Greening Greensburg:
Affordable and Sustainable Home Designs

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On May 4, 2007 an EF5 tornado nearly two miles wide and packing winds of up to 205 mph, cut a swath through Greensburg, KS, leveling 95% of the town's buildings and leaving the rest uninhabitable.

Miraculously, only twelve people were killed

Goal One: Design Affordable, Livable and Healthy Homes

Strategy 1: Size Matters--Create simple, compact “not so big” houses that feel large (via the use of ceiling height variety, built-in storage, contrasts of light, color and material, activity zoning and spatial layering and spatial hierarchy, long sight lines, forced perspectives, outdoor rooms that extend interior space, and so on)

Strategy 2: Design for high efficiency off-site manufacturing (Xtreme Homes)

Strategy 3: Use non-toxic, environment friendly building materials

Goal Two: Design Energy Efficient, Climatically Adapted Passive Homes

Strategy 1: Create well insulated building envelopes (SIPS & ICFs)

Strategy 2: Let the winter sun in and block the summer sun

Strategy 3: Use large amounts of interior thermal mass to store solar warmth and "coolth" for night time and cloudy days

Strategy 4: Provide for cross and stack ventilation

Strategy 5: Use energy efficient appliances and lights

Strategy 6: Use whole house fans and "earth-air tubes"

Goal Three: Design each home for maximum use of Building Integrated Photovoltaics (BIPVs) to meet all energy demands

Strategy 1: Provide maximum possible south-facing roof area for installation of Uni Solar laminate photovoltaics (on insulated standing seam steel roofs)

Strategy 2: Use ground source (geothermal) heat pump for heating, cooling and domestic hot water)

Course Outcomes

1) Exhibition of Home Designs
2) Greening Greensburg: Affordable and Sustainable Home Designs (Books and CDs)
3) A demonstration House as part of the Greentown Greensburg “Chain of Eco-Homes”

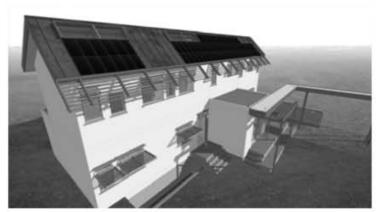
Mid-Term Review at the 5.4.7 Arts Building, Greensburg, KS

Mid-Term Review November 2, 2008

Mid-term Review, November 2

Final Presentation to Advisory Board, Sunday, December 14, 2008

Final Presentation, December 14, 2008

GREENING GREENSBURG

AFFORDABLE and SUSTAINABLE HOME DESIGNS

KANSAS STATE UNIVERSITY DEPARTMENT OF ARCHITECTURE STUDIO 108

edited by Gary J Coates

On May 4, 2007 an EF5 tornado, nearly two miles wide, with winds of up to 205 miles per hour, cut a swath through Greensburg, KS, leveling 95% of the town's buildings and leaving most of the rest of them uninhabitable. Some fourteen hundred people were left homeless. Miraculously only twelve people were killed by this catastrophic tornado.

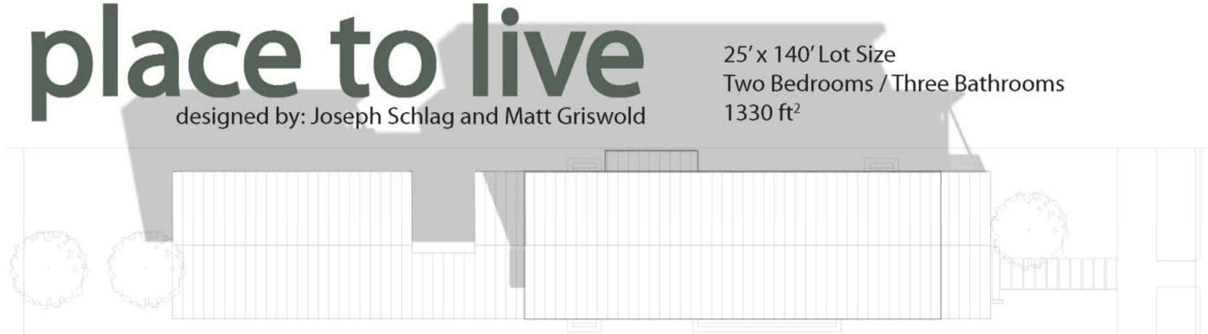
With great courage and vision, as well as full support from Kansas Governor Kathleen Sebelius and various agencies of the Federal government, Greensburg decided soon after the storm to rebuild itself as a model sustainable community for the twenty-first century. Toward that end, the town has already accepted a comprehensive plan prepared by the environmentally-oriented architecture and planning firm of BNIM in Kansas City as the basis for reconstruction. In addition, several green building projects are currently underway, including LEED Platinum designs for the John Deere dealership, the General Motors facility, the Sun Chips Business Incubator, the Kiowa County Hospital, and Greensburg High School. Already completed is the 5.4.7 Arts Studio, the state's first LEED Platinum building, which was designed and built by students from the University of Kansas. At present Greensburg is on track to have the greatest concentration of LEED certified buildings of any town in America.

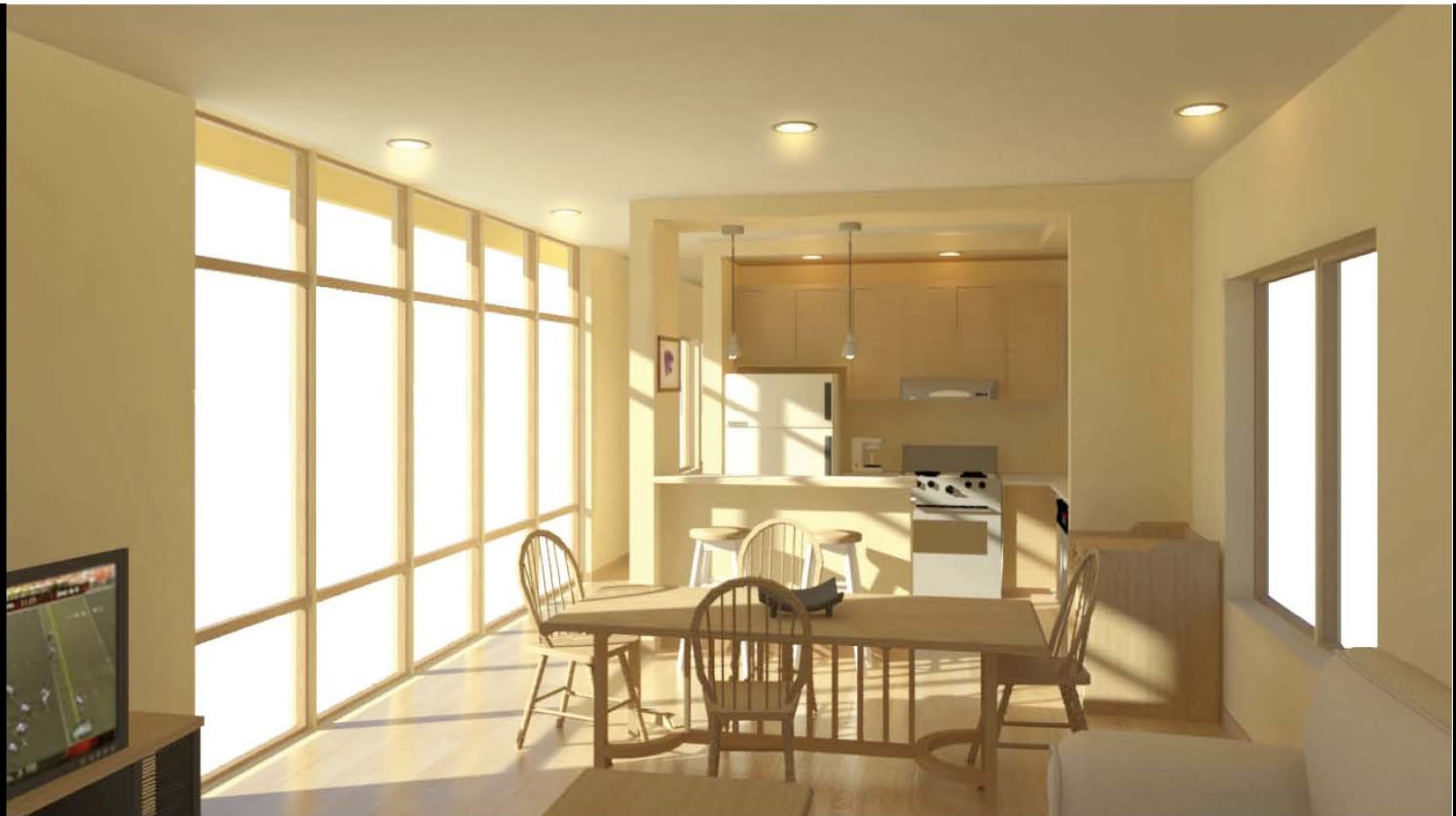
Perhaps the most daunting task facing Greensburg, however, is building affordable, beautiful and sustainable housing. During fall semester 2008 twelve graduate students enrolled in Architecture Design Studio 7 led by Professor Gary J. Coates joined forces with Daniel Wallach, Emily Schlickman and Mason Earles of Greensburg Greentown, a non-profit agency dedicated to rebuilding the town sustainably, to take on this particular challenge. Working with an Advisory Board comprised of town officials, area residents, members of Greensburg Greentown, and representatives of the business community, Kansas State students did background research and developed designs over the course of the entire semester.

a place to live

designed by: Joseph Schlag and Matt Griswold

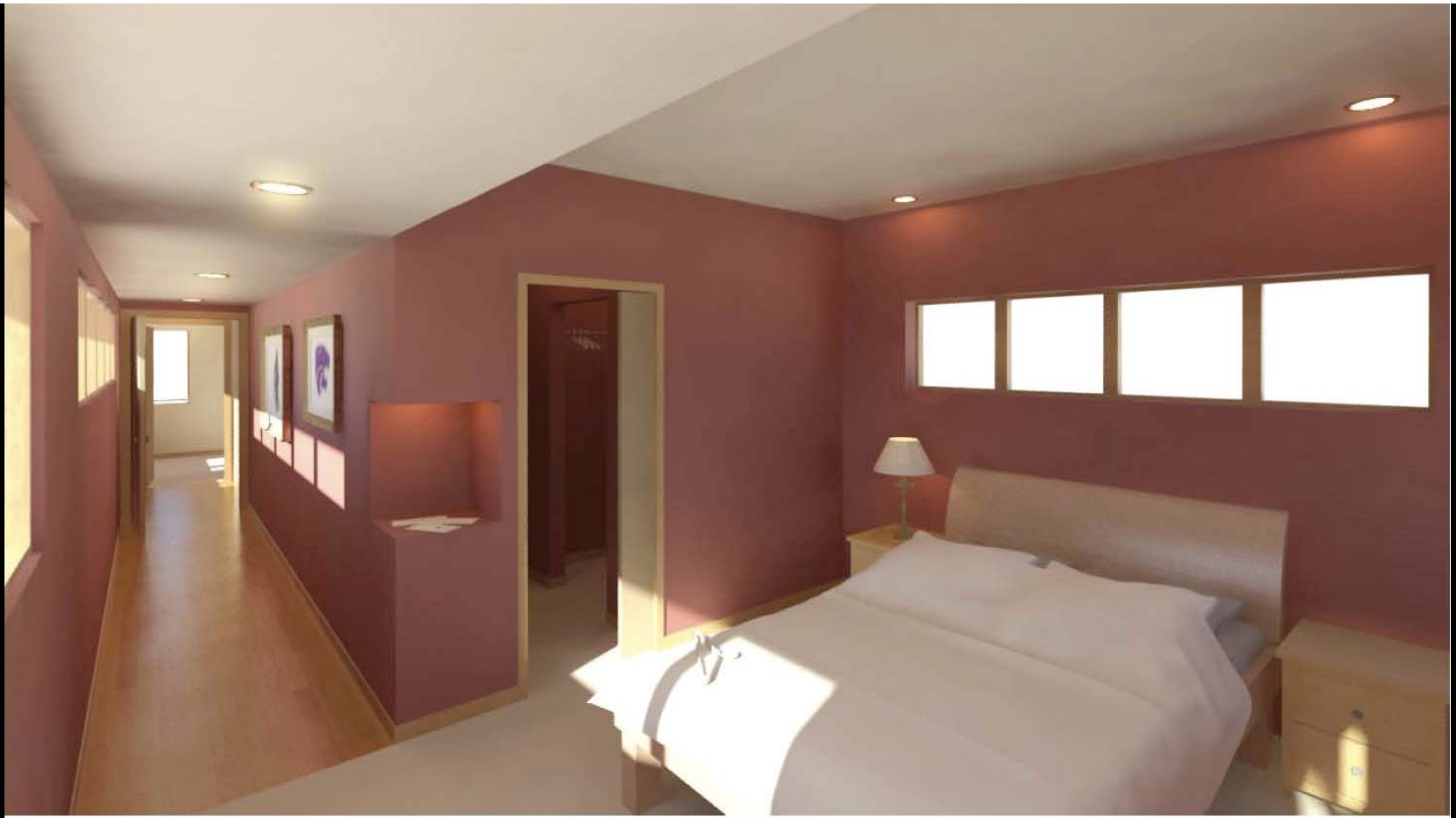
25' x 140' Lot Size
Two Bedrooms / Three Bathrooms
1330 ft^2





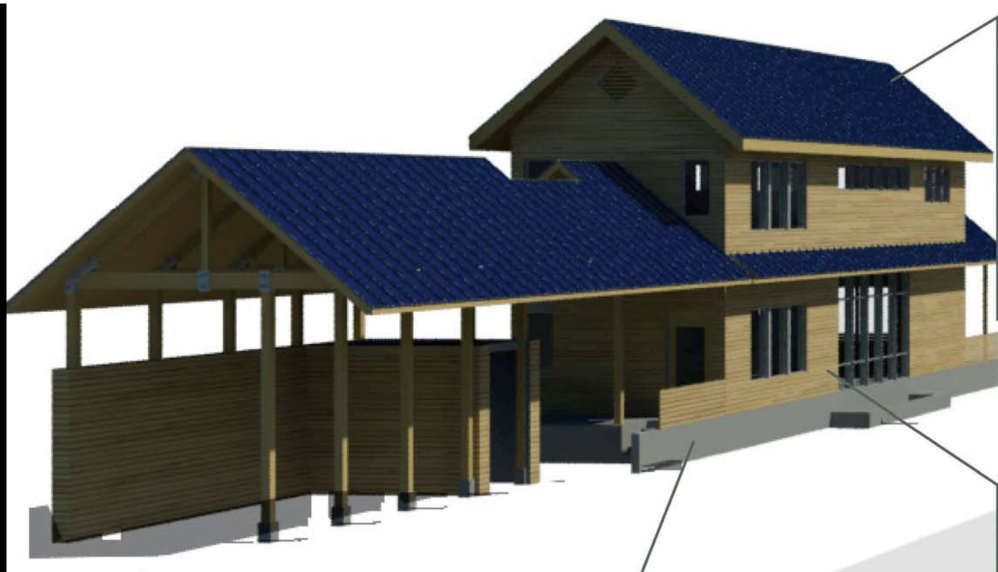
The house is designed around a single loaded corridor, one of the most efficient ways to layout spaces in a narrow house. This clear circulation space, which is located along the south wall, is always showered with light that flows into the other spaces, providing a well lit, warm interior environment. When entering from the street, the living, dining, and kitchen space create a large public realm devoid of partitions and visual obstacles.

Instead of walls, ceiling heights are used to call out where spaces begin and end. The kitchen is marked by a lower ceiling that visually separates the spaces of the public realm. By contrast the ceiling is raised higher than normal in the living and dining rooms to help create a comparatively more spacious environment.

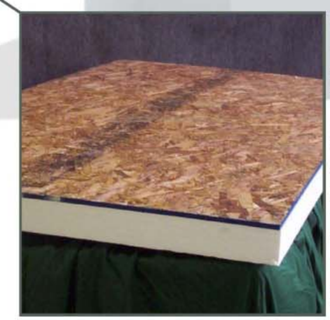


By freeing up all this space on the first floor and creating such a large public realm, two spacious bedrooms occupy the second floor. The master suite is joined to the stairs by a sun lit gallery space and provides a large walk in closet. The other bedroom is designed to be flexible in use, and is close enough to the master suite, yet still provides a degree of separation, so that it can be used by young children or teenagers.

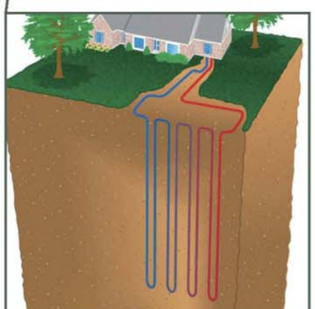
The basement is left mostly unfinished, but is designed with window wells to provide ultimate flexibility in future use. For example, if the basement was finished later and used for bedrooms, they would all have adequate access to fire escapes, sunlight and natural ventilation. In this case this design could accommodate up to five bedrooms.



Building integrated photovoltaics convert the sun's energy into energy the house can use. By being building integrated they also blend better with the standing seam metal roof.



Structural insulated panels take all the hassle out of stick built construction and provide higher insulative values. Higher levels of craftsmanship are possible by producing these offsite.



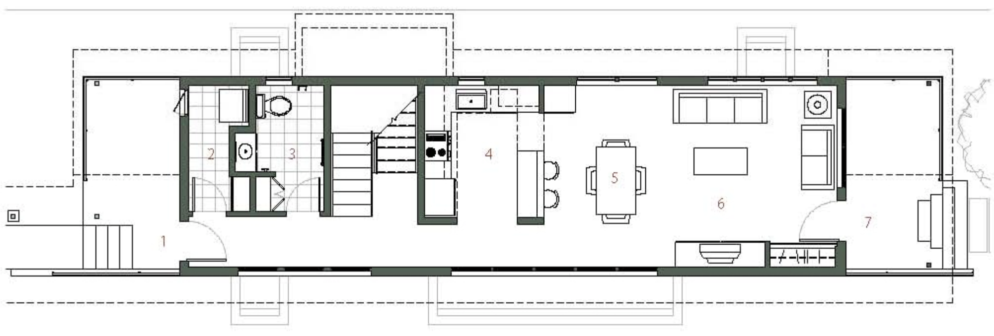
Geothermal heat pumps use the near constant temperature of the earth to provide heating and cooling in a much more responsible, economical way than traditional methods.

Insulating concrete forms provide heavily insulated, strong walls. The assembly method helps to protect against water penetration and better insulates from sound as well.

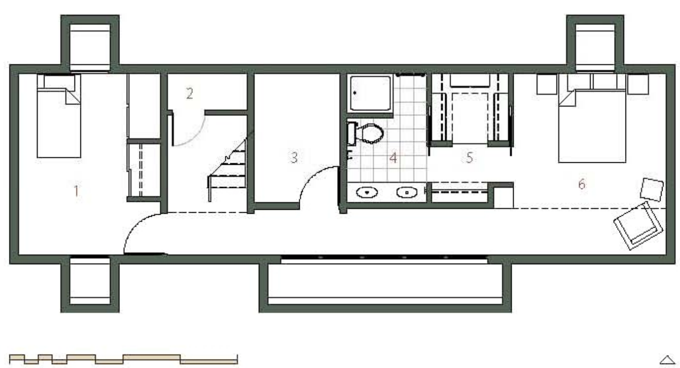
In response to environmental considerations, the house provides a wealth of solar access that is protected during the summer when solar heat gain isn't recommended. The large southern aperture provides for a solar savings fraction of nearly thirty-six percent. Basically what this means is that during the winter the sun will provide a significant percentage of the heating necessary to keep the home comfortable. The roof is also designed to maximize solar access in the event that photovoltaic solar panels are installed. Calculations show that the roof can account for the majority of electrical loads if the roof is utilized in this fashion.

If a situation arises where building heights need to be kept to a minimum with maximum building density in a neighborhood, a one story version of this house provides all the previously mentioned advantages by only sacrificing the unfinished basement. This alternative design allows for the bedrooms to be shifted into the basement, and because of the layout of window wells in the design, the rooms are still provided with solar access and fire escapes.

This is your house. Make it your own. We have provided the shell, the protective skin that allows you to live comfortably on a very limited lot. Inside we define space meant to be filled by your family; in the end we do not fill it for you. The walls and roof act to save you money, keeping temperatures consistent and possibly even making you money. What place is more desirable than one that brings the family together and offers a chance to offset living costs by simply living your life?



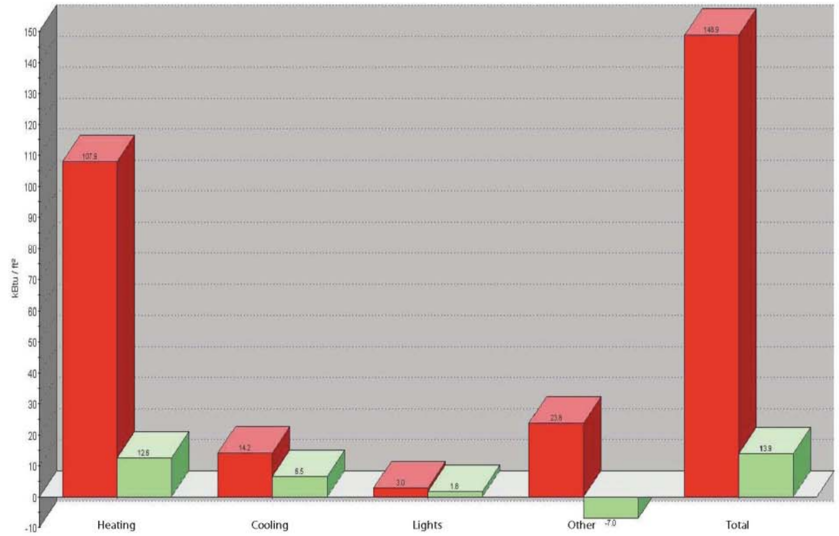
FIRST FLOOR PLAN
1. Back Entrance
2. Laundry Room 4.5'x 9.5'
3. Powder Room 5'x 9.5'
4. Kitchen 9'x 10'
5. Dining Room 8.5'x 13.5'
6. Living Room 13.5'x 13.5'
7. Street Entrance



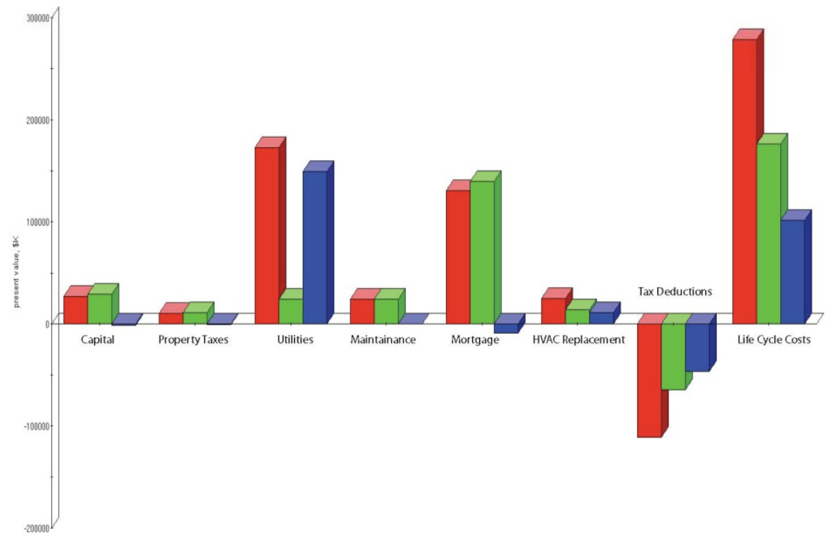
BASEMENT FLOOR PLAN
1. Bedroom 10' X 13.5'
2. Storage 3' X 6'
3. Mechanical/Storage 6.5'x 9.5'
4. Master Bathroom 6'x 10'
5. Master Walk-in Closet 6'x 10'
6. Master Bedroom 11.5'x 13.5'

PERFORMANCE DATA

Building Summary:	Reference	Low-Energy
Floor Area (ft^2)		
First Floor-	665	665
Second Floor-	665	665
Total Conditioned-	**1330**	**1330**
Basement (unconditioned)-	665	665
ENERGY PERFORMANCE:		
Photovoltaic		
Surface Area (ft^2)	n/a	1310
Angle of Surface	n/a	35
Solar Saving Fraction (SSF):		
Ratio of Glazing to Floor Area :	n/a	.183
SSF Without Night Insulation	n/a	35.5
SSF With Night Insulation (R=9)	n/a	61.4
Maximum Building Heat Loss:		
Total Conduction UA, Btu/hr	606.7	397.6
Average U-value, Btu/hr-ft^2-F	**0.123**	**.081**
Building Envelope (R-Values):		
Wall Type A-	12.6	22.4
Wall Type B-	n/a	n/a
Roof -	30	30
Windows-	u=0.50	u=0.31
Infiltration, in^2 =	**392.4**	**106.2**
HVAC system:		
Ground Source Heat Pump		
Annual Energy Performance		
Total Electric Demand, kWh	58032	16212
Total BIPV Supplied, kWh	n/a	5684
Percent Supplied by BIPV (%)	n/a	35.1
Internal/External lights, kWh-	1045/114	614/85
Heating/Cooling/Fan+Aux, kWh-	42062/5548/2282	4925/2521/2186
Heat Pump/Elec. Res., kWh-	0/0	4031/893
Hot water/Other, kWh-	3813/3168	2715/-7616
Peak Electric, kW-	42.3	14.2
Annual Emissions (lbs)		
CO_2	458	43
SO_2	238	22
NO_x	77995	7293
Energy Reduction (%):	n/a	90.7
COSTS:		
Initial Construction Cost	184392	148240
Life Cycle Cost	320419	176485



Annual Energy Use

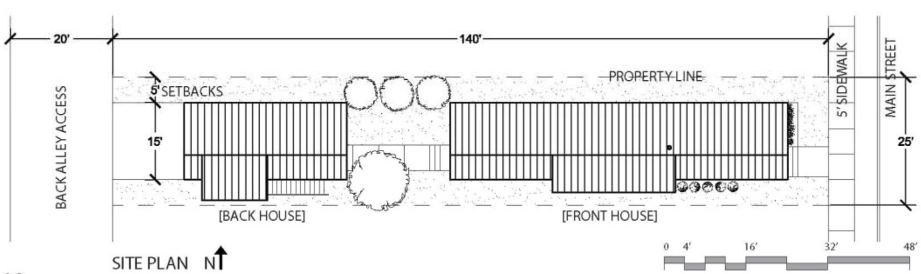


Life Cycle Cost

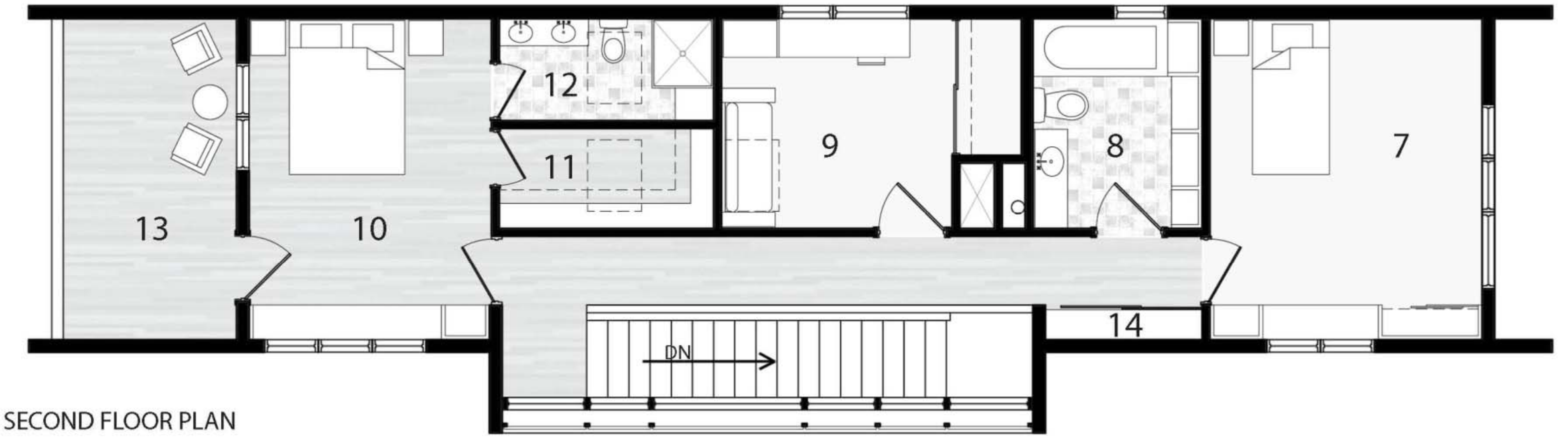
WRAP HOUSE

25' x 140' Lot Size
3 Bedrooms / 2.5 Baths
1460 square feet

designed by Adam Wagoner + Rebekah Udall



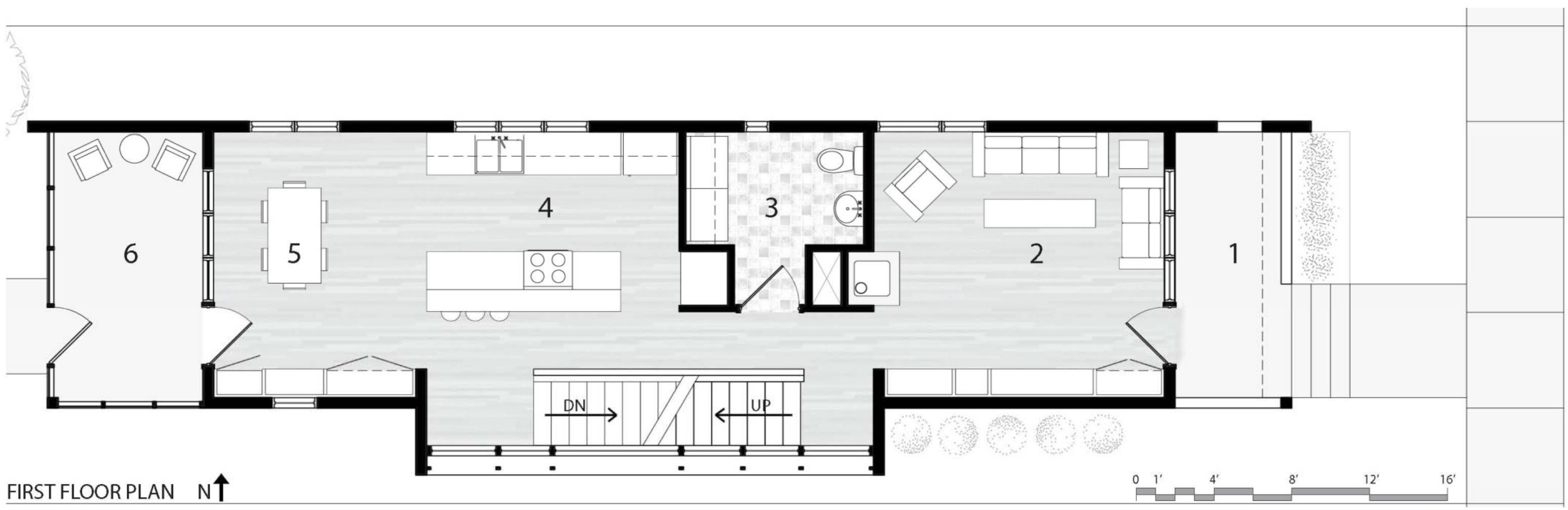
The benefits of compact residential development are significant. Higher density housing allows can create more mixed-use development and a pedestrian atmosphere. Encouraging walking, biking or public transportation reduces the current destructive dependence on the automobile and supports much healthier lifestyles. Compact development also helps to foster a sense of community, and a safer community, as those living in higher proximity are more likely to walk, shop locally, and get to know their neighbors. This support of local retail improves economic stability. And finally, the development of high-density housing leaves more open space for parks, trails, and the preservation of the natural environment.



SECOND FLOOR PLAN

LEGEND

1. Front Porch (76 ft^2)
2. Living Room (212 ft^2)
3. Bathroom/Laundry (66 ft^2)
4. Kitchen (170 ft^2)
5. Dining (145 ft^2)
6. Screened-In Porch (116 ft^2)
7. Bedroom (164 ft^2)
8. Bathroom (67 ft^2)
9. Study / Bedroom (109 ft^2)
10. Master Bedroom (145 ft^2)
11. Walk-In Closet (40 ft^2)
12. Master Bathroom (41 ft^2)
13. Covered Deck (112 ft^2)
14. Linen Closet (10 ft^2)



FIRST FLOOR PLAN N

KITCHEN + DINNING ROOM

LIVING ROOM

MASTER BEDROOM

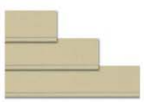
PHOTOVOLTAIC LAMINATE
a flexible and lightweight "peel & stick" application for 16" o.c. standing seam roofs

INSULATED STANDING SEAM METAL
interlocking metal panels that are very durable, require very minimal maintenance, and fire resistant laid over an additional layer of insualtion

STRUCTURAL INSULATED PANEL (SIP)
a sandwich of rigid insulation with two skins of oriented strand board that provide high performance building panels used in floors, walls, and roofs

SUN LOUVERS
roll-formed durable aluminum louvers provide shading during the warm summer months, while spaced appropriately to still allow the solar gain during winter months

DOUBLE, LOW-E, GLAZING
two lites of insulating glass separated by a dehydrated airspace, with a low-emissivity coating that suppresses radiative heat flow and improving the thermal resistance



FIBER CEMENT SIDING
a non-toxic, easily painted, and incredibly durable (resists cracking, rotting, hail damage, and termites) lap siding

RADIANT HEAT FLOORING
warm water is circulated through tubes laid into the floor, which provides more efficient, evenly distributed, and a quite heat source

INSULATING CONCRETE FORMS (ICF)
rigid plastic foam forms that hold concrete in place during curing and remain in place afterwards to serve as thermal insulation for the concrete walls

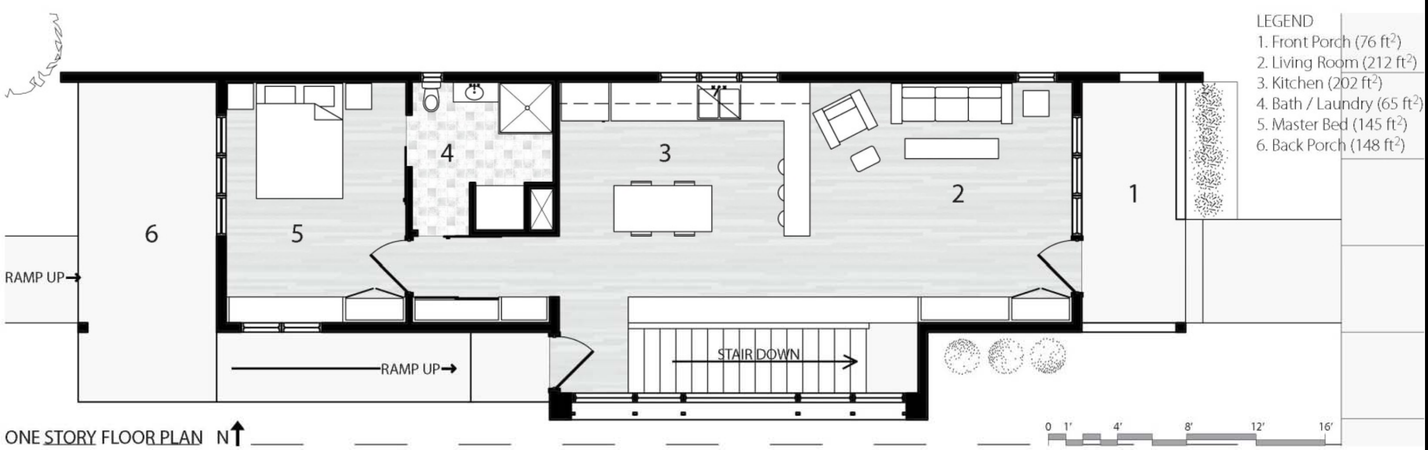
SOUTH ELEVATION: DECEMBER 21 SHADOWS

SOUTH ELEVATION: JUNE 21 SHADOWS

The large amount of southern glazing has been specially engineered to the considerations of each season. During the winter, the low sun angles can penetrate deep into the interior spaces, optimizing passive solar heat gain. Even if the house is placed in close proximity to adjacent houses, the height and expanse of these windows still capture significant sunlight. Allowing the natural, and free, energy of the sun to aid in heating the home will significantly reduce the overall energy load. However, during the summer months, a system of exterior louvers serve to shade the entire system of glazing from the unwanted sun, while the operable windows provide an efficient system of stack ventilation. Additionally, the standing seam metal skin "peels up" at specific locations and angles to provide optimum daylight, solar gain, and shading to the remaining interior rooms.

Adjustments and variations to the design can create multiple adaptable options. The following page explores a one-story option, which may appeal specifically to an aging generation. The master bedroom on the ground floor, a spacious and open floor plan, and a back approach with ramps allows this house to solve many accessibility concerns. The second floor of bedrooms from the original design could easily be replicated in a finished basement with this one-story option. Or, this option could just replace the first floor of the original plan, creating a 4 bedroom house with an unfinished basement. This unfinished basement in each design option, allows for flexible expansion options. As a family grows or a as funds allow, this space could be finished into more bedrooms, recreation space, or a home office.

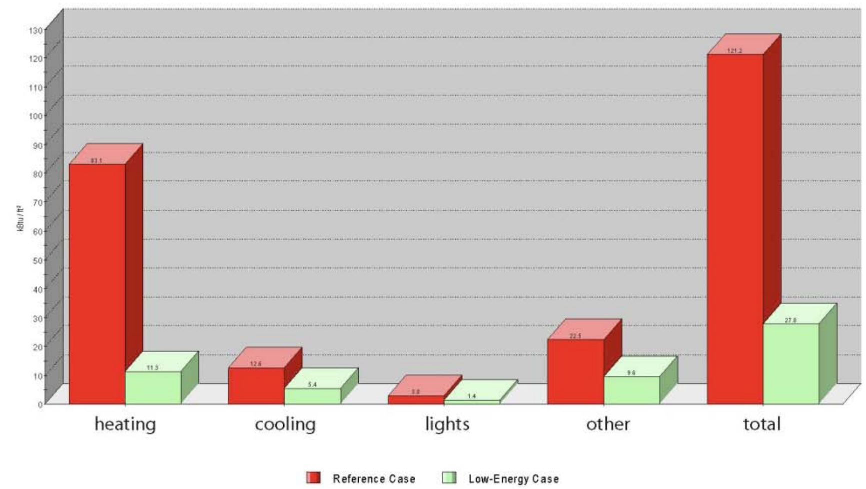
ONE STORY OPTION: INTERIOR VIEW



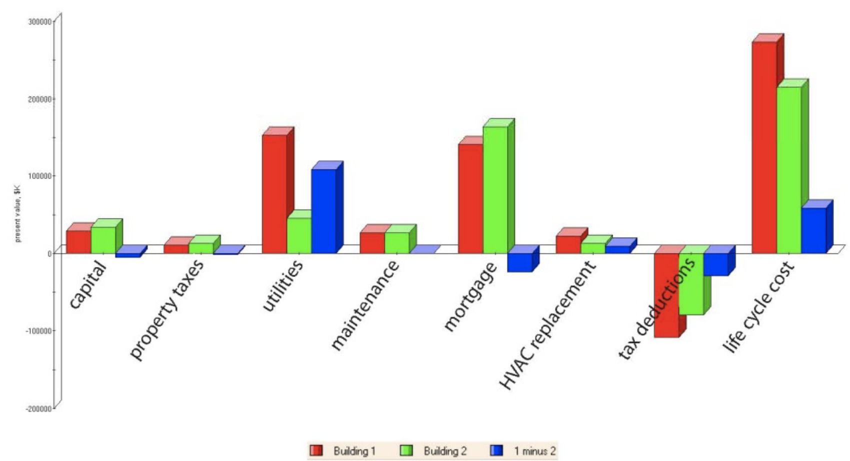
ONE STORY FLOOR PLAN N

PERFORMANCE DATA

Building Summary:	**Reference**	**Low-Energy**
Floor Area (ft^2)		
First Floor	738	738
Second Floor	722	722
Total Conditioned	**1460**	**1460**
Basement (unconditioned)	600	600
ENERGY PERFORMANCE:		
Photovoltaics:		
Surface Area (ft^2) @ angle	n/a	420 @ 45°
Surface Area (ft^2) @ angle	n/a	344 @ 24°
Total Surface Area (ft^2)		764
Solar Savings Fraction (SSF):		
Ratio of Glazing to Floor Area:	n/a	0.23
SSF Without Night Insulation	n/a	42
SSF With Night Insulation (R=9)	n/a	73
Maximum Building Heat Loss:		
Total Conduction UA, Btu/hr	546.2	282.5
Average U-value, Btu/hr-ft^2-F	0.130	0.067
Building Envelope (R-Values):		
Wall Type A	12.6	26.2
WAll Type B	12.6	30.6
Roof	27.8	46.2
Windows	2.04	3.85
Infiltration (in^2)	363.1	98.3
HVAC system:		
Ground Source Heat Pump		
Annual Energy Performance		
Total Electric Demand, kWh	51,841	11,892
Total BIPV Supplied, kWh	n/a	6129
Percent Supplied by BIPV (%)	n/a	52%
Internal/External lights, kWh	1147/125	519/94
Heating/Cooling/Fan+Aux, kWh	35573/5386/1943	4832/2330/2584
Heat Pump/Elec. Res., kWh	0/0	3147/1685
Hot water/Other, kWh	4185/3478	4185/-2652
Peak Electric, kW	**33.5**	**15.0**
Annual Emissions (lbs)		
CO_2	69674	115983
SO_2	410	94
NO_x	213	49
Energy Reduction (%):	n/a	74.2
COSTS:		
Initial Construction Cost	**199,548**	**227,150**
Life Cycle Cost	**319,805**	**262,880**



Annual Energy Use

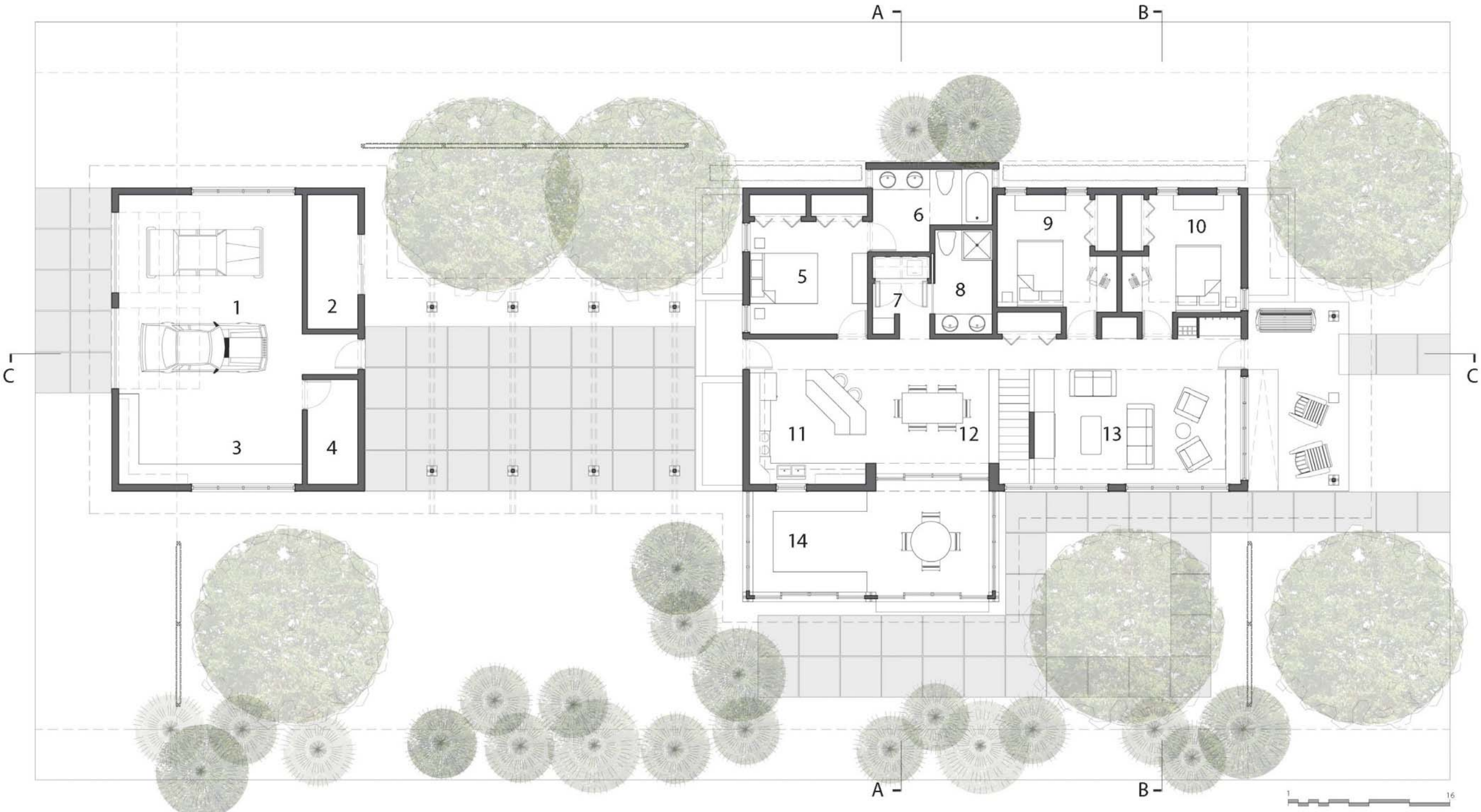


Life Cycle Cost Graph

SOLAR BUNGALOW

75'x 140' Lot Size
3 Bedrooms / 2 Baths
1500 sq. ft.

Designed by Trent Gareis

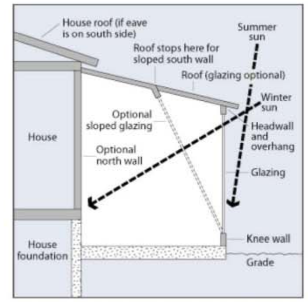


▲ FIRST FLOOR PLAN

1. Garage (360 sf)
2. Exterior Storage (66 sf)
3. Shop (160 sf)
4. Interior Storage (50 sf)
5. Master Bedroom (160 sf)
6. Master Bathroom (80)
7. Laundry Room (45 sf)
8. Bathroom (58 sf)
9. Bedroom (135 sf)
10. Bedroom (135 sf)
11. Kitchen (165 sf)
12. Dining Room (150 sf)
13. Living Room (300 sf)
14. Sunspace (235 sf)

LIVING ROOM

KITCHEN/DINING



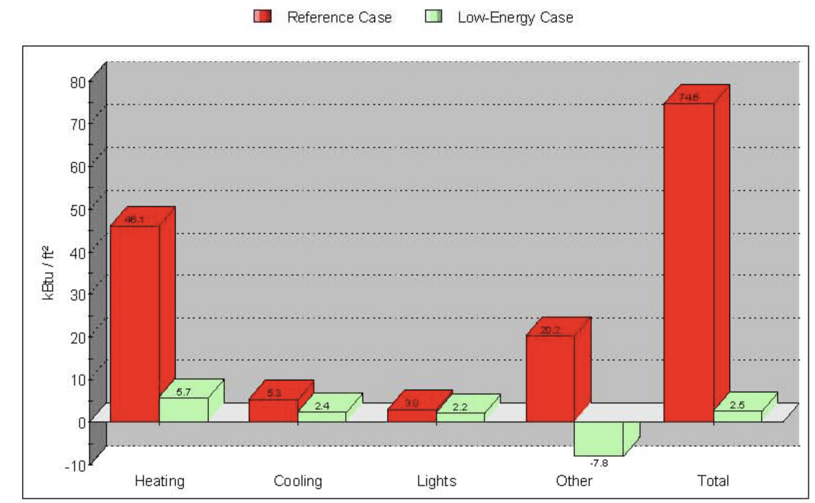
SUNSPACE

PHOTOVOLTAICS

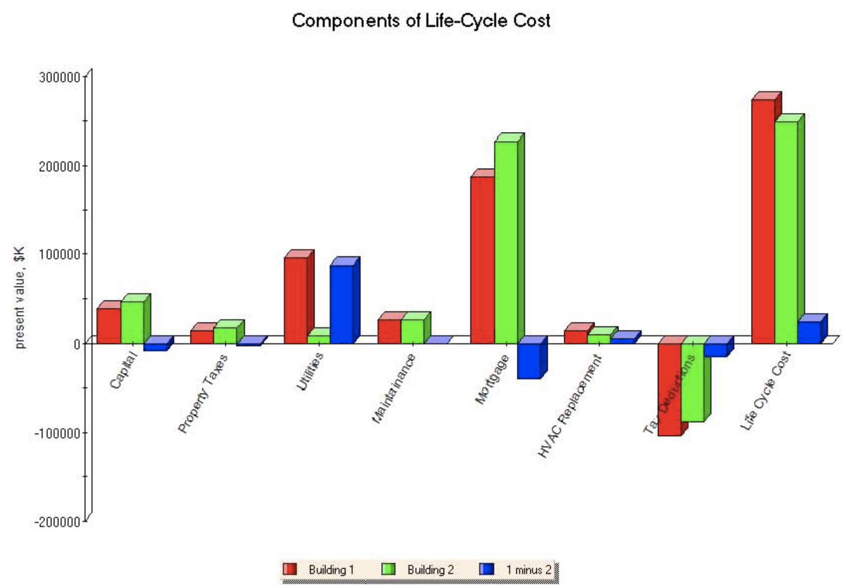
GROUND SOURCE HEAT PUMP

PERFORMANCE DATA

Building Summary:	Reference	Low-Energy
Floor Area (ft^2)		
First Floor	1500	1500
Total Conditioned	**1500**	**1500**
Basement (unconditioned)	0	0
ENERGY PERFORMANCE:		
Photovotaic		
Surface Area (ft^2)	N/A	2155.25
Angle of Surface	N/A	30
Solar Saving Fraction (SSF):		
Ratio of Glazing to Floor Area:	N/A	0.19
SSF Without Night Insulation	N/A	38.7
SSF With Night Insulation (R=9)	N/A	64.2
Maximum Building Heat Loss:		
Total Conduction UA, Btu/hr	N/A	3.96
Average U-value, Btu/hr-ft^2-F	N/A	3.36
Building Envelope (R-Values):		
Wall Type A	12.6	22.4
Roof	29.4	389.8
Windows	u=.51	u=.31
Infiltration, in^2	189.3	51.2
HVAC system:		
Ground Source Heat Pump		
Annual Energy Performance		
Total Electric Demand, kWh	32805	1111
Total BIPV Supplied, kWh	N/A	11466
Percent Supplied by BIPV (%)	N/A	1013
Internal/External lights, kWh	1179/129	875/96
Heating/Cooling/Fan+Aux, kWh	20276/2344/ 1005	2504/1063/ 1210
Heat Pump/Elec. Res., kWh	0/0	2051/453
Hot water/Other, kWh	4300/3573	3258/-7895
Peak Electric, kW	20.0	6.5
Annual Emissions (lbs)		
CO2	44090	1493
SO2	259	9
NOx	135	5
Energy Reduction (%)	N/A	99.97
COSTS:		
Initial Construction Cost	198253	241129
Life Cycle Cost	273870	249015



Annual Energy Use Graph

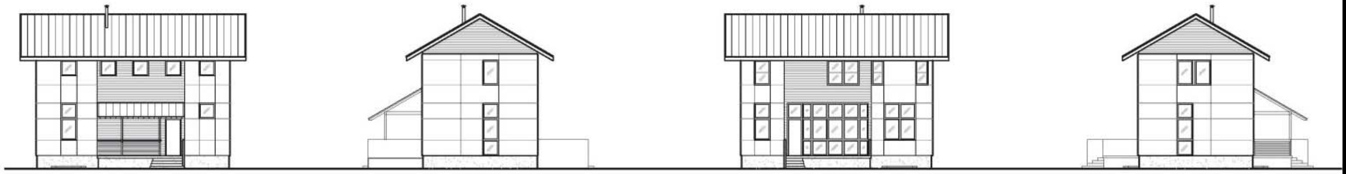


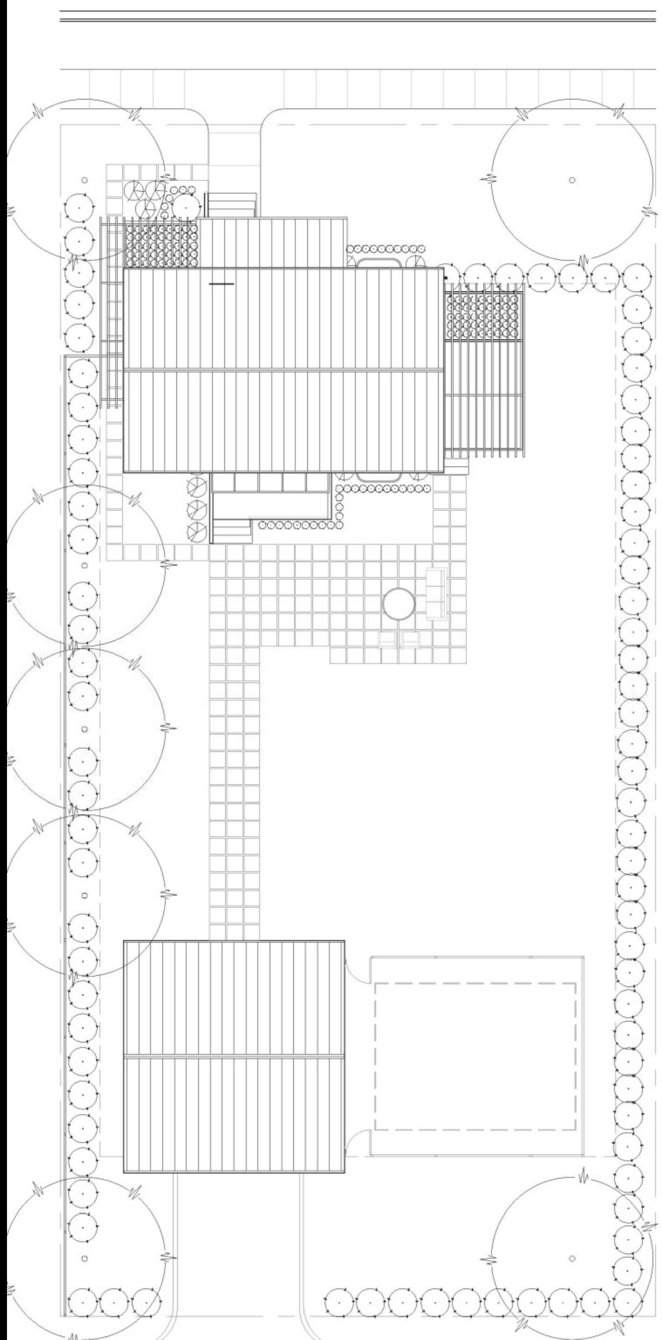
Life Cycle Cost Graph

Abbi House

designed by Jill Eckloff + TJ Siemons

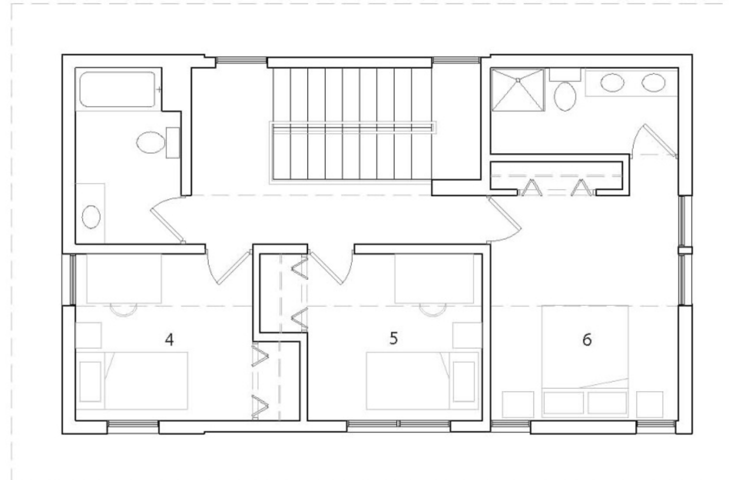
75′x 140′ Lot Size
3 Bedrooms / 3 Baths
1440 total sq. ft.





75' LOT SITE PLAN

0 8 16



SECOND FLOOR PLAN

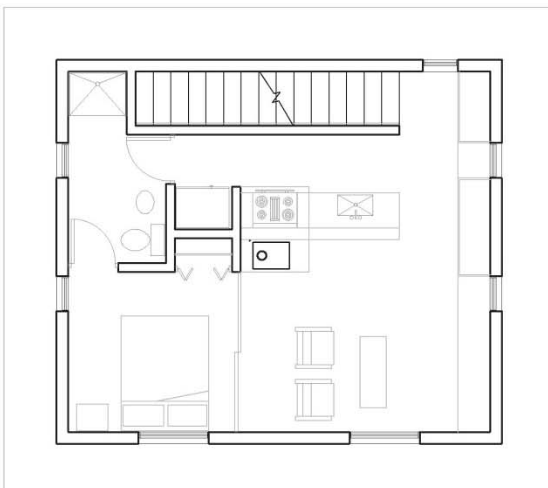
ROOM LEGEND

1. Living Room (200 sq. ft.)
2. Dining Room (115 sq. ft.)
3. Kitchen (120 sq. ft.)
4. Bedroom (98 sq. ft.)
5. Bedroom (98 sq. ft.)
6. Master Bedroom (140 sq. ft.)

FIRST FLOOR PLAN

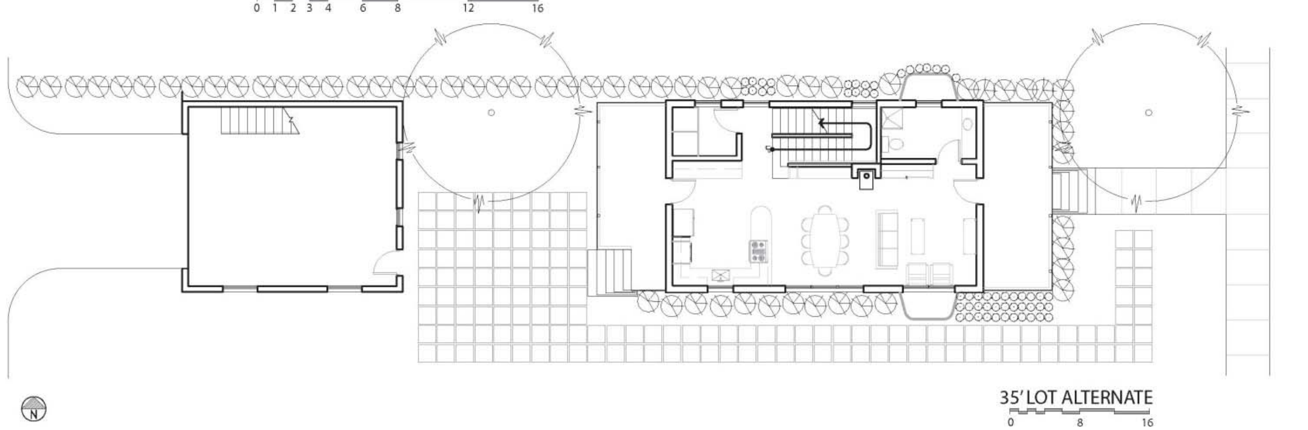
0 1 2 3 4 6 8 12 16

In addition to the various site orientations, this scheme presents the opportunity for a backhouse. The backhouse design is a simple structure, comprised of a two car garage and a small second floor apartment. This set-up would allow for extra living space that could be used as rentable space, a home office, studio, or a temporary living space while the front house is under construction. The lofted space includes a living room, kitchenette, small bathroom, and bedroom area, which can be enclosed by sliding doors. A centrally located wood burning stove helps to heat the space during winter. Operable windows are located on all sides of the house for ventilation during periods of agreeable weather. The loft space also features a vaulted ceiling for extra volume, making the small floor area seem larger.



BACKHOUSE APARTMENT PLAN

0 1 2 3 4 6 8 12 16

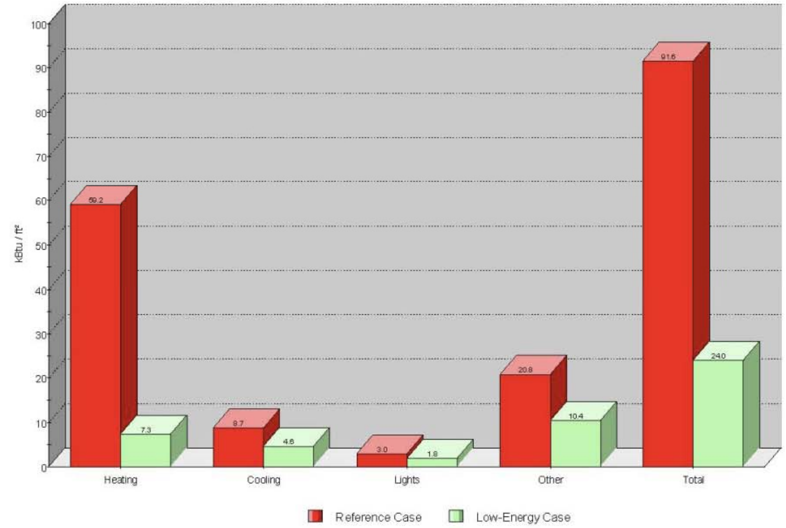


35' LOT ALTERNATE

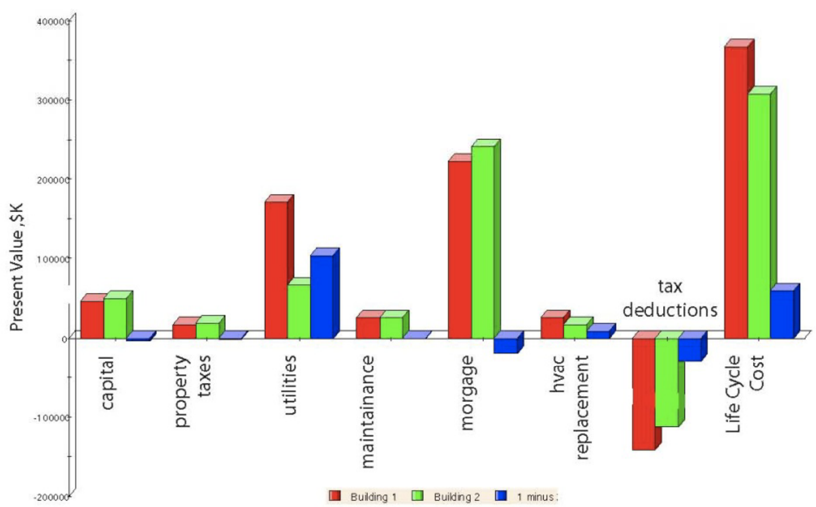
0 8 16

PERFORMANCE DATA

Building Summary:	**Reference**	**Low-Energy**
Floor Area (ft^2)		
First Floor	720	720
Second Floor	720	720
Total Conditioned	**1440**	**1440**
Basement (unconditioned)	720	720
ENERGY PERFORMANCE:		
Photovoltaic		
Surface Area (ft^2)	N/A	600
Angle of Surface	N/A	30
Solar Savings Fraction (SSF):		
Ratio of Glazing to Floor Area	N/A	0.17
SSF Without Night Insulation	N/A	37
SSF With Night Insulation (R=9)	N/A	60
Maximum Building Heat Loss:		
Total Conduction UA, Btu/hr	418.8	261.8
Average U-value, Btu/hr-ft^2-F	0.08	0.05
Building Envelope (R-Values):		
Wall Type A	12.6	22.4
Wall Type B	N/A	N/A
Roof	30	40
Windows	2.1	3.8
Infiltration, in^2	308.6	83.5
HVAC system:		
Ground Source Heat Pump		
Annual Energy Performance:		
Total Electric Demand, kWh	38649	10143
Total BIPV Supplied, kWh	N/A	7692
Percent Supplied by BIPV (%)	N/A	75.8
Internal/External lights, kWh	1132/123	652/93
Heating/Cooling/Fan+Aux, kWh	24961/3662/1212	3076/1948/1559
Heat Pump/Elec. Res., kWh	0/0	2647/429
Hot water/Other, kWh	4128/3430	4128/-1554
Peak Electric (kW)	22.9	8.8
Annual Emissions: (lbs)		
CO2	51944	13632
SO2	305	80
NOx	158	42
Energy Reduction (%)	N/A	73.7
COSTS:		
Initial Construction Cost	201021	222578
Life Cycle Cost	276408	255041



Annual Energy Use Graph



Life Cycle Cost Graph