Project Green Home

The Beyond LEED Platinum,
Zero Net Energy,
Passive House

ProjectGreenHome.org

Definition   Purpose   Features

314 Stanford Ave
Palo Alto CA

When we started thinking about building a home from “scratch”, we saw an opportunity to examine the environmental impact from the ground up, and what we could do to minimize the home’s “total lifetime carbon cost.” Within this context, we decided to put the theories and green rating systems (Leadership in Energy & Environmental Design, Zero Net Energy and Passive House) into practice. The result is this beautiful, functional, comfortable, ultra efficient, low carbon house. We hope that others may be inspired, and in their turn, move the efficiency bar even further forward.

Of course, nothing exists in a vacuum. Our work on this house has involved partner- contractors and architects, but also our friends, neighbors, high school and university students, and others. It is more than just our home;it has brought us closer to the community around us.

Wake up America! In our opinion, global warming is and will be the single most important issue for the current and next several generations. As shown below, the earth's atmospheric carbon dioxide (CO2) concentration has increased by almost 130 ppm since ~1850 and over 25 ppm just in the last 10 years! We have to do something!

Having now lived here for over two years, Project Green Home proves that we can address global warming and have a beautiful, comfortable, functional and sustainable home.

-Sven Thesen and Kate Kramer

Date / Activity	<1850 pre-industrial	2006 looking at homes	2008 bought property	2010 began construction	2012 moved in	**2016 present**
CO_2 (ppm)	280	380	384	388	392	**408**

October 2010, daughters Sophia and Genevieve indicate their position on Proposition 23. Primarily funded by out-of-state oil companies, Prop 23 would have rolled back California’s landmark Global Warming Solutions Act of 2006 requiring the State to reduce greenhouse gas emissions to 1990 levels by 2020 and a 80% reduction over 1990 emissions by 2050. The first fundraiser held at the then unfinished home was against Proposition 23.

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1. Purpose, Definitions & Background, Living Room

The goals of our project, and the background that goes with it.

1.1 Purpose, Living Room

What is the purpose of the home?

Project Green Home (PGH), located in Palo Alto, California, less than three blocks from Stanford University campus, is a single family dwelling of approximately 2,400 square feet completed in June 2011. The home:

- Meets (and exceeds) the State's residential 2020 zero net energy requirements now;
- Meets the Passive House standard, surpassing LEED platinum and California's Title-24;
- Integrates both cutting edge and available energy efficiency technologies;
- Incorporates the best, cheapest, longest-lasting, safest, most aesthetically pleasing product and materials available;
- Serves as a model and showcase for green/energy efficient building technologies;
- Meets California's Assembly Bill 32 requirement for 80% greenhouse gas emission reduction by 2050, right now;
- Created more "green jobs" in the construction industry versus incremental additional jobs in the fossil fuel industry.

As a working model of the possible, Project Green Home hopes to serve as a real-life replicable example, creating a virtuous circle of similar sustainable housing. As such we welcome the involvement of the community and, in particular, students in evaluating the home against the above design parameters, and likewise media coverage to publicize the possibilities.

1.2 Leadership in Energy & Environmental Design, Living Room

LEED is a rating scale for "green" homes; we aim to well surpass their Platinum rating

Leadership in Energy & Environmental Design (LEED) is an internationally recognized green building certification/numerical rating system, providing third-party verification that a building or community was designed and built using strategies intended to improve performance in metrics such as energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. To verify that the house is achieving the highest standards of green and sustainable design the project received the highest ranking, Platinum certification in the LEED for Homes rating system. This system covers every aspect of home construction, from integrated design; the use of materials, energy and water; the building's interaction with the surrounding community; and the quality and health of the indoor environment.

For a house our size and our climate, the difference between each of the LEED rankings (Certified, Silver, Gold and Platinum) as noted in the table below, is 15 points. We call our house “Beyond Platinum LEED,” as PGH received a LEED score of 109 which is 22 points above Platinum and 46% greater than the delta between each of the rankings.

LEED Potential Ratings for Project Green Home:

Certified	***Silver***	***Gold***	***Platinum***	***PGH***
42	*57*	*72*	*87*	*109*

The LEED Certification and backup documentation is found in Appendix 1

1.3 Zero Net Energy Building (ZNE), Living Room

A Zero Net Energy Building generates as much energy, on-site, as it uses.

In California, ZNE is defined as the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building. In essence, this means that the amount of externally generated electricity, natural gas or other energy stock used at the home must be equal to the energy generated by the home. This will be the 2020 standard for all new California residential construction. Depending on the location of the home, this can be accomplished by installing and operating photovoltaic (PV) systems (most common) but wind generation systems, small-scale hydropower and other on-site renewables are also options.

To meet the state’s ZNE goals, we installed a 5.9kW photovoltaic (PV) system to self-generate our electricity. This not only covers the annual house energy use but also 8,000 miles (2,000kWh) of electric car use.

The ZNE Certification Documentation is found in Appendix 2

1.4 Passive House, Living Room

Careful construction regulates the temperature of the house naturally, to save energy.

Passive House (***Passivhaus*** in German) refers to the rigorous, voluntary, *Passivhaus* standard for energy efficiency in buildings. It results in ultra-low energy buildings that require little energy for space heating or cooling. Passive design is not the attachment or supplement of architectural design, but an integrated design process with the architectural design. In the United States, a house built to the Passive House standard results in a building that requires space heating energy of 1 BTU per square foot per heating degree day, compared with about 5 to 15 BTUs per square foot per heating degree day for a similar building built to meet the California 2003 Model Energy Efficiency Code. This is between 75-95% less energy for space heating and cooling than current new buildings that meet today's US energy efficiency codes.

At present, essentially three components are needed to meet the Passive House standards: First, minimizing heat loss via insulation and building an airtight structure. Second, the home uses sunlight as its primary heat source in the winter. Third, in winter the heat in the air stream exiting the building is used to heat the incoming fresh air and vice versa in the summer time.

To be certified as a Passive House, there are three quantifiable standards that need to be met along with the results from Project Green Home (PGH) testing.

	Passive House reqirement	Project Green Home result
Annual space heating or cooling demand (site energy)	≤ 4.75 kBTU/sq. ft. (≤ 15 kWh/m^2)	3.94 kBTU/sq.ft. heating 0 kBTU/sq.ft. cooling
Annual total energy demand (source energy)	≤ 38.0 kBTU/sq.ft. (≤ 120 kWh/m^2)	26.6 kBTU/sq.ft.
Air tightness	0.60 ACH_{50}	0.55 ACH_{50}

As a result, this objective has been met and likewise brings all the benefits of a Passive House. The Passive House Certification Documentation is found in Appendix 3

1.5 Home Background, Living Room

Who we and the team are and the vision

Start with a family in Palo Alto desiring to change the world for the better with a focus on climate change and energy/water use. Add Arkin Tilt Architects and Josh Moore, our Project Manager, and a common vision is born. Combine this vision with a 7,500 square foot lot in Palo Alto, with a very small termite-ridden house constructed in approximately 1918. Deconstruct this structure (simultaneously recovering all the useable materials) and build a house that meets the above design parameters with the features detailed in Section 2.

2 Features

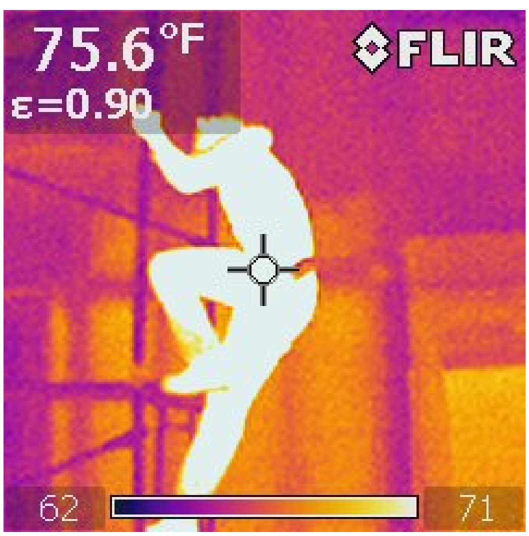
2.1 Design

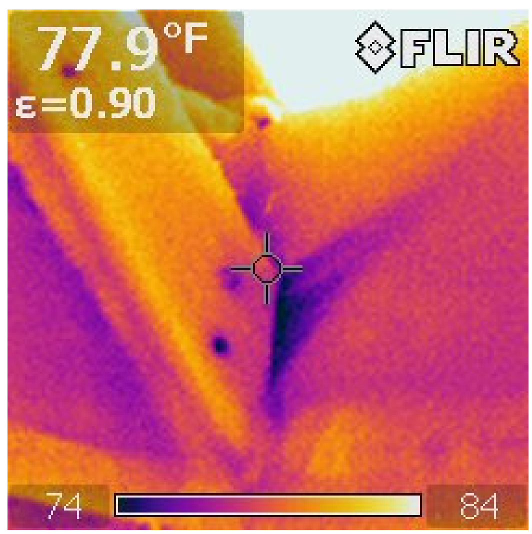
2.1.1 Airtight Construction, Sophia's Bedroom

Air tightness testing

There are three components to the Passive House standard. The first is that the house should be airtight and well insulated, so that heat is not transferred through the building membrane. Our walls were tested using an infrared camera, to show where air was seeping in. On the left is a picture taken to demonstrate the use of the camera to show heat. The picture on the right shows a plume of cold air, coming in around the edges of a beam, which (intentionally) punctures the building exterior membrane. This evaluation procedure was the brilliant idea of Josh Moore our Project Manager. Insulation is covered in section 2.2 as there are so many different insulation types used in the house.

The house is essentially a box. To make the structure airtight, the builder had to focus on three primary areas: Where the ground floor wall meets the slab, all window and door openings, and along the roof edge where numerous rafter tails poke through the air-tight envelope had to be sealed along every edge.

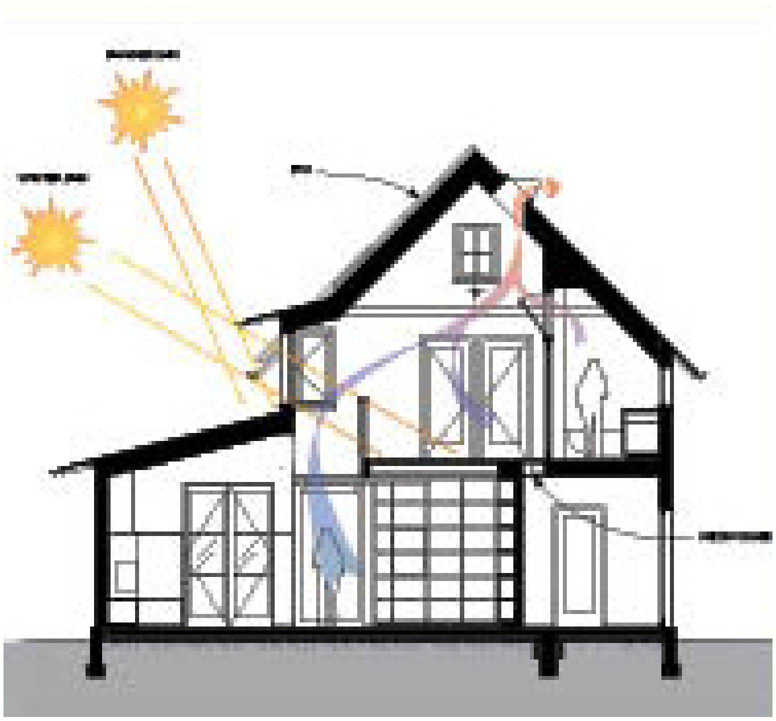




2.1.2 Passive Solar Design, Sophia's Bedroom

Using sunlight to provide ~60% of the heating requirements.

The second component of the Passive House standard is that it uses sunlight as its primary heater in the winter. Most of the windows face south, and the main living spaces are on the south side of the house. Bathrooms, storage, and staircase-parts of the house where less time is spent-are generally located on the north side. Solar heat is estimated to provide 60% of the annual space heating needs, and heat from occupants and appliances inside the house provides another ~15%, according to a simulation in the Passive House Planning Package (PHPP) software used. In addition to the relative inexpensiveness and reduced energy consumption, solar heating inherently does not create greenhouse gases, which also helps to reduce the effects of global warming.



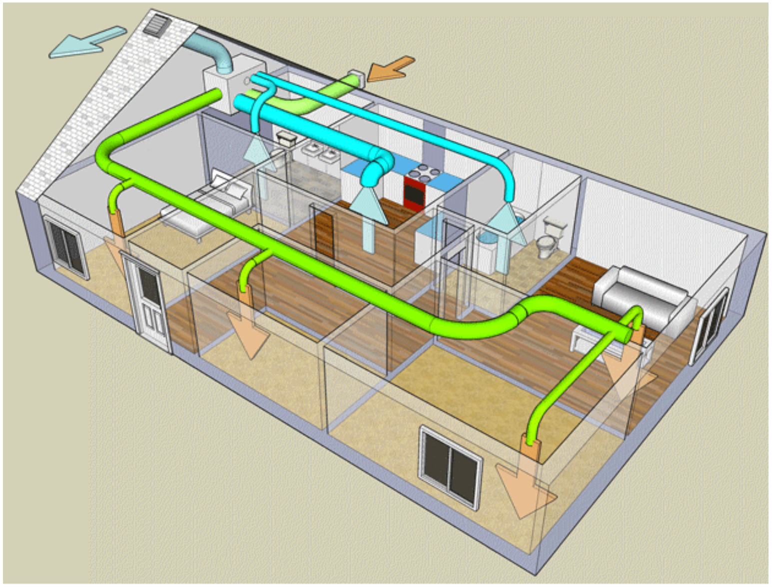
In passive solar heating, warm collected by certain areas of the house is circulated throughout the rooms to generate heating. Usually, large hard surfaces, such as a wall or floor that has been darkened, will absorb sunlight in the form of heat. In our case, the dark concrete floor is the home's primary thermal mass. This stores and gradually releases the heat through conduction, convection, and radiation processes. The overall architecture of the building, as well as the climate and location, also influence the overall ease and success of heat flow.

Outdoor living spaces are integrated on the south side of the house where they connect directly to the main rooms. These outdoor spaces tend to be comfortable for most of the year, shaded by trellises.

It's important to note that the heating (and cooling) needs were based on a computer model. After more than two years of living in the home, we find that overall it is quite comfortable.

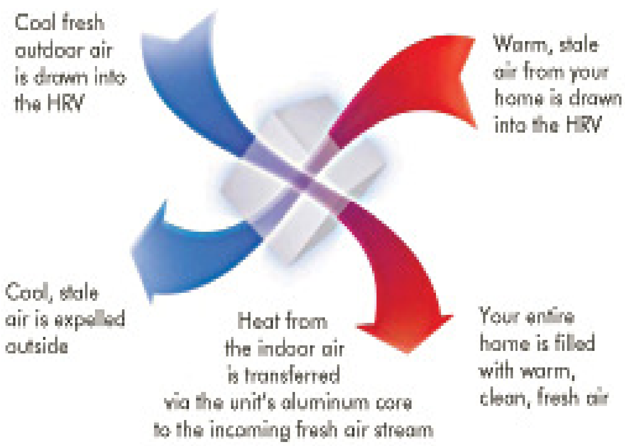
2.1.3 Filtered Fresh Air & Heat Recovery, Sophia's Bedroom

Air is recirculated, so that it stays fresh with closed windows in cold months.



The third Passive House component is ensuring a solid supply of fresh air while still meeting the energy efficiency requirements. Here, the house gets fresh air on-demand from a filtered ventilation system located in the attic. Specifically, the heat-recovery ventilation (HRV) equipment pulls a continuous exhaust of stale air from the bathrooms and kitchen, and "harvests" the heat before expelling the air to the outdoors. Simultaneously, outside air is filtered and absorbs heat from the exhaust air via a waffle-grid heat exchanger before being distributed to bedrooms and living rooms. The incoming and outgoing air streams never mix.

In addition to the energy recovery, the HRV also filters the air. Minimum Efficiency Reporting Value (MERV) is a rating system for air filters. The HRV uses a MERV 9 filter, which is suitable for hospital laboratories and filters ≥90% of particulates from the air. The volume is relatively low (80-150 cubic feet per minute), so small ductwork is used (4-6" round, rigid metal). Most of the ductwork is in a chase between floors. Despite the energy needed to run the fan, the HRV creates a net energy savings for the house, and superior indoor air quality.



After two years of operation, we find that we should have used larger diameter pipes. This would have reduced the noise and ongoing energy use by the fan. While we have not measured the noise level in the house, we do notice the "white-noise" caused by the system. In actuality, the HRV may or may not be noisy, in that the house is extremely well insulated and sealed which limits outside noise and may make low-level noise more noticeable.

In addition, since the installation of the unit, we have found similar units that are capable of bypassing the heat–exchanger. This is important as, in our Northern California climate, we have hot days and cool nights. In the summer, should we forget to close the windows in the morning (or those in the upper floor), which causes the upstairs to get hot by the end of the day, the feature to simultaneously quickly pull hot air out of the home and dump cool air in would have been beneficial.

If you are considering such a system, please do contact Sven Thesen for more information regarding a whole host of issues that could have been avoided.

Venmar EKO 1.5, VenMar.ca , installed by Bayside Mechanical, BaysideMech.com

2.1.4 2x8 Studs at 24" Spacing, Genevieve's Bedroom

Optimizing structural members limits thermal bridging and saves trees.

Advanced Framing or Optimum Value Engineered (OVE) framing is a system that uses wood only where it is necessary structurally. American builders trying to conserve limited resources in the past centuries used a similar framing system. Today, OVE framing typically uses 2x6 studs (5-1/2" thick) at 24" spacing, with less superfluous wood around windows and doors, and at the top and bottom of walls.

Since wood conducts heat much faster than insulation, reducing wood in the walls saves heating and cooling energy. In this house, 2x8 studs (7-1/4") are "balloon framed" over two stories, running from slab to roof, to reduce joints and connections at the intermediate floor. This also makes the house stronger against wind and earthquakes. We are looking for a student to determine if the 2x8 wood use 1) Reduces overall lumber use and 2) Given that a 2x8 requires a larger tree than a 2x6 (or 2x4), it is the appropriate ecological choice.

Do note that framing with this system takes significantly more detailed drawings and more coordination between builder, architect, and structural engineer. Most builder-architect-engineer teams have never framed this way, and the learning curve is steep and expensive due to the additional time required "to get it right." In our case, our first builder charged an additional $5,000 for this framing style. However, it is not clear if the first builder saved any monies in reduced material costs

2.1.5 Air Admittance Valves (AAVs), Children's Bathroom

Reduces need for membrane punctures and plumbing piping.

An AAV is a durable, one-way air valve, the size of a large vitamin bottle. It takes the place of a traditional plumbing vent through the roof. The purpose of both the traditional vent and the AAV is to admit relief air into the plumbing system when water is draining, in order to prevent a vacuum in the pipes that would suck water out of the P-traps under faucets. Typical houses have many vents breaking the integrity of the roof, acting as thermal bridges, and circulating outdoor air within the walls. This house has one such vent--the rest are AAVs. AAVs require less plumbing material and labor, and less roof work than conventional vents. When they are enclosed in a wall, AAVs require an access panel for inspection. At present, Palo Alto does not allow AAVs. To waive the prescriptive building code and allow the AAVs, the design team had to submit a formal request including significant documentation to the City of Palo Alto. The request was approved. Full Palo Alto approval documentation is located on ProjectGreenHome.org/features Sure-Vent, Oatey.com

2.1.6 White Metal Roof, Upstairs Open Space

Light colored roof reflects more solar heat, instead of absorbing it.

A "White Roof" is not necessarily white, but is a light color so that it reflects more sunlight, keeping the house cool, and reflecting more light into space. A dark colored roof absorbs more light, and converts it to heat energy. For example, a roof that is true black heats up by 90 degrees Fahrenheit in direct sunlight, while a true white roof heats up by only 14.6 degrees. This light absorbed by a dark colored roof is transferred into heat, and contributes directly to global warming. The light-colored roof also decreases the temperature inside of the building, which reduces energy use associated with cooling the building. However, there is incremental increased energy use in the winter compared to a darker roof.

The Palo Alto Planning Department was concerned about the aesthetic effect of glare on our neighborhood, so we are using a light grey, metallic color that is almost as reflective. Our roof's reflectivity is 58%, while the white option we had available is 63.3%. Because our roof insulation is so thick, the grey roof will have minimal impacts on heating the house in the summer time, and should save a small amount of energy on heating in the winter. The only drawback of the grey roof (versus the white roof) is from a climate perspective: over the course of a year a little more heat is absorbed from sunlight, and will be released into the air outside the house.

Note, white roofs are speculated to be effective only in warmer climates. Research is currently being conducted to determine if white roofs can save energy in all kinds of climates instead of simply warmer areas such as Palo Alto. For example, it may make sense for a roof to be reflective in the warmer seasons and then darker in the colder months.

In addition to the above, the metal roof was selected over a conventional tile or asphalt shingle tile roof based on a number of factors including aesthetics, (what is understood to be) low embodied energy, long lifetime and ease of recyclability. Asphalt and tile roofs have a sun reflectance of 25%-35%, which is significantly lower than that of metal, which has a 60-70% reflectance. As discussed above, higher reflectance absorbs less sunlight and heat energy, which will decrease the amount of heat energy present to increase the surface temperature of the Earth. In addition, our metal roof has a 40+ year warrantee versus asphalt shingles, which are on the order of fifteen to twenty. Asphalt roofing is also non-recyclable, which further increases the associated embodied pollution and waste. Though the upfront cost of asphalt shingles tend to be cheaper, in the long run, we believe metal roofs are more effective and energy efficient. ccsmr.com

2.1.7 Skylight Passive Ventilation, Upstairs Open Space

Open skylights create a thermal stack pulling cold air up from the ground floor.

Three electrically-operated skylights near the ridge of the roof are located to passively ventilate the house. Air moves freely past the upstairs mezzanine balcony/ open space and stairwell, and the height difference of 20+ feet above the ground slab ensures a strong stack effect, or updraft created by the buoyancy of warm air released from a high opening. Because the house does not have a “smart” heating and cooling system, we leave the skylights open in the summer and then close them once we initiate the radiant floor heating system. Without measurements, it is difficult to determine the efficacy of the skylights..

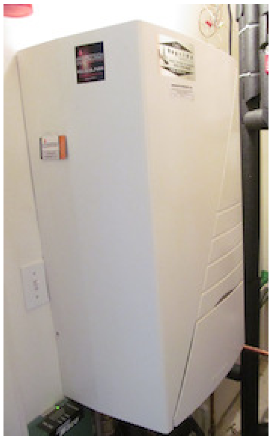
2.1.8 Active Ventilation, Ceiling Fan, Upstairs Open Space

Ceiling fan assists in moving warm air back down in winter & moving warm air out of house in summer &.

The mezzanine/ open space ceiling fan assists in moving warm air back to the inhabited spaces during winter. In summer, turning the fan in the reverse helps move warm air out the skylights. The switch to operate the fan is a manual switch and it is not clear if the unit can communicate to a remote controller or better “smart” heating and cooling system. Because of the manual operation, to date, we have not used the fan (to assist with either cooling or heating) so its efficacy has not been determined.

2.1.9Daikin Altherma heat pump water heater, Upstairs Utility Closet

Heat from the air outside, with technology much like a refrigerator, is more energy efficient.



This electric water heater transfers heat from the outside air into a water storage tank using refrigerant in a vapor-compression cycle, like an air-conditioner in reverse. The so-called "air-source heat pump" creates 3-4 times more heat from the same electricity as a standard electric water heater. The efficiency is comparable to a geothermal heat pump in this climate, but involves no expensive boring or excavation. In essence, the unit harvests and concentrates outside energy – for every one unit of energy we put into the unit, we get 3-4 units of heat out.

The Altherma costs more than a conventional water heater, but for a zero net energy project, the Altherma costs less upfront to save electricity than the photovoltaic panels (PV) that would be necessary to generate that electricity.

After two years of operation, we are surprised at how much heat is generated by the unit located in the mechanical closet and how warm/hot this closet is. Making lemonade out of lemons, that is, taking advantage of this waste heat, we use this room to dry shoes in, and it's also where the homemade yogurt goes to ferment and the bread to rise.

We are looking for a student to calculate how efficient this unit is, in comparing the winter electrical loading to that of our natural gas use at the rental home (same size) we were in prior to moving into PGH.

JTGMuir.com, installed by Bayside Mechanical, BaysideMech.com

2.1.10 Radiant Floor Heating, Living Room

More efficient thermal transfer reduces energy needs.

A variable-speed pump circulates warm water through tubing in the ground floor slab for winter comfort. Because of the large surface area, radiant slabs can deliver heat using lukewarm water (90ºF), compared to other water-based heating equipment such as radiators and baseboards (160ºF). The lower temperature improves efficiency at the heat source, allows the use of future solar-hot-water for space heating, and allows the use of an electric water heater (the Daikin Altherma) that would be less efficient at higher delivery temperatures.

A conventional slab with tubing everywhere, running at full output, would be barely warm enough to feel, because so little heat is needed to maintain a warm room temperature. Because heat delivered is proportional to (water temperature) x (surface area), we had to greatly reduce the surface area of tubing in this house to keep the water temperature warm enough to feel.

Hot water tubing was placed where the noticeable warmth would be most comfortable and social: the dining room table, the kitchen, the bathrooms, and walking paths around the ground floor.

After two years of use, we find the north side spare bedroom does not get as warm as the main ground floor as this room inherently does not capture the sun like the main floor does. As both rooms are on the same piping system, both areas get the same amount of heat from the radiant floor system per square foot. Additional warming for this room would have required either additional radiant pipes, closer together than those in main floor or a separate set of piping and temperature control for this room.
Bayside Mechanical, BaysideMech.com

2.1.11 Gas Fire Place, Living Room

The gas fireplace is our acceptance of, and nod to, our Neanderthal past, in that we occasionally like watching the flames flicker. In selecting the fireplace we had significant difficulties finding a small enough unit (<10,000 BTU), else we would roast inside. It will be interesting to see over the next winter how many times we actually do use it. This is the only natural gas powered device in the home.

2.1.12 Post & Beam Interior Designed for Remodeling, Library

Interior walls are not load bearing, so they can be remodeled easily.

The exterior shell of the house is largely self-supporting, and the interior is post-and-beam construction. Most of the interior walls are non-load-bearing, so they do not need a lot of structural wood, and they can be rearranged in the future should the family's needs change. We also put hot and cold water lines plus an associated drain and 20v wiring in the wall between the library and study should at some point we or a new owner wish to add a kitchen or move the kitchen to the back of the house.

2.1.13 Aging-In-Place or Extended Family, Study

Flexible space to use in many different ways, as family changes and grows.

The house has five bedrooms, including a ground floor suite with its own outside door that can accommodate an elderly relative, an au pair, elderly homeowners, or a young couple with a child. This bedroom and bathroom configuration strives to provide extended-family living, and flexible space for many future situations. To fully accommodate this, we also installed hot and cold water lines, a drain and 220v to the back area of the house, in case of an additional kitchen or relocated kitchen.

2.2 Insulation

2.2.1 Insulation Rating System/ Standard, Genevieve's Room

Insulation is one of the three keys to meeting the Passive House standard. While the house gets most of its winter heating from sunlight, there is still some energy spent to generate heat, and good insulation is required to conserve that heat as efficiently as possible. Insulation should also be combined with airtight construction in areas such as windows and doors to effectively reduce heat loss throughout the house.

The ability to insulate is termed the R-value, which essentially means the resistance to heat flow. The higher the R-value, the greater the insulating power. For insulation, the higher the R value the better, because a material with a lower R-value allows more heat to pass through (heat flow) under the same temperature conditions.

In California, houses are required to have walls with a minimum R-value of 13 to 21, depending on the climate zone in which they are located; Project Green Home's walls are required to have an R-13 value and actually have values of R-24 (second floor) and R-28 (first floor).

A summary chart noting California residential insulation levels over time follows:

Insulation, R	*1970's*	*2008, Title 24*	*PGH*
Walls	R-15 If insulated	R-15	R-28, 1st floor R-24, 2nd floor
Ceiling/Roof	R-15 If insulated	R-30	R-45
Windows	R-1	R-3 Center of glass	R-7 Center of glass
Floor Slab	None	R-15 If heated	R-18

2.2.2 Wall and Ceiling Insulation, Genevieve's Room

A Pro-Pink Complete Blown-In Wall System by Owens Corning was used to "super insulate" this home. Fiberglass was selected over a variety of other insulation products due to its high R-value, light weight, high-recycled content and affordable overall price compared to other insulation systems. Not only does this degree of insulation keep the house warm in winter and cool in summer, but it also significantly reduces noise transfer from the outside and also from room to room.

Cellulose insulation was a competing option, but fiberglass has slightly higher claimed R-value, at half the density of cellulose. Lower density helps with sheetrock installation over the roof rafters; the fiberglass will not sag in its netting as much as cellulose would have. The only drawback to fiberglass insulation is the higher embodied energy (the energy used to create the material is approximately 10 times as much). Cellulose requires the least amount of energy to manufacture out of all types of insulation, for it uses recycled paper. In addition, cellulose waste can be recycled or decomposed whereas fiberglass waste is typically landfilled. However, because of the added energy savings of fiberglass, the total energy cost is eventually lower than cellulose roughly after 1 year.

The Pro-Pink Complete Blown-In Wall System is a two-step process. First, a fiberglass mesh blanket fabric is stapled to the faces of the 2x8 studs and then the L77 loose fill fiberglass is blown in, yielding an R-Value of R28. This compares to a typical fiberglass batt and blown in cellulose both yielding R-values of 25, assuming 2x8 studs. The blown-in system itself works better than other methods of installing fiberglass insulation because it keeps the insulation dry and avoids moisture that could reduce the fiberglass R-value. The loose-fill fiberglass itself was created from glass that has been molten and spun or blown into smaller fibers.

Sprayed polyurethane foam (SPF) insulation was not used for several reasons:

1) While SPF has a higher R-value per inch of thickness than other types of insulation, the blowing agents currently used have global warming potentials (GWP) far in excess of CO_2. It would take decades of avoided emissions while operating this zero net energy house just to offset the GWP emissions from installation.
2) Although SPF is inherently air and vapor-impermeable, this is unnecessary, since the house uses the exterior plywood sheathing as the air barrier. Air barrier flaws at the sheathing layer are easier to diagnose and repair. Vapor-impermeable materials in this mild climate prevent the free diffusion of moisture, which may damage assemblies over time. Water-blown, open-cell SPF does not have these issues, but its R-value is no better than cellulose or fiberglass.
3) Foam insulation costs more than cellulose or fiberglass.
4) Walls and ceilings with loose-fill insulation will be easier to open and reconfigure during future remodeling. Ease of remodeling is essential to extending the usefulness of a building.

2.2.3 Unvented Roof (Full Cavity insulation), Genevieve's Room

The entire shell of this house has full-cavity insulation. The attic is usable, conditioned space, and there is no outside air vented between the rafters as with a typical home. Currently, the California Building Code requires rafter venting to prevent potential condensation damage in roof cavities. Condensation forms in roof cavities when a steady stream of humid interior air enters the roof cavity through air leaks, and the top of the roof remains cold for long periods of time. This house is so well sealed against drafts that there is no supply of humid air, and the roof sheathing is insulated from above with 1" of rigid polyisocyanurate ("polyiso") board. To waive the requirement for rafter venting and allow the modern roof assembly, the design team had to submit a formal request including significant documentation to the City of Palo Alto. The request was approved. BuildingScience.com

2.2.4 Insulated Header, Genevieve's Room

A header is the structural member spanning over an opening in a wall. Headers are typically solid wood and occupy the entire thickness of the wall, creating a significant thermal bridge. Headers in this house are 3-1/2" thick engineered lumber, set to the inside of the 7-1/4" wall, with 3-3/4" of expanded polystyrene (EPS) insulating the header from outside temperatures. EPS (white and crumbly) is the eco-friendliest of the rigid, plastic foam insulations. White Cap Construction Supply, San Leandro.

2.2.5 Floor Insulation, Ground Guestroom

Expanded PolyStyrene insulation was also used under the concrete slab. The slab was poured into a continuous "bathtub" of four-inch Type II EPS insulation that wraps up the sides to connect with the walls. This keeps the slab close to room temperature, even without the radiant heat activated. In addition to improving comfort, slab insulation greatly improves the home's energy balance. Slab insulation can never be retrofit, so insulating properly was important. Four-inch thick EPS sheets facilitate installation since they are less breakable than thinner sheets commonly used. Further, scraps of this thick material were used to insulate headers and wall cavities.

2.3 Electrical Energy

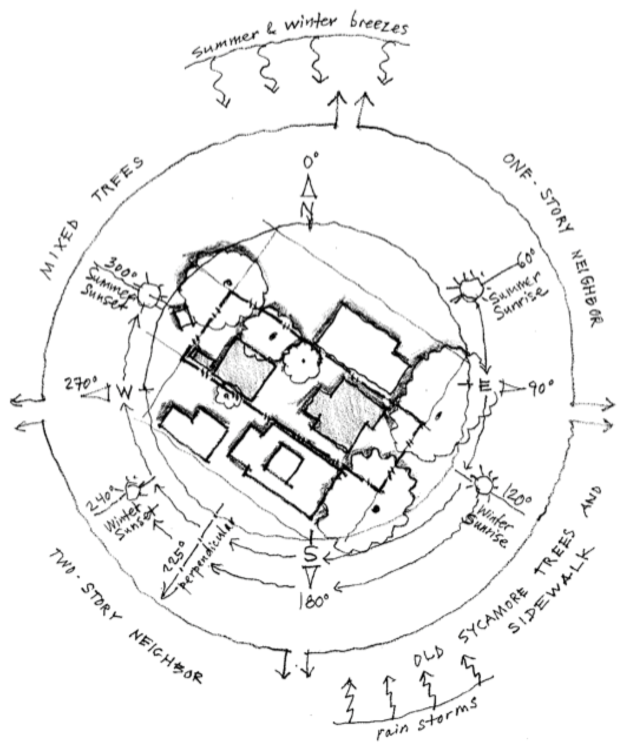
2.3.1 Electricity & Electrical Wiring, Sophia's Room

Minimizing wiring holes in the exterior membrane.

To keep the home as airtight as possible, the wiring configuration minimizes punctures in the exterior plywood sheathing. To accomplish this feat, the majority of outdoor wiring (serving the outside lighting, gray water pump, electric vehicle charging system) is addressed by an outside electrical panel. Further, as noted by the pictures, cuts through the outer wall have been made with the smallest hole that would allow the wiring through and sealed from the inside. A typical cut is on the right.

2.3.2 Photovoltaic System, Master Bedroom

Just a fancy word for solar panels.



A 5.9 kW photovoltaic (PV) system including locally designed micro inverters was installed on the west side of the home in March 2013. The system size is designed to cover the entire energy load of the house plus that of an electric car driving ~8000 miles per year. Based on system cost and projected generation over 25 years, electricity should be on the order of 7¢/kWh, this is compared to the current Palo Alto price of 16¢/kWh.

We endeavored to minimize the number of PV panels (that is the cost) required to achieve our zero net energy goal by locating the house as far back from the street trees as the City of Palo Alto would allow. This explains why we have the front covered porch and associated timber structure, this "front" is in alignment with all the other homes on the street while the body of the house sits ~8 feet back. Further, the roof slope conforms to the City of Palo Alto's "Daylight Plane" requirements, which minimize the house's shade on neighbors. Despite Planning Department constraints, annual PV generation from this roof is within 1% of that from a theoretically ideal slope and orientation, according to the PVWatts online calculator.

PVwatts.org

Further, we waited more than a year to install the system to determine actual electricity use and hence the PV system size needed. With this all-electric house, (heating, cooling, range, hot water, etc) we use roughly ~12 kWh/ day in the summer and ~22 kWh in the winter. In addition, we included electricity for an electric car at 4 miles per kWh and ~8,000 miles per year.

In late 2010, we reserved our spot in the Palo Alto PV rebate program at $1.4/watt. As such, we encourage those interested in PV to reserve a place in the program ASAP for the rebates are based on a tiered system – the sooner one signs up, the larger the rebate. For example the October 2012 rebate was $1.2/watt. Likewise, knowing that we were going to install PV, we included a ¾" EMT conduit from the roof to just next to the main breaker as part of the home construction. This was done to reduce installation cost of future PV and as a tradeoff between exterior wall punctures and exterior aesthetics.

In attempting to make the house "Solar Ready, " we made at least 3 mistakes. 1) We used a main circuit panel (the one that sits on the outside of the house) that positions the main house breaker at the top of the panel as opposed to one-third of the way down, 2) We should have marked the conduit as carrying electricity (Palo Alto has specific language for the signage) and had this piping inspected by the city before the sheetrock and insulation covered it up and 3) The conduit carrying the wires from the rooftop PV should have exited the house further from the main breaker panel.

As part of our community educational efforts, we partnered with Palo Alto Utility and Horizon Energy and held a "All you wanted to know about Residential Solar Energy But were Afraid to Ask" evening seminar at our local elementary school which was attended by ~12 families. PV Installer: Horizon Energy, gosolarnow.com

2.3.3 CAT6/Data Wiring, Desk Nook

We decided that data wiring isn't really necessary, with wireless connection.

We did not wire the house with CAT6 or other data wiring (except for phone jacks and cable) with the assumption that the future is wireless and will communicate via ZigBee or Powerline Carrier. In 2008 and 2009, and after touring numbers of houses that were wired with CAT6, this was a serious question. After two years of living in the house, this lack of wiring has not been a problem. However, what we still need to do is work out the sound system – if anyone has an interest in this project, please contact Sven.

2.3.4Energy Monitoring System, Laundry Room

The central control panel for the PV, plus some additional monitors.

Our advice: Depending on your personality, it may be better to hire an energy efficiency company to do a winter and summer energy snap shot. On the other hand, you could integrate your smart meter with your photovoltaic generation feed to determine live energy use. If you decide to measure live usage, ensure there is room inside and outside the breaker panel(s), and be prepared to spend several thousand dollars on monitoring equipment, and also install a simple roll type counter on the electric vehicle charging equipment. (If others charge their car at your house, it's quick and easy to know how much electricity they used.)

PGH Background: Initially, the thought was to use some form of whole house TED or TED like energy monitoring system to provide live data on 1) overall energy use, 2) that of a few large appliances (water heater, stove, EV chargers) and 3) photovoltaic generation. However, we have decided against this given the cost of a TED system combined with the need to build a stand or shelf abutting from just below the main indoors breaker panel to house the TED monitoring equipment plus same for the exterior breaker panel. If you are looking to do this level of live monitoring, understand 1) the up front costs ($2k+ for our house); 2) likewise that you, your architect and electrician understand the necessary equipment needed and the associated space both inside and outside the breaker panel and 3) how to integrate multiple breaker panels.   (For example our internal panel handles the inside electrics including the inside component of the 220v heat pump while the exterior panel handles the main feed from the city, the electric car chargers, and the exterior component of the 220v heat pump. Hence to accurately measure the heat pump, we need to operate two TED type systems, one at each breaker panel.

Instead, the non-profit Acterra*, as part of their energy audit services, provided a Blue Line Innovation Energy Monitor which reads the external utility meter (the classic spinning meter) and provides live data on the overall energy use (or generation if its spinning backwards) to a easily readable monitor inside the house. However this device was less than perfect in reading Palo Alto's old style spinning meter and/or in the data transmittal to the indoor monitor and has been removed.

In addition, the photovoltaic system has its own website noting instantaneous generation plus daily, weekly, etc generation. Once we get a smart meter from the Palo Alto Utility (we are part of a pilot program for the city utility to evaluate the various smart meters) we hope to integrate the PV generation data with the city data.

As for the past year's energy use, utility bills indicate that we use ~12 kWh/ day in the summer and ~24 kWh/ day in the winter. This doubling in energy use is due to primarily the heating needs of the house (see Sections 2.1.8 & 2.1.9 discussing the radiant floor heating system) combined with additional electric dryer use (in the summer we mainly use a clothes line). These numbers are pre- electric car charger installation.

We have also measured a number of the 110v appliances with Kill-A-Watt meters. For example, the Heat Recovery and Ventilation system uses 40w; to wash a load of laundry takes 0.1kWh versus the dishwasher which is 1 kWh per load (it uses a built in water heater in the cleaning cycle). The Acterra Audit examined other 110v loads and identified a number of minor vampire loads such as the microwave. Vampire loads refer to appliance electrical use even when the appliance is off but not unplugged) We were pleased to find out that the flat screen TV, a 2012 purchase, has no vampire load.

Kate Latham, an energy consultant with WattzON.com has also volunteered to do a detailed examination of the 220v loads in the next several months.

*As part of Acterra's energy audit they provide & install the Blue Line Innovation Energy Monitor for free to houses that use more than 10kWh/day

2.4 Illumination

2.4.1 Daylighting, Study

More light from outside means less light from electricity.

Within the constraints of the Palo Alto City Planning regulations, the lot size, and surrounding trees and structures, we have attempted to bring daylight into the house to maximize livability and to reduce the need for electric lighting. The large dormer over the loft illuminates the central space. The open stairwell is lit from above by operable skylights. The master bathroom is also lit by a skylight. Most rooms have light from at least two sides to balance the color and quantity of daylight.

2.4.2 Electric Lighting, Guest Bedrooms

LED lights and compact fluorescents save significantly over incandescent bulbs.

The great majority of the lighting is either Light Emitting Diode (LED) or fluorescent. The wall sconce LEDs are made by Phillips and the LED recessed ceiling lights are model LR4 by CREE. The LEDs are incrementally more expensive than standard fluorescent lights, but the payback on energy savings is rapid. In addition, LED lights are more cost effective than PV panels at reducing household energy drawn from the grid. Finally, compared to fluorescents, LEDs do not contain any mercury or lead and their dimming performance is typically superior.

In specifying the lighting, LED and fluorescent lamp color-temperatures were specified to feel warm and match our expectations of "home."

Compare and contrast the lighting in the downstairs and upstairs guest bedrooms. Include in the evaluation the ability to properly dim the lights, light output, color and noise.

The total lighting energy footprint from the home's approximately 60 different light bulbs was calculated to be just over 1 kW, the equivalent of 10 standard 100-watt incandescent bulbs, or 2, 500W halogen bulbs. The majority of the bulbs have also been scribed with the installation month and year to determine actual operating in-the-field lifetimes. In fact, so far, in the two years of living here we have not had yet had to change a light bulb – anywhere!

2.5 Interesting Materials

2.5.1 Quality Windows, Upstairs Guest Bedroom

Better windows, for better insulation.

We like the windows: their triple pane super seal and insulative qualities, the 2 ways of opening, and their look. They have a modern metal frame (nice colors) on the outside, with warm Scandinavian looking wood on the inside. Our one issue is that they open inward, so selecting appropriate drapes and curtains can be difficult.

About 25% of the windows have screens; some were placed to provide shading (kitchen) and others to prevent mosquitos from entering. As they were not ordered simultaneously with the windows, we went with a local manufacturer. We plan to keep screens on the windows for 3/4 of the year.

In an effort to spur North American manufacturers to improve their products, the house features triple pane windows and multi-panel doors by Sorpetaler from Germany. These units have thicker, stronger, better-insulating glass; better-insulating frames; and seal airtight. These features, combined with the attractive style, render them (sadly, in our opinion) superior to any American manufacturer as of early 2010. Sorpetaler windows are easier to install weather tight in any wall thickness because they can be set within the wall to optimize thermal performance, they permit over-insulation thereby further increasing whole window heat resistivity, and they have a modular aluminum sill and no nail flange. The block frame allows them to be taped airtight to the house. Sorptaler has also been working to reduce its company carbon footprint, which qualifies the company as a more sustainable choice. It uses wood that has been sustainably harvested from forests throughout Europe and Scandinavia, eliminating a net loss of trees. Also, by our architect's calculations, shipping the windows by sea is less of a carbon footprint than a 500-mile truck ride (in comparison to mid-western US made windows)

The "U-value" indicates the level of heat flow through a window, with lower numbers being better. Typical North American windows (again as of early 20100 have a U-value of about 0.33, the Sorpetaler U-value is less than half, 0.14, and reach as low as 0.09.

To date we are quite happy with the windows and accordion door leading to the front side porch. .sorpetalerusa.com

2.5.2 Concrete Slab, Dining Area

Made with materials often considered waste products, which require less energy to process.

The concrete mix design uses 50% slag and fly ash in place of Portland cement, which reduces the energy needed to make the concrete. Additionally, the slag and fly ash have traditionally been considered waste products. The mix achieves 3000 PSI of compressive strength after 28 days. Star Concrete, San Jose.

Figure 10 Concrete Slab

The rich rust-color of the slab comes from a non-toxic mixture of iron sulfate, which is sold in nurseries as fertilizer. Several months after the slab cured, the owners, architects, and team of helpers mopped several coats of iron sulfate solution onto the slab, then scrubbed and rinsed it to achieve the right surface character. This not only gave us owners a sense of putting elbow grease into our own house, but was a lot of fun as well.

2.5.3 FSC lumber, Dining Area

Forest Stewardship Council lumber.

FSC

The majority of the lumber used in this house is either 1) certified by the Forest Stewardship Council (FSC) as originating in a sustainably managed forest. (A competing certification set-up by the wood-products industry, Sustainable Forestry Initiative, offers little real protection for sustainable forest management.) FSCus.org

FSC lumber is more expensive and some sizes are unavailable in some markets. These realities make it more important to conserve wood in the design. (See the Section on Advanced Framing: 2x8 studs at 24" spacing) and using salvaged wood where feasible (which has its own issues such as potential lead contamination, and ensuring quality and standardization between the same specified type of material.)

2.5.4 The Tree Post, Dining Area

From sustainable logging, and presented to emphasize the connection with nature.

This madrone tree was thinned from a forest in Sonoma County. The upper half of the tree is incorporated into another a beam from a deconstructed house near Healdsburg. Using the un-milled beam brings a consciousness about the nature of building materials. The tree also relates to a traditional Japanese idea about deploying conspicuous materials in a manner that preserves and celebrates the inherent beauty of their unspoiled essence.

The tree is not a load bearing structure (it does not support the beam above) and yes the children have climbed it up to the 2nd floor. Because climbing strips the colorful bark off, please refrain from doing so.

2.5.5 Low-VOC Materials, Master Bedroom

Volatile organic compounds (VOCs) are used as solvents in products that are liquid-applied. Paint thinner is a common VOC. VOCs diffuse as gases to the air over time (off-gassing), creating poor air quality and health risks. Paints chosen for Project Green Home have very low or zero-VOC content; latex paints are one product where better manufacturers have eliminated VOCs. Other products were selected for low VOC levels that meet LEED for Homes criteria for health and safety. Some of these are: primers, clear wood finishes, floor coatings, wood stains, caulks, and adhesives. In general, LEED allows no more than 250 grams VOC per liter of product (less than 150 g/l for paints).

2.5.6 Hardie Plank, Carport

Hardie Plank is a wood fiber and cement composite material we've used for siding. It is extremely durable and dimensionally stable. The planks will last longer and have less environmental impact than other plank sidings.

2.5.7 Living/ Green Roof, Upstairs Open Space – Lost to Photovoltaics

The metal roof over the ground floor pop-out of approximately 220 square feet has a low slope and load bearing capacity of ~40 pounds per square foot which makes it an ideal candidate for a living roof. We had planned to install a living roof, which would have reduced water run-off, and kept the room warmer in winter and cooler in summer. However, we have to use this area for solar power generation as the Palo Alto Fire Department required us to keep the photovoltaic panels 3 feet from the top roof line. As such, we could not maximize the panel orientation on the upper roof and were required to also install them on this lower roof. It is important to note that not all municipalities have this 3 foot from the roof line requirement.

2.6 Reconstructed and Salvaged Materials

While reusing materials intrinsically makes sense, be aware that there is likely substantial time and money required to bring these pieces to a suitable condition for use. On the other hand, salvaged pieces may also provide a sense of timelessness and add significant aesthetic value. We encourage the use of these materials but also acknowledge that there may be a number of caveats in their use.

2.6.1 Golden Bear Recycled Stone Tile, Living Room

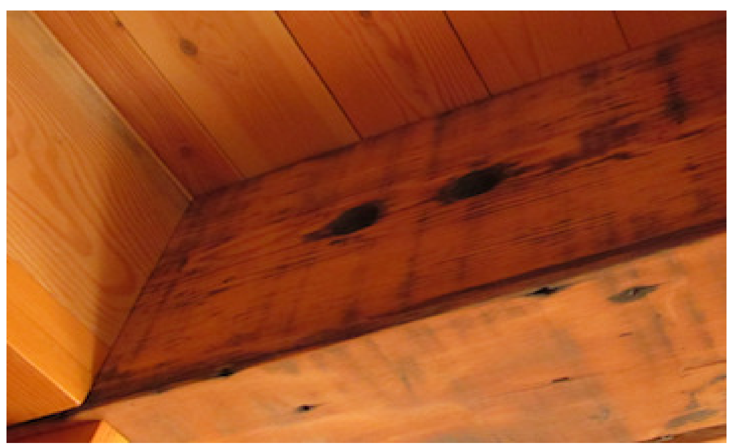
Tiles from mining by-products.

This tile is made from non-toxic "dust" that is a by-product of the mining industry. The color comes from the parent rock, and is integral to the material. It has the hardness of stone, but without pores or microscopic cracks that might stain. The tiles used in this house are a prototype run from Golden Bear Ceramics (GBC). GBC is seeking investment to get the kilns up and running again. Jim Wood, Golden Bear Ceramics in Grass Valley, 530-320-1276.

2.6.2 Salvaged beams, Living Room

Structural timber recycled from previous construction.

Some of the primary structural beams in this house are reclaimed from a Vacaville farm and deconstructed Richmond warehouse. These beams are exposed because the wood is old and beautiful, because we want to tie the house to a long history of building in the Bay Area, and because we want to tell the story of re-use. C&K Salvage in Oakland, (510) 569-2070.



2.6.3 Windows Upstairs Foyer, Upstairs Guest Bedroom

These interior windows were first external windows which we believe were added to the original house during an unpermitted ~1970s expansion. As part of the deconstruction in preparation for building PGH, the windows were saved from the landfill and then cleaned (including removing most of the lead paint). Economically, these "free" windows are likely an economic toss up due the labor involved in cleaning them. However, in addition to reducing the trash footprint of the deconstruction process, we also avoided the energy production associated with making new windows. Equally importantly, we like the aesthetics of these windows combined with the connection to the original house. Note: these windows should not be reused as exterior windows.

2.6.4 Sliding Interior Doors, Living Room

These antique glass doors borrow daylight from adjacent rooms to illuminate the living room/ library area. When they slide over the bookcases, the shelves can still be seen through the glass. The doors don't take up floor space when open, which is important for wide openings. While they do look lovely, preparing them was particularly laborious between stripping the (lead) paint, patching the holes in the woodwork and priming and painting them.

2.6.5 Wooden Flooring, Second Floor Hall

In selecting the wood flooring for the upstairs, Kate wanted something that reminded her of her Uncle Ken's wide planked 1700's New England home with its knots and nail marks. We found this in the clear-heart old growth Douglas fir from Stanford's Brown building complex built in 1914 and deconstructed in 2002.

According to Jim Steinmetz of Reusable Lumber Company from a transportation/ processing carbon perspective, the boards traveled under 150 miles from the source – to storage, to mill, to our home – which is 10 times more efficient than the industry average. Likewise the smaller boards came from a variety of homes on the peninsula. By Jim, conceptually, there are approximately 900 pounds of sequestered carbon in these floors.

These floors, while beautiful, have separated in a few places and we have found the wood to be softer than expected – or we are rougher on the wood! There are other sustainable flooring options that would have been equally effective including their aesthetic impacts and at a reduced cost. Finally, the builder (but not the flooring installer) has a real concern that the boards will become loose from the under-flooring in the mid-future.

2.6.6 Recovered Redwood Siding, Carport

Originally, the architects specified that the metal roof over the carport would be directly attached to the supporting beams. The roofers objected, as the roof would not hold and suggested placing plywood on the supporting beams and then the metal roof. Given that the plywood (and the manufacturing labels, stamps, instructions etc.) would be exposed to view and its cost, the team identified that recovered siding would accomplish the roofers goals, meet the architect's aesthetic requirements and not consume any new materials. It's important to note that the painted side of the siding faces up (and was not sanded) essentially encapsulating any lead paint. This was probably the best (environmental & cost) use of any salvaged material in the house.

2.6.7 Exterior Exposed Wood Siding, Living Room Porch

The exterior wood trim at the kitchen windows and siding at the master bedroom bay is salvaged redwood. Redwood is beautiful, rot-resistant, and will last for decades with minor upkeep. While this salvaged wood was challenging to work with (it splintered), the older wood is of superior quality and adds beauty and character to the house. Do note, as it is exposed to the elements, it does require annual staining to retain its color.

2.6.8 Front Fence & Vegetable Bed-Reused Material, Carport

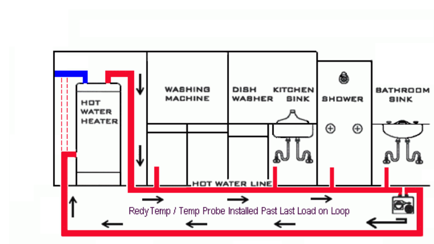
The front fence and the raised vegetable bed in the back are constructed primarily of recovered redwood from demolished 25+ year-old fencing. In that, when we deconstructed the West (left) screening fence between us and the neighbors, we trimmed off the rotten tops and bottoms of the old five-foot long and eight inch wide pickets then cut them to size (3"x36") and planned them. We did the same to the 4x4" posts (as they were redwood, they were not treated with chemicals, etc) In addition to increase the new fence's life, the posts are mounted in metal stirrups, versus being planted in concrete. While the wood (posts and pickets) was free and estimated to be worth $1,000, the labor in preparing this wood was considerable.

Further, as we needed more material, we recovered additional old fencing that would have otherwise ended up in the landfill from Mike Hampel at Sturdy Fence (650) 969-2844. This includes some very nice 7' 4x6" posts that we intend to use as supports for the children's to-be-constructed tree fort.

2.7 Water and Associated Energy Use

2.7.1 Recirculating Hot Water Line, Master Bathroom

Water is kept hot until needed. No more running the taps until it gets hot.



In a "structured plumbing" design, domestic hot water is plumbed in an insulated loop through the house, like a racetrack, with the water heater as the start/finish line. Water sits in the pipe until an occupant presses a button near a faucet, which activates a pump at the water heater. The pump circulates the loop--water runs through the racetrack--until hot water reaches the tap and the pump shuts off.

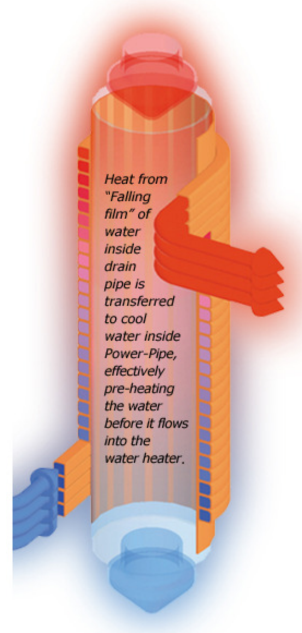
For us, this means there is very little time spent waiting for hot water at the shower. The shower ritual is now to press the button in bathroom, select clothes and by the time this is done (<2 minutes) , there is less than a 10 second wait for hot shower water – without wasting any water. How long is your wait at home?

This system saves both water and energy. Lukewarm water that was in the pipes goes back to the water heater to be reheated, rather than running down the drain while the occupant waits for hot. Since water recirculated inside the house is always warmer than water coming from the underground water main, the water heater consumes less energy bringing it up to temperature. GotHotWater.com

2.7.2 Drainwater heat recovery (Powerpipe unit) Downstairs Bathroom

Heat exchanger takes energy from water headed to the sewer and uses it to heat incoming water.

Soapy water that runs down the drain during a shower is still hot, but it usually runs directly to the sewer. Fresh, cold water is then heated to supply the shower. This house, however, uses a Powerpipe heat exchanger to pre-heat the incoming cold water using hot drainwater. A coil of incoming cold water runs in counter-current to the outgoing drainwater, which clings to the copper walls by surface tension and transfers heat. Free heat is reclaimed from the wastewater, taking a big load off the water heater during showers. Renewability.com



2.7.3 Toilets, Eco Flush, Childrens & Master Bathrooms

EcoFlush Ultra Low Flow and Urine-Diverting Toilet

We received approval from Palo Alto for a one-year pilot to install and operate two EcoFlush advanced ultra-low-flush (ULF) European toilets. This is the first time these toilets have been formally approved for use in the United States. As illustrated, the toilet has two compartments (solids and urine) which both currently drain to the city's sanitary sewer.

The EcoFlush toilet typically uses as little as 0.04 gallons (7 ounces) when flushing the urine compartment. Compare this to an old style 1.6-gallon (200 ounce) toilet and a modern 0.8/1.6 gallon per flush (100/153 ounce) dual-flush toilet. We find it interesting that people typically urinate anywhere from 5-20+ ounces per pee (a soda can is 12 ounces for reference) and that the typical home flushes with 10x the urine with fresh potable water.

How It Works - The user simply urinates in the front drain and defecates sitting back. The drains are located so that no additional effort is needed. A dual-flush flush button features two parts: one to flush urine and one to flush solids. Each discharge line has its own trap. While both drains are sent to the city's sanitation plant, we hope to one day route the urine-only drain to the gray water system.

Problems and Solutions - The problems after two years of operation are the occasional 1) “poop on the pee side” as caused by our 7 & 8 year-olds failing to remember to sit at the back of the toilet rather than the front and 2) toilet paper blocking on the pee side due to the kids not putting it at the back. When this occurs, we remove the solids and then flushing the “urine line” with water. As the toilet’s urine line drains to the home’s blackwater drain and hence to the city sewer, there is minimal contamination risk. We have also posted signs above the toilets to educate guests on how to properly use the toilet, and so far all the blockages have been caused by the children. Note, the toilet vendor offered us a solution – an insert seat that re-centers the toilet seat to the back but we never took her up on it.
ecovita.net/products.

2.7.4 Toilets, Caroma Smart, Downstairs Bathroom

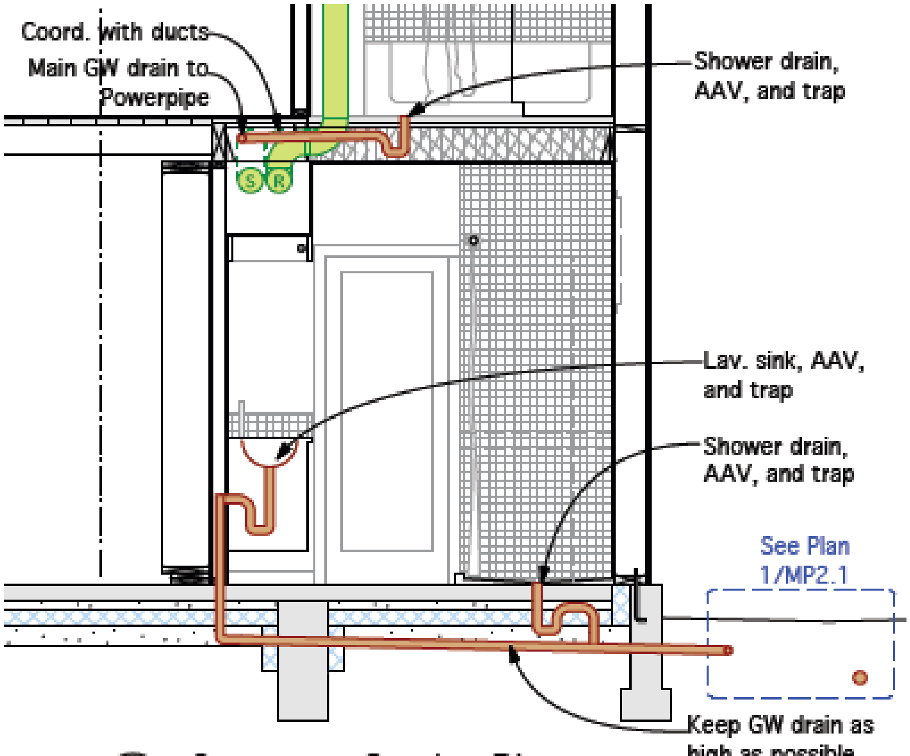
Caroma Smart toilet and hand washstand.

Downstairs we have a Caroma Smart toilet and hand washstand combination. Fresh water is used for hand washing and then flows into the tank to ultimately flush the toilet. It is also has dual flush capabilities at 0.8/ 1.2 gallon per flush. Using the above tank sink to wash one’s hands displaces that same quantity of water for use to flush the outgoing waste. In essence it's a mini greywater system. What is interesting is time it takes to fill the toilet tank. The falling water from the top of the facet creates a noticeable noise (at least to most first time guests) which in turn triggers a conversation with the guest on how much water we use to wash away our body waste. *caromausa.com/profile-smart*

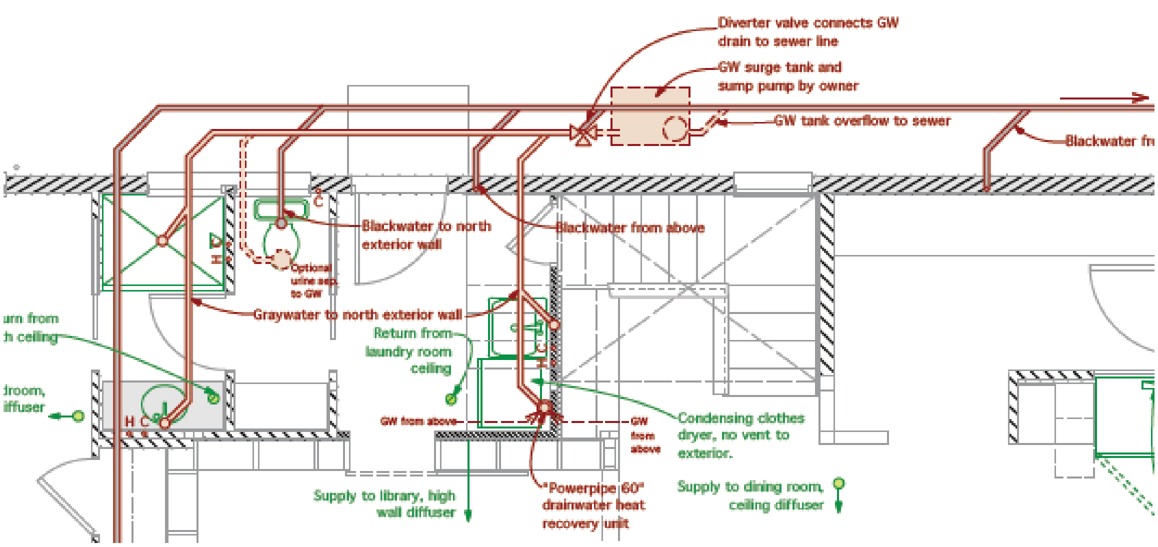
2.7.5 Graywater, Showers, Sinks, Laundry and 1% Urine, Laundry Room

Shower & sink water to water plants.

All the bathroom sinks and showers, plus the laundry and the urine stream from the Eco Flush toilets, have been double plumbed to drain into a future graywater irrigation system. The collection system exits through the slab on the east side of the house and runs to the front yard where it joins into the main black line leading to the street. Once we figure out the specific system, one that couples our greywater generation (estimated to be ~50 to 70 gallons per day) to the water needs of the landscaping, and how to address the Eco-Flush urine stream from we will work with the city to permit some form of graywater irrigation system. It may be an underground system or it maybe a series of ponds, maybe even some form of wetland. We welcome assistance in this area, please contact Sven or Kate if you wish to assist.

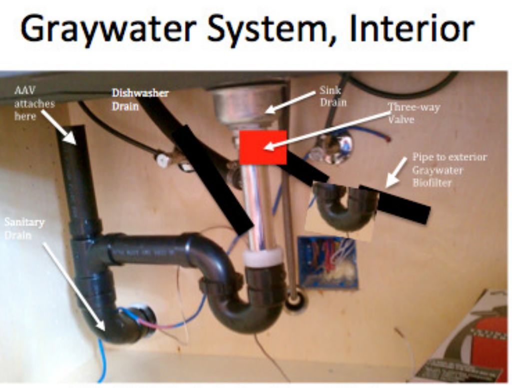


2 Graywater Section Diagram



2.7.6 Graywater, Kitchen Sink, Kitchen

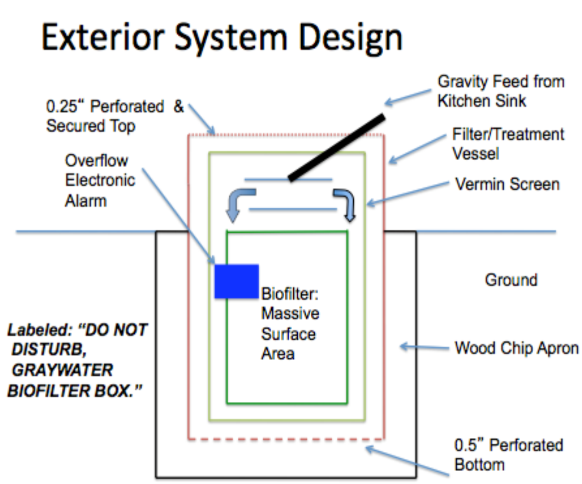
Palo Alto has granted conceptual permit approval for a kitchen sink graywater system. This is needed because the California Graywater Code does not include/ allow kitchen sink in their definition of graywater, because it tends to be relatively high in organic solids and grease, which can prevent water from infiltrating the soil. This will be a pilot program to evaluate use of a biofilter system to treat kitchen sink graywater onsite, which will include monthly evaluations of the system and a report to the city after one year.



Picture 3: Kitchen Sink Plumbing Configuration with Graywater Diversion

Piping labeled: "Graywater Drain, Do Not Drink" or "Sanitary Drain, Do Not Drink" as appropriate.

An average 12 gallons per day of kitchen sink graywater flows down through a 3-way valve, powered by gravity, into an exterior 25 gallon biofilter vessel: a plastic box filled with wood chips, with a perforated top and bottom, situated about 20 inches below ground. Food particles and grease are filtered out by the chips' large surface area and rough edges, as the water percolates into the soil around them. Content left behind on the wood chips is aerobically decomposed by microorganisms.



Since our household is vegetarian, no blood or uncooked meat will enter the system. These can potentially carry pathogens that are a danger to plant life, but those risks are typically eliminated by the aerobic digestion process anyway. To prevent vermin infestation, the interior of the filter vessel will be lined with a stainless steel wire mesh. The system does not connect to the potable water system in any way, so the chance of cross-contamination is effectively zero, as is the chance of surface water contamination.

The goal is to eliminate our household's kitchen sink wastewater flow to the city's wastewater treatment plant, without creating a hazard or nuisance to the neighborhood (flooding, odors, etc). This will reduce treatment costs and greenhouse gas emissions for the city and residences.

2.7.7 Low Flow Shower and Sink Faucets, Downstairs Bathroom

Most importantly, the low-flow showers provide an excellent shower with solid pressure and what appears to be a large flow. In fact, we like them more than the high volume shower at the rental we were living in prior to PGH. From an efficiency/ environmental perspective our showers meet EPA's WaterSense standard of less than 2 gallons per minute (gpm) flow and the sink faucets meet EPA's standard of less than 1.5 gpm. This compares to a standard new shower at 2.5 gpm+ and faucets at 2+ gpm. We were pleased to note that the Acterra environmental review plus two other follow up reviews by two different organizations likewise found that the showers do operate at these low flow levels. We win on comfort, plus both our wallet and environment win with the decreased use of energy and water!

2.7.8 Rain Water Collection, Backyard

Rainwater from all the roofs (~1,800 square feet) is collected and channeled to the northeastern side of the house (back right). At present it runs via a "rock stream" into a dry well, a large pit lined with a permeable geotextile membrane and filled with 1.5" diameter rocks. Because the rocks do not perfectly fill the pit, the interstitial space can hold roughly 100 gallons of rainwater, and with the large surface area of its bottom and sides, it accelerates rainwater absorption into the soil versus dispersing the water on the surface.

Not only is it functional but the rock stream is also was an aesthetic feature in the landscaping. Before the children and chickens covered it up

This is an important feature in that historically, rainwater runoff from roofs, parking lots, etc. has been directed off-property into nearby streams which often leads to significant erosion, damaging the aquatic and riparian ecosystems. Or, potentially worse, the runoff has been directed into the sewer drain. This can lead to flooding at the wastewater treatment plant, causing untreated sewer wastes to flow into the receiving water body. By treating/dispersing all generated rainwater *on-site*, we avoid these problems.

Finally, by directing all of the rainwater to one downspout, we have the potential to collect and use this rainwater for irrigation and/or toilet flushing. However given the ultra low flow toilets, the need for this water is extremely small and our Mediterranean climate of approximately four wet months followed by eight dry, makes irrigation difficult unless we were to install extremely large tanks - the excavation, soil disposal and installation of which has its own (large) carbon footprint and (large) cost.

2.7.9 Permeable Concrete, Front Entrance Porch

Both the small concrete driveway/pad and the front door concrete porch are made from permeable concrete. This enables rainwater to percolate thought the material and into the soils below rather than pooling or running off into a stream or drain as discussed above.

2.8 Kitchen and Appliances

2.8.1 Inductive Range/ Stove, Kitchen

This is has turned out to be one of our favorite devices in the house. In summary, the inductive stove has all the benefits of gas (ability to turn up and down extremely quickly) while using half the energy and safer for the user. For example, with an inductive stove, 84% of the energy goes to heat the food versus 75% for a typical electrical stove and only 40% for a gas stove. Because the surface of the cook top is only heated from contact with the vessel, the possibility of burn injury is significantly less than with other cooking methods. Obviously, the induction effect does not heat the air around the vessel, resulting in further energy efficiencies. It works by producing an oscillating magnetic field underneath the pot which induces an electric current in the pot. Current flowing in the metal pot produces resistive heating which heats the food. While the current is large, it is produced by a low voltage. Cooling air is blown through the electronics but emerges only a little warmer than ambient temperature. (Samsung Freestanding Induction Range FTQ307NWG from Sears.).

Inductive ranges are quite popular in Europe, particularly in restaurants as the design inherently produces significantly less waste heat than natural gas. As we like to cook and had never used one before, the architect had to challenge us to try it, to take a risk, and we are very glad that we did. This is another case of a triple (quadruple) win for convenience, comfort, cost and environment!

2.8.2 Refrigerator, Kitchen

The house has a conventional refrigerator that is EnergyStar-rated to consume 445 kilowatt-hours annually, one of the most efficient relative to its volume. Because the refrigerator runs continuously for decades, the design team considered using a direct-current refrigerator or superinsulated fridge such as the SunFrost. The high cost of the SunFrost relative to its energy savings means that using a conventional fridge and spending the incremental extra money on photovoltaics is a better conservation bang-for-the-buck strategy.

Given the short distance (~3 blocks) to currently two grocery stores and a conscious decision that as a family we do not need a standard sized fridge, we were challenged by the architect to go with a somewhat smaller fridge/ freezer with 18 cubic feet (the average American fridge for a family of 4 is 19-22 cubic feet.) To date, this has not presented a problem. Samsung model RB195ACPN.

Note, we have had problems with this unit, the drain keeps freezing and causing water to accumulate in the right bottom drawer and the internal thermometer is faulty causing temperatures to be lower in the freezer than what the display reads By the multiple service technicians that have come out and replaced various parts, the cause has nothing to do with the energy efficiency features but a Samsung design problem. We would not get this particular model fridge again. These problems are causing the unit to use ~1.9kWh/day versus the rated 1.3 kWh/day.

Palo Alto also gives a rebate for energy efficient appliances such as this one.

2.8.3 Appliances, Sink Garbage Disposal, Kitchen

Given that we are avid composters, we simply opted not to install a garbage disposal. Room has been provided for one underneath the sink and the required electrical connection installed in the off chance that we change our current behavior. We do realize that we have to educate our guests on the composting program to ensure that we don't end up with blocked pipes.

Now that we have chickens, over half of the daily compost goes to them as food and the remainder, egg shells, food contaminated paper products, onion and leek skins, corn husks and the like get composted.

Composting activities at our rental housing have annually produced pumpkins over the years (they grow right out of the compost) and we transported two plants from the rental to the new house and are now in our 2nd pumpkin generation here.

2.8.4 Kitchen Countertops, Kitchen

We selected a Paperstone countertop over Cambria, Silestone, Ceaserstone, concrete, wood, stainless steel, and Vetrazzo, each of which has its own pros and cons. Wood and stainless steel were eliminated over aesthetics. The remainder were scaled as indicated below. Note there was a small but vocal minority (Sven) that pushed wood due to its low environmental impact and low cost but was quashed due to staining potential, maintenance requirements and aesthetics. After a year's use, the countertop still looks beautiful. Gabby Beil, semolinadesign.com

	Weight	(Scale from 1 - 5) Paperstone	Cambria	Silestone	Ceaserstone	Vetrazzo
Cost	3	1	3	4	5	2
Ease of care	2	4	5	5	5	5
Aesthetics	3	5	4	3	3	2
Green-ness	3	5	2	2	2	5
TOTAL		**41**	**37**	**37**	**40**	**37**

Weight definition

4 Very important
3 Important
2 Something to consider
1 Not a concern

Scale definition

5 Excellent
4 Very good
3 Good
2 Neutral
1 Poor

2.8.5Kitchen Cabinetry, Kitchen

Originally we had chosen IKEA cabinetry as a cost containment measure. But after re-thinking this and realizing that the quality of the IKEA product may require that it be replaced sooner than a custom, wood-not-veneer option, we decided that paying for better quality cabinets from the outset may in the long run be cheaper and "greener". However, due to cost constraints we did not go full custom build. We went with Eco-Home in Berkeley and for semi custom FSC-certified/ low VOC cabinets. We found both the quality and customer service of Eco-home to be lacking; note this has noting to do with the environmental attributes of the cabinets. You are encouraged to talk to Sven or Kate before purchasing from Eco-Home.

2.8.6Clothes Washer, Dryer, and Dishwasher. Laundry Room

These appliances are each ranked in the top ~25% best of class for energy/ water efficiency. Of note is the clothes dryer which is a condensing dryer and “vents” to the interior of the house. Given the Palo Alto climate we primarily let the wind and sun dry our clothes via a clothes line. What was surprising was measuring the clothes washer and dishwasher energy use. The clothes washer uses ~0.1kWh per load and dishwasher uses ~1 kWh, a ten time more as it has a built-in electric heater.

Palo Alto also gives a rebate for energy efficient appliances such as these.

3 Landscaping, Work in Progress

In the spring of 2011, we engaged an extremely creative landscaper to design the garden. Unfortunately the resulting plan did not integrate the home’s greywater generation rate of ~50 to 70 gallons water per day with the selected plants and the cost to implement the design was three times that of our budget. (Sven, the owner, thought I’d communicated these parameters to her!) We have significantly scaled down her plan and only landscaped the front with a combination of native and edible landscaping that provide for wildlife and human inhabitants while looking reasonably attractive. At present, we are using a drip irrigation system with the goal to convert to grey water or non-potable shallow well water.

3.1 Cardboard Under the Oak/ Oxalis, Backyard

We used leftover cardboard as biodegradable ground cover to kill the oxalis (wood sorrel) growing under the oak tree drip-line. To us, the oxalis is a weed, aka a plant that is growing where it should not be growing. And we have been, in general, successful.

3.2 Chickens, Bees and other Pets

Chickens have been a surprising success. Having navigated the $60 per year Palo Alto permitting process, we have three hens. They lay approximately an egg each per day. We feed them the majority of our compost (the vegetable, stale bread, burnt oatmeal, etc. component). The routine of collecting the eggs, particularly by visiting children, is quite enjoyable and the chickens are quite humorous to watch.   The coop (their bedroom, laying area, food and pellet food) was bought used $150 on craigslist and the run, their daytime area, was made of scrap from recovered fence-boards and posts plus, of course, chicken-wire!

We also plan on bees but this is a longer-term project. The children are taking suggestions for other appropriate pets. (No donations please.)

3.3 Fruit Trees

We have planted ~10+ fruit trees believing these to be extremely easy to maintain and harvest from. In just over a year of being in the ground, we have harvested apples, figs, persimmons, plums, asian pears, and peaches. Yummy, healthy and an extremely low carbon diet!

4 Green Jobs, Master Bedroom

We acknowledge that the labor and material costs for a home of this nature are going to be more than the standard/conventional Californian home. On the positive side, to make these materials and provide the incremental labor, additional people will be employed. This is compared to the conventional home where more money (potentially significantly more money over the life of the home) will be spent buying energy, likely in the form of electricity (hopefully carbon free and from renewable sources) and natural gas (a fossil fuel and potentially from fracking, both bad). However, we believe the incremental employment created by the non-efficient home's energy demand is much less than the employment created by the more energy efficient one. (Power plants and natural gas production/ transportation simply do not require large numbers of employees) To confirm this position, we are looking for a student researcher(s).

5 Deconstruction, Master Bedroom

A 1920s, 2-bedroom, 1-bath termite infested house on the lot was deconstructed in late 2009 and the building materials were donated to a charity. Older homes are more commonly demolished, and the co-mingled waste is sent to a landfill. From an economic perspective, the donating/deconstruction path was essentially the same as demolishing the old house (though this may not be true everywhere).

More importantly, the new home (we very much hope) will comfortably accommodate an extended family and will age better than the previous house.

Recovered materials from the deconstruction include the interior single pane windows between the guest bedroom and the upstairs foyer, and Sophia's bedroom and the foyer.

In addition, we sawed the driveway into blocks and saved the more reasonable-looking (non-cracked) ones.   Due to the limited size of the garden, we decided to freecycle them and they are to be pavers at Greg's house in the near future.. The rest of the concrete went for recycling.

6 Transportation

6.1 Plug In Hybrid Electric Vehicle, Ground Floor Foyer

Our latest car is an all-electric Nissan Leaf, “Mrs. Blue” which we got used for $20k in November 2012. The car gets ~90 miles of range (depending on speed, etc) and costs, with our solar panels providing the electricity, less than 2-cent per mile to drive. Because of its great acceleration and handling, it’s the family’s favorite car to drive. Further, the children are the ones that do the fueling; they can and do plug the car in.

Our second car is a Toyota Prius converted into a plug in hybrid electric vehicle (PHEV) at Maker Faire in 2006 . It was converted to show the public, the automobile manufacturers, politicians, and pundits that plug-in hybrids work! In essence, local miles are powered partly or fully by electricity, and then gasoline provides the standard 300mile+ range. PHEVs (like fully electric vehicles) tackle energy security, jobs and global warming, all at once.

These conversions were successful! The Chevy Volt with 40 miles of all electric range followed by 380 miles of gasoline driving for those long distance trips is selling like hot cakes. How long is your daily drive? Would an all electric or PHEV work for you?

Environmental and Economic Benefits: While running on typical California electric power (from PG&E and the other large utilities) there is a 75% reduction in CO_2 compared to running on petroleum energy and provides a similar 75% reduction in fuel cost. Using Palo Alto Green’s carbon-free electricity, we have a zero carbon footprint while driving on electricity at a fuel cost of ~4-cents a mile. Compare this to ~20-cents per mile for a vehicle that gets 20 mpg and fuel at $4/gallon.

6.2 Electric Vehicles & Charging, Front Porch

The house was originally built with 3 locations pre-wired to enable electric vehicle (EV) charging. The first is at is at the back of the house in the "carport." The second is the concrete driveway pad plus a standard 110v outlet. The third is curbside. We recommend that all new houses come pre-wired for electric vehicles as it's much cheaper to pre-wire during construction than to retrofit later.

To promote EV driving, and facilitate charging when away from home, our house is listed on plugshare.com and we have charged unknown numbers of EVs through this portal and are likewise happy to charge your EV for free!

To facilitate EV charging, in September, PGH put forth the following to city council which was adopted unanimously:

Understanding that the city of Palo Alto wishes to take a leadership role as one of the most EV friendly cities in America, we encourage City Council to:

1) *Require all new parking construction (residential, industrial, commercial, research and development, etc) install, to some appropriate percentage, the necessary circuitry etc to be EV charger ready.*
2) *Streamline the EV charging permitting process and reduce the fee;*
3) *Include residential curbside charging as an option in the requested staff report; allow encourage and support residential curbside charging on a case by case basis and not limit the current pilot (the first in the nation) to one home.*

And we encourage those in other cities to request their city council enact a similar ordinance. Especially given that the effort to get this passed was less than expected.

My home EV Charger, my fueling station,
is always open, and there's never a line.

6.3 Curbside Side Electric Vehicle Charging Stations, Front Yard

As most are aware, with an electric vehicle (EV), one typically installs a charger at the driveway or garage. We wanted a second charger to serve EVs parked on the street outside our house, but the land between the street and the sidewalk is public property. We got a 2-year pilot permit to install and operate this curbside charger, from the city of Palo Alto. And we are providing the electricity for free! To our knowledge, this is the first such permit in the nation. If you are interested in doing same, see our website for the full saga and the issued permit which may help you in your quest. Why did we do it? To promote the technology, help reduce range anxiety, have a place for guests to charge when visiting, initiate conversations around fueling EVs and to begin normalizing residential curbside charging.

FREE CHARGE

Electric Car Charger

Please return the cord to this box on completion

This public charger is the nation's first known curbside residential charger. To see how we got the city permits go to ProjectGreenHome.org.

Electricity is provided for free by the home in front of you. If daylight, you are charging on 100% carbon-free renewable sunshine! If night, then it's 100% carbon-free with Palo Alto's electrical mix.

Did you find this charger helpful? Consider joining Plug In America - the voice of the EV Owner – at these suggested donation levels:

- Leafs, Volts, etc: $50/year
- Teslas & BMW i3s: $250/year

Plug In America (PIA) drives change, accelerating the shift to plug-in vehicles powered by clean, affordable, domestic electricity to reduce our nation's dependence on petroleum and improve the global environment. PIA played a pivotal role in the $7,500 rebate you received when you bought your EV and supported ProjectGreenHome.org in acquiring this charger through an arduous and lengthy permitting process.

7 Mistakes Made Along the Way, Downstairs Guest Room

7.1 Polyvinyl Chloride (PVC)

While PVC as a material is useful, its manufacturing process is quite toxic and burning it releases toxic gasses such a dioxins. Hence, as a society we should not use it unless absolutely necessary. Unfortunately, because of its usefulness and lack of awareness of PVC's life cycle toxicity, it can be a common building material. According to the Healthy Building Network, over 14 billion pounds of PVC are produced each year, 75% of which are used for construction due to its inexpensiveness and versatility for building. Though this material is often used, producing PVC can inadvertently emit toxic chemicals that can cause cancer, neurological damage, and other damaging side effects. Dioxin, an extremely powerful carcinogen, has also been found to pollute ecosystems and humans alike, causing dangerous health hazards to both people and wildlife. PVC also contains diethylhexyl phthalate (DEHP), which is a plasticizer that can escape from the plastic and have hazardous effects on the environment after long-term exposure. PVC is also non-recyclable due its high additive content and is an official contaminant.

Our mistake was not to specify at the beginning of the process that we didn't want to use the material and to work with the architect, builder, city permitting authorities and craftsmen to find alternatives. As noted below, we inadvertently used, and in some instances have been required to use, PVC materials.

PVC Conduit for the Photovoltaic System

Rather than mounting the wiring conduit for the photovoltaic on the exterior of the house (running from the west roof down the east roof and then down the exterior of the east wall), we opted to run the conduit internally. Aesthetically, this keeps the smooth, clean exterior lines of the house. However, in running the conduit internally, we had to puncture the house membrane both at the roof and the side of the house. Using metal conduit would have allowed significant heat loss (and gain) into the house due to metal's ability to conduct heat. The option taken was PVC conduit. Any suggestions of materials we could have used are most welcome.

PVC 4" Drain Pipe Around the house to the Sump box

The California State Building Code (?) City of Palo Alto requires a 4" pipe around the house slab foundation. This perforated piping collects any water that might pool around the house and drains it to a sump box/bubbler that sprays it on the yard. Again any suggestions of materials we could have used instead are also welcome.

The Heat Exchanger Condensation Drain Line

The heat exchanger in the attic has a condensation pipe made of PVC. It's not clear if PVC piping is required or there are other options. In our case, it's what came with the unit and what the HVAC crew installed. (In winter, the heat exchanger pulls external air into the house, heating it from the exiting warm interior air, which in turn cools. A portion of the water vapor in the new cooler exiting interior air may condense out depending on the interior/exterior temperature delta and the interior air water content.) One simple option would have been to use PEX, the same material used in the water pipes.

Stucco Edges
There are some concealed PVC edges on the stucco that we tried to substitute with galvanized steel, but we were unable to find a manufacturer that makes a metal equivalent or other material. Further, if we did find something, we would likely have the common problem of the installer refusing to use it because it's not part of the approved system and if installed becomes the contractor's liability.

PVC in electrical Wiring
Another issue, discovered post-installation, is the PVC insulation on our electrical wiring. Other rubber or plastic options may exist, but we have not researched them. (At this point, it is too late to replace existing wiring.)

7.2 Screening Fence West Side Between the Neighbors

In essence, we missed the opportunity to improve the backyard view-shed for us and our neighbor.

The Redwood (6 foot high) screening fence between us and our west (left) neighbor needed replacing. We and our neighbor agreed to replace it with essentially the same fence style and hired a contractor to do so. When the old fence was removed, we temporarily installed a low "dog fence" between the two houses. This low, somewhat innocuous fence was in place for ~2 weeks and increased the view-shed into each other's backyard plus provided more opportunity to be "neighborly." After the new fence was installed we (and the neighbors) realized we had traded the view and increased interaction with great neighbors for privacy. Given the chance to do this over, we may have opted for a lower fence in the back for these same reasons.

Further, we were also unable to find Forest Stewardship Council redwood lumber. However, we did mount the posts in stirrups and dug a 3-inch trench along the bottom of the fence and filled with drainage gravel, in efforts to decrease rotting.

8 Regulatory Barriers, Upstairs Open Space

Where we yielded to City permitting

8.1 White Roof

As discussed in Section 2.1.6, White Roof, we were not allowed by the city of Palo Alto to install a white roof. *"…The City is concerned about the potential impacts associated with glare and given the close proximity of homes in this neighborhood we believe this is a valid concern…"* As such, our building permit includes *"conditions of approval to assure the metal roof will not be painted white…"*

What is particularly interesting is the immediate city to the North, Menlo Park, seems to have embraced white roofs. See MenloGreen.TypePad.com

8.2 House Positioning

To gain maximum potential solar energy for the roof-mounted photovoltaic system, we needed to put the house in the rear of the lot rather than the front. Unfortunately because the majority (but not all) of the houses in the neighborhood are towards the front, we were likewise required to build the house towards the front. We have not yet worked out how much additional photovoltaic panels we will have to install because of this Palo Alto aesthetic requirement. If we had positioned the house at the back of the lot, according to the city we would have disturbed the "warp and the weave of the neighborhood."

8.3 Garage/ Carport Requirements

It is understood that the garage or carport requirement stems from the city's objective of keeping the residential streets clear of "car clutter." Unfortunately this policy seems to be ineffective in limiting the numbers of cars parked along the curbs. Further, as the majority (but not all) of the garages in the neighborhood are at the back of the lots, we likewise were required to include a rear garage/carport. This meant that valuable land on the side of the house had to be used as driveway versus a garden or play area. Further it forced the house to be more rectangular than desired, again causing a larger footprint over arable land. This was a permitting battle that we lost with the city of Palo Alto as we did not go high enough up the chain-of-command. Do not repeat our mistake! If need be, Sven and Kate the owners will go with you to city hall to prevent this from happening again. In our case we built a rather expensive outdoor, covered table tennis playing area that legally meets the definition of a carport. We park our electric car outside at the front on the short permeable concrete driveway beside the electric vehicle charger. The photo shows a home that we could have had with the garage at the front.

8.4 Graywater infused with 1% Urine

The laundry drain, all of the sinks and showers, plus the urine diverting toilets are kept well separate from the blackwater line. Given the 1% urine, permitting this system with a flow rate ~50-70 gallons per day is difficult. And we are looking for volunteers to assist..

9 Partners, Study, Upstairs Guest Bedroom

Research Institutions, Non Profit Organizations and Universities

9.1 Lawrence Berkeley National Laboratory (LBNL)

LBNL has conducted several tests on the home to determine airflow efficacy and levels/types of airborne chemical contaminants in tightly sealed homes such as ours and we are awaiting results of these studies.

9.2 Acterra

Acterra, a local non-profit environmental organization has conducted a performance review/ audit of the home via its Green@Home program. The Green@Home program allows everyday residents to play their part in combating climate change by delivering house calls to citizens in the Bay Area to help install energy saving devices and draft plans to reduce waste. During the visit, the total electricity, gas, and water usages were determined, as well as ways to reduce both consumption and costs. One finding of note at PGH was determining that the fridge's freezer compartment, while indicating -2C on the display (an appropriate temperature), the in-freezer measured temperature was -12C. We were wasting energy by keeping the freezer colder than necessary (we measured 1.9 kWh/day versus the rated 1.3 kWh/day, see Section 2.8.2) and this likewise explained the extremely hard ice cream. The freezer was found to have a faulty sensor which has since been replaced. The full report is in Appendix 2.

In summary, we would encourage every homeowner and renter to participate in the free Green@Home program, not only will you save energy but also money.

In addition, Acterra has adopted the educational component of Project Green Home. As such interns, and we are always looking for more, are being funded via tax-deductible donations to Acterra to perform research on the house, serve as docents and other educational related tasks.

9.3 Bay Area Climate Collaborative (BACC)

The BACC has been quite supportive of PGH particularly in serving as the lead organizer for PGH's June 2011 open house, which attracted over 400 attendees. This support stems from PGH and BACC sharing the same objectives in respect to green/ clean technological innovation and implementation, green jobs, and the imperative need to address global warming.

9.4 UC Berkeley

Early in the design process, graduate students assisted the architect in running various energy efficiency calculations/models for each of several initial designs. In addition, a group of undergraduate students calculated and wrote a paper evaluating how much photovoltaic energy would be required to make PGH a zero net energy house (they underestimated by ~20%). Finally, PGH has been included in various grant applications as a potential research subject by both UC Berkeley and Stanford.

10 Providers

The companies that built our home.

10.1 Architect – Arkin Tilt

Arkin Tilt Architects is an award-winning firm specializing in energy and resource efficient design. Our projects embody a marriage of thoughtful design and ecology, creating spaces that are comfortable and lyrical. We pay particular attention to the integration of the built and natural environments—from siting to careful detailing. We have extensive experience with alternative construction systems, including straw-bale and rammed earth, renewable energy systems, gray water, and non-toxic and recycled materials. Our projects include residential and commercial, park buildings, religious facilities, and Eco-Resort planning and design.

Winner of the Acterra Business Award for the Sustainable Built Environment, two COTE/AIA Top Ten Green Project Awards, and numerous other design awards, our work has been published nationally and internationally for excellence in design and sustainability. With electric and biodiesel cars and solar electricity, we are working to limit the office's carbon footprint. 510-528-9830 ArkinTilt.com

10.2 Construction Project Manager/ Builder/ Passive House Consultant

Joshua Moore, owner of Red Company LLC, is the Project Manager responsible for the home's construction. In addition to his Project Management skills, he is both a licensed architect and contractor, plus a Passive House Consultant who brings a wealth of building and design experience to the project. Moore is an advocate for the Design-Build process in that "only through accepting, embracing, and knowing the hard realities of construction will we be able to affordably and practically design our way to a better future." 510-812-5688 RedBuildings.com

10.3 Plumber – Moomau

Moomau Plumbing is a plumbing repair, construction, and replacement service with over 30 years of experience. A fully licensed and insured contractor, based in San Jose, Moomau plumbing serves the greater Bay Area for plumbing needs of all kinds. 408-396-3837 MoomauPlumbing.com

10.4 Roof – Custom Copper and Sheet Metal Roofing

Custom Copper and Sheet Metal Roofing is excited to be a part of Project Green Home. As third generation sheet metal experts, they are pleased to bring their sheet metal installation expertise to the Cool Metal Roofing system that will be used to further achieve a zero net energy home. Though they have been designing and installing similar sheet metal and copper roofing applications for many years, the recent technological advancements in the metal roofing finishes over the last several years have given way to "Cool Metal Roofing" products. Cool Metal Roofing systems provide a number of advantages over conventional roofing products. Some of these advantages include EPA EnergyStar approved high reflectivity values, up to 85% heat emissivity values, 45-year plus durability warranties, and the knowledge that metal roofs are 100% recyclable.

These fine metal products are also skillfully installed by their staff on additional building applications including siding, awnings, flashing, gutters and other exterior sheet metal customizations. 916-346-5436 Ccsmr.com

10.5 HVAC – Bayside Mechanical

Bayside Mechanical installed the Altherma unit (hot water for both the radiant floor system and potable water), the radiant floor system and the heat-recovery ventilator. They offer

expert mechanical engineering and plumbing services. Throughout the Bay Area they have helped residential and business customers achieve their desired Heating, Air conditioning, and/or Ventilation goals. Based on your needs Bayside Mechanical Inc. will design, install, service and/or repair any Heating, Ventilation, and Air Conditioning systems. Specializing in both residential and commercial projects, Bayside Mechanical is your solution for all your Heating, Ventilation, and Air Conditioning needs. □□ 650-578-9080
BaysideMech.com

10.6 Insulation – Tri-County Insulation

Tri-County Insulation and Acoustical Contractors is proud to be a part of Project Green Home. They have been specializing in insulation products in the Bay Area for over 36 years. As time has passed, the technological advances in insulation have escalated and so has the interest in insulation. As insulation has advanced so have their skills and knowledge of what can be done to make homes more energy efficient with cleaner air and more comfortable, responsible living.

The Owens Corning's Energy Complete System was used on Project Green Home, along with Pro-Pink Complete Blown-In Wall System, also by Owens Corning. Pro-Pink Complete Blown-In Wall System has a high recycled content of 53%, Green Guard Certified, and low VOC's. 800-246-7858 TriCountyInsulation.com

10.7 Stucco – Green Wall Tech

Green Wall Tech provided and installed the stucco. Their focus is drywall systems, plaster & stucco systems and architectural detailing and trim projects. 510-252-1170
GreenWallTech.com

10.8 Student Booklet Editors

Jessica Tam is a current senior at Palo Alto High School who has been collaborating with Sven Thesen and Project Green Home to provide updates and conduct research for the booklet. Her prior experience working with the environment includes an internship with the Acterra Stewardship Program, performing habitat restoration for Arastradero Preserve, and regularly volunteering with CuriOdyssey, an environmental education museum located in San Mateo. Jessica is also the 2012-2013 Associated Student Body President at Paly and a member of the Pacific Ballet Academy Studio Company. She enjoys educating the public about environmental consciousness and sustainability and hopes to pursue a future career in renewable energy.

In Memoriam

Dr. Edgar Wayburn, M.D., 1906-2010

Dr. Edgar Wayburn has been described as "America's most effective (and least known) wilderness advocate." A five term president of the Sierra Club, he was a major factor in the creation of the Golden Gate National Recreation Area, which includes roughly 200,000 acres in south and west Marin, San Francisco, and beyond. No other city in America -- perhaps the world -- has anything that can compare with it. When Dr. Wayburn was awarded the Presidential Medal of Freedom in 1999, President Clinton said, "He has saved more of our wilderness than any person alive."

Dr. Stephen Schneider, 1945-2010

Stephen Schneider was a renowned climate change researcher. A professor of biology at Stanford University, he founded the journal *Climactic Change*, and served as a scientific consultant to the White House under every president since Nixon. A MacArthur Fellowship recipient, and author of two books and countless scientific papers, he shared the 2007 Nobel Peace Prize with former Vice President Al Gore and the other United Nations Intergovernmental Panel on Climate Change scientists and engineers.

11 In Memoriam

11.1 Dr. Edgar Wayburn, M.D.

Dr. Edgar Wayburn died on March 5th, 2010, at the age of 103. In his life, he served as president of the Sierra Club for five terms, and he has been described as “America's most effective (and least known) wilderness advocate.”
Dr. Wayburn was the leading force in the expansion of Mt. Tamalpais State Park, from a mere 870 acres to more than 6,000 acres. Later, he spearheaded the establishment of Point Reyes National Seashore, the first national park unit of any size near a major metropolitan area. That was followed by the formation of Golden Gate National Recreation Area, which combines nearly all the open space in south and west Marin, plus some lands in San Francisco and beyond, including the city's beaches, Alcatraz and the Presidio. All told, it amounts to some 200,000 acres. No other city in America -- perhaps the world -- has anything that can compare with it.

For all his accomplishments, Ed Wayburn was never a full-time conservationist. A practicing physician and a family man, he dedicated his spare hours and weekends to the health of the planet. Neither was he well known, even within the environmental movement, having never gained the wide recognition of such contemporaries as David Brower and Ansel Adams. The low profile suited him fine. Dr. Wayburn preferred to do his work quietly, behind the scenes. He was a born facilitator and diplomat, someone who exuded the kind of authority and integrity that gets people -- even powerful people -- to listen.

Where others might have been content to save random parcels of land -- whatever scraps could be spared – Dr. Wayburn wanted nothing less than the protection of whole watersheds. As he explained in his memoir, ***Your Land and Mine***, "It wasn't enough simply to add a few acres here and there; nature doesn't divide herself into measured plots. A watershed encompasses the chain of life; if any part is developed, the integrity of the whole ecosystem is threatened."

That devotion to ecological principles guided him through many subsequent wilderness campaigns, including the decades-long struggle to found, and later expand, Redwood National Park. Years of travel in the Alaskan backcountry with his wife Peggy -- herself a prominent wilderness advocate -- led eventually to his crowning achievement: Passage of the 1980 Alaska National Interest Lands Conservation Act, which created ten new national park units and effectively doubled the size of America's National Park system. When Dr. Wayburn was awarded the Presidential Medal of Freedom in 1999, President Clinton said of him, "He has saved more of our wilderness than any person alive."

Most of this biography is taken from the Sierra Club website, and was written by Pat Joseph, the executive editor of California magazine.

11.2 Dr. Stephen H. Schneider

Stephen Schneider was a professor of biology at Stanford University. He died of a heart attack on July 19th, 2010, on his way back from a conference in Sweden. He was a leader among the Intergovernmental Panel on Climate Change scientists and engineers, whose climate research earned a Nobel Peace Prize in 2007, an honor they shared with former Vice President Al Gore.

Schneider was influential in the public debate over climate change and wrote a book, *Science as a Contact Sport: Inside the Battle to Save Earth's Climate,* about his experiences. He also wrote a book, published in 2006, about his battle with mantle cell lymphoma, *Patient from Hell*. He drew a parallel between his climate-change research and his involvement in designing the treatment regime for his cancer. In both cases, he said, there was a need to predict the future with incomplete evidence, and yet there was no room to be wrong.

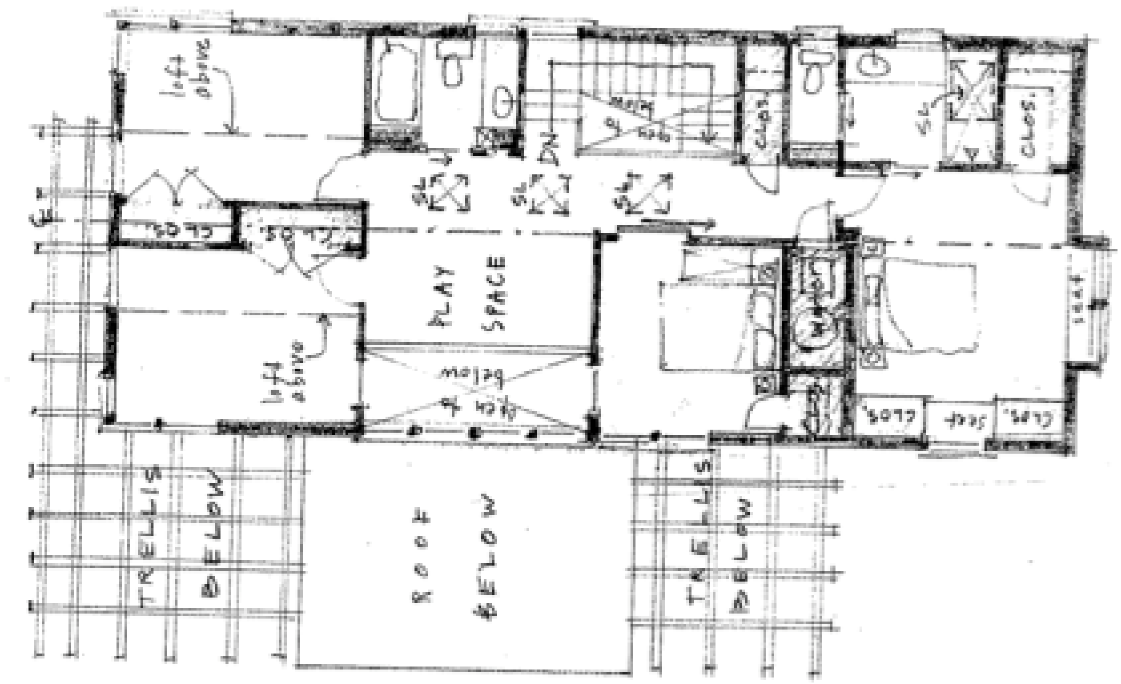
"The Stanford family is profoundly saddened by the loss of Stephen Schneider," said Stanford President John Hennessy. "He was a valued member of our community and a passionate advocate for our planet. A world-renowned scholar, he focused on the impact of human activities on climate change in his teaching and research, and his contributions extended well beyond our campus. Through the many ways he sought to increase understanding of the implications of climate research among the general public, policy makers and global leaders, Stephen Schneider worked to make the world a better place for us all."

At Stanford, Schneider was the Melvin and Joan Lane Professor for Interdisciplinary Environmental Studies, professor of biological sciences, professor (by courtesy) of civil and environmental engineering, and a senior fellow in the Woods Institute for the Environment.

In recent years, he mourned, with his usual high level of verbal energy, the loss of talented science writers from newspapers. In the sound-bite feuds of television, he said, climate researchers were given a scant few seconds to explain complicated issues. "So what I'm trying to do is get media and the political world to stop framing climate change in either/or terms, when we're really looking at a bell curve of possibilities," he recently told *Stanford* magazine.

Said Pamela Matson, dean of Stanford's School of Earth Sciences: "He is irreplaceable – as a colleague, adviser, friend and scientist. In his science, he has done more for the world than most of us recognize, and our children will thank him."

Most of this biography is taken from Stanford University's website, in the News section, and was written by Louis Bergeron and Dan Stober.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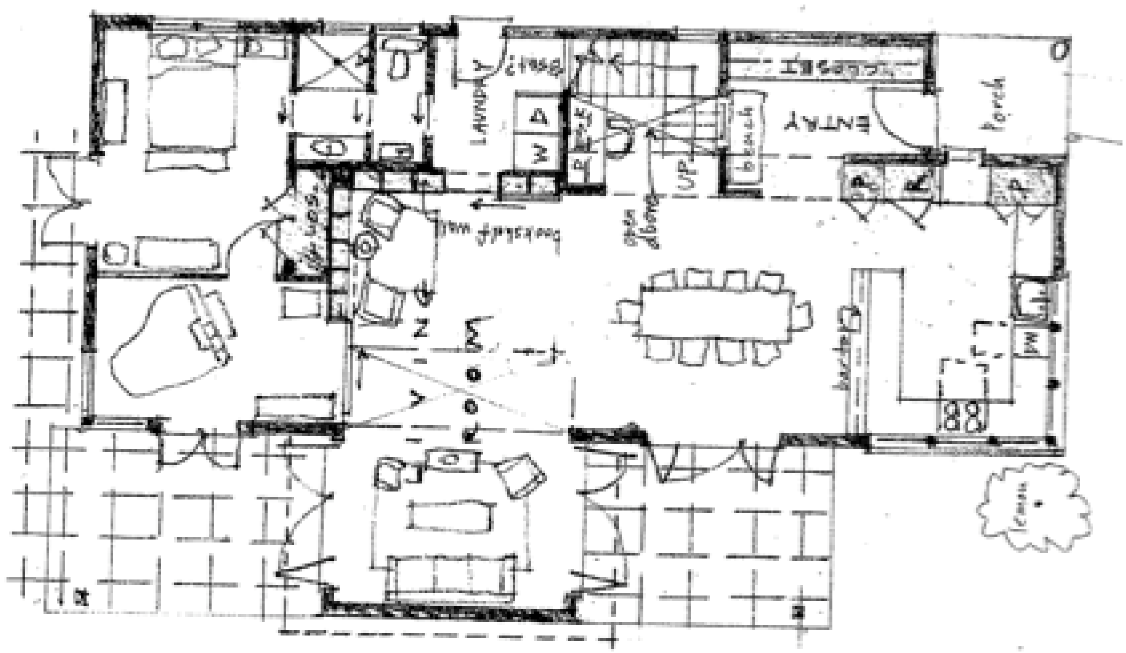
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