2013

Susquehanna Street Ph III

An Affordable Housing Initiative

ZERO ENERGY HOUSING |SPRING 13

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Executive Summary

The project proposal document highlights the various strategies that can be adopted in the Susquehanna Street Phase III housing project in the Homewood locality in Pittsburgh, PA. This project is an affordable housing project with the scope of 6 units constructed with a tight budget and sale price at half of the first cost of construction. The document provides a thorough documentation of various strategies that can be adopted in a house to reduce the energy consumption to a near net-zero construction. The simulation of the model is carried out in REM/Rate, software that highlights the compliance of the building model according to various regulatory texts and codes like the IECC 2012 and Energy Star v3.

Introduction

The site is located in the neighbourhood of Homewood in between Susquehanna Street and Finance Street. The project is an affordable housing initiative that has been undertaken by the city as part of its Susquehanna Development scheme with this project being its third phase of development.

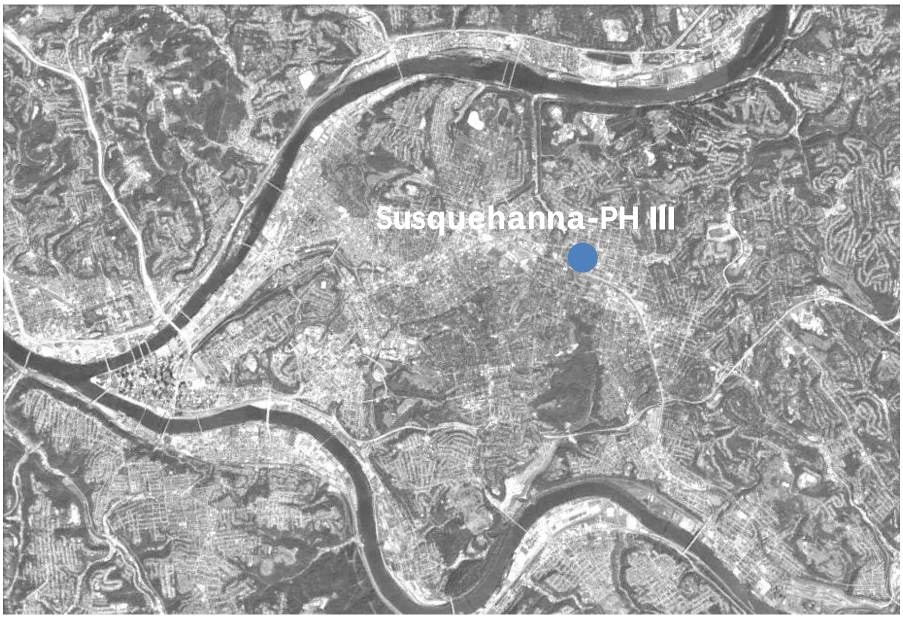


Figure 1: Location of Site in Pittsburgh

The proposed design consists of 3 types of Housing – single family detached housing units:

- A 3 Bedroom unit
- A 5 Bedroom Unit
- ADA Approved 3 Bedroom unit

The 3 types are randomly arranged to accommodate 6 units on the site which is oriented along the Northeast-Southwest axis with no true north facing or south facing façade. Each unit has an unconditioned basement which houses the Air conditioning unit, the mechanical equipment and the appliances – washer & dryer, and an attic space.

This study is majorly carried out keeping in mind the design of the 3 bedroom unit which has an unconditioned basement as well as an attic space that is not included in the livable space.

Site Area: 23160 SF

Conditioned Floor Area: 1693 SF

Total Volume: 21569 cu.ft

Conditioned volume: 14321 cu.ft

The expected year of construction is 2014.

Figure 2: Location of Site in Homewood

The adjoining figure highlights the optimum orientation for a building in Pittsburgh for maximum Solar heat gain and obtaining maximum benefits of the solar angle in Pittsburgh. The typical orientation that is most beneficial is identified as oriented tilted facing South-east. The designed units are along the Northeast Southwest axis with maximum exposure along the South-east which is highly appropriate for solar design in this project.

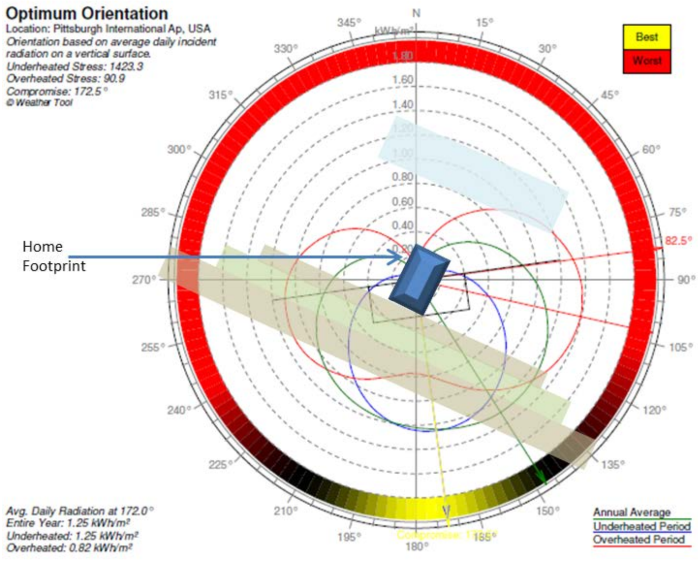


Figure 3: Optimum Orientation of Building in Pittsburgh vs Our Design

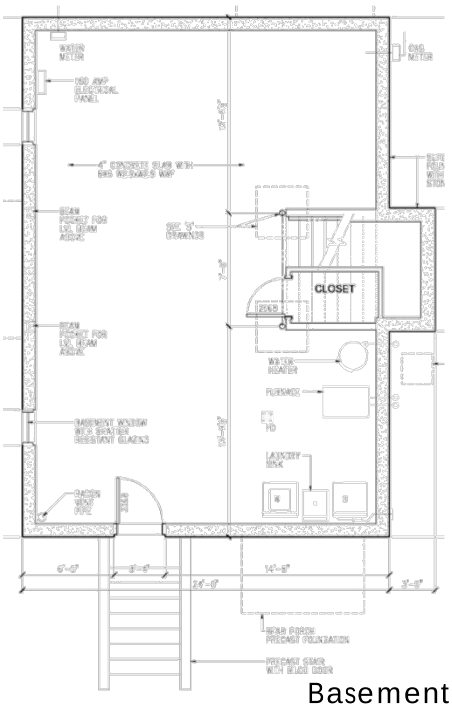
 

Figure 4 and 5: Site Photos

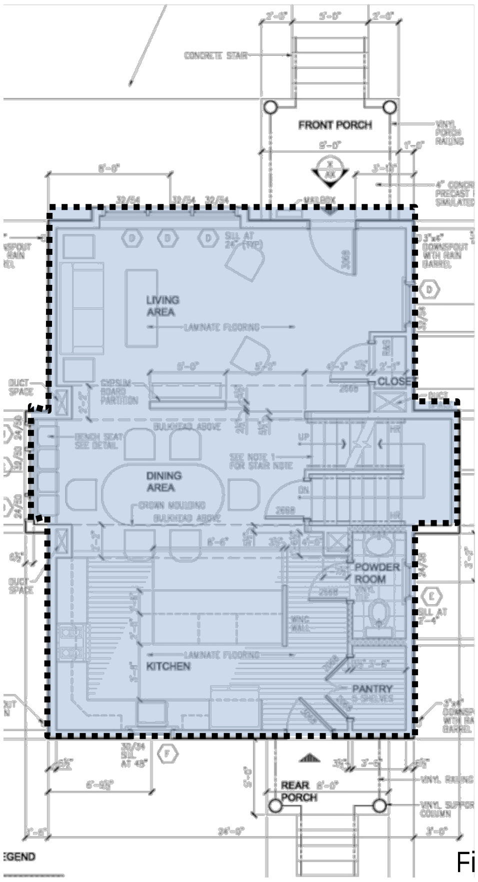
The present site is located in a community that is typically low-income with predominantly high single-mothers and working class occupants. It is located at an open end of Homewood, overlooking the busway and is therefore a prime location.

Thermal Boundary:

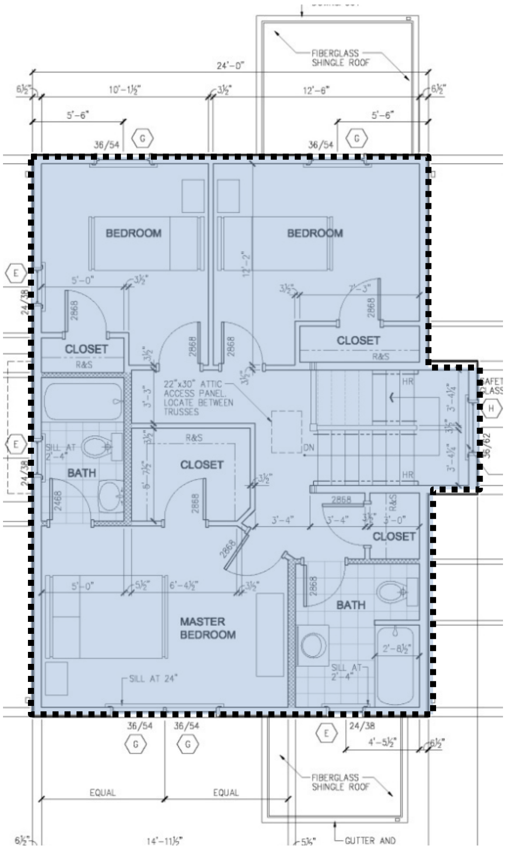
The diagrams below show proposed thermal boundary for Susquehanna 3 Bedroom unit



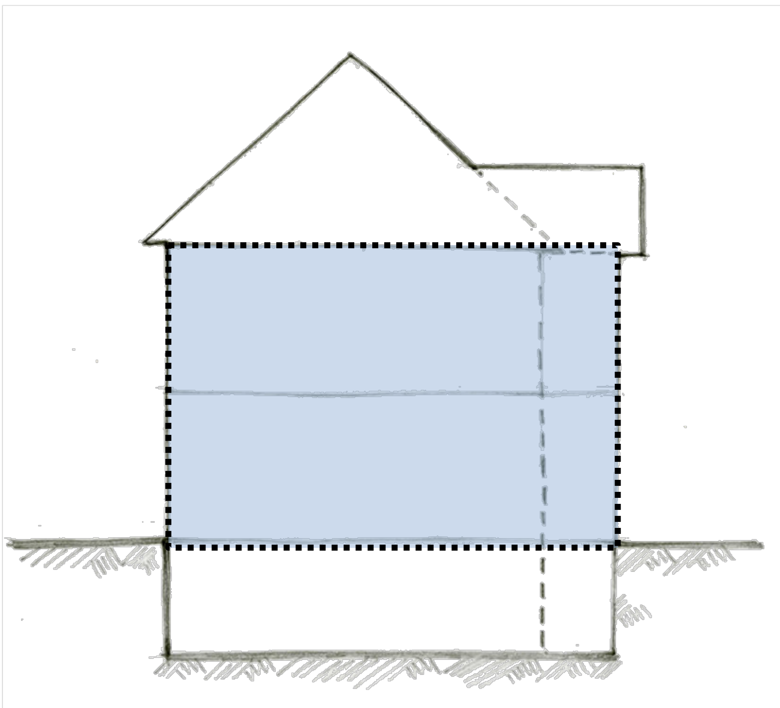
Basement Plan



First Floor Plan



Second Floor Plan



Schematic Section

Thermal boundary is a space that needs to be conditioned. In the projects aiming for zero energy, wisely defined thermal boundary can make a big reduction in energy consumption. Susquehanna housing units have all activity spaces on 1st and 2nd floor. The basement has mechanical equipment and it does not have any other designated purpose. From the design documents, we understood that original design considered basement in the conditioned space even though the grade slab was not insulated to avoid heat loss. We propose excluding basement and attic space from the conditioned space and adding insulation to the frame floor between basement and first floor to reduce heat loss.

Baseline:

Envelope

The baseline model input parameters were obtained from client and the design document. This section of report covers envelope and mechanical systems designed originally.

Component	Insulation type	R value
Above grade wall	Frame 2x4 construction	19
Below grade wall	Pre-cast superior wall	21.5
Attic	Blown in cellulose	48

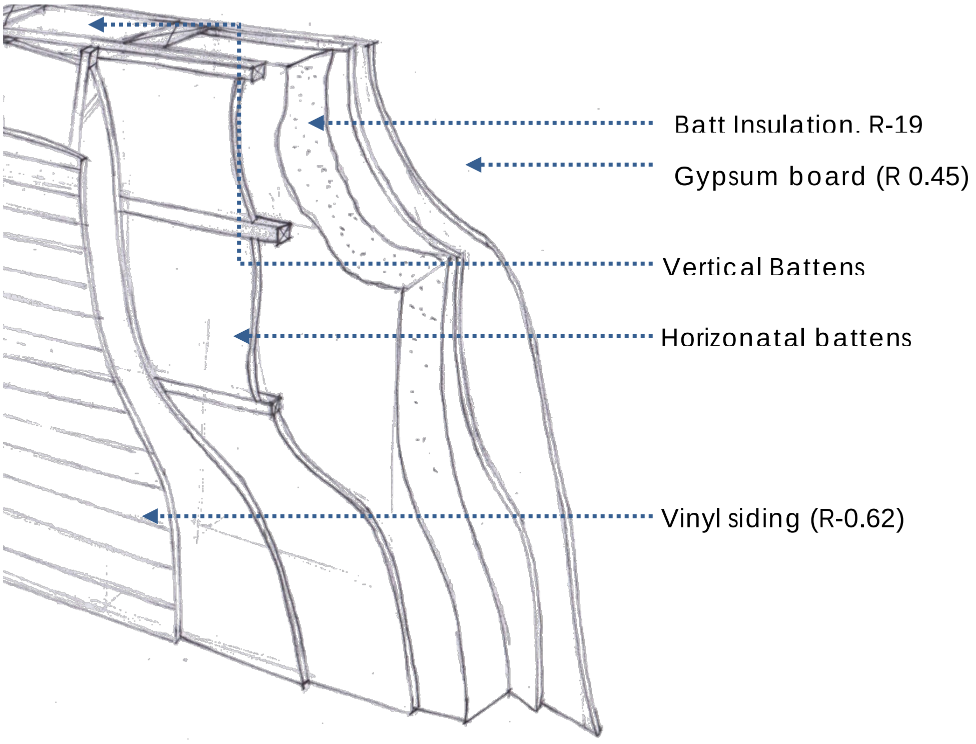


Figure: Details of baseline wall assembly

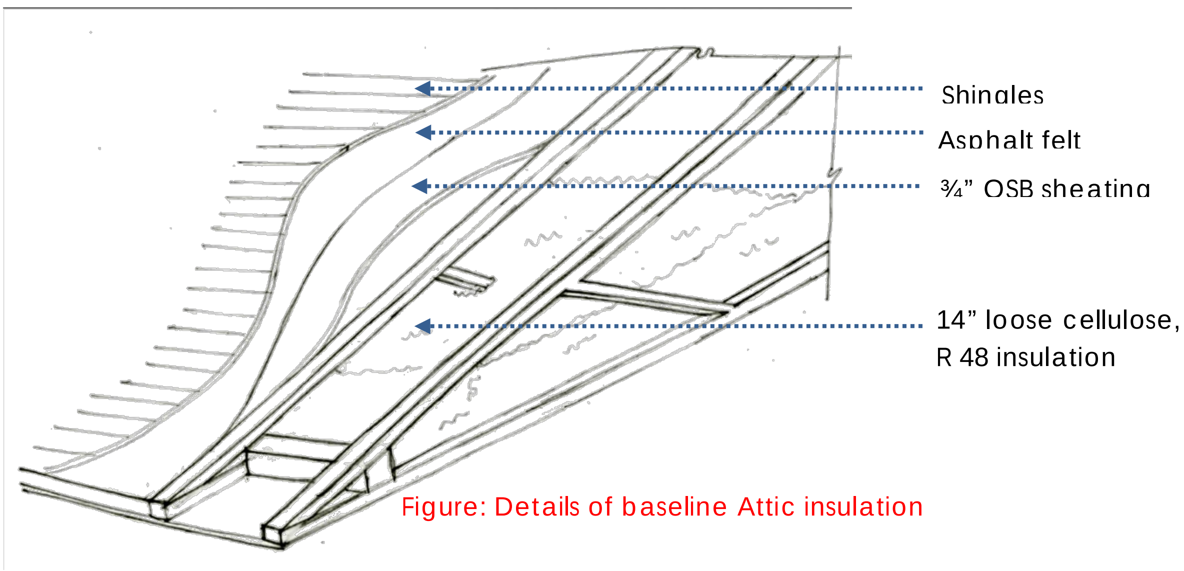


Figure: Details of baseline Attic insulation

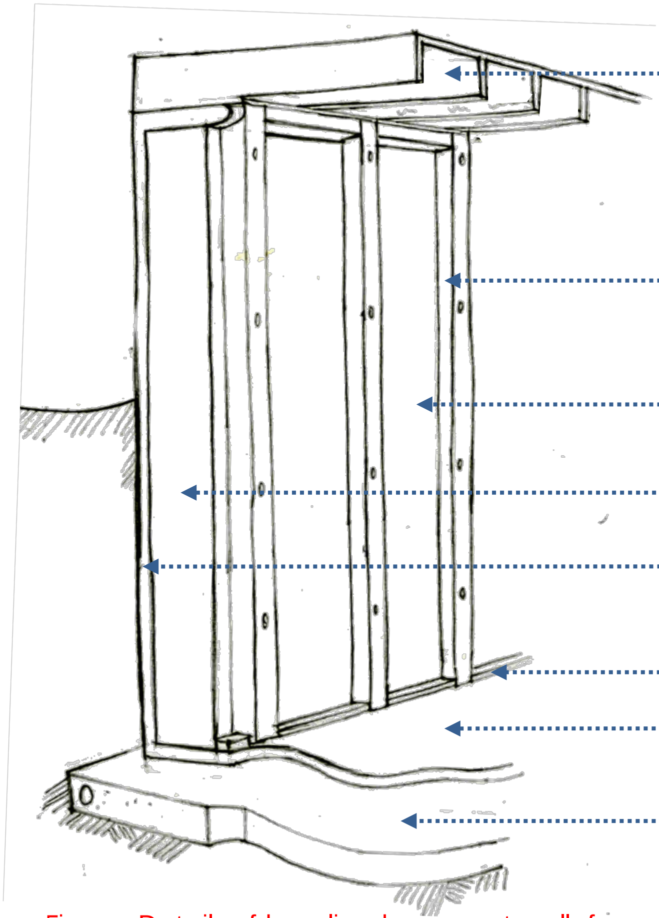


Figure: Details of baseline basement wall- frame floor assembly

The above grade wall is R19 wood frame wall with vinyl siding on exterior. The attic is insulated with loose cellulose of R 48. The wall system used in the basement is highly efficient 'superior wall' system. The basement floor is un-insulated as per the design.

Assumptions:

Windows:

The design document did not provide information on window type and we made an assumption. The appropriate window type was selected from 'efficientwindow.com' and IECC compliance guide. The window type assumed is a energy star window and qualifies its requirements. The baseline windows are efficient windows with U-value of 0.31(Btu/h °F ft2) and SHGC of 0.41. These windows will be double glazed, argon filled and have low e coating.

Mechanical equipment:

Design documents specified proposed type of mechanical heating-cooling for the unit, but did not give specifications such as efficiency and manufacturer. In order to gain parameters required for REM-RATE model, we made assumptions based on market study. All the equipment in the baseline are energy star qualified and efficient. Following tables describes the type and relevant parameters.

Purpose	System type	Efficiency
Space heating	Gas furnace	95% AFUE
Space cooling	Air conditioner	13.2 SEER
Water heating	Residential water heater	Energy factor: 0.7

We referred to AHRI directory to find appropriate products for baseline. Description of each product is elaborated in this section. All the manufacturer and products were chosen considering the cost limitation and location

Gas Furnace:
Manufacturer: AIRE-FLO
AFUE: 96%
Output heating capacity: 43 MBTUH
Input: 44 MBTUH
Eae: 393 KWh/yr
configuration: down-flow
Fuel type: natural gas

Air conditioner
Manufacturer: AAON, INC.
Cooling capacity: 57000Btuh
EER rating: 11.40
SEER rating: 13.2

Residential water heater:
Manufacturer: A.O.Smith water products co.
Energy factor: 0.7
First hour rating: 80 Gallons/ hr
Energy source: natural gas
Recovery efficiency: 80%s

Baseline Results:

With all the information stated above, annual energy requirements and cost were estimated from REM-RATE model. This section of report analyses these results and compares source- site energy consumption with the breakdown by end use. The table below shows annual loads.

	Annual Heating (MMBtu/yr)	**Annual Cooling (MMBtu/yr)**	**Annual Water (MMBtu/yr)**	**Annual Energy Cost ($/yr)**	**HERS score**
Results	35.3	9.4	15.2	1578	63

Table : Annual load breakdown

Since, compliance with Energystar V3 and IECC 2012 were one of the requirements even for the baseline. Hence, results obtained for baseline are good with original design. Table below shows the natural gas, electric usage and site-source energy consumption.

	Site Energy			Source Energy		
	MMBTUs	MJ	kWh	MMBTUs	MJ	kWh
Natural gas,	55	57448.9	**16,086**	60	193315.6	54,128
Electricity	23	23753.9	**6,651**	76	79931.9	22,381
Total Energy Consumed (kWh)	78	81,203	22,737	136	2,73,248	78,509

Site EUI: 31.08 Mbtu/ft2 ; Source EUI: 54.2 Mbtu/ ft2

Table : Annual load breakdown

The table # breaks down energy consumption per fuel type. The total site energy consumption id 78 MMbtu and source consumption is almost twice site consumption i.e. 136 MMbtu. The site EUI is 31.08Mbtu/ Sf , which is better than US average home that has EUI of 44 Mbt/sf. From all these results we know that the house already has systems and envelope that is better than average home. We attempt to make this building more energy efficient by further recommendations.

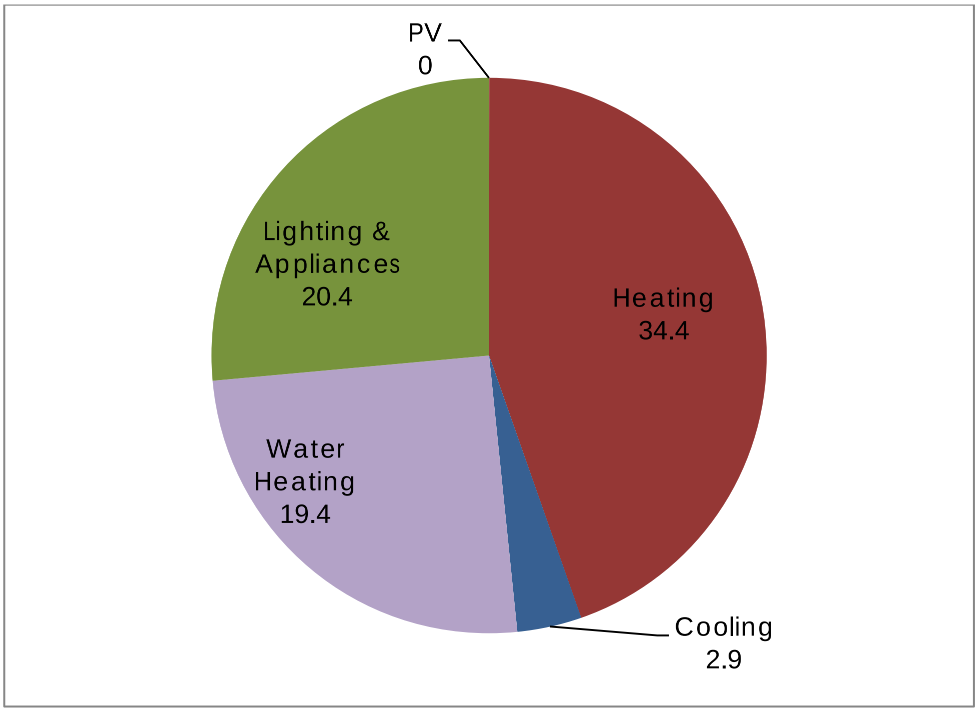


Table : Annual load breakdown

The above pie chart shows the energy consumption in a house by end use. We used this information to know source of energy consumption and targeted these areas for potential energy use reduction. At present hearing and water heating are the areas that need more attention. We investigated into better building envelope and systems to reduce these load.

Recommendations:

After analysing baseline results and various building, HVAC components used in the building we identified areas that could perform better with efficient technology. We have made recommendations for above grade wall assembly, frame floor between basement and first floor, attic insulation, windows, HVAC systems and renewable onsite energy generation. These recommendations and predicted results are elaborated in this section of the report.

Envelope

Since project is an affordable housing initiative; we looked at cases that are affordable near zero energy houses. From the studied cases we realized the fiscal and environmental benefits of using SIPs construction and we investigated further in this technology to arrive at most suitable wall assembly for our project.

SIPs case studies:

i) Near zero energy homes- Lenoir city, Tennessee

This study is of five near zero energy home built together by Habitat for humanity, Department of energy and Tennessee valley authority. The long term goal of this collaboration is to arrive at a model for affordable zero energy homes.

The envelope used in the houses is airtight with 1 air change per hour at 50 Pascals. The SIPs are used for wall assembly. The rigid foam insulation is sandwiched between two OSB panels. The panel thickness varies in the building depending on the specific area of the house. It uses two wall thicknesses 4.5” and 6.5”. This system has demonstrated superior insulation, strength and air tightness. As this system is pre-fabricated, they took only 5 hours for installation. Use of SIPs reduced heating-cooling energy loads.

This enveloped was studied by Todd Helton, construction supervisor of Loudon County’s habitat for humanity. From his study, he claims the SIP type building envelope to be 30% more efficient than standard wood-frame construction. The average operational energy cost of these houses is $1/ day whereas for conventional house it is $5/ day.

In addition to SIPs construction, these houses use high efficiency HVAC, solar panels and other systems that contribute to the energy consumption reduction. But, contribution of SIPs cannot high when looked at design load reduction and affordability.


Image: Houses in the project

Image: SIPs construction at site

In addition to this project, we referred to projects that are not aiming for zero energy but have used SIPs to achieve affordability in communities hit by natural disasters that required cheap and quick construction. From the background research of this technology, we listed the advantages of SIPs construction that are listed below:

- Reduced labor cost
- Faster construction
- Less waste during construction
- 15 times more airtight than wood frame construction
- Quieter and stronger than conventional construction
- Reduces energy bills
- Improves indoor environment for occupants

Above Grade Walls- SIP Assembly:

After looking at all the advantages of SIP construction we decided to propose this system for above grade walls. We referred to 'Murus –structural insulating panels' manufacturer to ensure feasibility. Murus has manufacturing unit in Mansfield (PA) and this would reduce transportation cost. We recommend using 10-1.4" thick XPS core insulation as it gives us desired R value of R 48. The image below elaborates further on the recommended above grade SIP assembly.

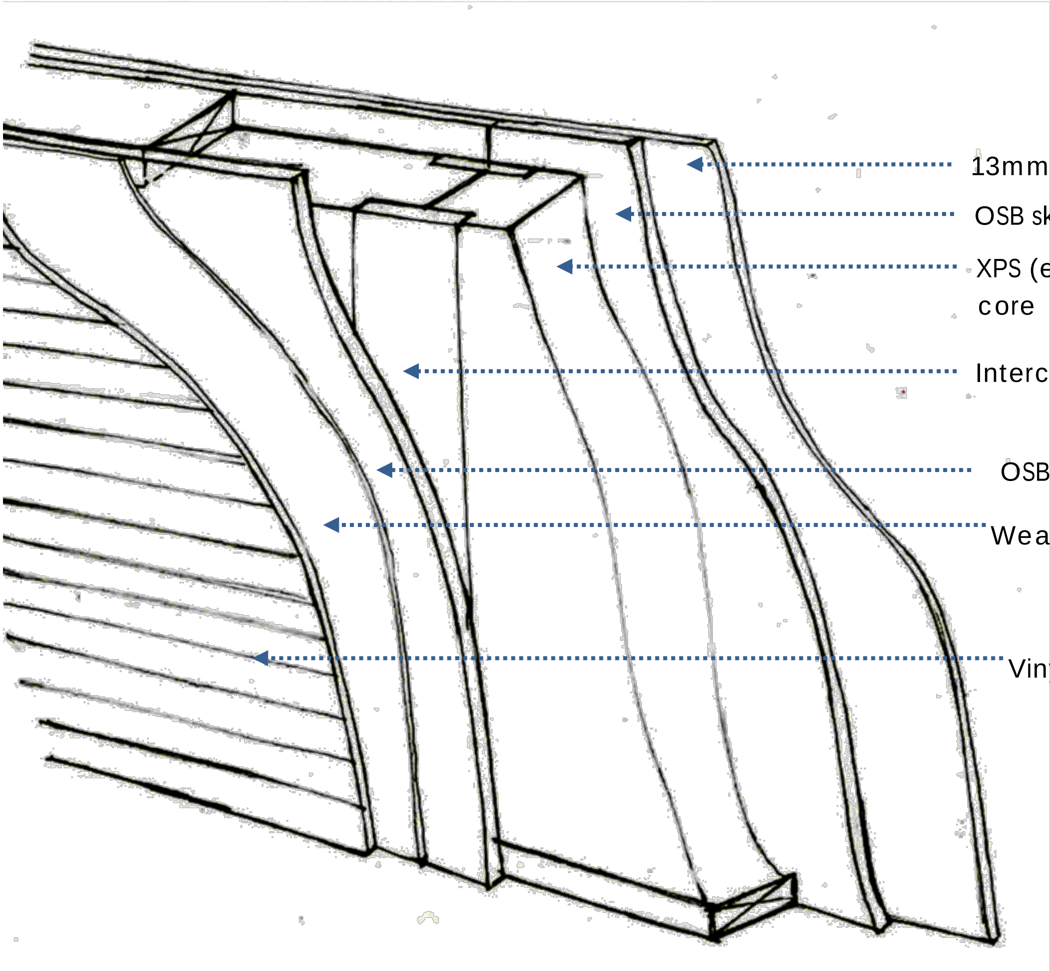


Figure: Details of recommended above grade SIP wall assembly

Results of AG wall upgrades:

The table below shows annual energy consumption and energy-cost reductions achieved by using SIPs construction over original wall design. It is clear from the table that upgrading walls will bring positive change for less investment cost.

	Annual Heating (MMBtu/yr)	**Annual Cooling (MMBtu/yr)**	**Annual Water (MMBtu/yr)**	**Annual Energy Cost ($/yr)**	**HERS score**
Baseline	35.3	9.4	15.2	1578	63
SIP walls	24.2	9.6	15.2	1459	56
Reduction/ increase	**11.1**	**+0.2**	**0**	**119**	**8**

Table: Benefits from individual AG wall upgrade strategy

Attic insulation:

The original attic insulation is designed for R value of 48.As per passive house standard of envelope insulations, desired R value is 60. We anticipated further reduction in heating cooling loads. The only change suggested is of increasing thickness of insulation to 18" from 14". No other change in the assembly is required as the original design good enough

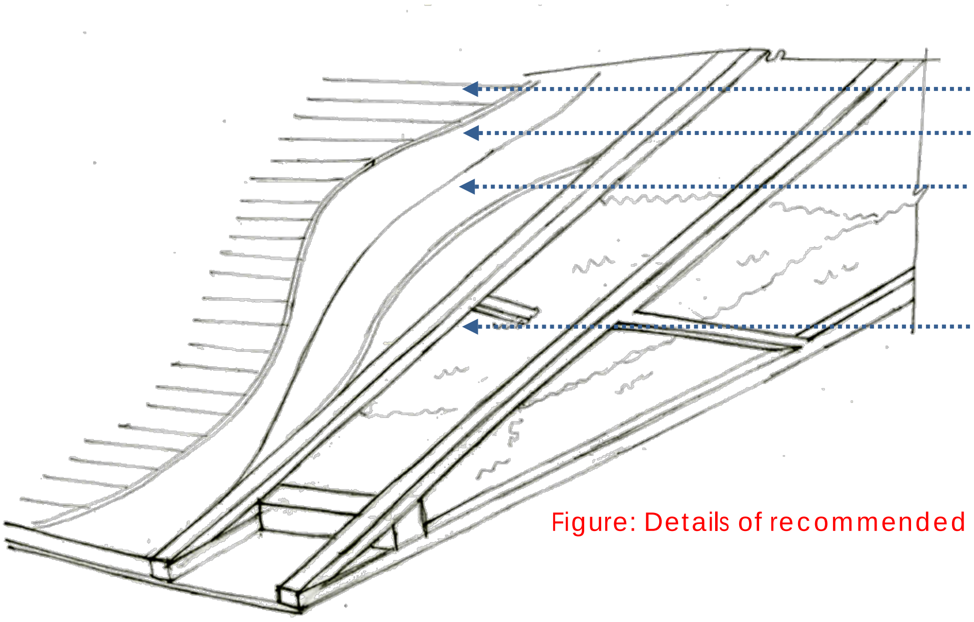


Figure: Details of recommended attic insulation (R-60)

The table below shows the increase/ decrease in energy usage- cost due to attic insulation upgrade. From the results it is clear that increasing only attic insulation will not reduce heating-cooling load. It is decreasing HERs index by 1. This strategy was combined with AG SIP recommendation to check if results are better in conjunction. These results from combination are also shown in the table and it is noted that increasing attic insulation by R value of 12 will not lead to any significant reduction apart from reduction in HERs index.

Impact from strategies	**Annual Heating (MMBtu/yr)**	**Annual Cooling (MMBtu/yr)**	**Annual Water (MMBtu/yr)**	**Annual Energy Cost ($/yr)**	**HERS score**
Baseline	35.3	9.4	15.2	1578	63
1. Attic(R60 insulation)	32.8	10	15.2	1556	62
Reduction/increase by 1:	**-2.5**	**+0.6**	**0**	**-22**	**-1**
2. Attic + AG wall upgrades	25.9	9.6	15.2	1477	55
Reduction/increase by 2:	**-9.7**	**+0.2**	**0**	**-103**	**8**

Table: Increase/ decrease from 'Attic insulation upgrade (1)' and 'AG wall + Attic insulation upgrade(2)'

Frame floor Insulation:

Original design has the 'superior wall' for basement and we recommend using same technology as it is efficient system. The design does not insulate the frame floor between basement and first floor. Since, we have excluded basement from thermal boundary (conditioned space) we recommend adding R-30 Fiberglass blanket insulation to the floor. The results by this change are shown in the table below.

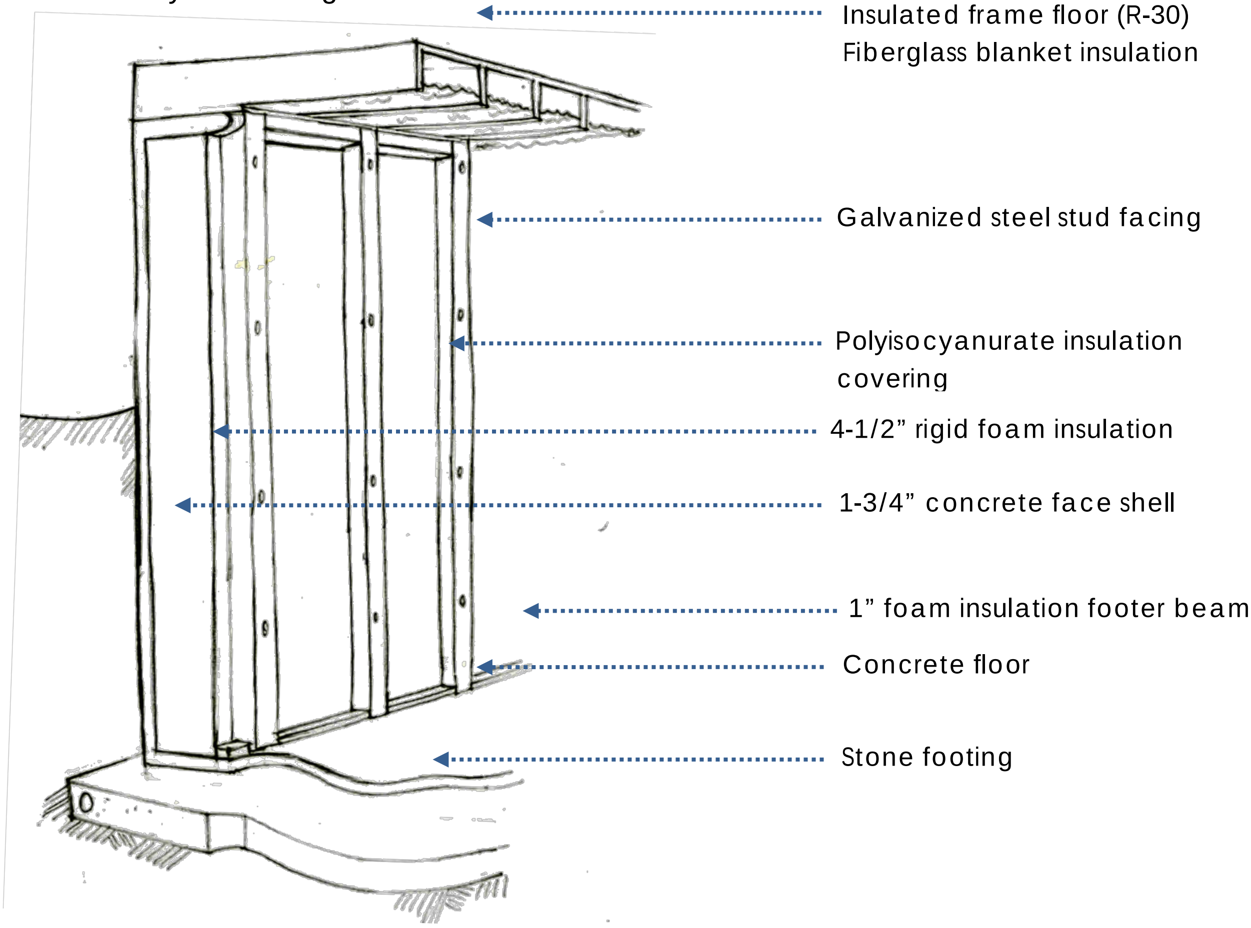


Figure: Details of recommended a basement frame floor and wall system

Impact from strategies	Annual Heating (MMBtu/yr)	Annual Cooling (MMBtu/yr)	Annual Water (MMBtu/yr)	Annual Energy Cost ($/yr)	HERS score
Baseline	35.3	9.4	15.2	1578	63
Frame floor insulation (R-30)	33.1	10	15.2	1559	62
Reduction/increase by 1:	**-2.2**	**+0.6**	**0**	**-19**	**-1**
2. Attic + AG wall +Floor upgrades	23.5	10.3	15.2	1456	54
Reduction/increase by 2:	**-11.8**	**+0.9**	**0**	**-122**	**9**

Table: Benefits from 'Frame floor insulation strategy-1' and ' Attic+ AG wall+ floor upgrades- 2'

From these results the need to insulate floor between basement and 1st level is clearly seen. The table also shows combined benefits obtained from all the recommendations made so far.

Windows:

The baseline considered windows that comply with minimum energy star requirements. In order to reduce energy loads further, we looked at more efficient windows with lower U-values. Followings are the details of the selected product.

Window Specifications:
Manufacturer: Marvin doors and windows
U-value: 0.23 btu/ (h°F ft2)
SHGC: 0.35
Description: Triple glazed argon filled, low e coating
Energy star certified

The table below shows the increase/decrease in energy consumption and cost from window upgrades

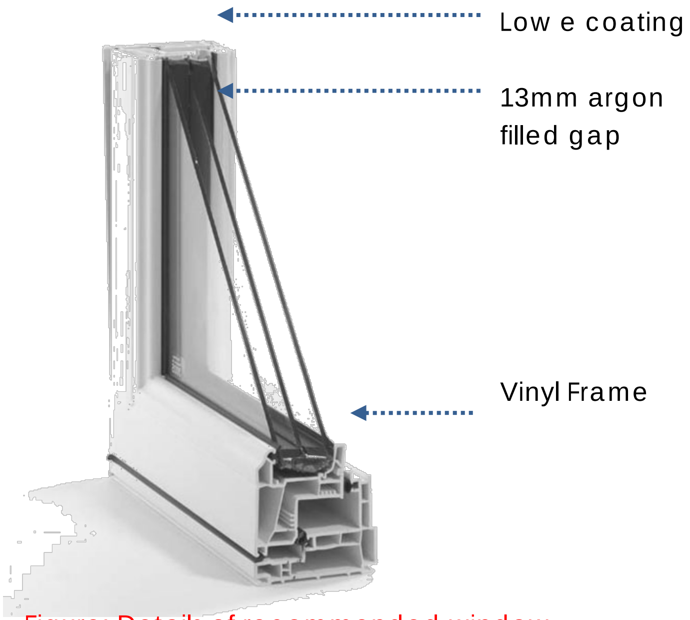


Figure: Details of recommended window

Impact from strategies	**Annual Heating (MMBtu/yr)**	**Annual Cooling (MMBtu/yr)**	**Annual Water (MMBtu/yr)**	**Annual Energy Cost ($/yr)**	**HERS score**
Baseline	35.3	9.4	15.2	1578	63
Window upgrades	31.6	9.5	15.2	1538	61
Reduction/increase by 1:	**-3.7**	**+0.1**	**0**	**-40**	**-2**
2. Attic + AG wall +Floor +Window upgrades	22.0	9.6	15.2	1435	53
Reduction/increase by 2:	**-13.3**	**+0.2**	**0**	**-143**	**-10**

Table: Benefits from 'window upgrades-1' and 'Attic+ AG wall+ floor+ windows upgrades- 2'

Above results prove the benefits of window upgrades. Even with the individual window upgrades, energy demands could be reduced significantly. When all the envelope upgrade strategies were combined and results were compared with the baseline huge reduction in energy cost, demand and HERS index was noted.

After testing individual strategy and their impact on energy reduction, we recommend changing standard AG wall construction to SIP construction. This has been the most effective strategy for envelopes. Making all the recommended upgrades resulted in reduction in design loads and this helped us further in reducing size of mechanical equipment.
The highlighted cells in the table show results from all recommended envelope upgrades.

After working with the Upgrades to the Envelope, the next step was to work to make the home more efficient by incorporating efficient HVAC and mechanical systems that shall reduce the overall energy consumption.

HVAC & Mechanical equipment:

AS part of our proposal, we aimed at incorporating a variable Energy Recovery Ventilator combined with a Geothermal pre-heat/pre-cool system which shall ensure maintaining comfortable temperature ranges throughout the year.

Case Study: Solar Harvest, Boulder Colorado

The Solar Harvest designed by the EcoFutures firm in Colorado is a Net Zero Energy home which has a HERS score of -3 as it produces more electricity than it consumes.

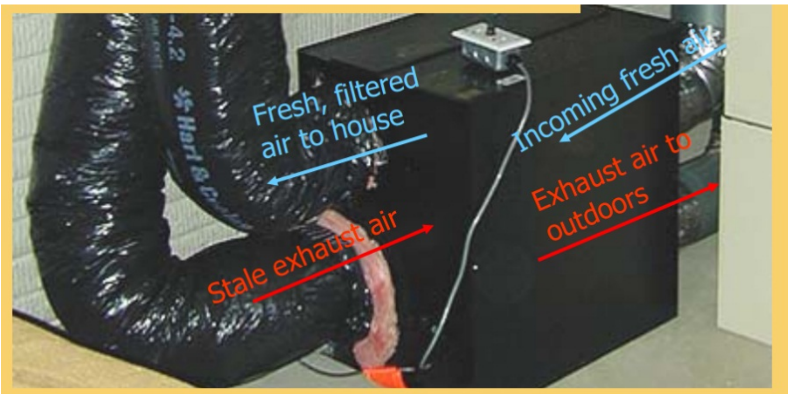
This is majorly possible due its highly efficient HVAC system.

The system used is the UltimateAir RecoupAerator 200DX which is a variable ERV system combined with a geothermal heat pump system. Considering the city of Boulder experiences a more humid climate compared to Pittsburgh , they used a Coolerado high efficiency fan unit which need not be installed in the city of Pittsburgh.

The major features of this project that further aided lowering the utility bills were:

- Using the shading provided by natural vegetation on both east and west facades
- Shading the south roof using solar panels
- Allow the chimney stack effect to enable air movement

The ERV lowered the monthly utility bills to a mere $18 .



The HVAC study was carried out with two major aspects:

1. Study of HVAC equipment requirements if we just added Geothermal systems to the existing baseline case as obtained from the architects.

2. Study of HVAC upgrade impact when added to the building along with the recommended envelope upgrades.

Impact from strategies	Annual Heating (MMBtu/yr)	Annual Cooling (MMBtu/yr)	Annual Water (MMBtu/yr)	Annual Energy Cost ($/yr)	HERS score
Baseline	35.3	9.4	15.2	1578	63
Geothermal +ERV only	34.5	9.8	15.2	1439	52
Reduction/increase by 1:	**-0.8**	**+0.4**	**0**	**-139**	**-11**
2. Envelope uprgrades + HVAC	16.7	10.5	15.2	1261	43
Reduction/increase by 2:	**-18.6**	**+1.1**	**0**	**-317**	**20**

Table: Benefits from HVAC Upgrades: Geothermal Heat Pump + Variable ERV

The above table exemplifies the importance of an effective HVAC system. Just by adding a geothermal heat pump system and a Variable ERV, we are able to obtain a considerable reduction in the HERS score but not a significant reduction in the heating and cooling loads. When combined with the recommended envelope upgrades there is a significant reduction in the heating load which can largely be attributed to the geothermal system that is situated in the ambient scene with just the ERV located inside the basement.

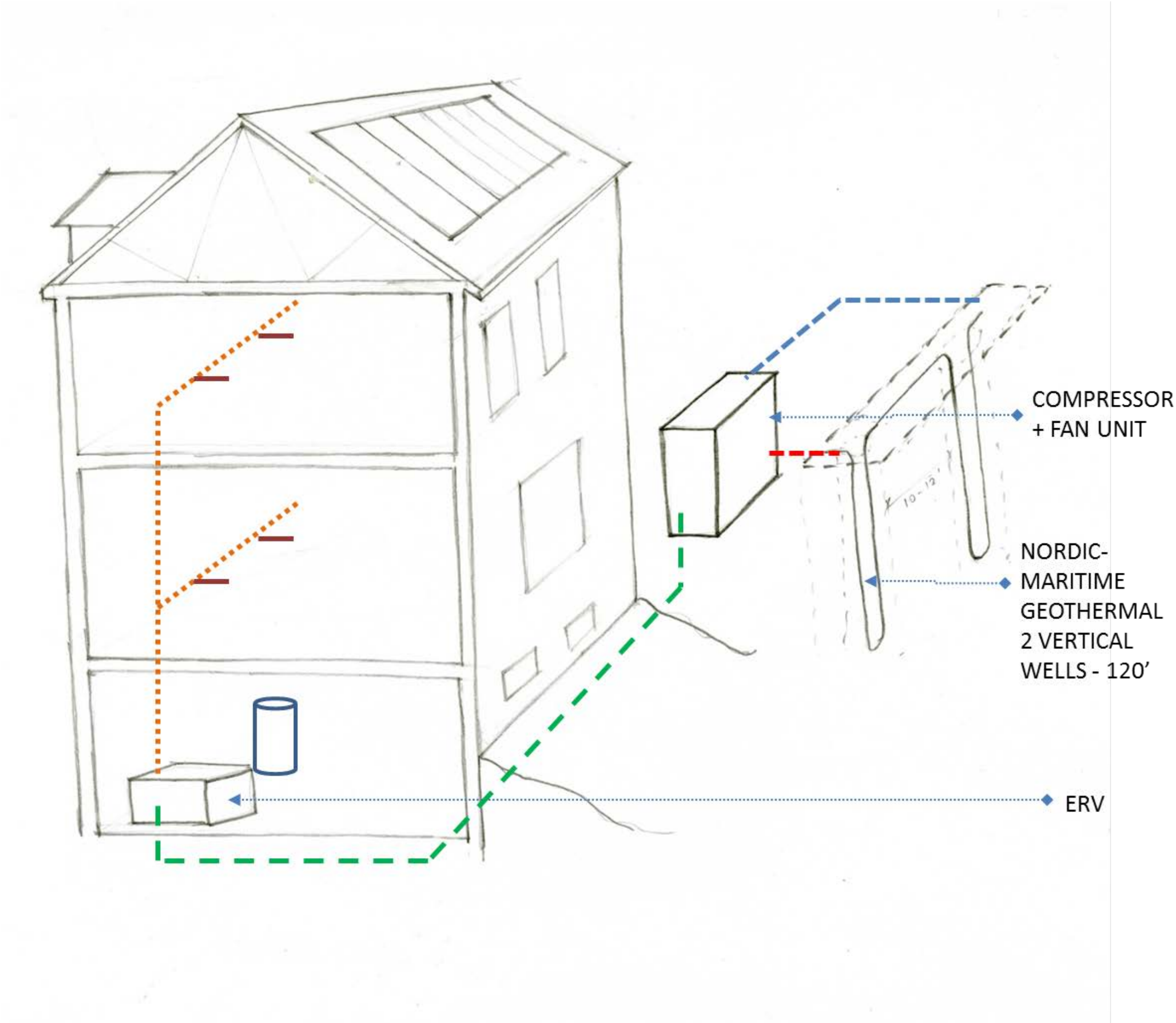


Figure 5: Schematic diagram of HVAC systems & Ducting

Cylinder	DHW Storage unit	Blue dashed line	Cold line from Compressor to geothermal loop	Orange dotted line	Supply duct to conditioned floor
Red dashed line	From closed loop geothermal to compressor unit	Green dashed line	Air line to ERV from Compressor unit	Brown solid line	Supply to individual inlet grill

The figure on the previous page denotes the location of mechanical equipment in the housing unit. The ERV is located in the basement which is connected to the external fan and compressor unit which are in turn connected to the vertical geothermal loops.

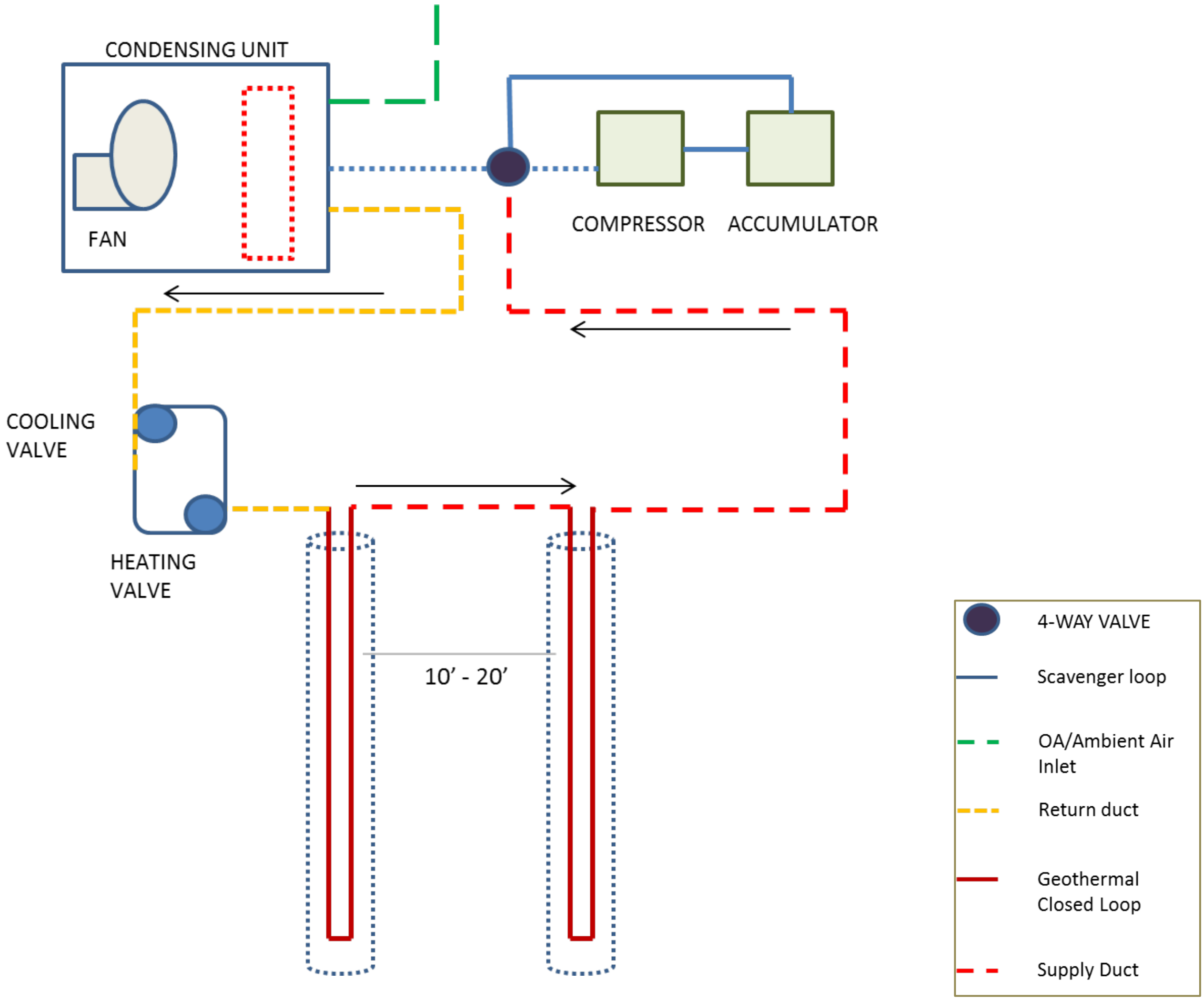


Figure 6: Layout of Geothermal system

The system suggested for this project is the UltimateAir RecoupAerator 200 DX which is the Direct Exchange series as the Variable ERV.

Sensible Recovery efficiency – 81%

Total Recovery Efficiency – 49%

Fan Rate @ 64 cfm: Fan watts = 49 W

For the Geothermal system, the NORDIC DX-Series Geothermal systems are recommended for both stages of study. In the initial phase of analysis, it is observed that though the system can be used, it effectively does not satisfy the sizing requirements as the heating and cooling loads are higher than the capacity of the available GHPs. This leads to unavoidable oversizing of equipment. This further advocates the need for envelope upgrades to reduce the energy consumption.

Figure 7: NORDIC DX 25/45

Advantages of using the NORDIC equipment compared to conventional geothermal systems:

1. Smaller well diameter : 3” (typically 6”)

2. Lesser loop length: well depth required is reduced to 120’ (conventional systems require 150’)

The system creates a scavenger loop that allows for waste heat to be recovered and recycled in the loop.

For the proposed upgrades, a 2-ton system is recommended as it is the smallest sixe of Geothermal Heating system available

For the Hot water systems, no upgrades are suggested due to two major reasons:

1. the Gas furnace system for DHW is efficient as it satisfies Energy star v3.

2. the site to source conversion for electricity is much higher as compared to natural gas. This encouraged the use of the specified gas furnace without having to install any further upgrades.

Appliances:

The appliances and plug loads play a major role in determining the energy consumption of any home. These are the general phantom loads as they are invariably left switched on and are necessities that cannot be done without.

The basis of this project is to adhere to the principles of Zero Energy Housing which satisfies the criteria specified by Energy star version 3. To satisfy the requirements specified by Energy star, the appliances have been chosen according to the minimum requirements so that the equipment aren't overpriced as well and are still as efficient as most energy star certified equipment.

CFLS: The Energy Star v3 asks for 80% CFLs in the living spaces. To provide for better lighting conditions and higher efficiency, GES CFL bulbs are recommended. These bulbs are comparatively cheaper and have a high lumen output which shall ensure the quality of light isn't diminished in any way. 0% of the lights are still modelled as pin-source lights.

Refrigerator: The refrigerator is chosen keeping in mind the popularity of brands and the company's reputation and commitment to lowering carbon footprint of a home. The refrigerator suggested is the Whirlpool refrigerator (Energy Star approved):

- Top-mounted freezer
- Auto Defrost
- No through-the door Ice service
- Capacity: 21.2 cu.ft
- Estimates annual electric consumption: 364 kWh
- Estimated yearly operating cost: $39

Washer & Dryer: Typically the instant choice of most homeowners is to opt for a front load washer and dryer. As part of this proposal, a top load washer and front load dryer are recommended.

- The top load washer has a lower Water use for the same capacity as that of front load washer
- More cost effective as for the same capacity and washer MEF, the front load is 1.5 times costlier.
- This allows for more clothes washed
- The dryer used is an electric front load dryer with moisture sensing, to reduce the number of cycles.

Recommended washer & dryer:

Samsung: 4.5 cu.ft King-size high efficiency top load washer – WA456DRHDWR/AA

- MEF: 2.45
- Energy consumption: 169 kWh/yr
- Energy Star approved
- Max. Spin speed: 1000 RPM

Samsung: 7.2 cu.ft Electric front load dryer – DV400EWHIDWR/AA

- Moisture sensing
- Energy consumption: 24 kWh
- Dryer Efficiency: 3.01

Dishwasher: The Bosch standard dishwasher is recommended as it is uses lesser water and is cheaper compared to a compact washer.

Details: Bosch SHE68E05UC

- Annual Energy use: 180 kWh
- Energy Factor: 1.19
- Water used: 2.22 Gallon per cycle

Figure 8: Energy Star approved appliances

Impact from strategies	Annual Heating (MMBtu/yr)	Annual Cooling (MMBtu/yr)	Annual Water (MMBtu/yr)	Annual Energy Cost ($/yr)	HERS score
Baseline	35.3	9.4	15.2	1578	63
1. Envelope uprgrades + HVAC+ Appliances	17.2	10.1	14.3	1211	41
Reduction/increase by 1:	**-18.1**	**+0.7**	**-0.9**	**-367**	**22**

Table: Benefits from Lighting and Appliance upgrades (complying to Energy star)

Onsite renewable energy: Solar panel

after reducing energy needs of the house by improvements in HVAC and envelope we also explored the solar panel systems and measured benefits of their use. The solar panel selection was driven by two factors cost and efficiency. The selected solar panel system is Hyundai's MG-series. This system would be appropriate as it is less expensive and has high module efficiency. The detailed information of solar panels is given below:

Manufacturer: Hyundai MG-Series-Poly crystalline
Peak power per panel: 230 watts
Panel size: 3.2'x 5.3'
Array area: 152.6 Sf
Array tilt: 45
Cost per panel: $280
Module efficiency: 14.2
Cost of array: $2520

Figure: recommended PV panel

Southeast side of the roof is chosen for PV panel installation. This side will produce maximum solar energy considering its optimum location. The available roof area for PV installation is 279 SF. Total number of panels that could be accommodated in this area are 9, giving total array peak power of 2070 watts.

Impact from strategies	Annual Heating (MMBtu/yr)	Annual Cooling (MMBtu/yr)	Annual Water (MMBtu/yr)	Annual Energy Cost ($/yr)	HERS score
Baseline	35.3	9.4	15.2	1578	63
PV panels	33.2	10	15.2	1294	51
Reduction/increase by 1:	**-2.1**	**+0.6**	**0**	**-284**	**-12**
2. Envelope+ HVAC+Pv panels	17.1	10.2	14.3	945	30
Reduction/increase by 2:	**-18.2**	**+0.8**	**0.9**	**-633**	**-33**

Table: Benefits from 'PV panel-1' and 'Envelope+ HVAC+ PV panels- 2'

The above table describes individual benefits of PV panel installation. PV panel installation is a good strategy to reduce HERS score and annual energy cost as considerable amount of energy will be generated on site (7.6 MMBtu/ yr). Even though PV panel is a relatively expensive technology, by use of recommended panels estimated payback period is 9.5 years. Hence, PV installation is feasible technology to achieve high energy efficiency. Considering all the upgrades and PV installation, annual site and source energy consumptions table was created and results were compared with the baseline annual consumption. Table below shows results with all upgrades on baseline and impact of PV panel installation.

	Site Energy (include renewable energy consumed)			Source Energy		
	MMBTUs	**MJ**	**kWh**	**MMBTUs**	**MJ**	**kWh**
Natural gas,	21	22393.6	**6,270**	46	24453.78	6,847
Electricity	21	21765.7	**6,094**	70	73241.62	20,508
Total Energy Consumed (kWh)	42	44,159	12,365	116	97,695	27,355
Renewable Energy	**MMBTUs**	**MJ**	**kWh**			
Produced on site	7.6	7952.9	2,227	26	26,761	7,493
Total Energy (Total consumption-On site production)	35	36206.4	10,138	90	70,934	19,862

Site EUI: 13.9 Mbtu/ft2 ; Source EUI:35.8 Mbtu/ ft2

Table : Energy balance sheet with site and source energy breakdown

The site energy consumption with all upgrades is 42MMbtu and source is 116MMbtu. After introduction of PV panels, energy requirements further reduced to 35 MMBtu and giving total source energy of 90MMbtu.

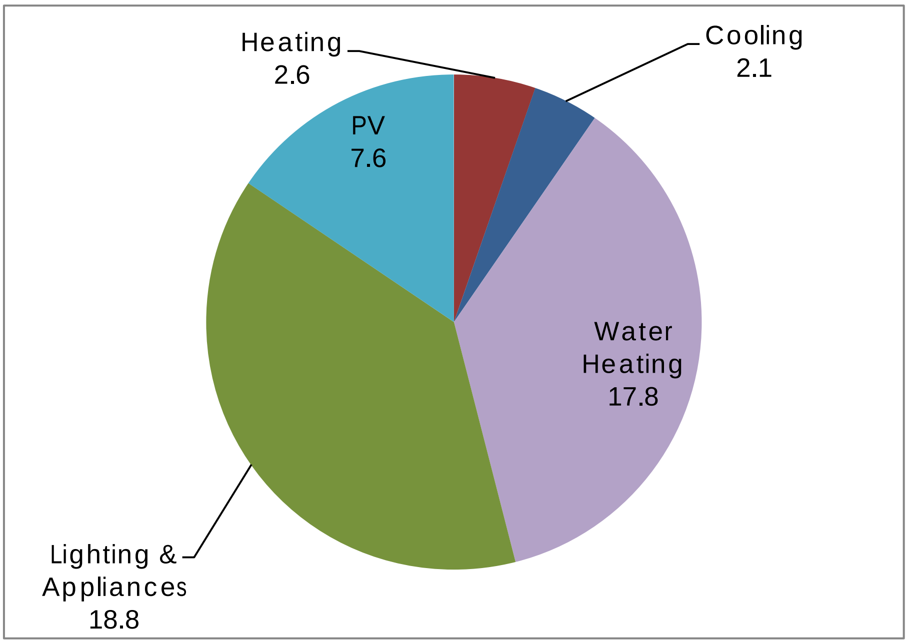


Table : Annual load breakdown for design case

The above piechart shows the energy use breakdown. Compared to baseline heating requirements were reduced drastically. The PV contribution is also seen in the pie chart. The maximum energy consumer is lighting and appliances. This factor is subjective and relies on occupant behaviour to large extent. Also, REM-RATE does not have provision where occupant behaviour can be controlled or tested. Hence, we could not predict benefits due to sensible plug load, appliance use.

Proposal II:

As part of this proposal, conversion of the existing detached single family unit layout to a joint townhouse scheme is suggested to highlight the possible benefits of common wall construction which might allow for further savings through reduced heat loss or heat gain through exposed surfaces.

The existing layout is as depicted in the picture below:

The 3 types of units are each assigned a number 1-3 and arranged in sequence accommodating only 6 units. The setbacks are fixed based on the zoning codes and these assumptions help create a tentative layout.

Figure 9: Tentative layout: Baseline design

Our proposal aims at creating a townhouse scheme by combining the longer edges of the houses. This scheme allows for increasing the number of houses by 3 to a total of 9 houses. This increase in number of units has the following advantages:

1. Common wall construction : lesser material cost

2. Faster construction

3. Reduced Heat loss/Gain through the exposed wall surfaces and reduced glazing allowing for reduced solar heat gain through fenestrations.

4. More number of units in the same plot area :Denser communities

This layout is depicted in the figure below.

Figure 10: Proposed townhouse scheme layout

Common wall assembly detail:

We are proposing SIP wall construction for town house proposal. In order to check feasibility of this system as common wall, we studied some cases where this system is already used. The challenges associated with common walls in townhouse are fire and acoustic proofing. As SIP walls have higher ability to perform against fire and acoustical issues, these issues were already taken care of to some extent. To give additional fire and acoustical protection we recommend adding 3M's fire barrier in the cavity between two walls and Acoustical mat. The details of this assembly are shown in the figure below:

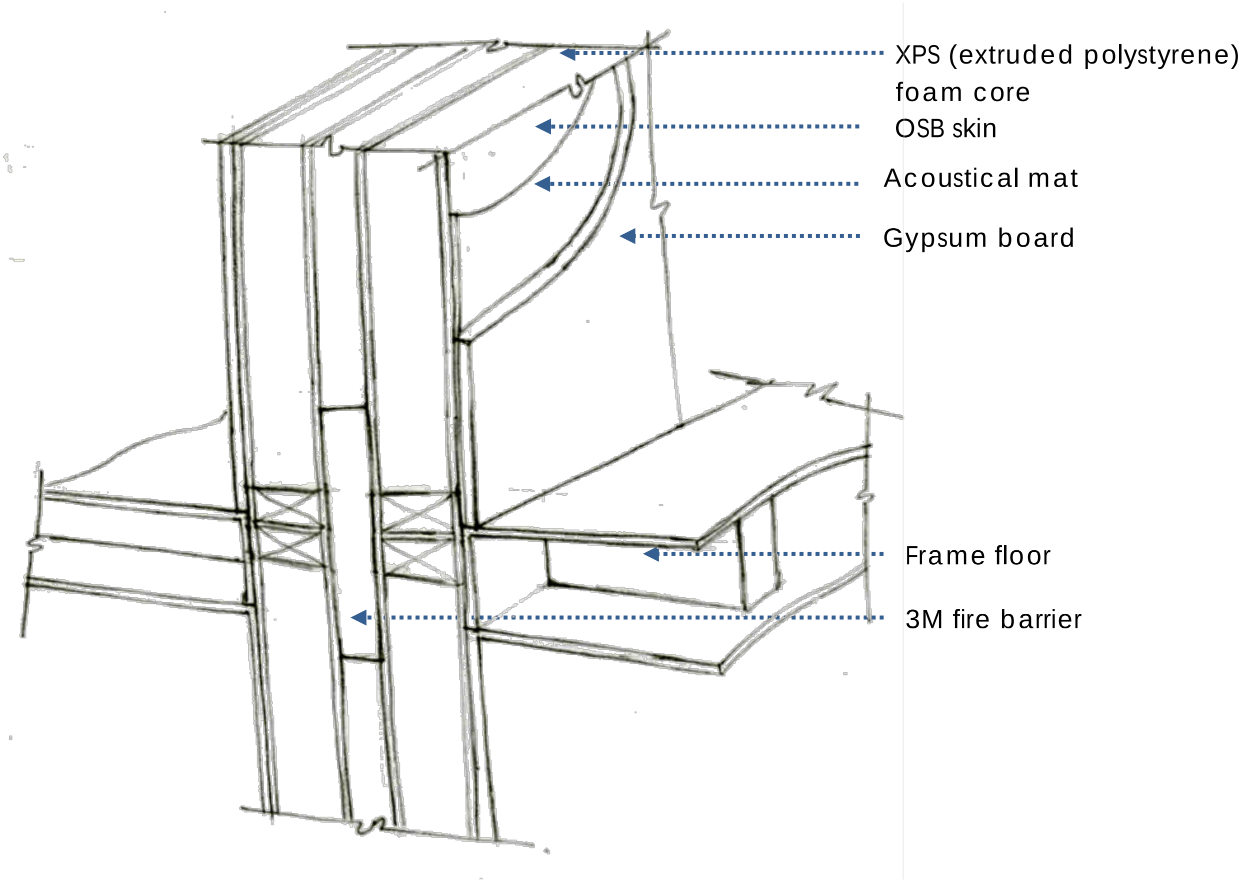


Figure 11: Common Wall SIP construction detail

The scheme was further tested in two stages:

1. Applying the scheme directly to the baseline design without any upgrades

2. Applying the scheme after all the design upgrades are tested individually.

Impact from strategies	Annual Heating (MMBtu/yr)	Annual Cooling (MMBtu/yr)	Annual Water (MMBtu/yr)	Annual Energy Cost ($/yr)	HERS score
Baseline	35.3	9.4	15.2	1578	63
Baseline-Townhouse scheme	29	9.1	15.2	1250	63
Reduction/increase by 1:	**-6.3**	**-0.3**	**0**	**-328**	**0**
Townhouse scheme with all upgrades	14.8	9.5	14.3	921	31
Reduction/increase by 2:	**-20.5**	**+0.1**	**-0.9**	**-657**	**-32**

Table: Benefits from converting to townhouse layout

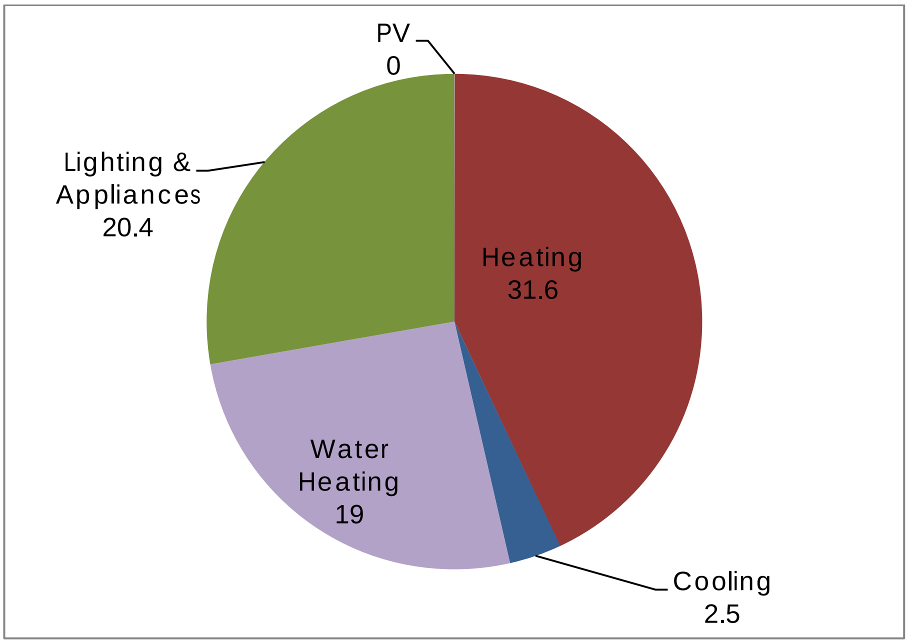
As exemplified by the above impact assessment table, the conversion to a townhouse layout is a complete win-win solution to the project.

ENERGY BALANCE SHEETS FOR PROPOSAL II:

	Site Energy			Source Energy		
	MMBTUs	MJ	kWh	MMBTUs	MJ	kWh
Natural gas,	51	52,949	**14,826**	53	55,438	**15,523**
Electricity	23	24,068	**6,739**	77	80,387	**22,508**
Total Energy Consumed (kWh)	74	77,017	**21,565**	130	135,825	**38,031**

Table : Energy balance sheet with site and source energy breakdown for Baseline Townhouse scheme

Site EUI: 43.4 MBtu/sf | Source EUI: 76.67 MBtu/sf



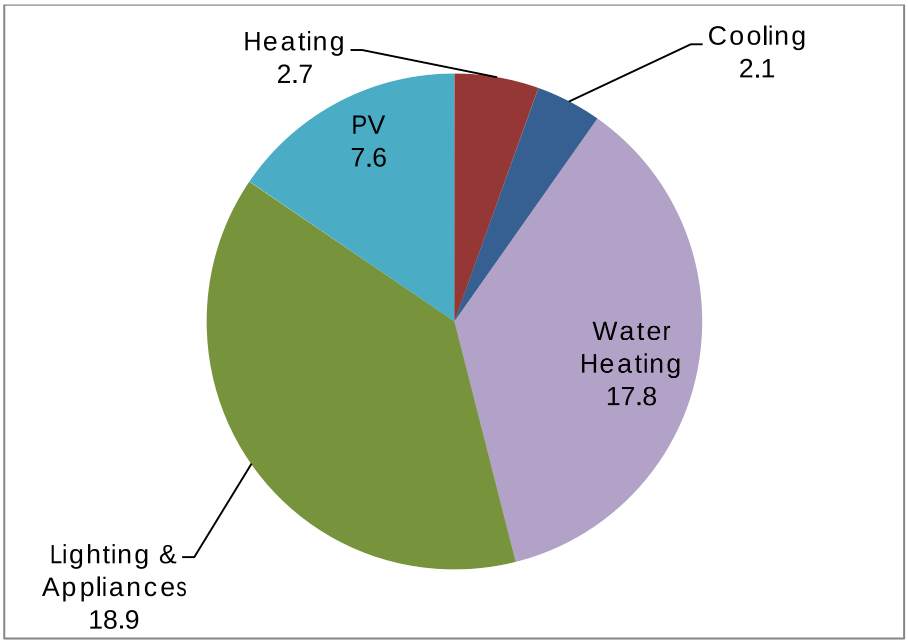
Annual Energy Consumption Breakdown – Baseline Townhouse scheme

The above graph depicts the slight reduction in energy consumption as compared to the baseline detached housing. This introduces the case for combined housing as the benefits have been proven to be widespread.

	Site Energy (include renewable energy consumed)			Source Energy		
	MMBTUs	MJ	kWh	MMBTUs	MJ	kWh
Natural gas,	17.8	18,626	**5,215**	18.6	19,502	5,461
Electricity	23.7	24,800	**6,994**	79.1	82,833	23,193
Total Energy Consumed (kWh)	41.5	43,427	**12,160**	97.7	102,335	28,654
Renewable Energy	**MMBTUs**	**MJ**	**kWh**	**MMBTUs**	**MJ**	**kWh**
Produced on site	7.6	7953	2,227	26	26,761	7,493
Total Energy (Total consumption-On site production)	33.9	35474	9,933	71.7	75,574	21,161

Table : Energy balance sheet with site and source energy breakdown for Baseline Townhouse scheme with upgrades

Site EUI: 24.5 MBtu/sf | Source EUI: 57.76 MBtu/sf



Annual Energy Consumption Breakdown – Baseline Townhouse scheme with all upgrades

This piechart outlines exactly how drastically the energy consumption by heating is reduced once the design is converted to a townhouse layout with all the recommended upgrades.

This leads us to ascertain the credibility of our proposal especially the recommendations for the various upgrades each described in earlier sections.

- It adds to the proposition as it increases the number of housing units
- Reduces the annual heating energy consumption by 20 MMBtu per household
- This allows for a creation of a community geothermal well system thereby reducing the number of wells required to meet the required heating loads
- Even solar PV could be installed as a community array thereby reducing the costs and increasing tax benefits.
- Helps create a more vibrant society.

The above reasons help conclude that though the project doesn't reach Zero Energy, it is possible to impact the energy consumption drastically by simply creating a tighter house with better insulation, envelope assemblies and investing in efficient appliances. Solar PV and Geothermal though are the major contributors to the energy reduction can be a choice in case the budget is too tight.