HILLTOP RESIDENCE AND SITE SUSTAINABLE DESIGN

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INTRODUCTION

Sustainability on a residential renovation can be difficult to achieve. As this project was a complete gut renovation and two small additions, which included a new third story space, roof, and a rear addition, it was easy to investigate a wide variety of sustainable options. The building envelope was improved, interior aspects modified, and the energy generation systems explored and selected to all work in unison to enhance the end result of the project.

In order to measure the degree of sustainability, ODG wanted to use a residential design rating system. At the time this house was designed there were few recognized residential rating systems available and none appeared to be as stringent and broad reaching as the LEED Commercial Rating system. ODG used the LEED 2.2 rating system as a guideline. When this project began, LEED for Homes had not yet been developed. The Hilltop Residence project sought to infuse an existing residence with the following qualities: cost effective technology, a "not to exceed" budget, a 75-year life cycle, the client's aesthetics, functional living, sustainable design, and allow for productive healthy residents. ODG used the LEED categories of Sustainable Sites, Water Efficiency, Materials & Resources, Energy & Atmosphere, and Indoor Air Quality.

The sustainable goals that were met affect both the building and the site. The home was designed to use rapidly renewable materials, use less water, conserve energy, generate its own electricity, automate the mechanical house processes, and reduce stormwater runoff. The renovated home conserved existing material and used new materials that are rapidly renewable. By designing to a 75-year life cycle, materials selected were either rapidly renewable or incredibly durable. Buildings designed for longer lifespans are inherently sustainable because their components will not need to be replaced as often. The reduction of operating and maintenance costs will pass savings directly to the client, providing a return on investment for the costs of the renovation and addition. By increasing the native vegetation, the site reduced runoff from the roof and decreased the amount of water being added to the storm sewer system. These goals, once realized and incorporated into the redesign of the townhome provide a clean, healthy indoor environment and highlight a residence with a climate responsive design and conservation practices.

KEYWORDS

Residential, renovation, sustainable, stack effect, passive solar, energy efficiency, photo-voltaic panels, LEED, Smart Home, ventilation, open plan, high efficiency, high performance exterior envelope, water efficiency

THE HILLTOP RESIDENCE

The client's goals included a more open residence, more reliance on natural systems, and a well designed residence. In contrast with many of the passive energy strategies used in the design of the residence, the client also wished to integrate Smart Home concepts and automate many of the building's systems. This allows the temperatures throughout each zone of the residence to be controlled from one location. This location also incorporated an access point for the security system and a hardwired sound system. While the traditional Smart Home methodology means eliminating redundancy of systems so there are fewer wires, ODG took an opposite approach of building in redundancy to avoid failure. By building with redundancy ODG was able to provide assurance the technology would operate properly and also provide room for expansion of future technologies.

This townhouse is located in a Planned Urban Development (PUD) and was constructed in 1955. ODG began work on the renovation project in February. Because of the relatively limited budget of the project and client's desire to save money, the client selected the general contractor based primarily on price. The general contractor had a great deal of

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FIGURE 1. Exterior photograph of existing building, prior to renovation.

FIGURE 2. Exterior photograph of renovated residence, under construction, with long south facade and front facade with new porch.

experience with residential construction but was less familiar with the sustainable initiatives selected for the project. Construction began in August with most of construction completed by July 2007.

The Hilltop Residence is set back from a quiet side street in the Metropolitan Washington, D.C. area. This single family home is on a hill and is the southernmost unit of a cluster of eight townhouses. It is oriented along an east-west axis, with the front facade facing east and the long side facade to the south. The orientation and position of the home is incredibly advantageous. With the broad side facing south and the building elevated on a small hill, the potential for harvesting solar energy increases.

The existing masonry structure included two main living floors occupying 1,150 gsf and a 470 gsf unfinished basement. There was also a flat roof that would be replaced. The existing home was comprised of three small rooms on the first floor and four small rooms on the second floor, both floors had low 8′-0″ high ceilings.

The existing unfinished basement ceiling height is 7′-2″. The Hilltop Residence required complete interior demolition. All existing finishes, mechanical, electrical, and plumbing systems were removed and replaced in the residence. The design goals were to replace the former small rooms with a modern layout of open spaces defined by different architectural elements including beams and columns as well as to bring the outside environment into the residence through increased daylight, ventilation, and views.

The height on the first floor was marginally increased. This was achieved best on the second floor, which increased the floor ceiling height to 10′-6″ along the wall and up to 17′-6″ at the peak of the cathedral ceiling. The structure was left exposed in the two story loft space. The Hilltop Residence renovation is based on passive solar design with new tall south facing windows, deep eaves, and new deciduous trees.

The slope of the new roof was designed at the optimal angle for photo-voltaic panels at this latitude and reflects the future solar energy generation capacity. A revised open floor plan throughout the basement, main floor, and a two story space on the second floor satisfy the client's desire for a modern layout. The new spaces are larger and filled with abundant daylight. New windows and skylights provide additional daylight and views of the garden and the Potomac River. Three new porches provide protection from the elements and allow for outdoor living three-quarters of the year.

The renovated residence totals approximately 1,750 gross square feet, which includes a new two story loft on the second floor, an attic, and a basement. The basement is 472 gsf, first floor is 630 gsf, second floor is 515 gsf, and attic (not including the 50 gsf cat walk) is 120 gsf. By this estimation, the actual total is 1737 gsf or 1617 gsf without the attic. Three new porches were added to create an additional 340 gsf, one was built on the front and two on the rear with access from each of the floors.

The renovation of the Hilltop Home removed many interior walls, changing the standard townhome of many small

rooms to one with an open plan and a functional layout. The kitchen remains in the same location but now opens into the dining room with a silestone island and bar separating the two spaces. While the client is cooking, they have views through the dining and living rooms into the garden beyond.

The living room has four full height glass panels on the west wall and doors that open to the new rear porch, patio, and garden. The backyard may be small but it is efficient and it includes a bluestone patio, shed, and garden. Future development includes installation of a spa.

The client had sustainable initiatives of his own—he brought these to the project in a thick binder of approximately 100–200 pages of notes and products. All these ideas had to be reviewed and vetted to determine if they were viable, long lasting, efficient solutions. He collected a great deal of material that was merged with traditional sustainable design solutions as criteria to develop the program.

ODG followed LEED Version 2.2 in the sustainable design of this house. Some of the design criteria was beyond LEED, such as domestic water filtration and long life materials. These

FIGURE 3. Site plan indicating extent of addition, new porches, and landscaping including underground stormwater retention area.

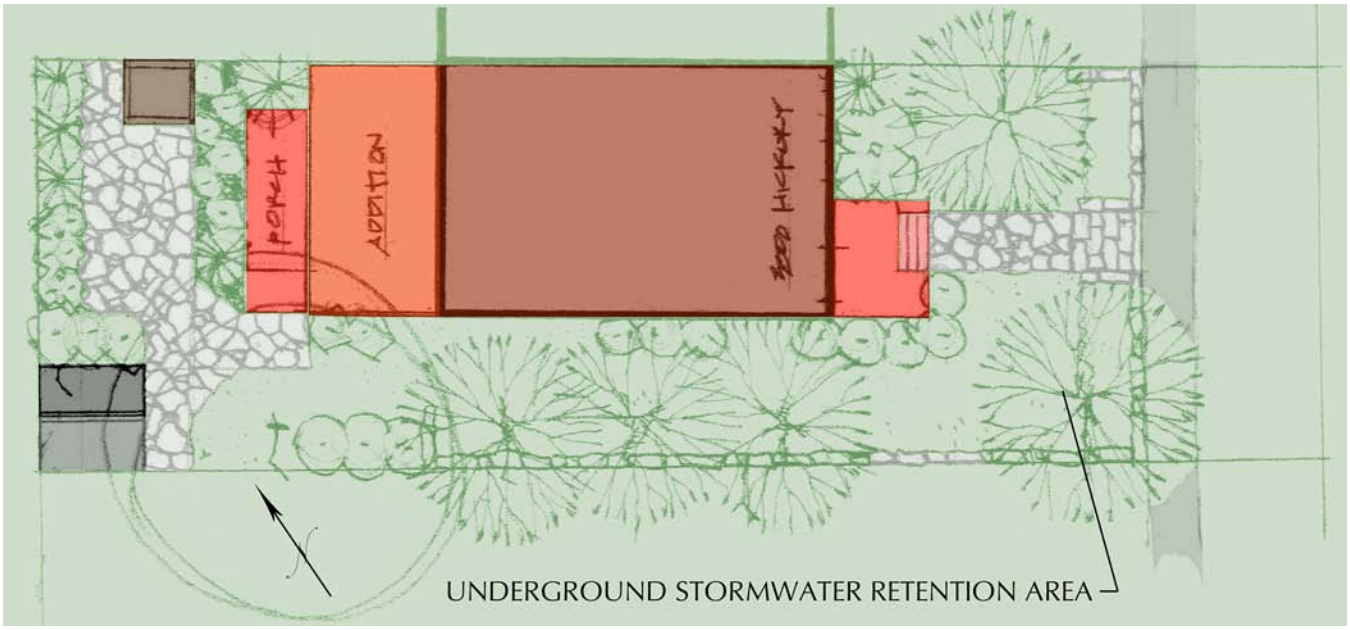
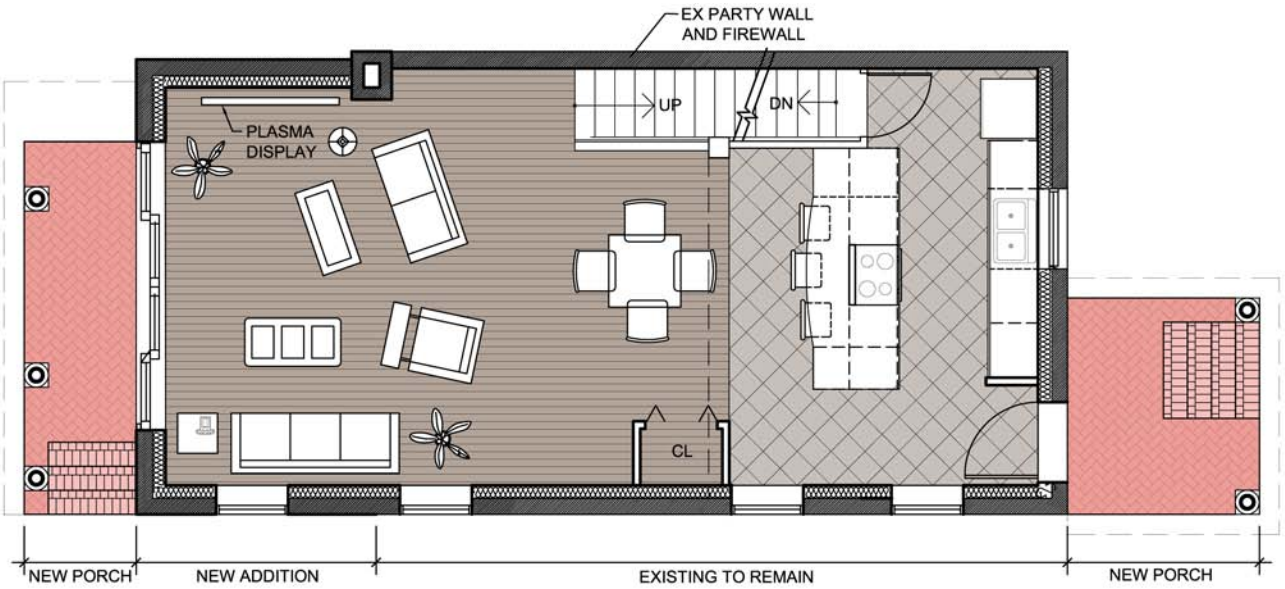


FIGURE 4. First floor plan showing new open floor plan and new brick porches.



could be considered "Innovation & Design" Credits. We have described these strategies and design under the beginning of the appropriate heading.

SUSTAINABLE SITES

SS 1 – Redeveloped an urban site.

The Hilltop Residence involved a complete renovation and addition to a townhome five miles from Washington, D.C. designed with sustainability always in mind. The client wished to renovate instead of build new to keep the convenient location and to conserve land and materials.

SS 2 – Constructed on a previously developed dense site within 1/2 mile of at least 10 basic services.

The location in a previously developed neighborhood and is convenient to many amenities, resources, and employment opportunities. Basic services for this residence include at least five banks, over a dozen restaurants, seven churches, and over four medical professional offices.

SS 4.1 – Project is located within 1/4 mile of stops for two or more public bus lines.

Because of the proximity to the city, the home is located within a quarter mile of three public bus lines. This is a direct benefit of living in proximity of Washington, D.C. and the Metrorail system.

SS 5.1 – Restored native species including trees and shrubs to 70% of site.

Additional native vegetation selected and a plan designed for the site incorporated deciduous shade trees and flowering shrubs into the existing landscape. By selecting native vegetation that is drought tolerant, no potable water needs to be used for irrigation.

SS 5.2 – Maximized open space by adding only 200 SF to existing building footprint.

There was minimal development of Open Space as only a 200 sf footprint was added to the building. An additional 72 sf for each porch was added to the front and rear of the house. There was minimal vegetation on the existing site, and the new design increased the vegetation dramatically, by nearly 74%. The 3,000 sf site improvements included a new slate entry walk to the new brick front porch and a new field stone retaining wall along the front and side yards.

The balance between increasing the interior space of the home and retaining a back yard was found by adding only 200sf to the building footprint. The new addition to the rear of the building increased the length of the south facade of the townhouse by ten feet and therefore expanded the area available for photo-voltaic panels.

Because the addition is two stories, 400 sf of useable space is added to the residence. On the first floor this increased the living room. Upstairs the added space is divided between enlarging the master bedroom by three feet and creating a private exterior porch.

The second floor interior addition includes building a raised roof that provided for a two story master bedroom and office with a catwalk along the north wall and a mechanical room stacked above the master bathroom. The master bedroom porch is partially enclosed by the continuation of the firewall on the north side. The articulation of the two-story mass includes the cut-out of the second floor rear porch. Porch mass articulation includes cut-outs of all the steps, expressing "negative space."

FIGURE 5. Second floor plan showing open floor plan and new exterior enclosed porch.

FIGURE 6. View of new retaining wall, light wells for the basement, and yard prior to planting of trees and shrubs.

SS 6.1 and 6.2 – Provided underground retention area for filtration of storm water.

This new landscape plan is designed to control stormwater and reduce the amount of runoff entering the storm drains. A new underground drainage area was designed to retain runoff to slowly filtrate into the soil. This also reduces erosion as rainwater remains on site. The earth is stabilized with a retaining wall. The rear yard improvements include a new brick rear porch, slate patio with spa, and small shed. See site plan, Figure 3.

SS 7.1 – Planted trees along south side of the house and site to provide shade for the site and lower windows of house in summer.

These new trees will shade the home in the summer and allow sunlight to pass directly into the home during winter. Coniferous trees were planted along the border of the yard for privacy.

WATER EFFICIENCY

Domestic water is filtered after it enters the residence. The client requested a whole house domestic water filtration system, ODG designed this system at the domestic water entry point. This is not a LEED credit but shows an additional level of clean technology beyond LEED.

WE 1.1 and 1.2 – No potable water is used for irrigation on site.

ODG considered installing a cistern to store water for irrigation of the vegetation. However, the rainfall calculations indicated there is not enough roof surface area to collect sufficient water to irrigate the yard. The use of native vegetation ensures plants selected will be drought tolerant and not require irrigation.

WE 3 – Water use reduction, efficient low flow fixtures.

Water efficiency is employed through use of two efficient water closets, one is an ultra-low dual flush fixture that uses 0.8 or 1.6 gallons per flush and a low flow fixture that uses 1.6 gallons per flush. Composting waterclosets were considered but the client preferred a low maintenance solution, so efficient flush fixtures were selected and installed. The faucets in the bathrooms are both low flow, with a maximum rate of 1.5 gallons per minute. The kitchen faucet has a maximum flow of 2.2 gallons per minute. There are also interior cut-off switches for water. This is for ease of use and to ensure excess water is not used.

MATERIALS AND RESOURCES

Long life materials.

The client requested the building be designed with a long lifespan; with ODG's assistance the renovation and addition were designed with a 75-year lifespan. Long life exterior envelope materials include 100-year exterior brick wall, 100-year clay tile roof, and estimated 75-year new porch floor and roof. The roof over the master bedroom porch has a 20-year warranty on the waterproofing membrane. There are examples of this membrane lasting over 50 years in harsh salt-water environments near the ocean. It is expected to last 75 years but has not yet been tested for that longevity. This long life design strategy goes beyond the LEED credits.

PVC piping was specifically not used for waste pipes. All new waste pipes are cast iron, this is beyond LEED credits.

MR 1.1 – Maintained high percentage of existing walls, floor, and roof.

At project completion, it was calculated that 84% of the original walls and 100% of original joists remained. The interior finish floors on the first and second floor were completely replaced with bamboo. The roof was completely replaced with one at the optimal angle for photo-voltaic panels.

MR 5.1 and 5.2 – Use of local materials, within 500 miles of site.

The new bricks used to construct the addition and porches were from a local source in Maryland to reduce the amount of pollutants and costs associated with transportation.

MR 6 – Rapidly renewable materials, bamboo flooring used throughout first and second floors.

Sustainable materials were used throughout the Hilltop Residence. Rapidly renewable materials including bamboo flooring were used throughout the first and second floors and on all stairs. The contractor was of the opinion that bamboo was

prone to warping and should not be used. However, it was used in the majority of the house and it has performed well so far. Because, as the contractor explained, bamboo flooring scratches more easily than wood during installation and throughout the final phase of construction great care was taken to protect the bamboo floor.

ENERGY AND ATMOSPHERE

Energy Star rated appliances

The air conditioner selected is better than the recommended efficiency level, with a near best level of 14 SEER. The new clothes washer and all new kitchen appliances, with the exception of the range, are Energy Star rated. The clothes washer is a 3.5 cu.ft. king size capacity front load washer with a stainless steel basket that uses 247 kWH/year and has an estimated operating cost or $12 per year when used with a natural gas water heater. The refrigerator is a GE Profile 22.2 cu.ft. bottom-freezer drawer refrigerator that uses 483 kWh/year with an estimated operating cost of $44 per year. The dishwasher is also a GE Profile with SmartDispense Technology that uses 322 kWh/year, an estimated operating cost of $25 per year. Inclusively, the residence qualifies for an EPA Energy Star Label and an Energy Star Mortgage.

EA P.3 – No CFCs

The existing air conditioning system that used chlorofluorocarbons (CFCs) as refrigerants was replaced.

EA 1.0 – Passive solar design reduces heating/cooling loads.

ODG performed a Residential Energy Services Network (RESNET) calculation on the residence that identified 50% overall energy savings. ODG did not perform a Whole Building Energy Simulation on the Hilltop Residence, as we lost our Mechanical Engineer early in the project.

The new roof was also designed with deep eaves to cast shade on the second floor windows in summer. In the winter when the sun is lower, the larger windows will allow a deeper penetration of light into the home.

By designing the eaves to project two feet past the face of the building, they became key shading elements for the second floor windows.

Low-E, argon filled windows

All of the windows, with one exception, were replaced with larger and more energy efficient windows. The new windows greatly increased the thermal properties of the exterior envelope. They are argon filled, Low-E, and have a U-0.28 rating. The one exception was the window in the kitchen that was not enlarged, though it was replaced with one that is energy efficient. It had to remain "as is" because the height of the counter was incompatible with the size of the new windows.

High performance exterior wall and roof

The existing exterior walls had been painted for many years. The layers of paint were removed; the masonry wall was cleaned and repointed. For the addition the new brick color and texture were selected to match the existing residence as close as possible. The exterior wall and new roof are part of a high performance building envelope, the wall has an R-value of R-21. The thermal properties of the exterior wall are superior to conventional construction as they are composed of two layers of brick. The wall's mass takes longer to heat up and cool down. Because of the high R-values of the exterior envelope, there was a dramatic reduction to the client's total energy bills, the results were actually a lower cost than expected. Through use of energy efficient fixtures and equipment, ODG was able to calculate projected significant savings, estimated at $1,545 a year. The expected annual utility bills total $533, approximately $45 per month.

The new roof is part of a high performance building envelope with an R-value of R-38. There is a 100-year projected lifespan on the clay tiles used on the roof. These tiles provide air pockets that allow for ventilation and a cooler roof in summer months. The clay Spanish tile was attached to the roof with non-corrosive copper nails. The tiles rested directly on two layers of #30 asphalt impregnated roofing felt. This was fixed to a 3/4″ plywood roof deck that was nailed to the structural 2″×12″ wood rafters. The clay tile roof emphasizes the solidity of the mass.

Because of the historic nature of the neighborhoods in northern Virginia, several months of meeting with the City of Alexandria and other groups and extensive research was required to get the new roof approved. ODG had to obtain city and Homeowner Association approval, and some research included review of historic documents.

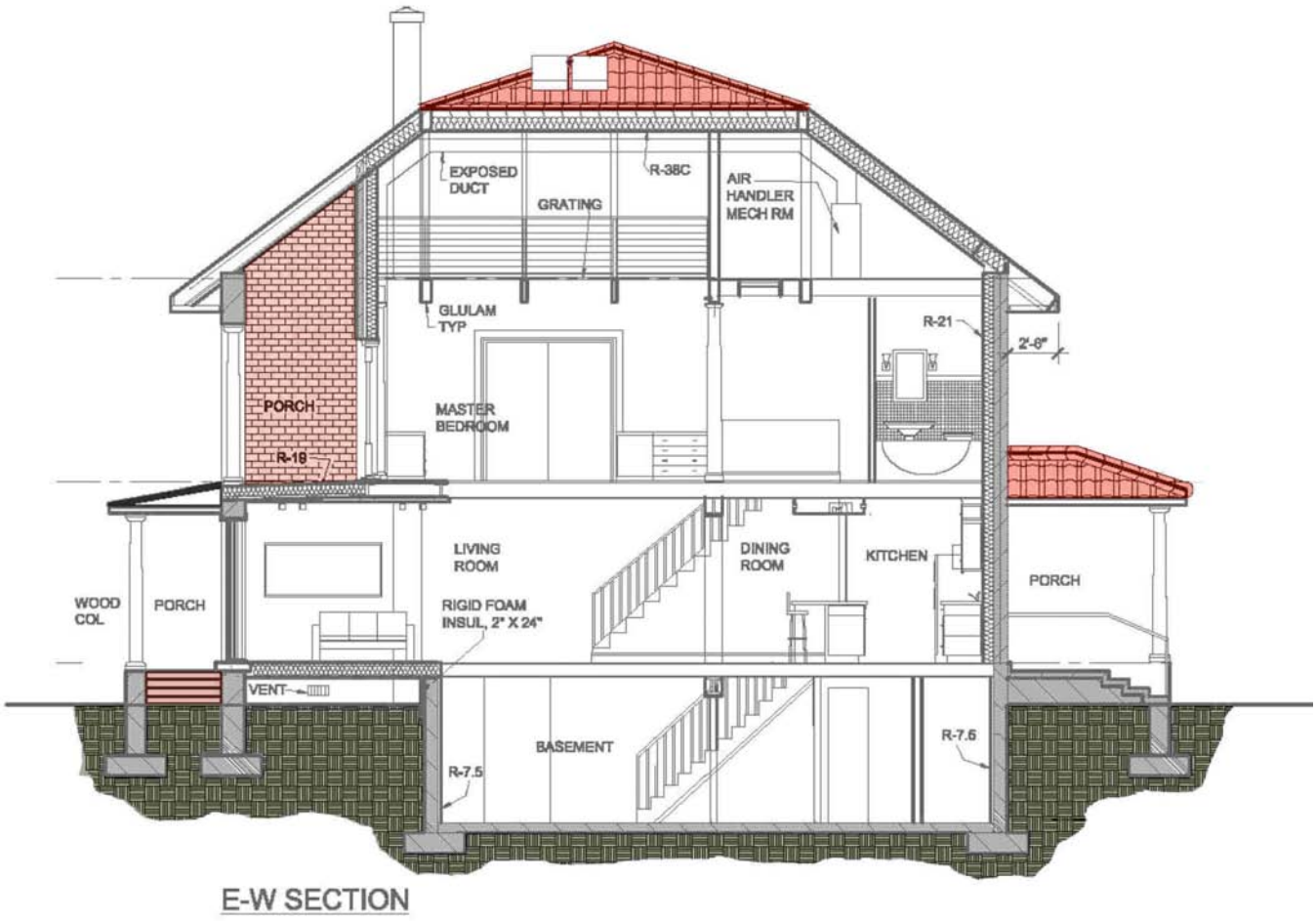
The entrance into the residence was also improved. The lightweight exterior front door was replaced with a new door that was heavier, thicker, and had a heavy duty latch. This tied into a full house security system implementation of the Smart Home concept.

Efficient boiler and air conditioner

The Hilltop Residence renovation and addition was designed with a 75-year life cycle in mind. Over this time the client will save substantially on energy and utility bills as they are expected to be very low. Some of the new energy efficient equipment was unfamiliar to ODG, and the client had very specific requests. The final design integrated passive sustainable features and new innovative equipment.

One of the key pieces of equipment was a 95% efficient gas boiler. This new combination condensing boiler includes a 36-gallon built-in water heater. ODG recommended replacing the existing radiant heating elements with new copper piping and lower, less obtrusive copper finned radiators. The client selected this boiler for its efficiency. The unit vents out the wall horizontally. Last winter the ice drippings almost

FIGURE 7. Building section showing thick exterior envelope and two story "loft space" on second floor, longitudinal cross ventilation on 1st and 2nd floor and stack ventilation through roof skylights.



completely sealed off the vent because the cowl was missing; after it was reattached there were no further issues of which ODG is aware. The future outdoor spa will most likely be relocated as the vent faces it.

Ultimately, ODG used the RESNET rating system to measure the expected cost of future utility bills and the expected pollutant levels. This project achieved energy efficiency that is 50% better than the International Residential Code requirements. The primary pollutants measured include sulfur dioxide (SO_2), nitrogen oxide (NOx), and carbon dioxide (CO_2). The Hilltop Home is anticipated to produce fewer pollutants: SO_2, 45.46 lbs; NOx, 27.66 lbs; and CO_2 = 8.73 tons. (In comparison, the EPA has calculated the emissions of a typical passenger car traveling 12,000 miles over the course of a year to produce 38.2 lbs of NOx and 5.73 tons of CO_2.) Additional documentation containing the specific results of the RESNET rating is available upon request.

The Home Energy Rating System (HERS) score rating was estimated at 88.7, which is based on the 1993 Council of American Building Officials' (CABO) Model Energy Code. The lower the HERS score is, the more efficiently it uses energy. A home that produces as much energy as it uses has a HERS score of 0. Typical residences have a score between 130 and 150 so the Hilltop Residence is exceptionally efficient.

EA 2 – Photovoltaic panels sell back to the grid

The highlight of the structural changes was the addition of a sloped roof. The previously flat roof was removed and replaced with one sloped to the most efficient angle to receive the sun's rays. Approval for the design of the new roof and the installation of photovoltaic panels had been granted after many meetings with local jurisdictional agencies.

After construction of the new roof, installation of the photovoltaic panels was delayed because of budget limitations, modified scope, and significant expense associated with purchasing the system. The client decided to install the photovoltaic panels at a later date. This was the biggest disappointment of the Hilltop Residence as the photovoltaic panels are an integral feature of the design and the client will not see the fruition of this for some time.

FIGURE 8. Rear elevation showing new porches, new roof, and photovoltaic panels.

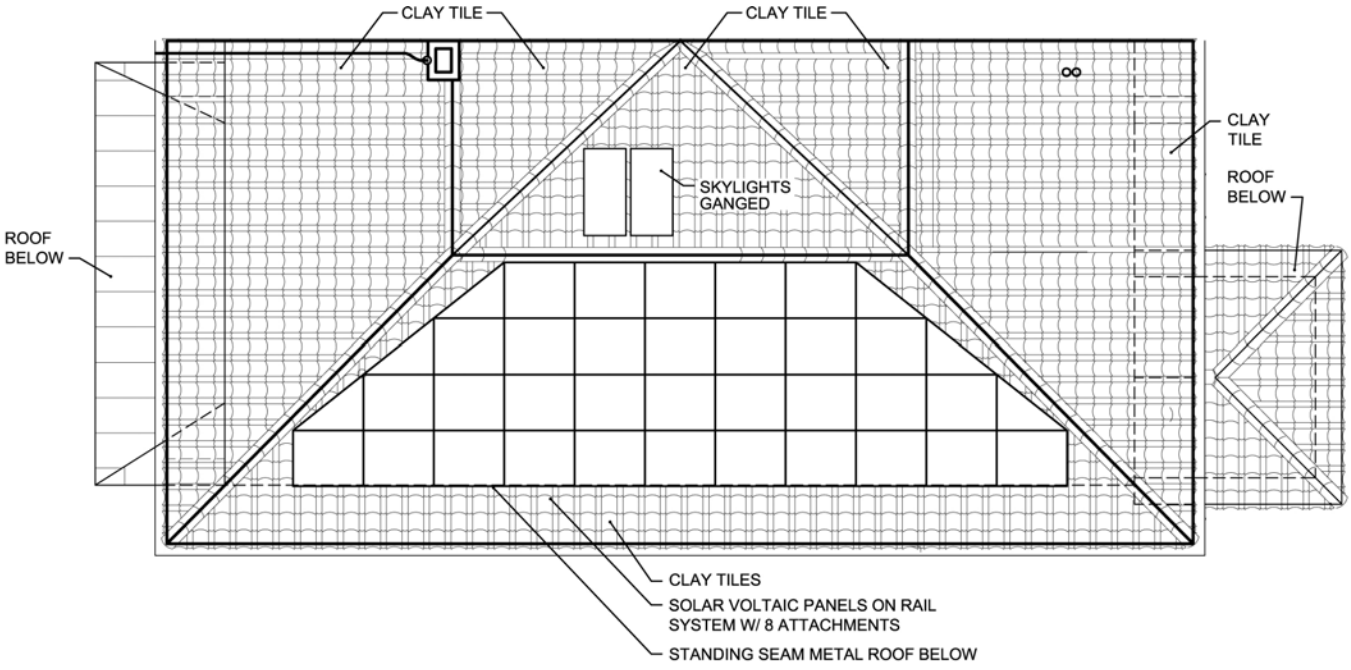
By adding a 340 sf array of photovoltaic panels, the homeowner will be able to generate a projected 4,083 kwh per year in electricity. Produced by BP, the BP-3160 panels are ideal for small home systems. Today as technology has improved, other manufacturers may be considered. With an array rating of 3,200 watts the panels produce an average of 11.2 kwh per day estimated based on available 30-year average weather data for Northern Virginia.

This fluctuates depending on the season, the photovoltaic panels produce on average 7.4 kwh per day in December and around 13.4 kwh per day in June. During normal conditions, the photovoltaic panel array generates electricity to offset the energy typically purchased from the utility company. The array is designed to sell energy back to the grid in times of excess. When main power is disrupted, energy from the photovoltaic panels is used to power the load of the home directly and also charges a battery backup. The backup system was initially designed to provide 24 hours of uninterrupted power to the house. If the size of the battery bank increases, the length of time the house is capable of operating without standard electricity increases.

A new shed was built in the backyard to house the battery backup for the photovoltaic panels and yard equipment.

ODG had a difficult time working with professionals and contractors on this small sustainable residence in uncharted territory on a limited budget. One particular difficulty was finding a mechanical engineer familiar with current sustainable principles and willing to work on a small project. The mechanical engineer originally selected did not believe the amount of photovoltaic panels provided could generate

FIGURE 9. Roof plan showing placement of photovoltaic panels & skylights.



enough electricity to make them worthwhile. After research and calculations, this proved to be incorrect, "old school" thinking as modern photovoltaic panels are much more efficient than their predecessors and a sustainable home would have a lower demand for electricity. ODG parted ways with the mechanical engineer early in the project and worked instead directly with product representatives and installers. While this approach may have been more difficult, it was ultimately more effective and incredibly successful.

With the client, ODG went through several scenarios of how to harness natural energy for this project. After solar, the second leading consideration was geothermal. Geothermal would have been an efficient heat source for the entire townhouse block but not economically efficient for one townhouse.

INDOOR ENVIRONMENTAL QUALITY

Several project features go beyond LEED Indoor Environmental Quality, EQ, credits. Some of these features include the following. Hydroponic gardens were designed for the ability to grow food year round.

Hazardous material removal includes asbestos that was found in the pipe insulation, drywall compounds, and floor tiles. The Smart Home System provides control of numerous systems. It is described under LEED credit EQ 6.1 and 6.2 but actually includes lighting, security, clean house, entertainment, daylight, and thermal comfort.

EQ 2 – Maximized cross ventilation, all operable windows

- **Exposed structure, stack effect**
- **Removed small rooms, replaced with modern layout to increase ventilation**

In tandem with the design of the high performance building envelope, ODG ensured thermal comfort with recommended detailing for moisture dynamics, which includes a liquid applied air barrier. Hot summer heat can be removed with ventilation in the cathedral roof.

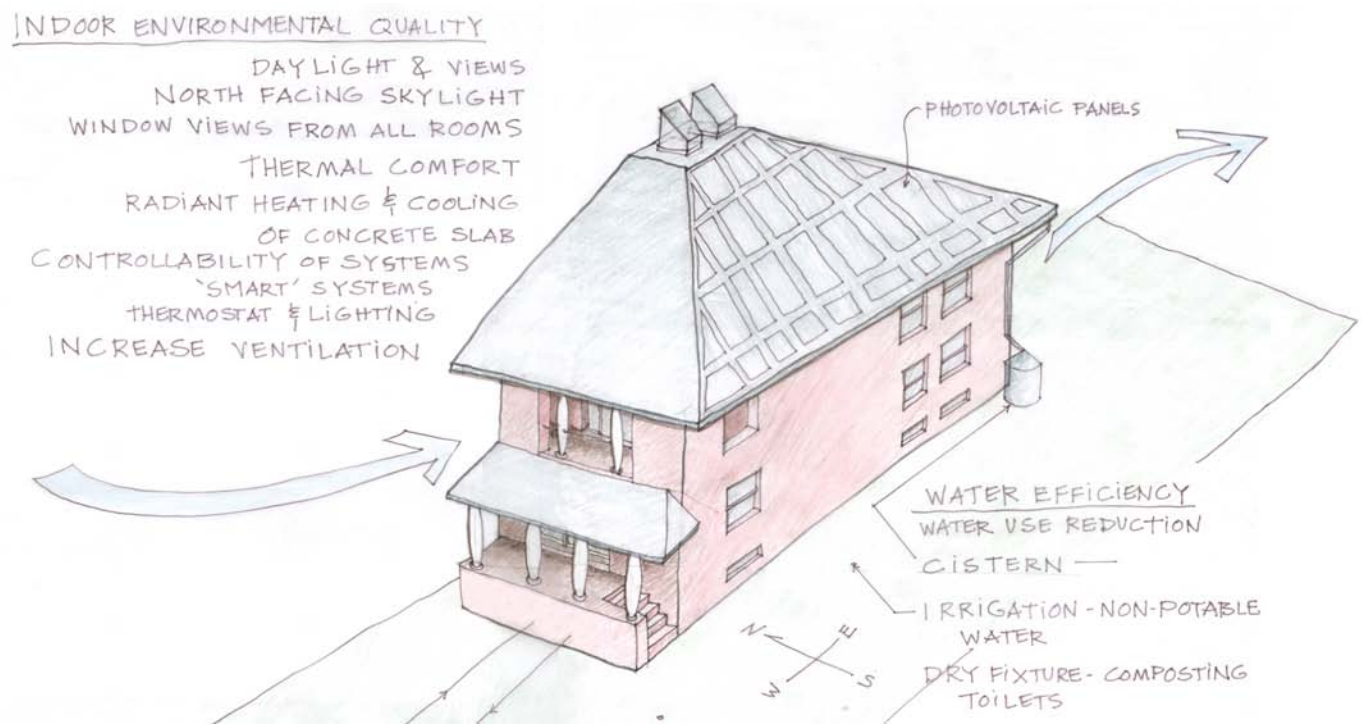
Near the top of the roof on the south facing slope are two skylights. Initially ODG designed light wells for the roof to allow north light in and keep south light out. Because of budget cuts, the light boxes were eliminated. One attempted innovation that was not able to be realized was the use of a highly efficient glazing in the skylight. The glazing selected had several layers including a translucent veil in the center core. This would filter direct light and still allow the space to have daylight.

ODG reviewed this project several times with the manufacturer but the company that makes the skylights did not have an established relationship with the makers of the glazing and translucent veil and would not produce the skylights in time to incorporate them into the Hilltop Home. The final result involved skylights that have blinds. These skylights are Pella Fixed Skylights made with aluminum exterior, wood interior frame, and Low-E argon-filled insulating glass. While they are primarily designed for daylighting, the skylights can also be employed to cool down the house. On hot days the skylights can be remotely opened to create an updraft through the stack effect.

FIGURE 10. Interior construction photo showing patio doors on first floor, exposed beams in 2-story Master Bedroom, and opening for skylights above.

Originally the windows were unevenly spaced and not proportionate to the mass of the building. The new windows were placed rhythmically along the front, side, and rear elevations. These replacement windows were taller, resulting in a more pleasing elongated proportion in context with each facade. All windows are operable to take advantage of natural breezes and strategically located at opposite ends of the residence to ensure cross ventilation. The client will enjoy a clean, well lit interior with an abundance of daylight and shades to block it when necessary. There is a 1-to-2 mile view from the townhouse, including views of the Potomac River. The views, paired with the increase in ventilation, considerably improve the interior environment.

FIGURE 11. Axonometric rendering of cross ventilation, also indicates location of photovoltaic panels.



EQ 4.1 – Low emitting adhesives/sealants

All interior sealants used contained low levels of Volatile Organic Compounds (VOC) and are low emitting.

EQ 4.2 – Paints have low VOCs

All interior sealants used contained low levels of Volatile Organic Compounds (VOC). After painting, all odor was gone in less than a day in comparison with traditional paint.

EQ 4.3 – Low-Emitting Materials, No carpet

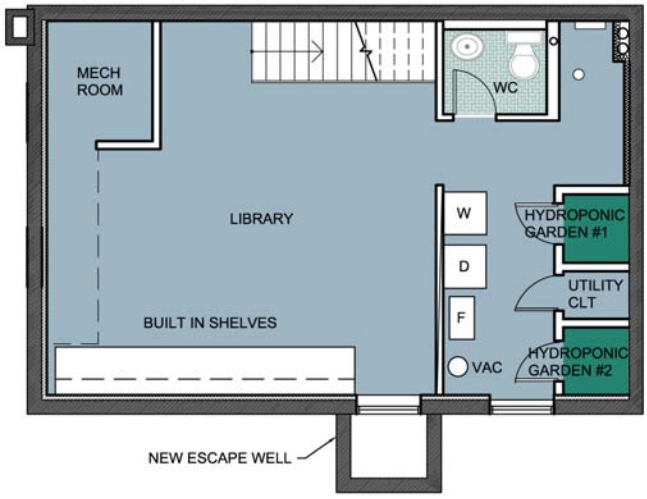
The two main living floors are both finished with bamboo flooring. The previously unfinished basement now includes a designated laundry area and garden rooms for growing plants year round. The client wished to start growing vegetables hydroponically, and the inclusion of this feature in the basement required additional thermal and moisture barrier considerations.

The basement also includes an area for the future build out of library shelving. Other attributes of the basement include a small mechanical room and a low flow watercloset.

EQ 6.1 – Controllability of Systems: Lighting control, Smart House

One of the client's top priorities was to automate the residence, or develop the Hilltop Residence into a Smart Home. The primary result of this initiative was a single access point on the second floor, through which the client can manipulate the temperature, music, and security settings in each zone of the home. Light fixtures can also be controlled from this point. In addition, zones can be modified with preset definitions within each zone.

FIGURE 12. Basement floor plan indicating location of hydroponics.



ODG had a difficult time working with established industry professionals on this aspect of the project. The client contracted with a commercial company that had shown the intention of expanding their business into residential projects. After many months and meetings, the initial company dropped that line of their business. ODG was able to complete the design of the Smart Home, as an employee called

upon his electrical engineering background. Paired with this innovation, the heating, cooling, and lighting loads of the house were reduced through climate-responsive design and conservation practices.

The Smart House system is based on the Levaton X-10 control system. The Smart Home includes a security system distributed throughout. One of the client's requests included a whole-house distributed audio video system including a home theatre with hi-fi sound. The entire house has been wired for current systems and future technologies. This was achieved by adding extra 3/4″–2″ conduit within the walls for ease of threading next generation cabling. The current electronics include wiring for Internet and HDMI (high definition media interface) throughout all rooms in the house. Other special features of the Smart Home include a new central vacuum system and remote operable skylights with blinds. The central vacuum has separate system controls on each floor. The central vacuum is a bagless system, NuTone Cyclonic CV554 with a six gallon capacity, ideal for small to midsized homes.

There are interior cut off switches for exterior electricity to ensure that excess energy is not used.

EQ 6.2 – Controllability of Systems: Thermal comfort

Three-floor zoned system

The Hilltop Residence's mechanical systems were separated into zones to increase the energy efficiency of the heating and cooling systems; the interface for this system is through a single panel on the second floor. The home is divided into three zones, for each floor of the house, basement (auxiliary space), first floor (primary living space), and second floor (master suite). The heating, ventilation, and air conditioning equipment was set on automatic timers to synchronize the flow of systems. The thermostat is a sophisticated Honeywell 7-Day Programmable Thermostat with controls located in each zone and a master panel where the Smart Home system is located. The Smart Home panel also regulated the whole house humidifier.

Natural Ventilation

The windows and a ceiling fan in the master bedroom allow the client many options for natural ventilation. The taller operable windows and doors on the first floor and open plan are able to catch the predominately northeast winds and provide cross-ventilation.

Humidity Control

A whole house dehumidifier was installed to provide occupant comfort throughout the house.

EQ 8.1 and 8.2 – Daylight and views in 90% of spaces.

All windows have shades to better regulate solar gain and ensure privacy. The loft space continues from the master bedroom into the office space. The office is separated from the bedroom by two columns, continuing the open layout from the first floor. The office user will find a very productive environment as the taller windows bring in additional daylight and emphasize the tremendous views. From the east windows of the office there are one to two mile views of the Potomac River and beyond.

FIGURE 13. Exterior photograph of front elevation showing new porch, new taller windows (with the exception of the kitchen window), and the new roof. Photograph was taken during construction.

The purpose of angling the new roof optimally for photovoltaic panels yielded an incredible benefit by opening up the master bedroom and new office into a double height space. This larger two story space includes the design of a catwalk above the closet and along the north wall to access the mechanical room and attic in the east corner of the loft. The catwalk extends three feet into the room but is well above head height.

The structural glue laminated beams were left exposed as was the aluminum ducts. All of these design facets allowed ODG to achieve and exceed the client's objectives for a loft space. The new addition on the rear of the home increased the master bedroom's length by three feet and provides access to a new exterior porch. The porch has a vaulted ceiling and is also partially enclosed, enabling the client to step outside and retain privacy. While this residence does not have a large footprint, the two story master suite makes the townhome feel much larger.

CLOSING

As the Hilltop Residence was completed on a limited budget, cost estimating and value engineering were prepared at each phase of design. Value engineering challenges including eliminating the plan for a larger basement and replacing it with a crawl space. Specific items were delayed in purchasing until a later date including: photovoltaic panels, basement floor finishes, installation of the rear yard spa, and final installation of the landscape vegetation. The primary impediment to the project's progress was the client's wish to not exceed the budget; therefore the project was put on hold several times until a lower cost of product or installation could be found.

With Smart Home technology, the client can modulate the interior climate and temperature of the residence through many physical controls, including cross ventilation through opposing operable windows and doors, stack effect through the operable skylight, the ceiling fan on the second floor, and deep eaves and shades to control sunlight. The addition also provided exterior living space on each floor as the new porches provide protection from the weather. The Hilltop Residence was designed with low operating and maintenance costs in mind and to use natural resources efficiently. This was achieved through use of long life materials and superior technology, resulting in extremely low annual utility bills.

Even with the anticipated achievements in energy efficiencies of the exterior envelope and interior systems in the Hilltop Residence, there are a few aspects ODG would like to improve in the process of future projects. With sustainable projects it is critical to remain involved after completion to better measure specific system performance. This allows effective technology to be incorporated in future work and further research to improve less successful strategies.