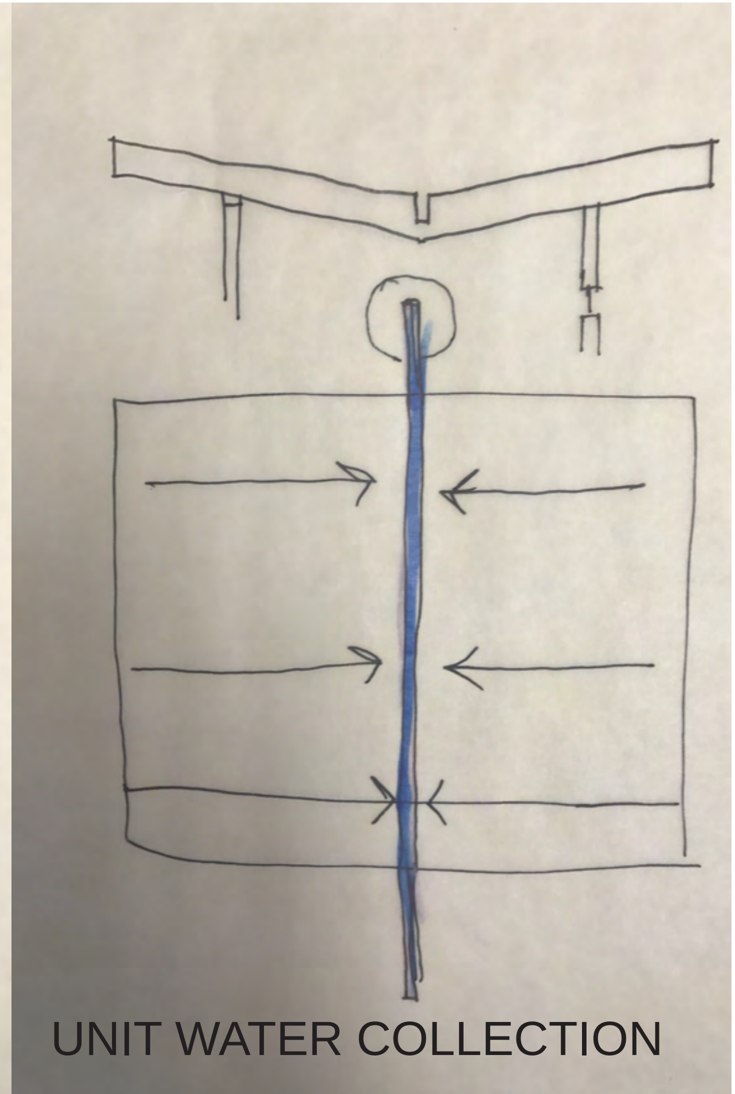
## FALL FINAL REVIEW



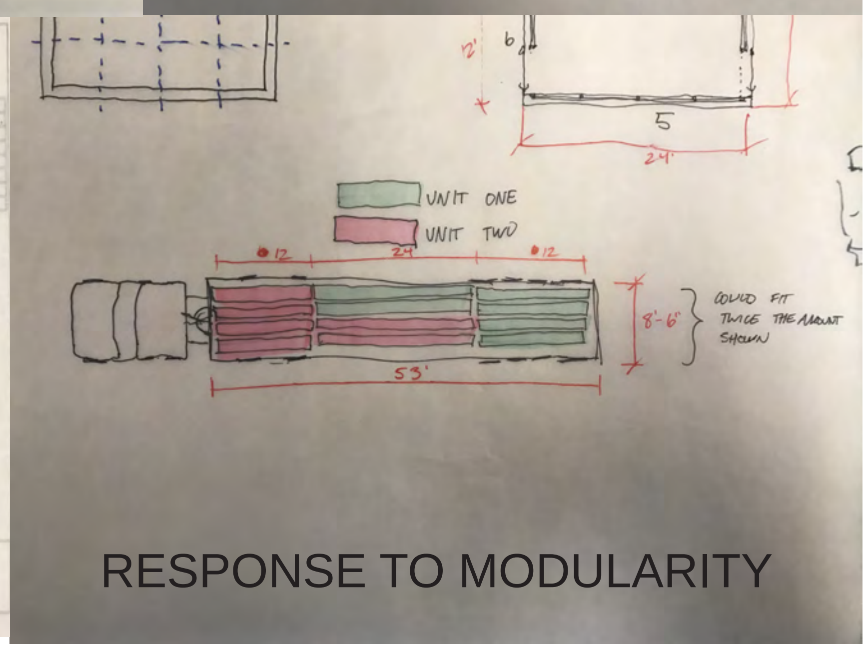




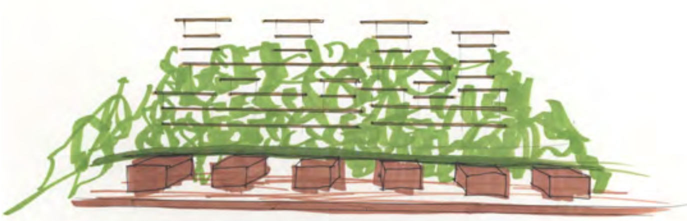

SITE WATER COLLECTION



UNIT WATER COLLECTION


RESPONSE TO MODULARITY



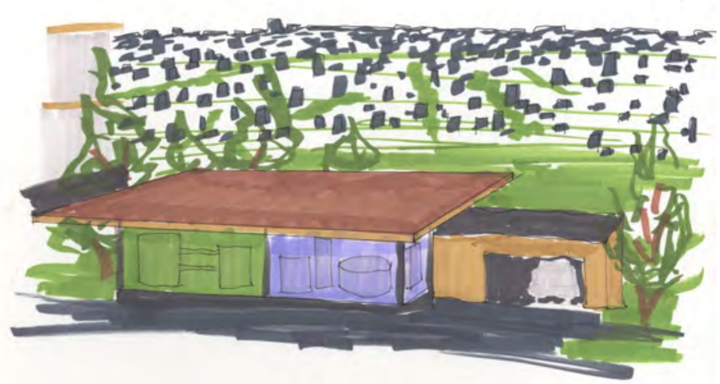
SITE PARTI

CONNECTION

MATERIALITY

FLOATING PLANES

PANORAMA



MECHANICAL UNVEIL

AMENITIES


MECHANICAL COLORED GLASS

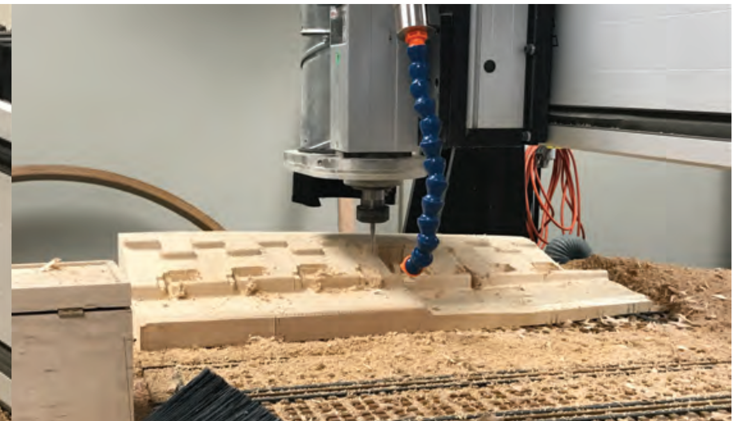
BASE UNIT

PROCESSION

BASE SECTION

GARDEN

# FINAL PRODUCTION



# DEVOU HILLS | dallas michael puckett

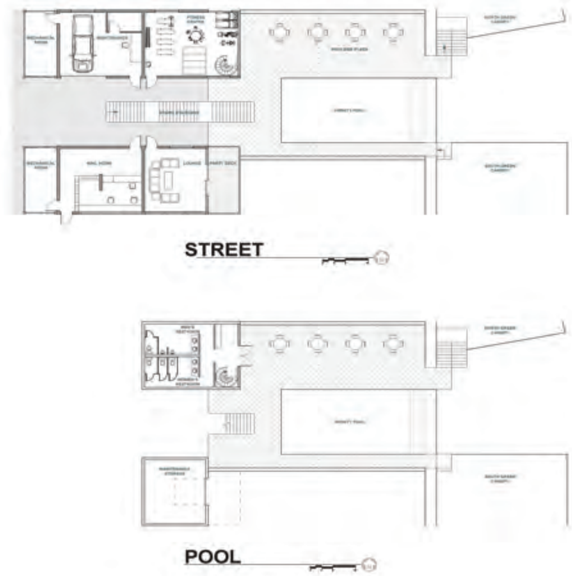
## EMPOWERMENT FOR ARCHITECTURE LIES WITHIN SUSTAINABILITY. AND CONVERSELY, THE SUCCESS OF SUSTAINABILITY LIES WITHIN THE EMPOWERMENT OF THE ARCHITECT.

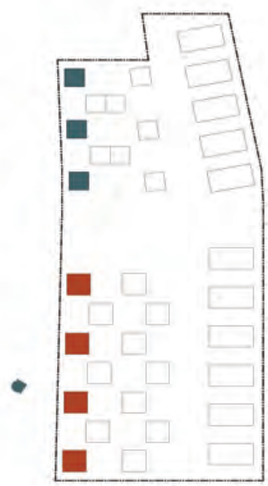
DEVOU
WESTERN
CRESCENT
I-75/71
143.4’
100.0’
50.8’
14.3’
A
B
C
D
N

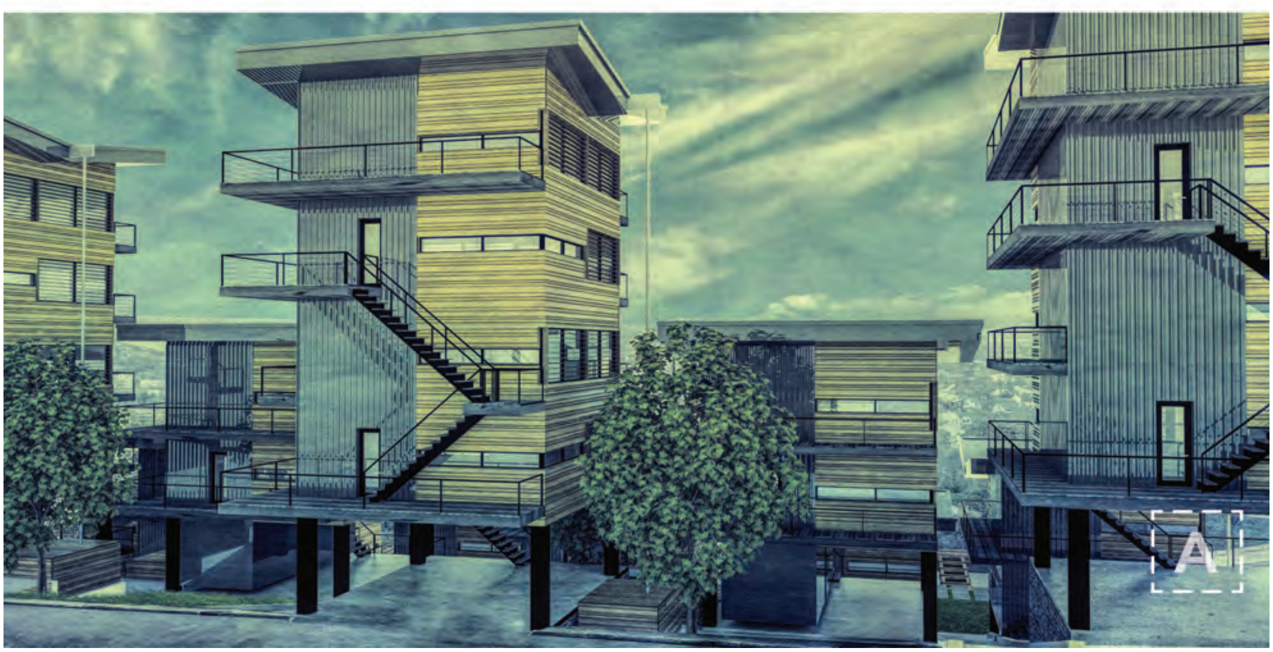

**3 STRUCTURES**
**6 UNITS**
**696 SF**

**4 STRUCTURES**
**8 UNITS**
**968 SF**

## AMENITIES PACKAGE



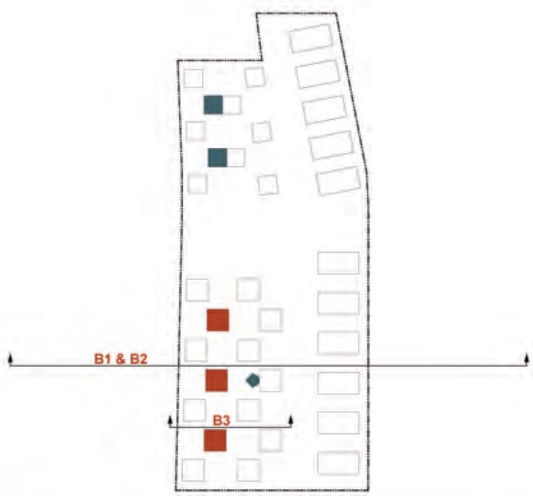



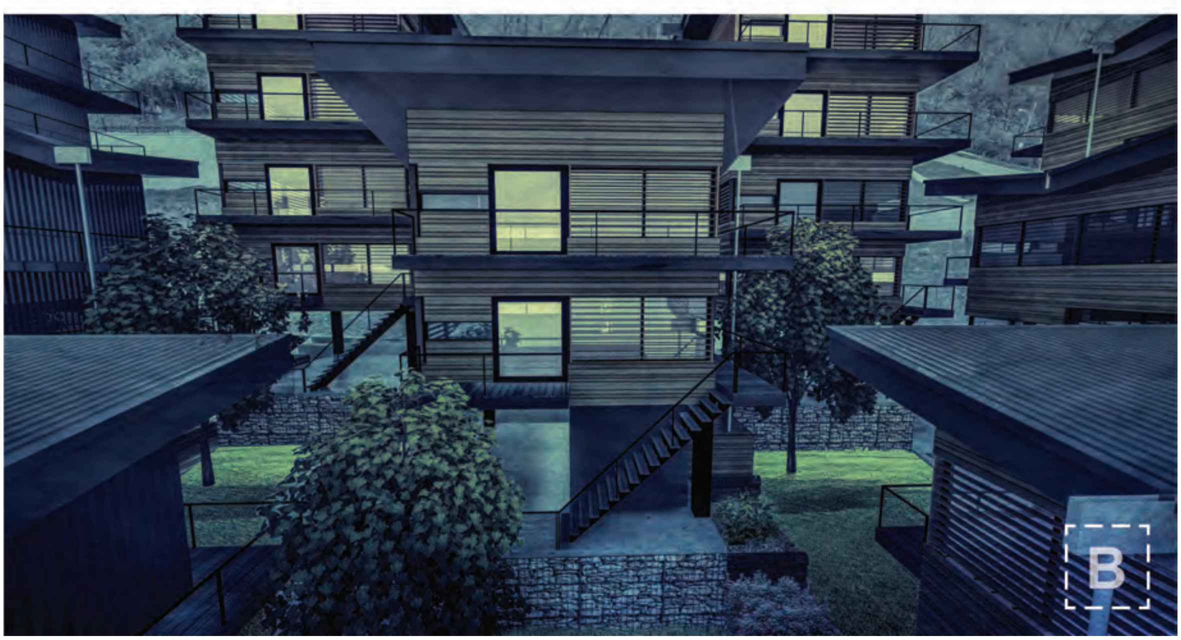


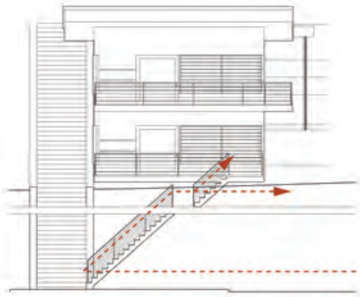
B1 | CONTEXT SECTION



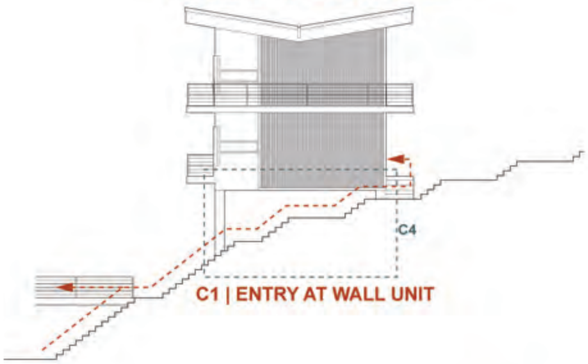
B3 | TERRACED GARDENS



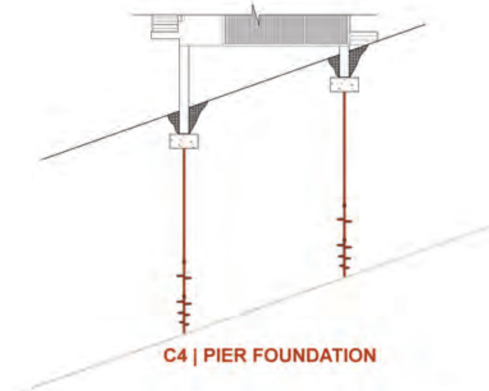





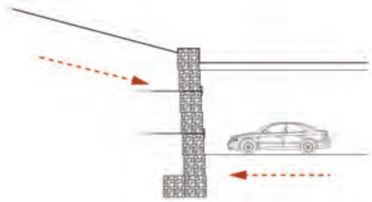
C2 | ENTRY AT MID-LEVEL UNIT



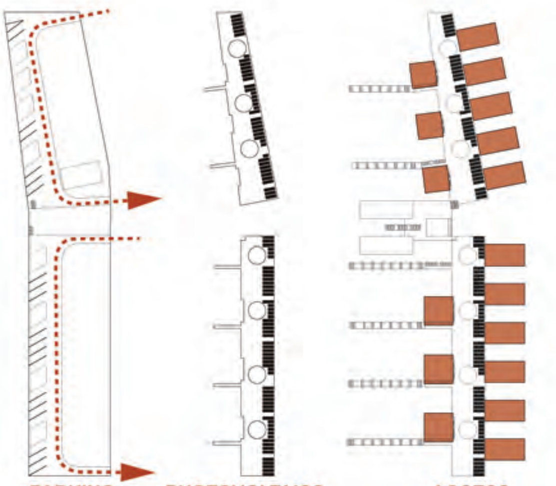

C1 | ENTRY AT WALL UNIT



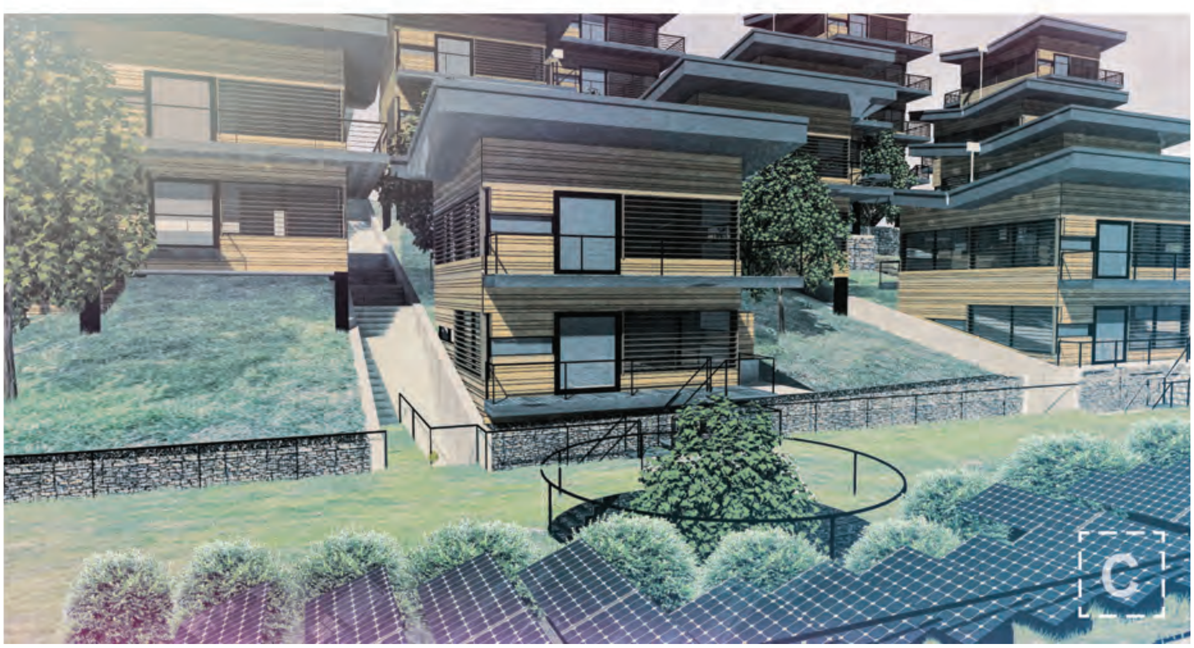
C4 | PIER FOUNDATION

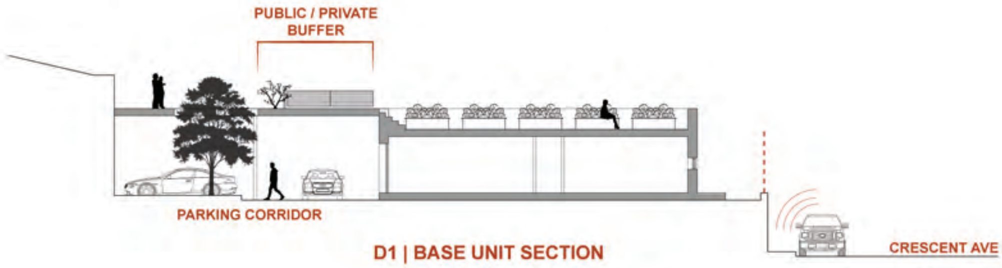


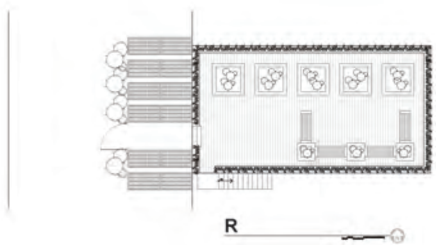
C3 | GABION RETAINING WALL



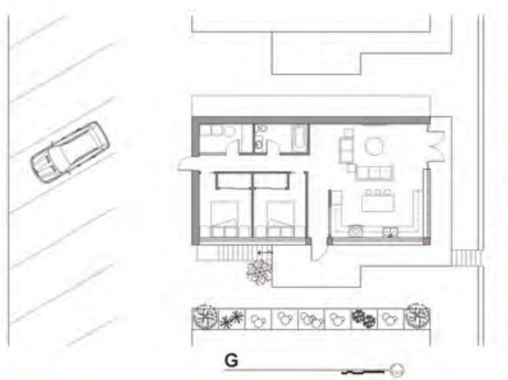
PARKING PHOTOVOLTAICS ACCESS

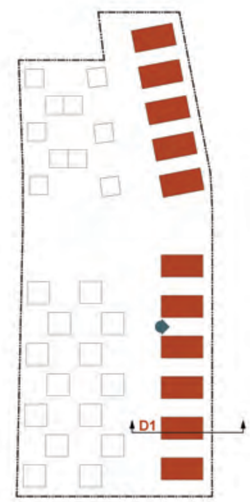










**11 UNITS**
**917 SF**

**OVERALL PROJECT COST** $12,049,245

**PROJECT PROFIT** $2,888,986

**MARGIN (20-30%)**

**AMENITIES** $428,797

**SITE WORK (PER UNIT)** $51,580

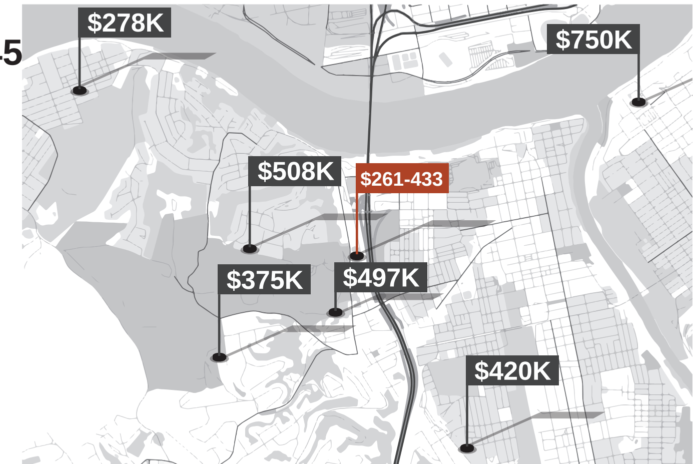
**UNIT COSTS:**

**A** $207,142 / $255,796

**B** $283,371 / $346,937

**C** $279,343 / $338,317

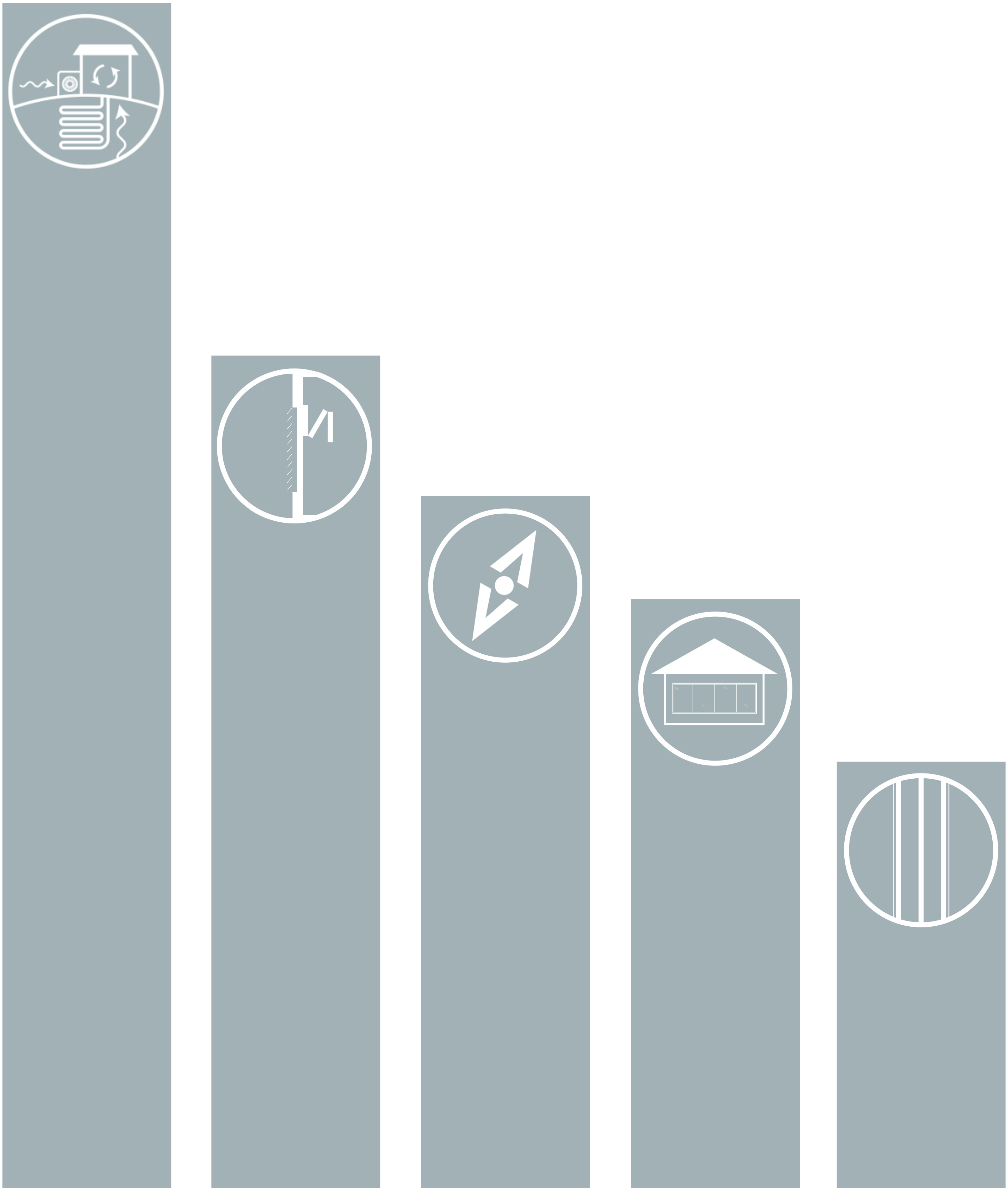
**D** $307,957






# APPENDIX

## PRO-FORMA AND ENERGY ANALYSIS

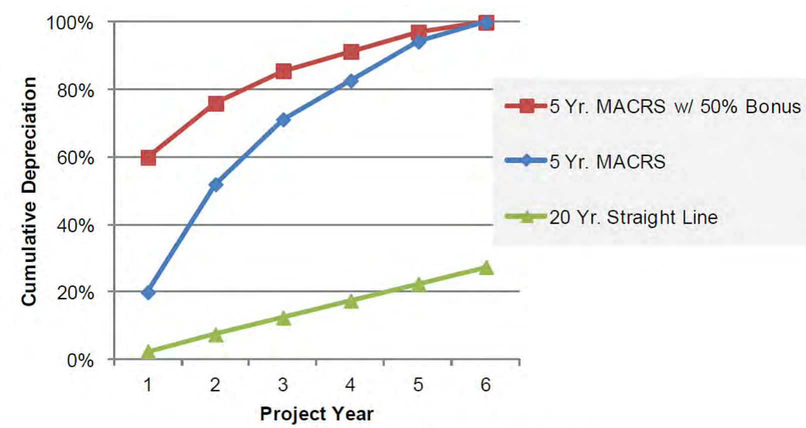


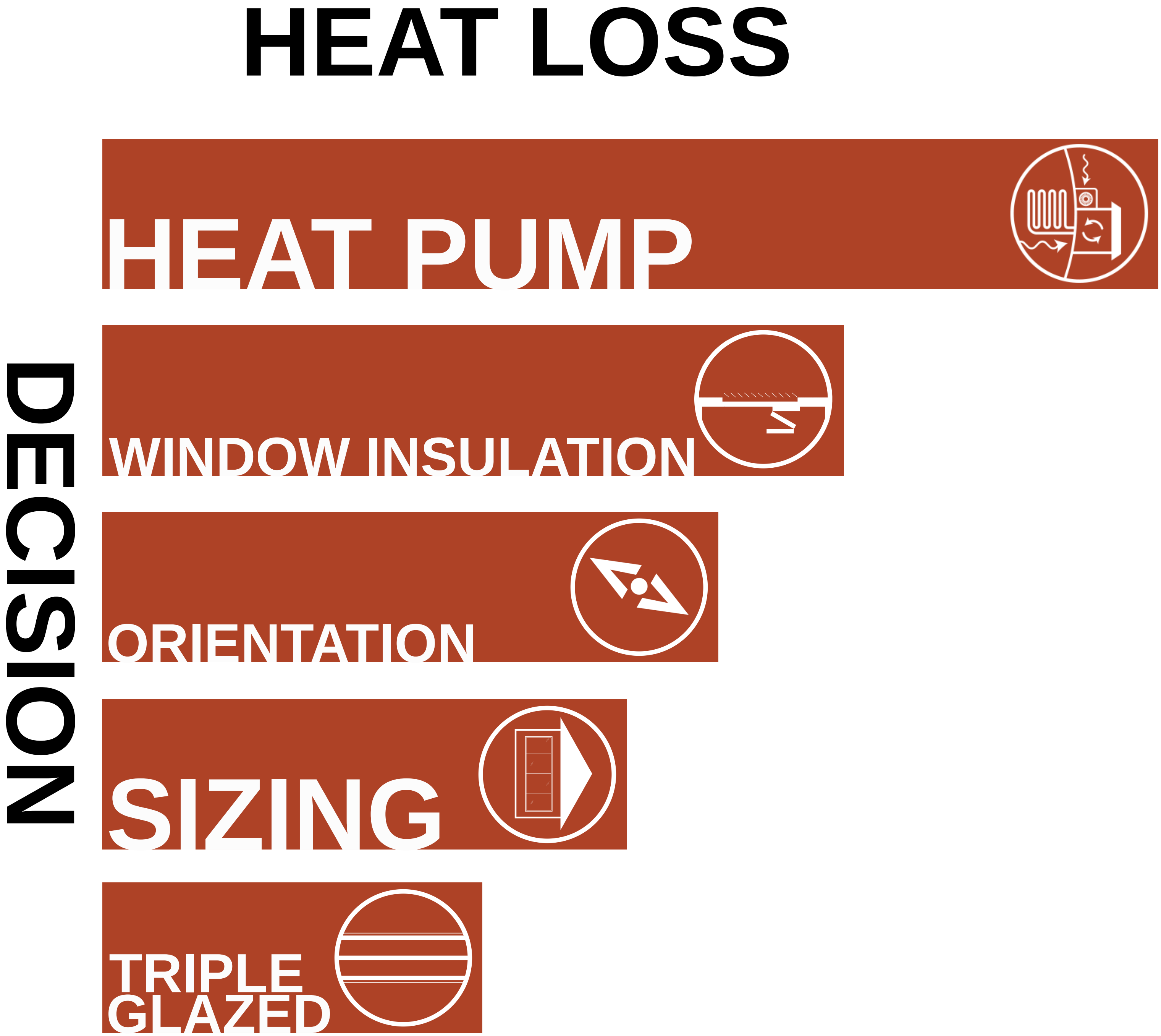
Note: Price per SF includes one full bath, one half bath, one kitchen, asphault shingles on roof, forced hot air heat/air conditioning, gypsum wallboard interior finishes, and materials & workmanship above average.

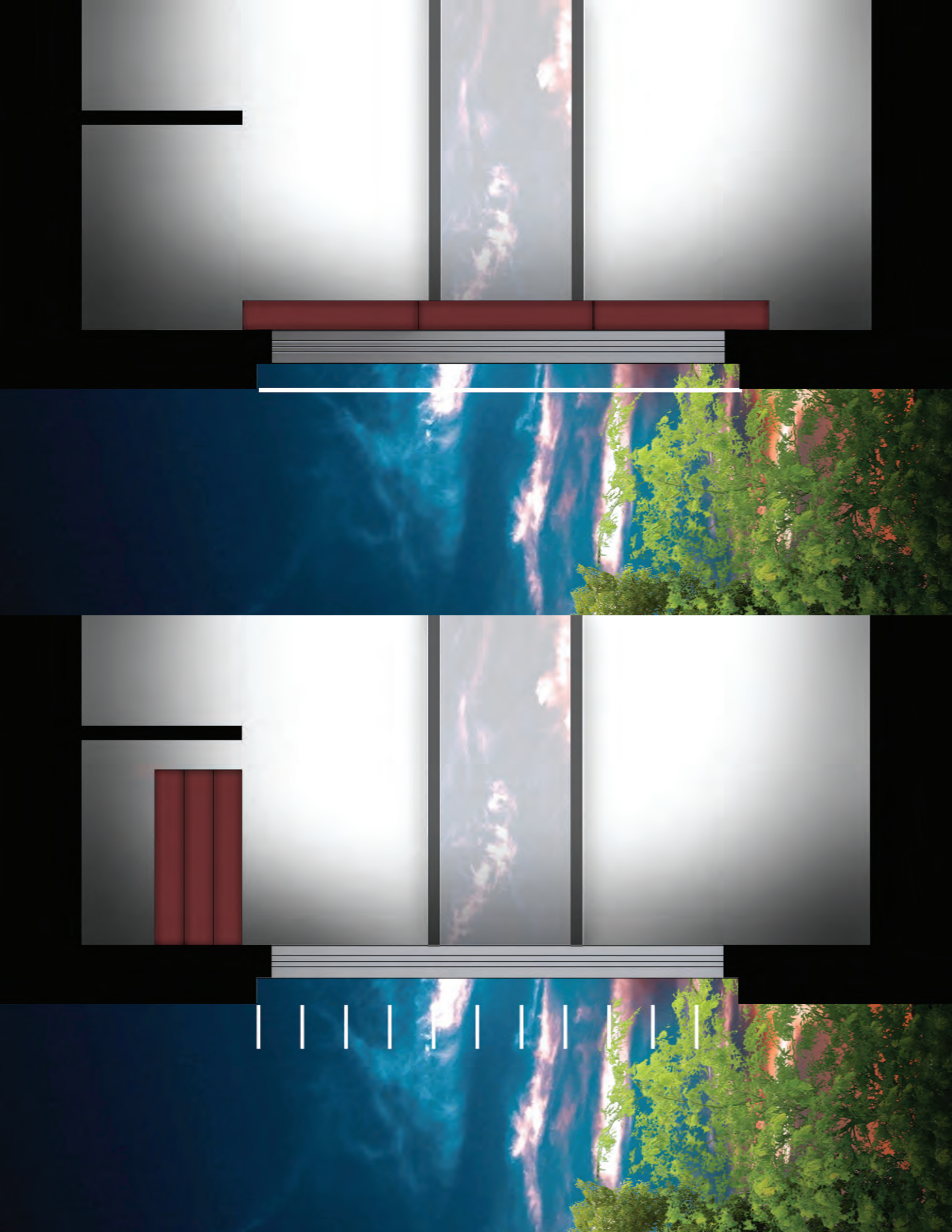
| Unit | Living Area SF | Cost per SF | per SF Cost | Modifications | Mod. Cost | Applicance | Appliance Cost | Total Unit Cost | # of Structures | # of Units | Unit Type Cost | Sell Price | $/SF (Cost) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24' 2 Story with Carport | 1152 | 170.35 | 196,243.20 | Kitchen Cabinets | 1736.00 | Range | 1415 | 346,937.40 | 3 | 3 | $1,040,812.20 | $1,301,015.25 | $301.16 |
| | | | | (2) Additional Entry/Exit | 3352.00 | Range Hood | 666 | | | | | | |
| | | | | Heat Pump | 1843.20 | Microwave | 526 | | | | | | |
| | | | | (10) Fixed Picture Windows (5'x6') | 13500.00 | Washing Machine | 770 | | | | | | |
| | | | | Deck | 17160.00 | Dryer | 790 | | | | | | |
| | | | | Carport | 5800.32 | Water Heater | 1238 | | | | | | |
| | | | | Pier Foundation Reinforcement | 13824.00 | Refrigerator | 655 | | | | | | |
| | | | | Concrete Driveway, 10' Wide | 1980.00 | | | | | | | | |
| | | | | Erosion Control | 602.88 | | | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2073.48 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 51580.97 | | | | | | | | |
| | | | | Gabion Retaining Wall, 3' Wide | 840.00 | | | | | | | | |
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | **Line Total** | 144634.20 | **Line Total** | 6060 | **Sell Price (25%)** | $433,671.75 | | | | |
| 24' 2 Story | 1152 | 170.35 | 196,243.20 | Kitchen Cabinets | 1736.00 | Range | 1415 | 338,317.08 | 7 | 7 | $2,368,219.55 | $2,841,863.46 | $293.68 |
| | | | | (2) Additional Entry/Exit | 3352.00 | Range Hood | 666 | | | | | | |
| | | | | Heat Pump | 1843.20 | Microwave | 526 | | | | | | |
| | | | | (10) Fixed Picture Windows (5'x6') | 13500.00 | Washing Machine | 770 | | | | | | |
| | | | | Deck | 17160.00 | Dryer | 790 | | | | | | |
| | | | | Pier Foundation Reinforcement | 13824.00 | Water Heater | 1238 | | | | | | |
| | | | | Erosion Control | 602.88 | Refrigerator | 655 | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2073.48 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 51580.97 | | | | | | | | |
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | **Line Total** | 136013.88 | **Line Total** | 6060 | **Sell Price (20%)** | $405,980.49 | | | | |
| | | | | | | (2 Each) | | | | | | | |
| 24' 4 Story with Carport | 2304 | 135 | 311,040.00 | Kitchen Cabinets | 1736.00 | Range | 2830 | 511,592.40 | 4 | 8 | $2,046,369.60 | $2,660,280.47 | $222.05 |
| | | | | (3) Additional Entry/Exit | 5028.00 | Range Hood | 1332 | | | | | | |
| | | | | Heat Pump | 3686.40 | Microwave | 1052 | | | | | | |
| | | | | (20) Fixed Picture Windows (5'x6') | 27000.00 | Washing Machine | 770 | | | | | | |
| | | | | Deck | 36450.00 | Dryer | 1580 | | | | | | |
| | | | | Carport | 5800.32 | Water Heater | 2476 | | | | | | |
| | | | | Pier Foundation Reinforcement | 21888.00 | Refrigerator | 1310 | | | | | | |
| | | | | Concrete Driveway, 10' Wide | 495.00 | | | | | | | | |
| | | | | Erosion Control | 602.88 | | | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2073.48 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 51580.97 | | | | | | | | |
| | | | | Gabion Retaining Wall, 3' Wide | 2520.00 | | | | | | | | |
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | | | | | **Ea. Unit Cost** | $255,796.20 | | | | |
| | | | | **Line Total** | 189202.40 | **Line Total** | 11350 | **Sell Price (30%)** | $332,535.06 | | | | |
| Base, Single Floor | 1080 | 185.95 | 200,826.00 | Kitchen Cabinets | 1736.00 | Range | 1415 | 307,957.51 | 11 | 11 | $3,387,532.62 | $4,065,039.15 | $285.15 |
| | | | | (2) Additional Entry/Exit | 3352.00 | Range Hood | 666 | | | | | | |
| | | | | Heat Pump | 1728.00 | Microwave | 526 | | | | | | |
| | | | | Fixed Picture Windows (5'x6') | 1350.00 | Washing Machine | 770 | | | | | | |
| | | | | Porch | 8970.00 | Dryer | 790 | | | | | | |
| | | | | Storm Sewer | 1307.31 | Water Heater | 1238 | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | Refrigerator | 655 | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2013.19 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 51580.97 | | | | | | | | |
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | **Line Total** | 101071.51 | **Line Total** | 6060 | **Sell Price (20%)** | $369,549.01 | | | | |
| | | | | | | (2 Each) | | | | | | | |
| 20' 4 Story with Carport | 1600 | 158 | 252,800.00 | Kitchen Cabinets | 1736.00 | Range | 2830 | 414,285.54 | 3 | 6 | $1,242,856.62 | $1,615,713.60 | $258.93 |
| | | | | (3) Additional Entry/Exit | 5028.00 | Range Hood | 1332 | | | | | | |
| | | | | Heat Pump | 3686.40 | Microwave | 1052 | | | | | | |
| | | | | (18) Fixed Picture Windows (5'x6') | 24300.00 | Washing Machine | 770 | | | | | | |
| | | | | Deck | 24480.00 | Dryer | 1580 | | | | | | |
| | | | | Carport | 4028.00 | Water Heater | 2476 | | | | | | |
| | | | | Pier Foundation Reinforcement | 17920.00 | Refrigerator | 1310 | | | | | | |
| | | | | Concrete Driveway, 10' Wide | 495.00 | | | | | | | | |
| | | | | Erosion Control | 602.88 | | | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2073.48 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 34744.43 | | | | | | | | |
| | | | | Gabion Retaining Wall, 3' Wide | 700.00 | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | | | | | **Ea. Unit Cost** | $207,142.77 | | | | |
| | | | | **Line Total** | 150135.54 | **Line Total** | 11350 | **Sell Price (30%)** | $269,285.60 | | | | |
| 20' 2 Story with Carport | 800 | 204.3 | 163,440.00 | Kitchen Cabinets | 1736.00 | Range | 1415 | 283,371.34 | 2 | 2 | $566,742.68 | $708,428.35 | $354.21 |
| | | | | (2) Additional Entry/Exit | 3352.00 | Range Hood | 666 | | | | | | |
| | | | | Heat Pump | 1843.20 | Microwave | 526 | | | | | | |
| | | | | (9) Fixed Picture Windows (5'x6') | 12150.00 | Washing Machine | 770 | | | | | | |
| | | | | Deck | 8580.00 | Dryer | 790 | | | | | | |
| | | | | Carport | 4028.00 | Water Heater | 1238 | | | | | | |
| | | | | Pier Foundation Reinforcement | 11600.00 | Refrigerator | 655 | | | | | | |
| | | | | Concrete Driveway, 10' Wide | 1980.00 | | | | | | | | |
| | | | | Erosion Control | 602.88 | | | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2073.48 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 34744.43 | | | | | | | | |
| | | | | Gabion Retaining Wall, 3' Wide | 840.00 | | | | | | | | |
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | **Line Total** | 113871.34 | **Line Total** | 6060 | **Sell Price (25%)** | $354,214.17 | | | | |
| 20' 2 Story | 800 | 204.3 | 163,440.00 | Kitchen Cabinets | 1736.00 | Range | 1415 | 279,343.34 | 5 | 5 | $1,396,716.69 | $1,745,895.87 | $349.18 |
| | | | | (2) Additional Entry/Exit | 3352.00 | Range Hood | 666 | | | | | | |
| | | | | Heat Pump | 1843.20 | Microwave | 526 | | | | | | |
| | | | | (9) Fixed Picture Windows (5'x6') | 12150.00 | Washing Machine | 770 | | | | | | |
| | | | | Deck | 8580.00 | Dryer | 790 | | | | | | |
| | | | | Pier Foundation Reinforcement | 11600.00 | Water Heater | 1238 | | | | | | |
| | | | | Concrete Driveway, 10' Wide | 1980.00 | Refrigerator | 655 | | | | | | |
| | | | | Erosion Control | 602.88 | | | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Unit Site Work Contingency | 2073.48 | | | | | | | | |
| | | | | Entire Site Cost (per Unit) | 34744.43 | | | | | | | | |
| | | | | Gabion Retaining Wall, 3' Wide | 840.00 | | | | | | | | |
| | | | | Amenities Package | 10209.46 | | | | | | | | |
| | | | | **Line Total** | 109843.34 | **Line Total** | 6060 | **Sell Price (25%)** | $349,179.17 | | | | |
| Amenities | 2909 | 119.6 | 347,916.40 | Pool | 20000.00 | | | 428,797.26 | | | | | $147.40 |
| | | | | (2) Additional Entry/Exit | 3352.00 | | | | | | | | |
| | | | | Heat Pump | 4654.40 | | | | | | | | |
| | | | | Pier Foundation Reinforcement | 24726.50 | | | | | | | | |
| | | | | Fixed Picture Windows (5'x6') | 5400.00 | | | | | | | | |
| | | | | Erosion Control | 602.88 | | | | | | | | |
| | | | | Storm Sewer | 1307.31 | | | | | | | | |
| | | | | Underground Detention Allowance | 5769.00 | | | | | | | | |
| | | | | Construction Staking | 976.00 | | | | | | | | |
| | | | | Landscaping & Irrigation | 2500.00 | | | | | | | | |
| | | | | Offsite Water | 9579.58 | | | | | | | | |
| | | | | 10% Amenities Site Work Contingen | 2013.19 | | | | | | | | |
| | | | | **Line Total** | 80880.86 | | | | | | | | |
| | | | | | | | | | 35 | 42 | | | |
| | | | | | | | | **Preliminary Grand Total** | | | $12,049,249.95 | $14,938,236.14 | |
| | | | | | | | | **Preliminary Profit Margin** | | | | $2,888,986.19 | |
| | | | | | | | | **Architect's Profit Margin** | | | | $602,462.50 | |
| | | | | | | | | **AVG. $/SF** | | | | | $276.47 |

| Assembly Number | Description | Qty. | Unit | Total Cost Unit | Total |
|---|---|---|---|---|---|
| Site Work | Clear and grub medium brush | 12.1 | Acre | 760 | 9196 |
| | Medium Trees, to 10" Dia., cut & chip | 12.1 | Acre | 1075 | 13007.5 |
| | Land Excavation Labor | 19547 | Hours | 17 | 332299 |
| | Land Excavation Equipment Allowance | 1 | Job | | 162.15 |
| | Land Excavation Debris Disposal | 14026 | Cu. Yard | 32.14 | 450795.64 |
| | Concrete Sidewalk System, 3' Wide Walk | 1059 | L.F. | 10.34 | 10950.06 |
| | Dumpster | 42 | Tot | 750 | 31500 |
| | Supervison | 42 | Tot | 10200 | 428400 |
| | Final Clean Up | 42 | Tot | 350 | 14700 |
| | Gabion Retaining Wall, 3' Wide | 1017 | Cu. Yard | 35 | 35595 |
| | Parking Canopy with Green Roof | 15609 | SF | 30 | 468270 |
| | 1.5kW Solar System | 2490 | EA. | 42 | 104580 |
| | Land Acquisition | | | | 70000 |
| | | | | Net Total | 1969455.35 |
| | | | | 10% Cont. | $196,945.54 |
| | | | | **Site Cost** | $2,166,400.89 |
| | | | | **Per Unit** | $51,580.97 |

| Incentive Provider | Description | Payoff |
|---|---|---|
| Tennessee Valley Authority | Pays $1000 per solar collector system for upfront costs, as well as $0.02 plus retail rate of all excess energy produced per kWh. | Best month: (42) 1.5kW systems x 175 kWh = 7350 x $.11 = $808.50<br>50% annual sale = $4,851 |
| State of KY | Solar easement preventing anything being built that would minimize effectiveness of solar collectors. | N/A |
| Duke Energy | $350 per geothermal heat pump | $14,700 |
| Kentucky Office of Energy Policy | 100% sales and use tax rebate on all efforts to construct solar colelction (materials, machinery, labor, etc.) | N/A |
| Department of Energy | Energy Investment Tax Credit (ITC) provides a 30% Federal Tax credit for 8 years on business | N/A |
| Internal Revenue Service (IRS) | "MACRS - Modified Accelerated Cost Recovery System. The IRS allows businesses to recover green building investments in certain property through depreciation deductions. MACRS is a favorite tool of many solar photovoltaic array buyers because it accelerates the rate of return on solar energy investments.<br><br>The following chart, from The Butler Firm, shows the benefits of MACRS for solar investments, compared to other assets which may have a depreciation period of over 20 years." |   Note: Only the first six project years are shown |


HEAT LOSS
DECISION
HEAT PUMP
WINDOW INSULATION
ORIENTATION
SIZING
TRIPLE
GLAZED



| Wall | Type | Location | | | |
|---|---|---|---|---|---|
| #1 | Roof | all of the roof | | | |
| | | R-value @ SectionA,B,C | | | |
| | Construction Material | A | B | C | Reference |
| 1 | Outside air | 0.17 | 0.17 | | |
| 2 | Asphalt shingles (1/4") | 0.44 | 0.44 | | |
| 3 | Vapor barrier | 0 | 0 | | |
| 4 | Plywood sheathing (5/8") | 0.78 | 0.78 | | |
| 5 | Batt Insulation (4") | 13.8 | 13.8 | | |
| 6 | rigid Insulation (1 1/4") | 8.13 | 8.13 | | |
| 7 | 2"x4" wood rafters | 0 | 4.38 | | |
| 8 | Batt Insulation (3.5") | 12.08 | 0 | | |
| 9 | 5/8" gyp Board | 0.56 | 0.56 | | |
| 10 | Inside air- ceiling | 0.61 | 0.61 | | |
| 11 | | | | | |
| 12 | | | | | |
| | R-total for each wall condition | 36.4 | 28.7 | 0 | |
| | % of wall | 90.63% | 9.38% | | |
| | **R-average for wall** | | | **35.678125** | |
| | **U-average for wall = 1/R** | | | **0.028028379** | |

| Wall | Type | Location | | | |
|---|---|---|---|---|---|
| #2 | Corrugated Metal Wall | North and West Walls | | | |
| | | R-value @ SectionA,B,C | | | |
| | Construction Material | A | B | C | Reference |
| 1 | Outside air | 0.17 | 0.17 | | |
| 2 | Corrugated Metal | 0.1 | 0.1 | | |
| 3 | Wood Sheathing | 0.63 | 0.63 | | |
| 4 | Batt Insulation | 20 | | | |
| 5 | 2x6 Stud Framing | | 6.88 | | |
| 6 | 5/8" gyp Board | 0.56 | 0.56 | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| | R-total for each wall condition | 21.46 | 8.34 | 0 | |
| | % of wall | 90.63% | 9.38% | | |
| | **R-average for wall** | | | **20.23** | |
| | **U-average for wall = 1/R** | | | **0.049431537** | |

| Wall | Type | Location | | | |
|---|---|---|---|---|---|
| #3 | Wood Siding Wall | North, South, East West Walls | | | |
| | | R-value @ SectionA,B,C | | | |
| | Construction Material | A | B | C | Reference |
| 1 | Outside air | 0.17 | 0.17 | | |
| 2 | Wood Sidings | 0.8 | 0.8 | | |
| 3 | Wood Sheathing | 0.63 | 0.63 | | |
| 4 | Batt Insulation | 20 | | | |
| 5 | 2x6 Stud Framing | | 6.88 | | |
| 6 | 5/8" gyp Board | 0.56 | 0.56 | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| | R-total for each wall condition | 22.16 | 9.04 | 0 | |
| | % of wall | 90.63% | 9.38% | | |
| | **R-average for wall** | | | **20.93** | |
| | | | | **0.047778309** | |

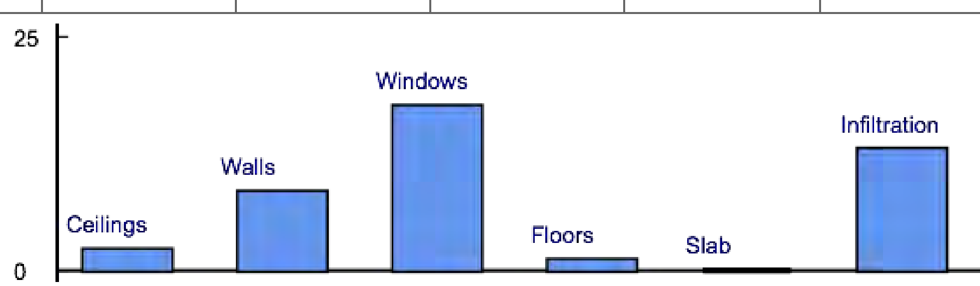
| Wall | | | | | |
|---|---|---|---|---|---|
| | Windows with 4" operable insulation | All Windows | | | |
| | | R-value @ SectionA,B,C | | | |
| | Construction Material | A | B | C | Reference |
| 1 | Outside air | 0.17 | 0.17 | | |
| 2 | Triple Pane Glazing | 1.8 | 1.8 | | |
| 3 | air space (5/8") | 2.15 | 2.15 | | |
| 4 | Rigid Insulation | 20 | 20 | | Polystyrene |
| 5 | Inside air | 0.68 | 0.68 | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| | R-total for each wall condition | 24.8 | 24.8 | 0 | |
| | % of wall | 90.63% | 9.38% | | |
| | **R-average for wall** | | | **24.8** | |
| | **U-average for wall = 1/R** | | | **0.040322581** | |

| DESIGN TEMPERATURE AND FUEL TYPE INPUTS | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Two-Story, 24′, Windows Insulation up during the day | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

| AREA AND R-VALUE INPUTS | | | | | |
|---|---|---|---|---|---|
| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Roof | 576 | 35 | 16.5 | 1152 | 2.2 |
| Wall 1 | 212 | 20 | 10.6 | 742 | 1.4 |
| Wall 2 | 438 | 20 | 21.9 | 1533 | 2.9 |
| Wall 3 | 226 | 20 | 11.3 | 791 | 1.5 |
| Wall 4 | 402 | 20 | 20.1 | 1407 | 2.7 |
| Windows 1 | 244 | 4.1 | 59.5 | 4166 | 7.9 |
| Windows 2 | 18 | 4.1 | 4.4 | 307 | 0.6 |
| Windows 3 | 230 | 4.1 | 56.1 | 3927 | 7.4 |
| Windows 4 | 54 | 4.1 | 13.2 | 922 | 1.7 |
| Floor 1 | 288 | 35 | 8.2 | 576 | 1.1 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 10944 | 0.5 | 98 | 6895 | 13 |

| SUMMARY OUTPUTS | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
| Ceiling Loss | 16 | 1152 | 2.2 | 25 | 406 | 318 |
| Wall Loss | 64 | 4473 | 8.4 | 99 | 1575 | 1234 |
| Window Loss | 133 | 9322 | 17.6 | 206 | 3283 | 2572 |
| Floor Loss | 8 | 576 | 1.1 | 13 | 203 | 159 |
| Slab Loss | 0 | 0 | 0 | 0 | 0 | 0 |
| Infiltration | 98 | 6895 | 13 | 152 | 2428 | 1903 |
| Totals | 320 | 22418 | 42.3 | 496 | 7895 | 6186 |

Heat Loss--
Millions of
BTU/Year

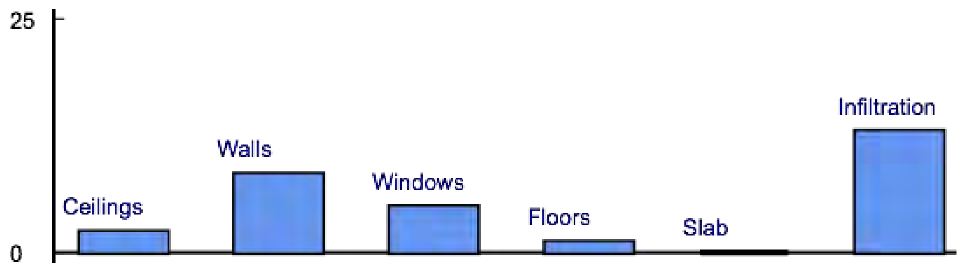


| DESIGN TEMPERATURE AND FUEL TYPE INPUTS | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Two-Story, 24′, Windows Insulation down at night | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

| AREA AND R-VALUE INPUTS | | | | | |
|---|---|---|---|---|---|
| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Roof | 576 | 35 | 16.5 | 1152 | 2.2 |
| Wall 1 | 212 | 20 | 10.6 | 742 | 1.4 |
| Wall 2 | 438 | 20 | 21.9 | 1533 | 2.9 |
| Wall 3 | 226 | 20 | 11.3 | 791 | 1.5 |
| Wall 4 | 402 | 20 | 20.1 | 1407 | 2.7 |
| Windows 1 | 244 | 24 | 10.2 | 712 | 1.3 |
| Windows 2 | 18 | 24 | 0.8 | 53 | 0.1 |
| Windows 3 | 230 | 24 | 9.6 | 671 | 1.3 |
| Windows 4 | 54 | 24 | 16.8 | 1173 | 2.2 |
| Floor 1 | 288 | 35 | 8.2 | 576 | 1.1 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 10944 | 0.5 | 98 | 6895 | 13 |

| SUMMARY OUTPUTS | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
| Ceiling Loss | 16 | 1152 | 2.2 | 25 | 406 | 318 |
| Wall Loss | 64 | 4473 | 8.4 | 99 | 1575 | 1234 |
| Window Loss | 37 | 2608 | 4.9 | 58 | 918 | 720 |
| Floor Loss | 8 | 576 | 1.1 | 13 | 203 | 159 |
| Slab Loss | 0 | 0 | 0 | 0 | 0 | 0 |
| Infiltration | 98 | 6895 | 13 | 152 | 2428 | 1903 |
| Totals | 224 | 15703 | 29.6 | 347 | 5530 | 4333 |

Heat Loss--
Millions of
BTU/Year

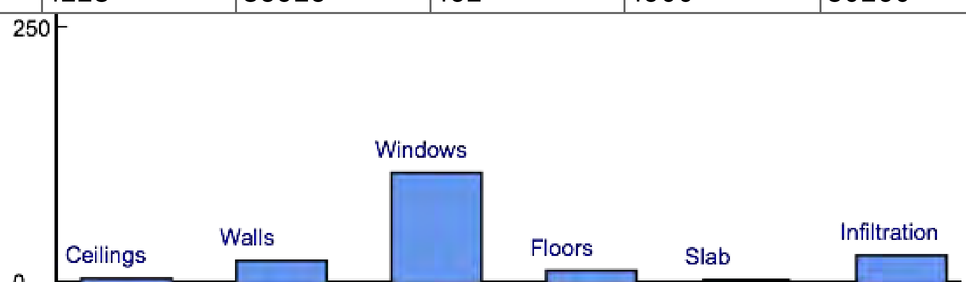


| DESIGN TEMPERATURE AND FUEL TYPE INPUTS | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Four-Story, Window Insulation up during the day, Single Glazed Windows | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

| AREA AND R-VALUE INPUTS | | | | | |
|---|---|---|---|---|---|
| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Roof | 576 | 35 | 16.5 | 1152 | 2.2 |
| Wall 1 | 524 | 20 | 26.2 | 1834 | 3.5 |
| Wall 2 | 912 | 20 | 45.6 | 3192 | 6 |
| Wall 3 | 590 | 20 | 29.5 | 2065 | 3.9 |
| Wall 4 | 948 | 20 | 47.4 | 3318 | 6.3 |
| Windows 1 | 460 | 1.2 | 383.3 | 26833 | 50.6 |
| Windows 2 | 72 | 1.2 | 60 | 4200 | 7.9 |
| Windows 3 | 394 | 1.2 | 328.3 | 22983 | 43.3 |
| Windows 4 | 36 | 1.2 | 30 | 2100 | 4 |
| Floor 1 | 576 | 35 | 16.5 | 1152 | 2.2 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 20736 | 0.5 | 187 | 13064 | 24.6 |

| SUMMARY OUTPUTS | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
| Ceiling Loss | 16 | 1152 | 2.2 | 25 | 406 | 318 |
| Wall Loss | 149 | 10409 | 19.6 | 230 | 3666 | 2872 |
| Window Loss | 802 | 56117 | 105.8 | 1241 | 19762 | 15485 |
| Floor Loss | 74 | 5184 | 9.8 | 115 | 1826 | 1430 |
| Slab Loss | 0 | 0 | 0 | 0 | 0 | 0 |
| Infiltration | 187 | 13064 | 24.6 | 289 | 4601 | 3605 |
| Totals | 1228 | 85925 | 162 | 1900 | 30260 | 23710 |

Heat Loss--
Millions of
BTU/Year

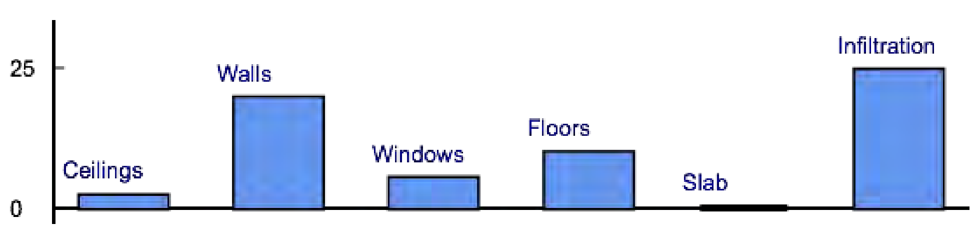


| DESIGN TEMPERATURE AND FUEL TYPE INPUTS | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Four-Story, Window Insulation Down at Night, Single Glazed Windows | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

| AREA AND R-VALUE INPUTS | | | | | |
|---|---|---|---|---|---|
| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Roof | 576 | 35 | 16.5 | 1152 | 2.2 |
| Wall 1 | 524 | 20 | 26.2 | 1834 | 3.5 |
| Wall 2 | 912 | 20 | 45.6 | 3192 | 6 |
| Wall 3 | 590 | 20 | 29.5 | 2065 | 3.9 |
| Wall 4 | 948 | 20 | 47.4 | 3318 | 6.3 |
| Windows 1 | 460 | 24 | 19.2 | 1342 | 2.5 |
| Windows 2 | 72 | 24 | 3 | 210 | 0.4 |
| Windows 3 | 394 | 24 | 16.4 | 1149 | 2.2 |
| Windows 4 | 36 | 24 | 1.5 | 105 | 0.2 |
| Floor 1 | 576 | 35 | 16.5 | 1152 | 2.2 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 20736 | 0.5 | 187 | 13064 | 24.6 |

| SUMMARY OUTPUTS | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
| Ceiling Loss | 16 | 1152 | 2.2 | 25 | 406 | 318 |
| Wall Loss | 149 | 10409 | 19.6 | 230 | 3666 | 2872 |
| Window Loss | 40 | 2806 | 5.3 | 62 | 988 | 774 |
| Floor Loss | 74 | 5184 | 9.8 | 115 | 1826 | 1430 |
| Slab Loss | 0 | 0 | 0 | 0 | 0 | 0 |
| Infiltration | 187 | 13064 | 24.6 | 289 | 4601 | 3605 |
| Totals | 466 | 32615 | 61.5 | 721 | 11486 | 9000 |

Heat Loss--
Millions of
BTU/Year



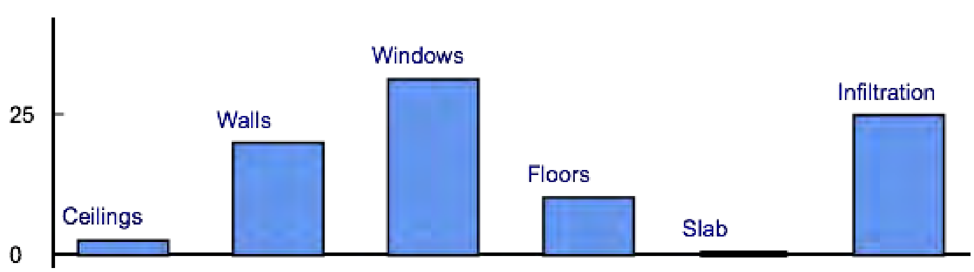

http://www.builditsolar.com/References/Calculators/HeatLoss/HeatLoss.htm

| DESIGN TEMPERATURE AND FUEL TYPE INPUTS | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Four-Story, Window Insulation up during the day, Triple Glazed Windows | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

| AREA AND R-VALUE INPUTS | | | | | |
|---|---|---|---|---|---|
| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Roof | 576 | 35 | 16.5 | 1152 | 2.2 |
| Wall 1 | 524 | 20 | 26.2 | 1834 | 3.5 |
| Wall 2 | 912 | 20 | 45.6 | 3192 | 6 |
| Wall 3 | 590 | 20 | 29.5 | 2065 | 3.9 |
| Wall 4 | 948 | 20 | 47.4 | 3318 | 6.3 |
| Windows 1 | 460 | 4.1 | 112.2 | 7854 | 14.8 |
| Windows 2 | 72 | 4.1 | 17.6 | 1229 | 2.3 |
| Windows 3 | 394 | 4.1 | 96.1 | 6727 | 12.7 |
| Windows 4 | 36 | 4.1 | 8.8 | 615 | 1.2 |
| Floor 1 | 576 | 35 | 16.5 | 1152 | 2.2 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 20736 | 0.5 | 187 | 13064 | 24.6 |

| SUMMARY OUTPUTS | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
| Ceiling Loss | 16 | 1152 | 2.2 | 25 | 406 | 318 |
| Wall Loss | 149 | 10409 | 19.6 | 230 | 3666 | 2872 |
| Window Loss | 235 | 16424 | 31 | 363 | 5784 | 4532 |
| Floor Loss | 74 | 5184 | 9.8 | 115 | 1826 | 1430 |
| Slab Loss | 0 | 0 | 0 | 0 | 0 | 0 |
| Infiltration | 187 | 13064 | 24.6 | 289 | 4601 | 3605 |
| Totals | 660 | 46233 | 87.2 | 1022 | 16282 | 12758 |

Heat Loss--
Millions of
BTU/Year




http://www.builditsolar.com/References/Calculators/HeatLoss/HeatLoss.htm

## DESIGN TEMPERATURE AND FUEL TYPE INPUTS

| | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Four-Story, Window Insulation Down at Night, Triple Glazed Windows | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

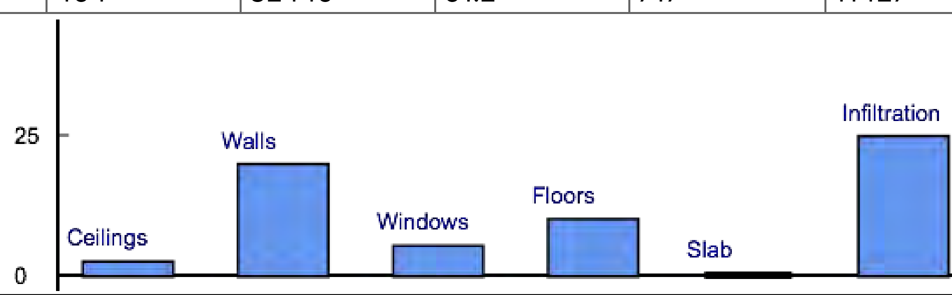
## AREA AND R-VALUE INPUTS

| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
|---|---|---|---|---|---|
| Roof | 576 | 35 | 16.5 | 1152 | 2.2 |
| Wall 1 | 524 | 20 | 26.2 | 1834 | 3.5 |
| Wall 2 | 912 | 20 | 45.6 | 3192 | 6 |
| Wall 3 | 590 | 20 | 29.5 | 2065 | 3.9 |
| Wall 4 | 948 | 20 | 47.4 | 3318 | 6.3 |
| Windows 1 | 460 | 25.5 | 18 | 1263 | 2.4 |
| Windows 2 | 72 | 25.5 | 2.8 | 198 | 0.4 |
| Windows 3 | 394 | 25.5 | 15.5 | 1082 | 2 |
| Windows 4 | 36 | 25.5 | 1.4 | 99 | 0.2 |
| Floor 1 | 576 | 35 | 16.5 | 1152 | 2.2 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 20736 | 0.5 | 187 | 13064 | 24.6 |

## SUMMARY OUTPUTS

| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
|---|---|---|---|---|---|---|
| Ceiling Loss | 16 | 1152 | 2.2 | 25 | 406 | 318 |
| Wall Loss | 149 | 10409 | 19.6 | 230 | 3666 | 2872 |
| Window Loss | 38 | 2641 | 5 | 58 | 930 | 729 |
| Floor Loss | 74 | 5184 | 9.8 | 115 | 1826 | 1430 |
| Slab Loss | 0 | 0 | 0 | 0 | 0 | 0 |
| Infiltration | 187 | 13064 | 24.6 | 289 | 4601 | 3605 |
| Totals | 464 | 32449 | 61.2 | 717 | 11427 | 8954 |

Heat Loss-- Millions of BTU/Year



## DESIGN TEMPERATURE AND FUEL TYPE INPUTS

| | | | | |
|---|---|---|---|---|
| **Unit Type and Condition** | Base Unit, No Window Insulation | | | |
| **Design outdoor Temperature** | 0°F (Coldest temperature expected in a normal year) | | | |
| **Heating Degree Days** | 5500 | | | |
| **Furnace Type** | Ground Source Heat Pump | $ 0.12 per KWH | 300 | Furnace Efficiency (%) |

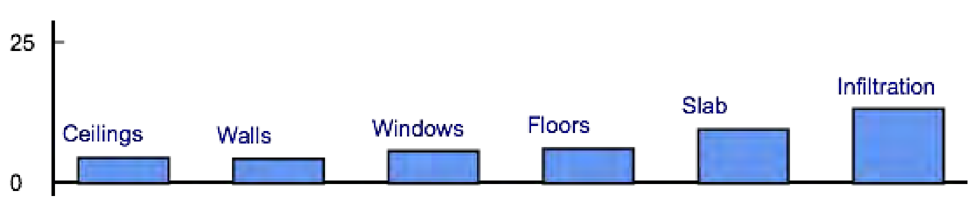
## AREA AND R-VALUE INPUTS

| **Building Surface** | **Area** *(sqft)* | **Rvalue** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
|---|---|---|---|---|---|
| Roof | 1080 | 35 | 30.9 | 2160 | 4.1 |
| Wall 1 | 540 | 50 | 10.8 | 756 | 1.4 |
| Wall 2 | 463 | 50 | 9.3 | 648 | 1.2 |
| Wall 3 | 201 | 50 | 4 | 281 | 0.5 |
| Wall 4 | 288 | 50 | 5.8 | 403 | 0.8 |
| Windows 1 | 77 | 4.1 | 18.8 | 1315 | 2.5 |
| Windows 2 | 87 | 4.1 | 21.2 | 1485 | 2.8 |
| Windows 3 | 0 | 0 | 0 | 0 | 0 |
| Windows 4 | 0 | 0 | 0 | 0 | 0 |
| Floor 1 | 1080 | 25 | 43.2 | 3024 | 5.7 |
| **Infiltration** | Typical Air Changes Per Hour:<br>0.33 -- very tight<br>0.5 -- tight -- new, careful construction<br>1.0 -- leaky -- typical existing construction | | | | |
| | **House Volume** *(cubic ft)* | **Air Changes per hour** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Yearly Heat Loss** *(million BTU/yr)* |
| Whole House | 10800 | 0.33 | 97 | 6804 | 12.8 |

## SUMMARY OUTPUTS

| **Item** | **UA** *(BTU/hr-F)* | **Design Loss** *(BTU/hr)* | **Year Loss** *(Million BTU/yr)* | **Fuel Cost** *(US dollars)* | **Ten Year Cost** *10% infla $"s* | **Greenhouse Gas** *(lb CO2)* |
|---|---|---|---|---|---|---|
| Ceiling Loss | 31 | 2160 | 4.1 | 2 | 26 | 163 |
| Wall Loss | 30 | 2089 | 3.9 | 2 | 25 | 158 |
| Window Loss | 40 | 2800 | 5.3 | 2 | 34 | 211 |
| Floor Loss | 43 | 3024 | 5.7 | 2 | 36 | 228 |
| Slab Loss | 69 | 4830 | 9.1 | 4 | 58 | 364 |
| Infiltration | 97 | 6804 | 12.8 | 5 | 82 | 513 |
| Totals | 310 | 21707 | 40.9 | 16 | 261 | 1637 |

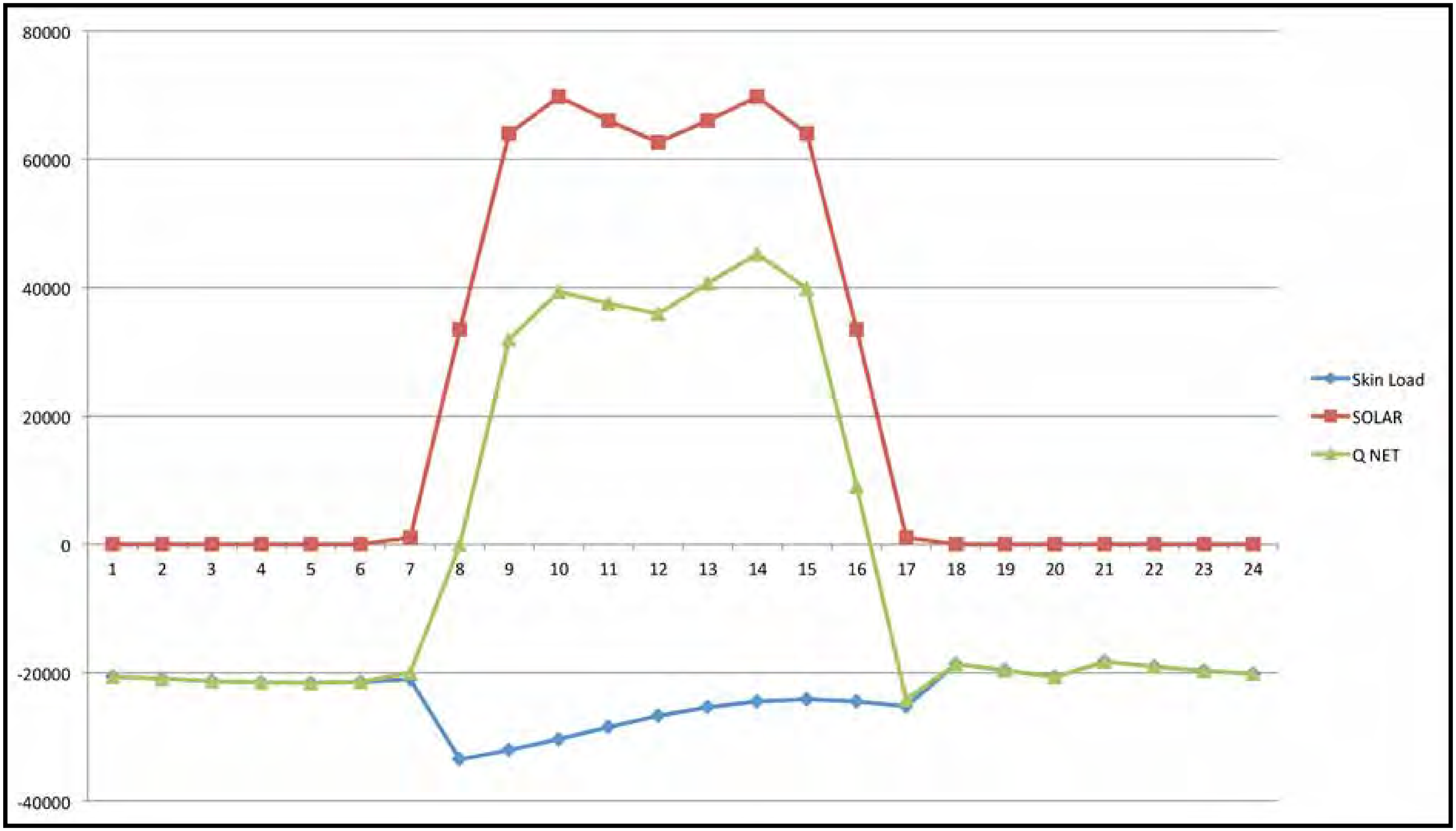
Heat Loss--
Millions of
BTU/Year




http://www.builditsolar.com/References/Calculators/HeatLoss/HeatLoss.htm

| Unit | Window | Day Heat Loss | Night Heat Loss | Daily Heat Loss | Internal Gains (Q-Net) | Total Heat Loss | Measure | Solar Collector Needed | Sources |
|---|---|---|---|---|---|---|---|---|---|
| 24' 4 story | Triple-Glazed low-E | 46233 | 32449 | 39341 | 21126 | 18214.9 | (BTU/HR) | 1.07 DC kW | http://www.builditsolar.com/References/Calculators/HeatLoss/HeatLoss.htm |
| | | | | | | 5.3 | (kW) | | http://www.rapidtables.com/convert/power/BTU_to_kW.htm |
| | | | | | | 128.1 | (kWh) | | http://www.rapidtables.com/calc/electric/kW_to_kWh_Calculator.htm |
| | | | | | | | | | http://www.affordable-solar.com/solar-tools/residential-solar-calculator/ |
| 24' 4 story | Single-Glazed Clear | 85925 | 32615 | 59270 | 37281 | 21989.2 | (BTU/HR) | 1.29 DC kW | |
| | | | | | | 6.4 | (kW) | | |
| | | | | | | 154.7 | (kWh) | | |
| 24' 2 story | Triple-Glazed low-E | 22418 | 14595 | 18507 | 9679 | 8827.6 | (BTU/HR) | 0.52 DC kW | |
| | | | | | | 2.6 | (kW) | | |
| | | | | | | 62.1 | (kWh) | | |
| Base Single Floor | Triple-Glazed low-E | 21707 | 21707 | 21707 | 10289 | 11417.9 | (BTU/HR) | 0.67 DC kW | (Note: No operable glazing due to minimal openings and R-50 walls) |
| | | | | | | 3.3 | (kW) | | |
| | | | | | | 80.3 | (kWh) | | |

| Month | East Windows | West Windows | North Windows | South Windows | Average | |
|---|---|---|---|---|---|---|
| Triple-Glazed Low-E | | | | | | |
| January | 2300 | 2300 | 620 | 7300 | 3130 | |
| February | 3600 | 3600 | 930 | 8400 | 4132.5 | |
| March | 5800 | 5800 | 1600 | 9300 | 5625 | |
| April | 8100 | 8100 | 2500 | 7800 | 6625 | |
| May | 9400 | 9400 | 3500 | 6000 | 7075 | |
| September | 7800 | 7800 | 2300 | 10000 | 6975 | |
| October | 5500 | 5500 | 1500 | 11000 | 5875 | |
| November | 2600 | 2600 | 710 | 7500 | 3352.5 | |
| December | 1900 | 1900 | 520 | 6500 | 2705 | BTU/SF/Month |
| Single-Glazed Clear | | | | | | |
| January | 4800 | 4800 | 1200 | 15000 | 6450 | |
| February | 7300 | 7300 | 1700 | 18000 | 8575 | |
| March | 12000 | 12000 | 2900 | 19000 | 11475 | |
| April | 17000 | 17000 | 4600 | 16000 | 13650 | |
| May | 19000 | 19000 | 6700 | 12000 | 14175 | |
| September | 16000 | 16000 | 4200 | 21000 | 14300 | |
| October | 11000 | 11000 | 2800 | 24000 | 12200 | |
| November | 5400 | 5400 | 1300 | 16000 | 7025 | |
| December | 3900 | 3900 | 960 | 14000 | 5690 | BTU/SF/Month |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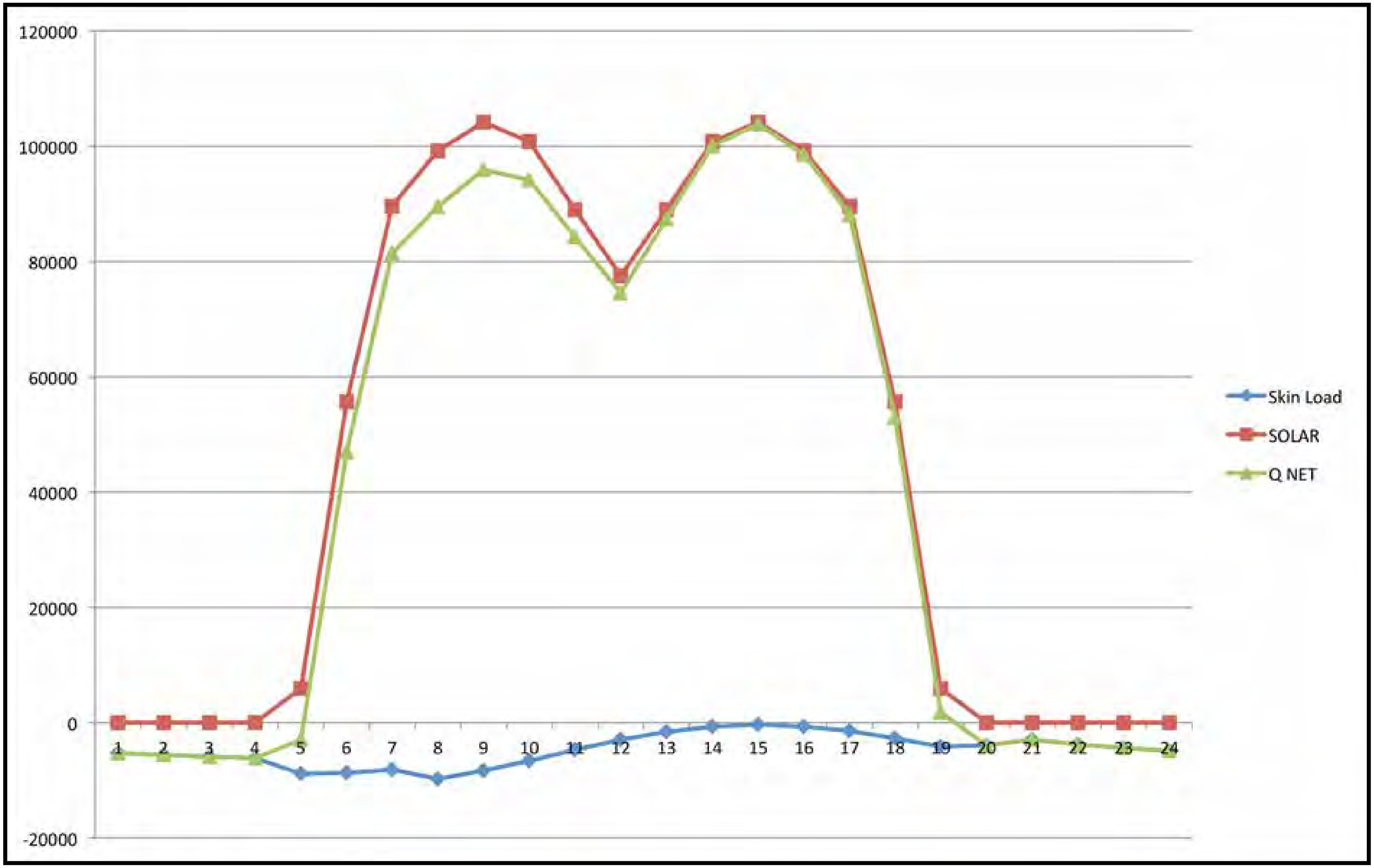
Skin Load
SOLAR
Q NET

# JANUARY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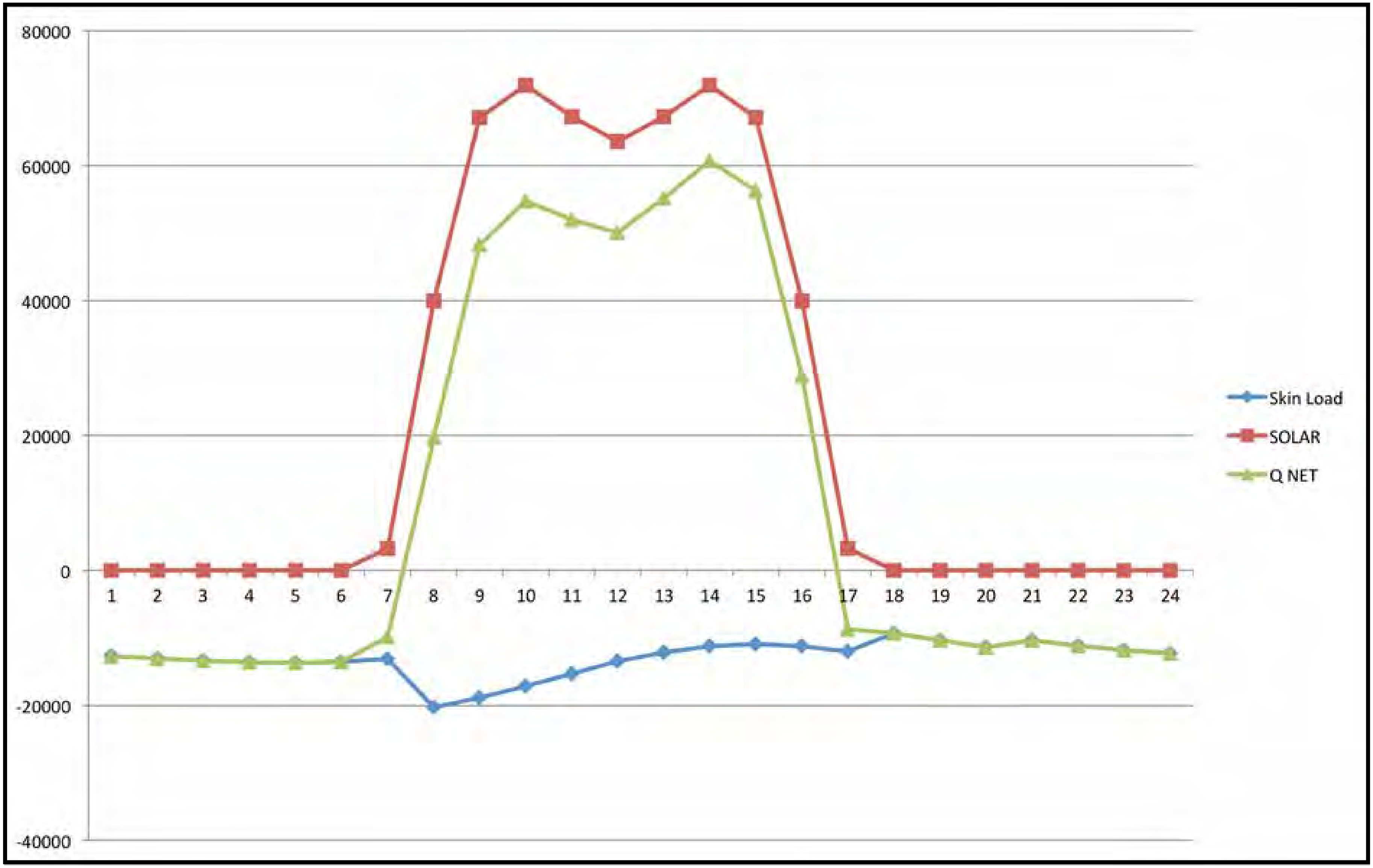
Skin Load
SOLAR
Q NET

# MAY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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Skin Load
SOLAR
Q NET

# NOVEMBER

## CLEAR DAY HEAT HOURLY ENERGY BALANCE

**Project :** 4 story Unit, January

**Date :**

| | | | | | | |
|---|---|---|---|---|---|---|
| **TEMP** | | | **Ventilation ?** | | Y | Y or N |
| **high (h)=** | 75 | high (day) thermostat setting | **Volume =** | | 23616 | cu ft |
| **low (l)=** | 68 | low (night) thermostat setting | | | | |
| **out =** | 30 | average daily o/s temperature | **UA** | **day =** | 660 | Btu/hr/°F |
| **range =** | 17 | daily o/s temperature range | **UA** | **night =** | 464 | Btu/hr/°F |

| | HR | Skin Load | **SOLAR** | Q NET | Q vent | **T (h/l)** | T in | T out | **UA (d/n)** | UA | ACH/Hr Required |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | | -20551 | 0 | -20551 | 0 | l | 68 | 23.7 | n | 464 | |
| 2a | 2 | -20945 | 0 | -20945 | 0 | l | 68 | 22.9 | n | 464 | |
| 3a | | -21260 | 0 | -21260 | 0 | l | 68 | 22.2 | n | 464 | |
| 4a | 4 | -21497 | 0 | -21497 | 0 | l | 68 | 21.7 | n | 464 | |
| 5a | | -21576 | 0 | -21576 | 0 | l | 68 | 21.5 | n | 464 | |
| 6a | 6 | -21418 | 0 | -21418 | 0 | l | 68 | 21.8 | n | 464 | |
| 7a | | -21024 | 1085 | -19939 | 0 | l | 68 | 22.7 | n | 464 | |
| 8a | 8 | -33515 | 33480 | -35 | 0 | h | 75 | 24.2 | d | 660 | |
| 9a | | -32056 | 63984 | 31928 | 31928 | h | 75 | 26.4 | d | 660 | 1.5 |
| 10a | 10 | -30373 | 69750 | 39377 | 39377 | h | 75 | 29.0 | d | 660 | 2.0 |
| 11a | | -28466 | 66030 | 37564 | 37564 | h | 75 | 31.9 | d | 660 | 2.0 |
| 12p | 12 | -26671 | 62620 | 35949 | 35949 | h | 75 | 34.6 | d | 660 | 2.1 |
| 1p | | -25324 | 66030 | 40706 | 40706 | h | 75 | 36.6 | d | 660 | 2.5 |
| 2p | 14 | -24427 | 69750 | 45323 | 45323 | h | 75 | 38.0 | d | 660 | 2.9 |
| 3p | | -24090 | 63984 | 39894 | 39894 | h | 75 | 38.5 | d | 660 | 2.6 |
| 4p | 16 | -24427 | 33480 | 9053 | 9053 | h | 75 | 38.0 | d | 660 | 0.6 |
| 5p | | -25212 | 1085 | -24127 | 0 | h | 75 | 36.8 | d | 660 | |
| 6p | 18 | -18592 | 0 | -18592 | 0 | h | 75 | 34.9 | n | 464 | |
| 7p | | -19618 | 0 | -19618 | 0 | h | 75 | 32.7 | n | 464 | |
| 8p | 20 | -20643 | 0 | -20643 | 0 | h | 75 | 30.5 | n | 464 | |
| 9p | | -18263 | 0 | -18263 | 0 | l | 68 | 28.6 | n | 464 | |
| 10p | 22 | -19052 | 0 | -19052 | 0 | l | 68 | 26.9 | n | 464 | |
| 11p | | -19683 | 0 | -19683 | 0 | l | 68 | 25.6 | n | 464 | |
| 12a | 24 | -20156 | 0 | -20156 | 0 | l | 68 | 24.6 | n | 464 | |

| | Heat loss | Solar | Q net | Q vent | | | |
|---|---|---|---|---|---|---|---|
| | | | | | **% SOLAR heating =** | **95.1%** | |
| **TOT** | -558839 | 531278 | -27561 | 279795 | **Net % SOLAR heating =** | **45.0%** | plus extra 10% stored in walls, floors, ceiling |

**CLEAR DAY HEAT HOURLY ENERGY BALANCE**

**Project :** 4 story Unit, May

**Date :**

| **TEMP** | | | **Ventilation ?** | | Y | Y or N |
|---|---|---|---|---|---|---|
| **high (h)=** | 72 | high (day) thermostat setting | **Volume =** | | 23616 | cu ft |
| **low (l)=** | 68 | low (night) thermostat setting | | | | |
| **out =** | 63 | average daily o/s temperature | **UA** | **day =** | 660 | Btu/hr/°F |
| **range =** | 17 | daily o/s temperature range | **UA** | **night =** | 464 | Btu/hr/°F |

| | HR | Skin Load | **SOLAR** | Q NET | Q vent | **T (h/l)** | T in | T out | **UA (d/n)** | UA | ACH/Hr Required |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | | -5239 | 0 | -5239 | 0 | l | 68 | 56.7 | n | 464 | |
| 2a | 2 | -5633 | 0 | -5633 | 0 | l | 68 | 55.9 | n | 464 | |
| 3a | | -5948 | 0 | -5948 | 0 | l | 68 | 55.2 | n | 464 | |
| 4a | 4 | -6185 | 0 | -6185 | 0 | l | 68 | 54.7 | n | 464 | |
| 5a | | -8910 | 5952 | -2958 | 0 | l | 68 | 54.5 | d | 660 | |
| 6a | 6 | -8686 | 55645 | 46959 | 46959 | l | 68 | 54.8 | d | 660 | 8.4 |
| 7a | | -8125 | 89590 | 81465 | 81465 | l | 68 | 55.7 | d | 660 | 15.6 |
| 8a | 8 | -9755 | 99200 | 89445 | 89445 | h | 72 | 57.2 | d | 660 | 14.2 |
| 9a | | -8296 | 104160 | 95864 | 95864 | h | 72 | 59.4 | d | 660 | 17.9 |
| 10a | 10 | -6613 | 100750 | 94137 | 94137 | h | 72 | 62.0 | d | 660 | 22.1 |
| 11a | | -4706 | 88970 | 84264 | 84264 | h | 72 | 64.9 | d | 660 | 27.8 |
| 12p | 12 | -2911 | 77500 | 74589 | 74589 | h | 72 | 67.6 | d | 660 | 39.8 |
| 1p | | -1564 | 88970 | 87406 | 87406 | h | 72 | 69.6 | d | 660 | 86.8 |
| 2p | 14 | -667 | 100750 | 100083 | 100083 | h | 72 | 71.0 | d | 660 | 233.1 |
| 3p | | -330 | 104160 | 103830 | 103830 | h | 72 | 71.5 | d | 660 | 488.5 |
| 4p | 16 | -667 | 99200 | 98533 | 98533 | h | 72 | 71.0 | d | 660 | 229.5 |
| 5p | | -1452 | 89590 | 88138 | 88138 | h | 72 | 69.8 | d | 660 | 94.2 |
| 6p | 18 | -2686 | 55645 | 52959 | 52959 | h | 72 | 67.9 | d | 660 | 30.6 |
| 7p | | -4145 | 5952 | 1807 | 1807 | h | 72 | 65.7 | d | 660 | 0.7 |
| 8p | 20 | -3939 | 0 | -3939 | 0 | h | 72 | 63.5 | n | 464 | |
| 9p | | -2951 | 0 | -2951 | 0 | l | 68 | 61.6 | n | 464 | |
| 10p | 22 | -3740 | 0 | -3740 | 0 | l | 68 | 59.9 | n | 464 | |
| 11p | | -4371 | 0 | -4371 | 0 | l | 68 | 58.6 | n | 464 | |
| 12a | 24 | -4844 | 0 | -4844 | 0 | l | 68 | 57.6 | n | 464 | |

| | Heat loss | Solar | Q net | Q vent | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | **% SOLAR heating =** | **1037.8%** |
| **TOT** | -112362 | 1166034 | 1053672 | 1099481 | **Net** | **% SOLAR heating =** | **59.2%** plus extra 10% stored in w

**CLEAR DAY HEAT HOURLY ENERGY BALANCE**

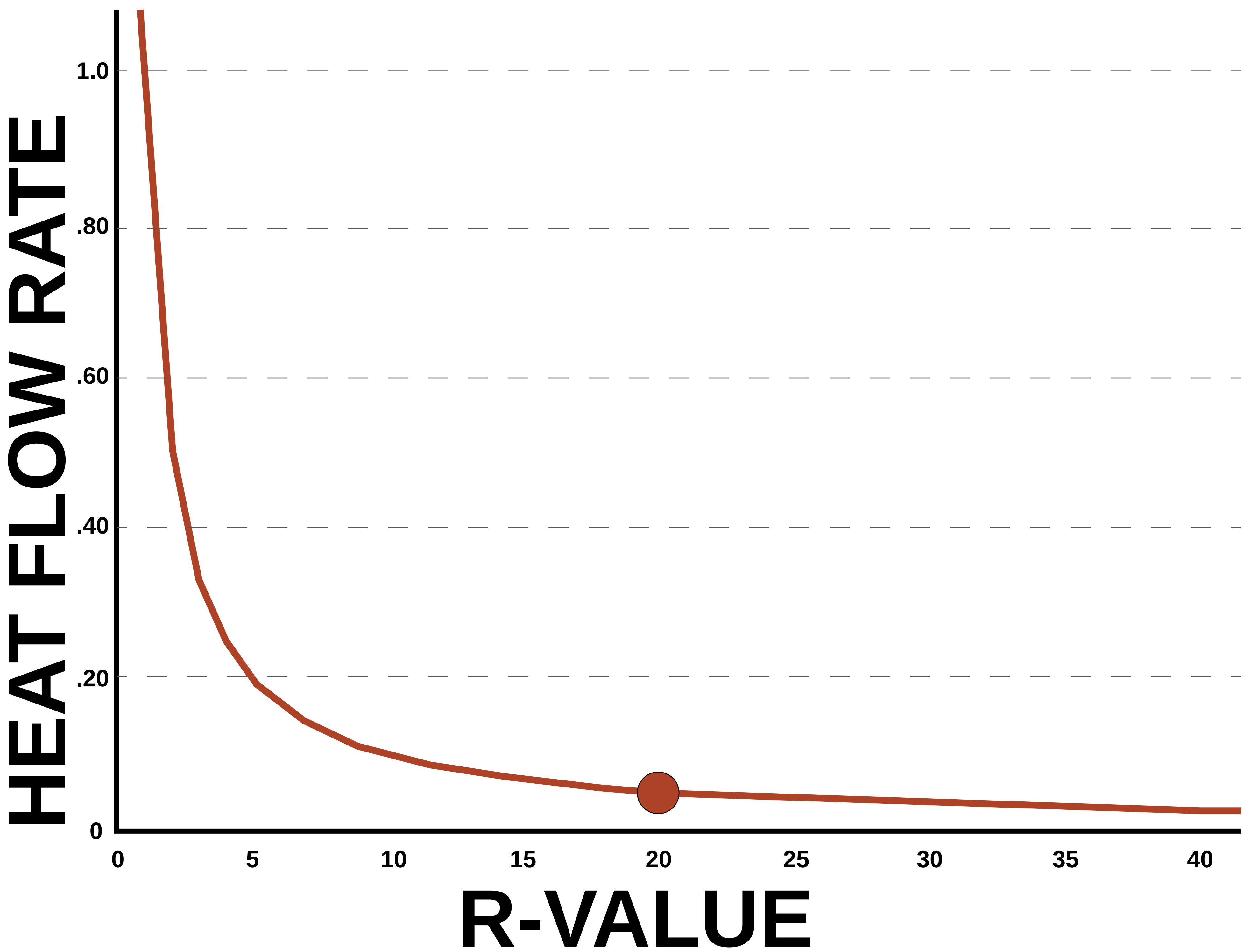
**Project :** 4 story Unit, November

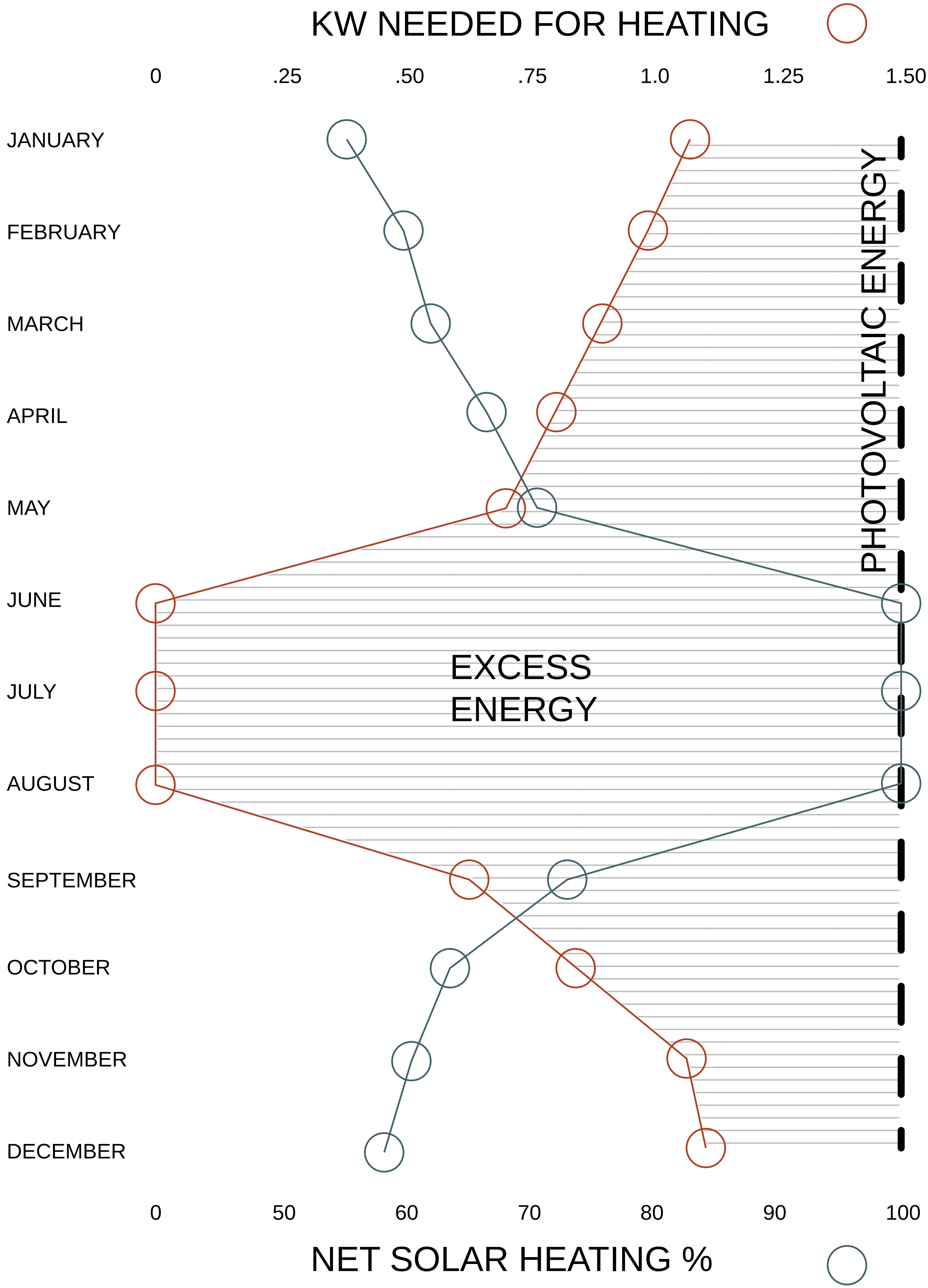
**Date :**

| | | | | | | |
|---|---|---|---|---|---|---|
| **TEMP** | | | **Ventilation ?** | | Y | Y or N |
| **high (h)=** | 72 | high (day) thermostat setting | **Volume =** | | 23616 | cu ft |
| **low (l)=** | 68 | low (night) thermostat setting | | | | |
| **out =** | 47 | average daily o/s temperature | **UA** | **day =** | 660 | Btu/hr/°F |
| **range =** | 17 | daily o/s temperature range | **UA** | **night =** | 464 | Btu/hr/°F |

| | HR | Skin Load | **SOLAR** | Q NET | Q vent | **T (h/l)** | T in | T out | **UA (d/n)** | UA | ACH/Hr Required |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | | -12663 | 0 | -12663 | 0 | l | 68 | 40.7 | n | 464 | |
| 2a | 2 | -13057 | 0 | -13057 | 0 | l | 68 | 39.9 | n | 464 | |
| 3a | | -13372 | 0 | -13372 | 0 | l | 68 | 39.2 | n | 464 | |
| 4a | 4 | -13609 | 0 | -13609 | 0 | l | 68 | 38.7 | n | 464 | |
| 5a | | -13688 | 0 | -13688 | 0 | l | 68 | 38.5 | n | 464 | |
| 6a | 6 | -13530 | 0 | -13530 | 0 | l | 68 | 38.8 | n | 464 | |
| 7a | | -13136 | 3255 | -9881 | 0 | l | 68 | 39.7 | n | 464 | |
| 8a | 8 | -20315 | 39990 | 19675 | 19675 | h | 72 | 41.2 | d | 660 | 1.5 |
| 9a | | -18856 | 67146 | 48290 | 48290 | h | 72 | 43.4 | d | 660 | 4.0 |
| 10a | 10 | -17173 | 71920 | 54747 | 54747 | h | 72 | 46.0 | d | 660 | 4.9 |
| 11a | | -15266 | 67270 | 52004 | 52004 | h | 72 | 48.9 | d | 660 | 5.3 |
| 12p | 12 | -13471 | 63550 | 50079 | 50079 | h | 72 | 51.6 | d | 660 | 5.8 |
| 1p | | -12124 | 67270 | 55146 | 55146 | h | 72 | 53.6 | d | 660 | 7.1 |
| 2p | 14 | -11227 | 71920 | 60693 | 60693 | h | 72 | 55.0 | d | 660 | 8.4 |
| 3p | | -10890 | 67146 | 56256 | 56256 | h | 72 | 55.5 | d | 660 | 8.0 |
| 4p | 16 | -11227 | 39990 | 28763 | 28763 | h | 72 | 55.0 | d | 660 | 4.0 |
| 5p | | -12012 | 3255 | -8757 | 0 | h | 72 | 53.8 | d | 660 | |
| 6p | 18 | -9312 | 0 | -9312 | 0 | h | 72 | 51.9 | n | 464 | |
| 7p | | -10338 | 0 | -10338 | 0 | h | 72 | 49.7 | n | 464 | |
| 8p | 20 | -11363 | 0 | -11363 | 0 | h | 72 | 47.5 | n | 464 | |
| 9p | | -10375 | 0 | -10375 | 0 | l | 68 | 45.6 | n | 464 | |
| 10p | 22 | -11164 | 0 | -11164 | 0 | l | 68 | 43.9 | n | 464 | |
| 11p | | -11795 | 0 | -11795 | 0 | l | 68 | 42.6 | n | 464 | |
| 12a | 24 | -12268 | 0 | -12268 | 0 | l | 68 | 41.6 | n | 464 | |

| | Heat loss | Solar | Q net | Q vent | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | **% SOLAR heating =** | **180.2%** |
| **TOT** | -312231 | 562712 | 250481 | 425654 | **Net** | **% SOLAR heating =** | **43.9%** plus extra 10% stored in w


HEAT FLOW RATE
1.0
.80
.60
.40
.20
0
0
5
10
15
20
25
30
35
40
R-VALUE


KW NEEDED FOR HEATING
0
.25
.50
.75
1.0
1.25
1.50
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
PHOTOVOLTAIC ENERGY
EXCESS
ENERGY
0
50
60
70
80
90
100
NET SOLAR HEATING %