The first home of the NorCal Collaborative (NCC)

to meet the

Thousand Home Challenge

Ellen & George Beeler

Live/Work Building Rehabilitation

1940 Vintage - Petaluma, CA

CASE STUDY

Updated 3/23/2011

In 1997 we decided to get serious about living a green life style. We bought an existing house worthy of rehabilitation, in town to reduce use of our cars.

BEELER FAMILY PORTRAIT by Emily Vincent 5/2010
George holding Rudy and Ellen holding Iggy

Location is critical to a green lifestyle

- **Rehabilitate existing building**
- **Or use infill site**

To reduce driving, be close to:

- **Work**
- **Schools**
- **Friends**
- **Groceries, etc.**
- **Able to walk & bike**

Utilize existing infrastructure

Avoid destruction of habitats

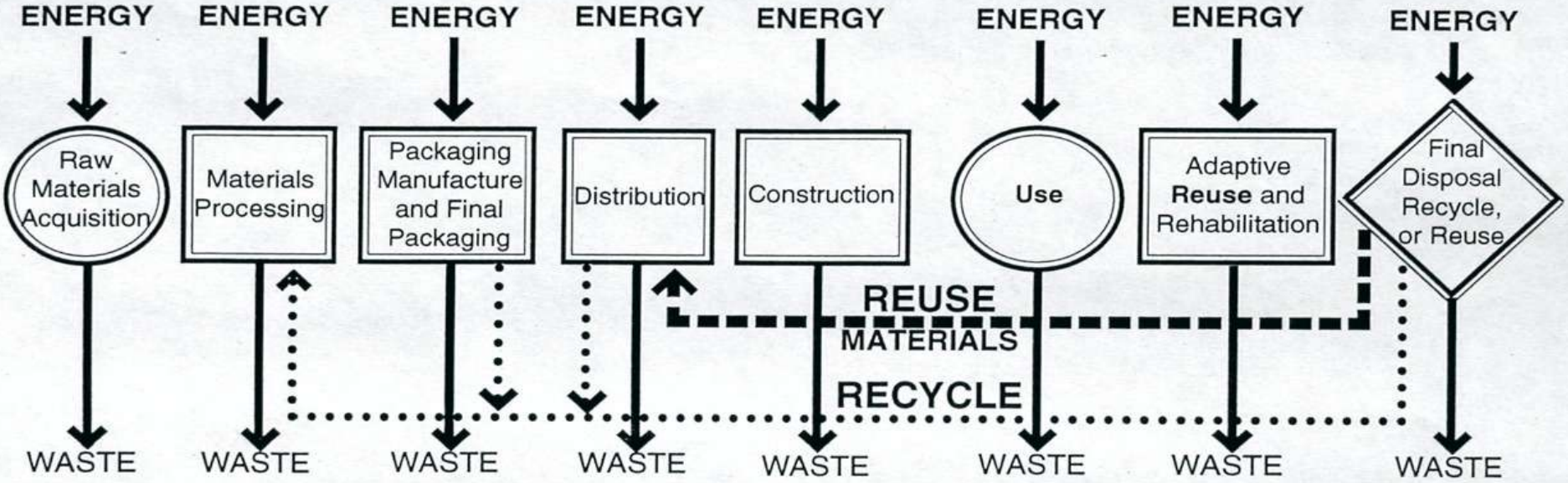
Avoid destruction of farm land

LOCATION • ELLEN & GEORGE BEELER LIVE/WORK REMODEL

WE CANNOT TRANSITION TO A SUSTAINABLE SOCIETY WITHOUT REHABILITATING EXISTING BUILDINGS

DO NOT TEAR DOWN A BUILDING THAT CAN BE FIXED

BUILDING LIFE CYCLE



REHABILITATING of EXISTING BUILDINGS SAVES EMBODIED ENERGY & RESOURCES

AIM Associates Sustainable Architecture talk by George Beeler
at Sonoma State University to The Energy Forum of the
Department of Environmental Studies and Planning, 2 December 1992.

9200.10 Building Life Cycle

FORMULA FOR ZERO NET ENERGY BUILDINGS

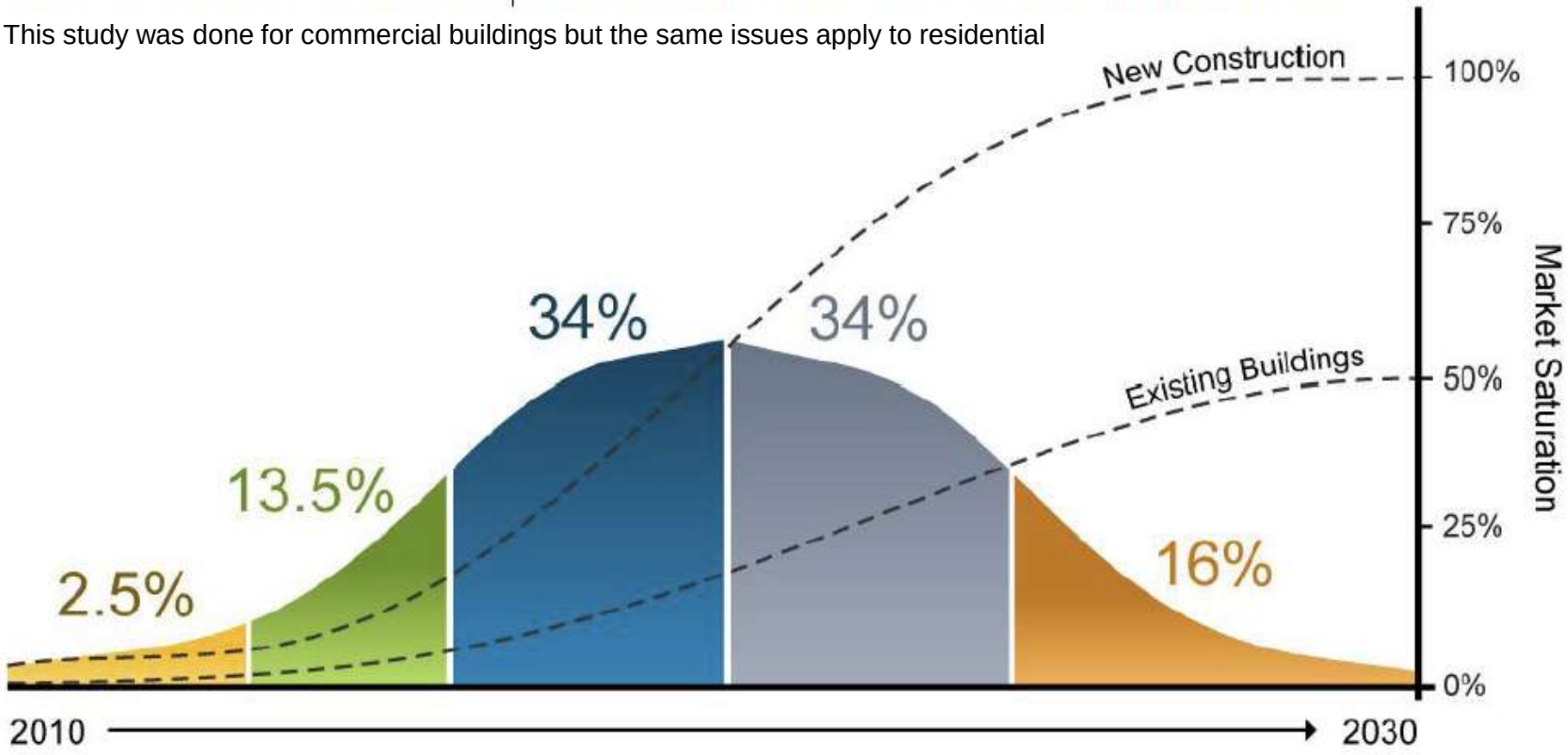
The Contribution of Each Category May Vary Considerably

← Later Phases for Active Systems →

BUILDING ENVELOPE	COMFORT EQUIPMENT	BEHAVIORAL CHOICES	RENEWABLE ENERGY	=	ZERO-NET ENERGY
Orientation Building Massing Insulation Air Sealing Windows Thermal Mass Cocoon Room	Heating Cooling Ventilation Water Heating Lighting Appliances Entertainment Other Plug Loads	Pay Attention to All Resource Use Monitor & Refine Thermostat Settings Adaptive Comfort Clothing Sail the Building Community Solutions Like District Heating	Passive Heating, Cooling, Ventilation Solar Thermal Photo-Voltaic		All of the Energy Used by & in the Building is Harvested on Site or in Community

CONCEPTUAL MARKET DIFFUSION FOR ZERO NET ENERGY TARGETS

This study was done for commercial buildings but the same issues apply to residential



Innovators

1-4/1-5: Innovative Finance Tools & Incentives

Early Adopters

1-3: Path to Zero/ZNE Pilots
1-6: Integrated Design
2-6: Existing Building Finance Tools
2-8: Plug Loads

Early Majority

2-1: Lead by Example
2-4: Benchmarking
2-5: Business case
2-7: Integrated Energy Management

Late Majority

2-2: Codes for Existing Buildings

Laggards

1-1: ZNE Codes
1-2: T24 and T20
2-3: Code Compliance

CA Energy Efficiency Strategic Plan, Appendix C, page 34
http://www.cpuc.ca.gov/NR/rdonlyres/6C2310FE-AFE0-48E4-AF03-530A99D28FCE/0/ZNEActionPlanFINAL83110.pdf

At Left is Typical Neighborhood Bungalow
At Right is 1940'S Building Before Renovation

Southwest View

Pre-renovation of 2005 Southeast View

The deciduous wisteria vine on cable trellis provides good summer shading on the arched southeast window, but leaves hang on until December so solar heating is compromised

FIRST PHASE: 1998 PURCHASED BUILDING - EXTENSIVE REMODEL

Energy Efficiency Features to Reduce Energy Use ~75%

Existing house had no insulation

- Added R-30 blown-in cellulose attic insulation
- Added R-13 dense-pack cellulose wall insulation main floor (2x4 studs)
- R-20 dense-pack cellulose wall insulation ground floor (2x6 studs)
- Replaced existing conventional single glazed aluminum windows with Low-E^2 glass in fiberglass frames

  However arch top window in living room very costly to change so kept single glazed & added “R-4” triple honeycomb shade but sealing edges is weak point

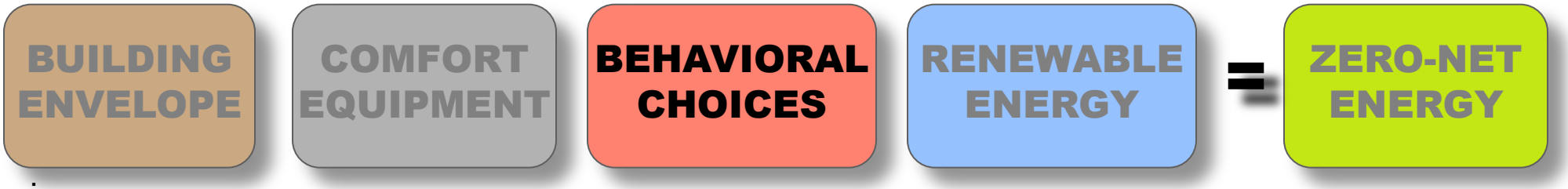
FIRST PHASE: 1998 PURCHASED BUILDING - EXTENSIVE REMODEL

Energy Efficiency Features to Reduce Energy Use ~75%

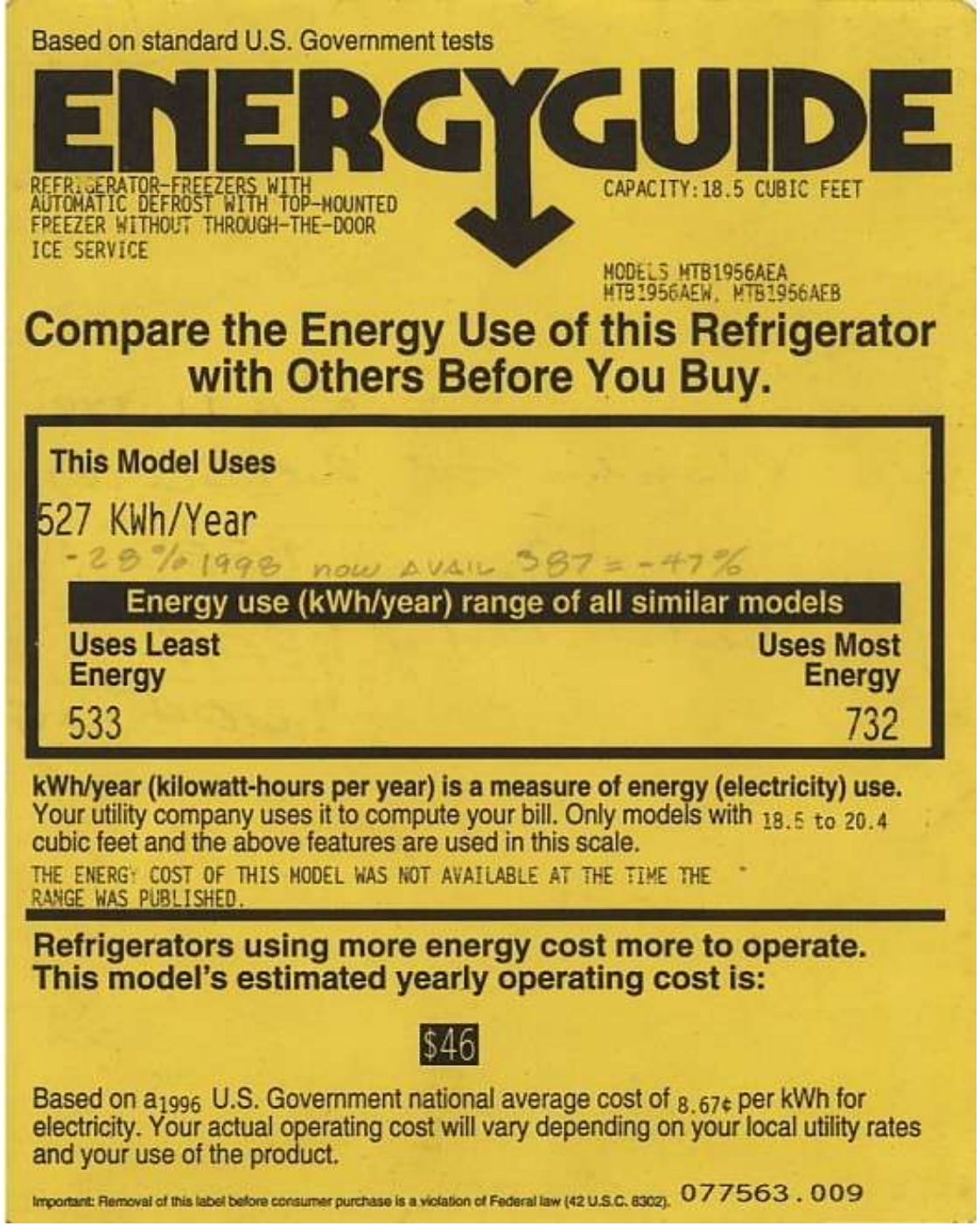
- Replaced existing ~ 60% efficient furnace with 96% efficient condensing natural gas furnace with
  - Two-level gas burner
  - High-efficiency variable speed blower
  - Duct air pressure auto adjustment so that we may use manual, central duct dampers for zone control of heating each room
  - Sealed combustion
- Multi-set back thermostat
- Removed conventional water heater & added demand type water heater
- Energy Star appliances (chose most efficient, top 10% of Energy Star)
- Changed to laptop computer & LCD displays for other computers
- Changed almost all incandescent lights to fluorescent or CFL
- Whole house fan for night cooling

FIRST PHASE: 1998 PURCHASED BUILDING - EXTENSIVE REMODEL

Energy Efficiency Features to Reduce Energy Use ~75%



- Pay attention to all resource use
- Frequently adjust multi-set back thermostat
- Carefully open & close shades and windows for solar gain or passive cooling
- Turn off lights, computers & entertainment devices when not using
- Wait for full loads for dishwasher & clothes washer
- Use solar clothes dryer = clothes drying lines



Energy Star Appliances

(I looked at ACEEE appliance guide to find the most efficient models which would be in the top 10% of those qualifying for Energy Star)

Paying $100 more for the refrigerator saved $1,000 when the PV system was installed in next phase

ENVIRONMENTAL & RESOURCE EFFICIENCY FEATURES

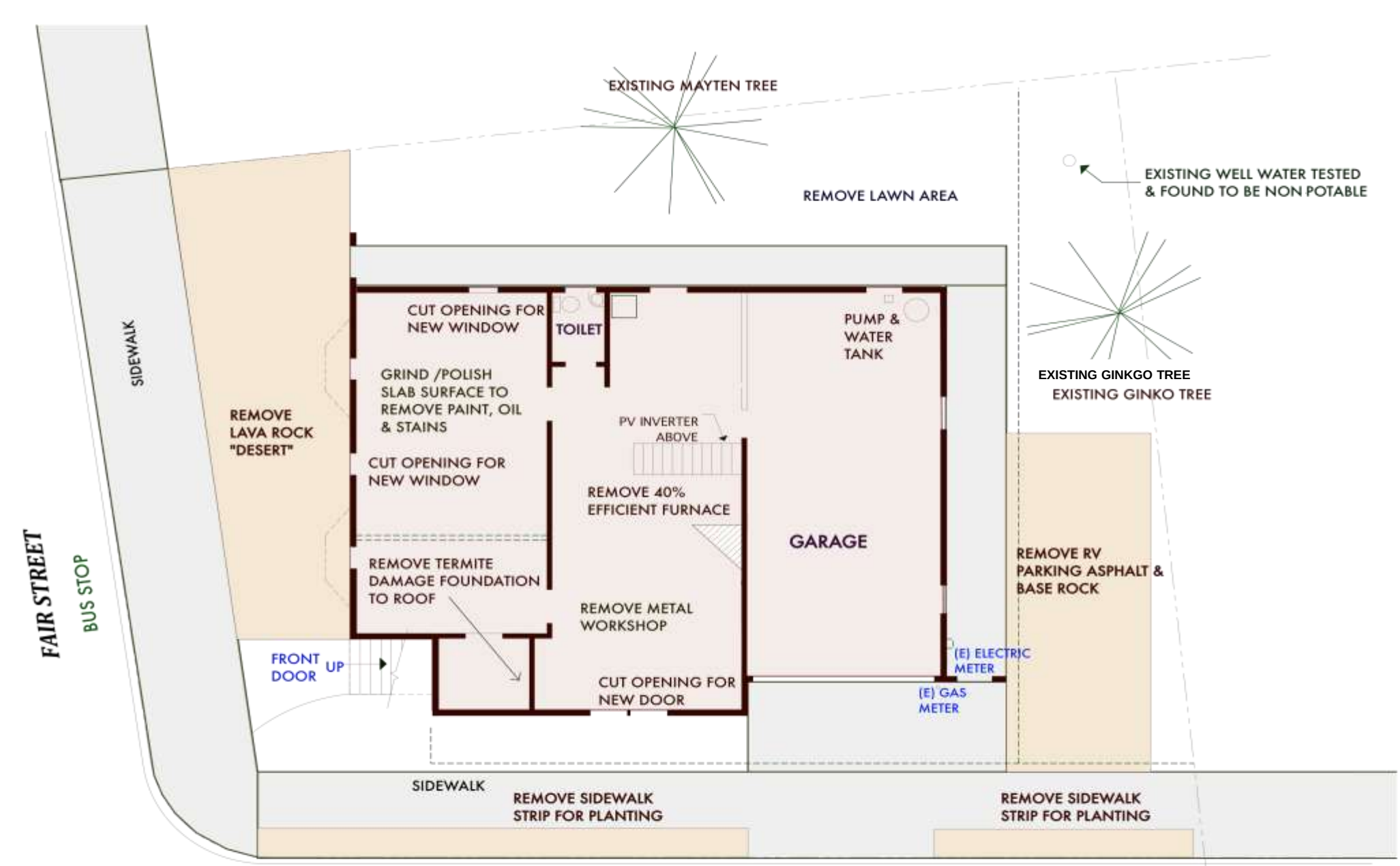
- Selected house within walking distance of grocery store, post office, & bank
- 100% recycling of cardboard, metal, & paper construction waste
- 75% reuse of wood, plywood, & siding construction waste
- Old windows reused in friend's greenhouse
- Salvaged bricks used for permeable paving (brick on sand bed & sand joints)
- FSC-certified lumber, trusses, & plywood for new roof framing (Hayward Lumber)
- Finger-jointed door frames
- OSB basement interior sheathing & additional anchor bolts for seismic reinforcement
- Recycled plastic lumber window trim (Durawood of 100% HDPE) & garden planters (Epic of mixed plastic)
- Recycled plastic/wood composite lumber (Trex) low (18" high) retaining wall
- Exposed concrete as finished floor was ground to expose aggregate & sealed
- Water-efficient fixtures & appliances
- On-demand hot water circulation pump (Taco)
- High-efficiency, drip irrigation uses nonpotable shallow well water (Irritrol)
- Toilet modified for one-gallon flush (hold lever for about four seconds for a full flush)
- We both drive gas hybrid cars when we cannot walk, bike, carpool, or use public transit

INDOOR AIR QUALITY & HEALTH FEATURES

- Central vacuum system
- Removed all carpet & refinished hardwood floors (carpet harbors dust that is brought in on people's shoes that contains pesticides, herbicides, motor oil, etc.)
- Sealed combustion furnace with high-efficiency air filter
- Carbon drinking water filter
- Avoided insulation with formaldehyde adhesive
- Termite abatement: less toxic biological control & borate-based methods
- Solar Wall brand air heating brings in 100% outside air to dry out basement
- New shower pan with coved tile base for easier cleaning to avoid mold
- Existing 1970 down draft range hood (Jenn-Air) vented to outside

SAFETY & DURABILITY FEATURES

- Reinforced ground floor walls to remodel, industry standards for earthquakes & windstorms
- Remodeled areas have 5/8" fire-rated gypsum board & solid core wood doors for better fire safety, acoustical separation, & improved thermal mass
- Smoke detectors in all rooms
- New electrical wiring where accessible. New GFI circuit breaker & outlets
- Connected to city water for house because poor quality of well. Use well for irrigation.

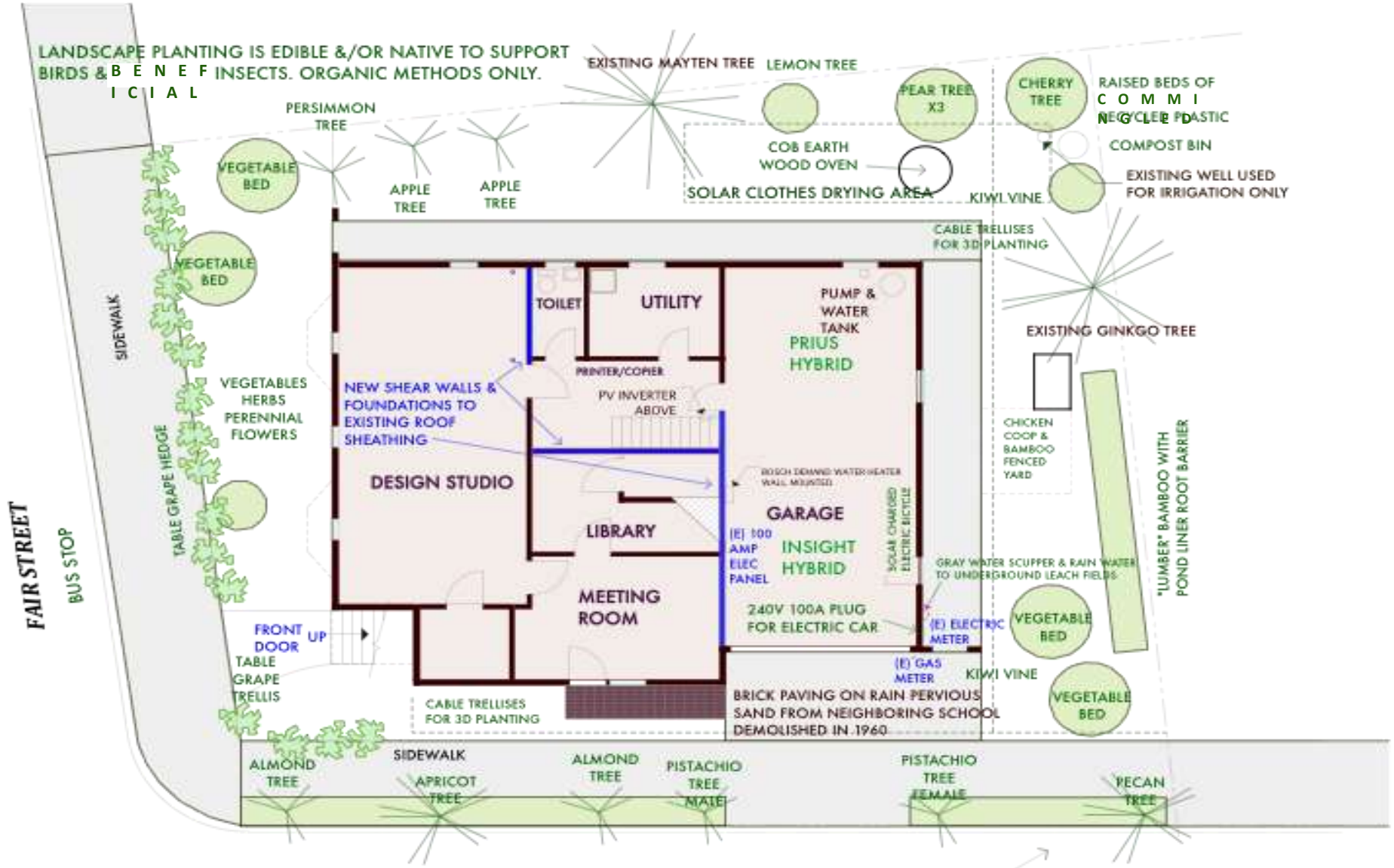


DEMOLITION SITE PLAN

DOUGLAS STREET

PERMACULTURE INSPIRED LANDSCAPING USING ORGANIC METHODS

- Removed asphalt RV parking and planted vegetable garden
- All newly planted trees are nut or fruit
- Planted street trees
- Installed raised beds of recycled plastic boards
- Organic herb & food production (no pesticides, herbicides, or chemical fertilizers)
- Native wildlife is welcomed with drinking water & native plants
- Non-potable shallow well water used for drip irrigation
- On-site composting of kitchen vegetable waste and yard waste
- Added chickens in 2010 to eat vegetable scraps & provide eggs & manure



SITE PLANTING & GROUND FLOOR PLAN

DOUGLAS STREET

EXISTING 60-YEAR-OLD WOOD WINDOW TRIM

Even if repaired, wood trim needs painting & sealing almost every year

The original 1940 wood windows were replaced by single glazed aluminum windows in the 1970's

BEST PRACTICE WINDOW INSTALLATION

Photos from **Installing and Flashing Windows *by* Rob Moody**
http://www.finehomebuilding.com/how-to/install-replacement-windows-and-flashing-correctly.aspx

**Window installation in a wall with siding removed
Best practice is to seal window flanges first with compatible elastomeric sealant under flange & with flashing tape over flange**

Installing new windows in existing stucco wall is difficult because the old window edges are typically embedded in the stucco

It is difficult, expensive, & risky to embed the new windows into the new stucco patches. The patches are likely to crack & leak air & water

We ground the existing stucco smooth, primed it, then applied elastomeric sealant under the flange & flashing tape over the flange. Recycled plastic (HDPE) trim was installed to cover the flashing tape

EXISTING WINDOW PRE-1998 NEW WINDOW 1998

Wood trim needs painting & sealing almost every year

Single glazed aluminum windows = R-1, replaced except for nonconditioned garage

New Low E^2 fiberglass windows = R-4

Recycled HDPE trim looks new 12 years later. It covers aluminum clad adhesive flashing over window flanges

MAIN FLOOR INTERIOR IN VERY GOOD CONDITION, *EXCEPT:*

Termites had eaten damp wood from the foundation to the roof in the southeast corner of the living room

The shag carpet was in good condition & given to neighbors who wanted it

Windows given away for greenhouse

The dampness came from a tiny hole in a solder joint of an interior rain water pipe, probably from when the house was built in 1940

VIEW OF UNFINISHED BASEMENT DURING 1998 REMODEL

Black tar on wall was previous owner's attempt at waterproofing

EARTHQUAKE UPGRADE

Additional 5/8" foundation anchor bolts @ 4' o.c.

Metal ties from top plates to floor sheathing

1/2" plywood on inside of all exterior walls & interior bearing walls

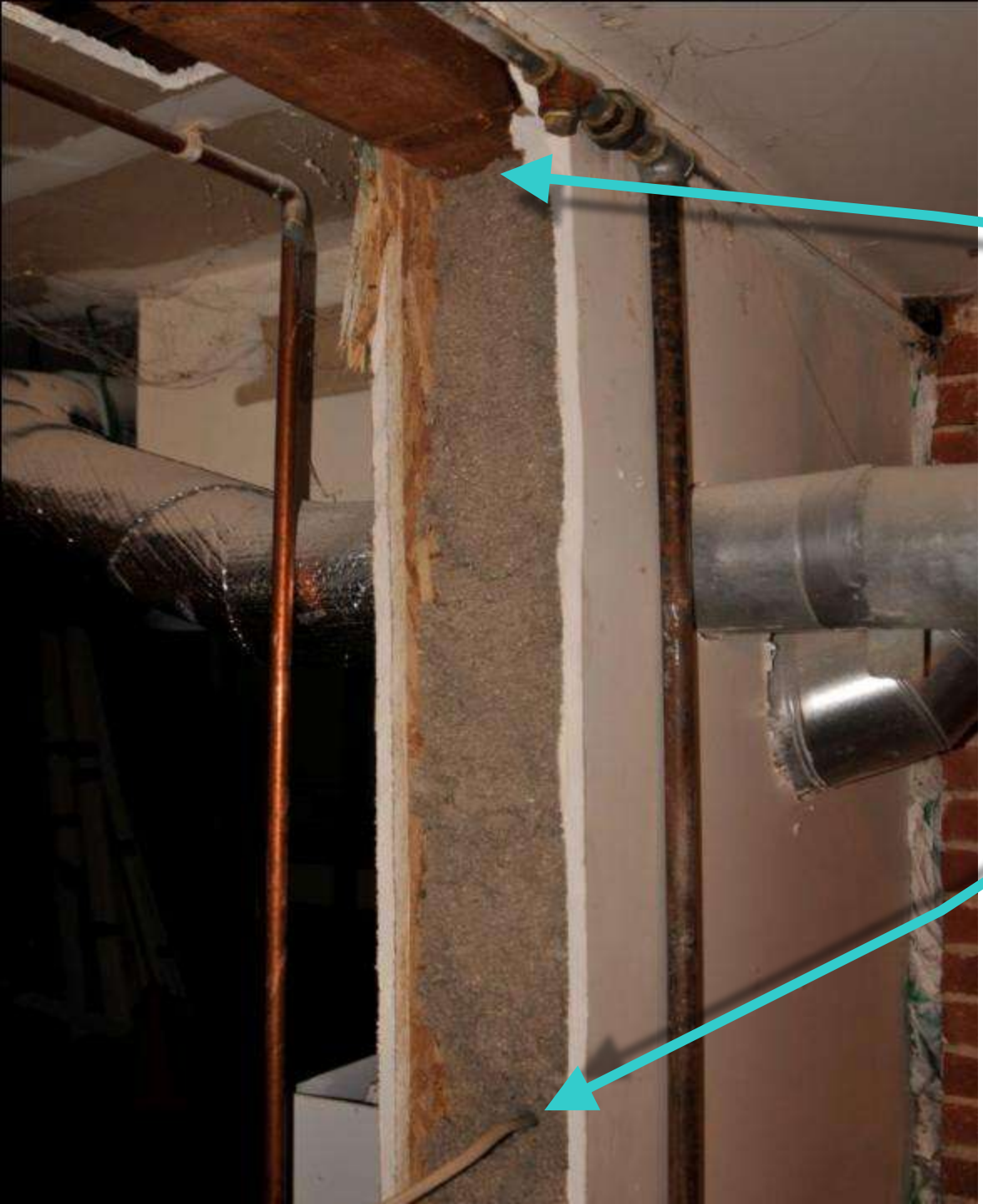
ENERGY UPGRADE

Basement louvers vented to the outside were closed off

Dense pack R-20 cellulose was added to 2x6 wall stud spaces

R-7 EPS insulation boards were added to outside of concrete foundation walls

Milgard windows, with fiberglass frames & Cardinal LoĒ²-272® glazing using argon fill



GOOD WORKMANSHIP!

No voids in the insulation from settling!

Dense pack cellulose insulation was blown into all exterior walls & interior wall of the garage in 1998

This wall was opened up in 2010 for additional earthquake strengthening

Cellulose also fills voids around wiring & pipes

PERMACULTURE INSPIRED LANDSCAPING
... ALL ORGANIC
REMOVED ASPHALT RV PARKING AND
PLANTED VEGETABLE GARDEN
PLANTED FRUIT & NUT STREET TREES

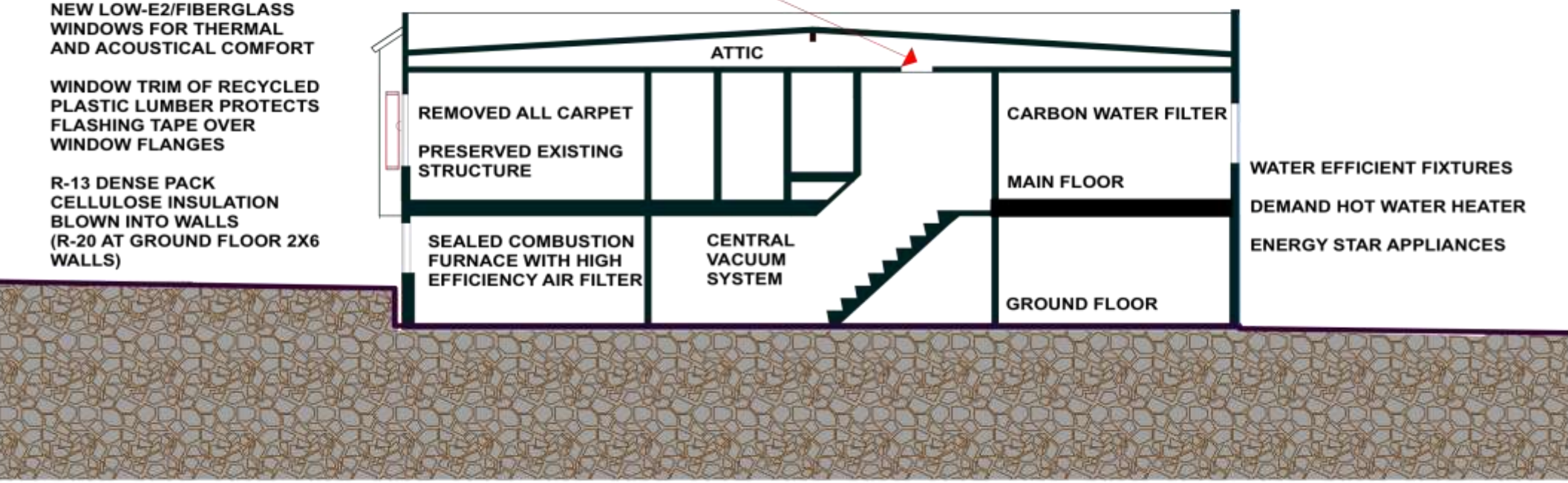
EXISTING ARMSTRONG FOAMED URETHANE ROOFING COST PREVIOUS OWNER AS MUCH AS A 4-PLY 20-YEAR ROOF BUT ONLY CAME WITH A 5-YEAR WARRANTY

CELLULOSE INSULATION BLOWN INTO ATTIC
R-38 INTENDED BUT DIFFICULT WORKING CONDITIONS ONLY ACHIEVED APPROXIMATELY R-30
SMALL ACCESS PANEL WAS ONLY ATTIC ACCESS

NEW LOW-E2/FIBERGLASS WINDOWS FOR THERMAL AND ACOUSTICAL COMFORT

WINDOW TRIM OF RECYCLED PLASTIC LUMBER PROTECTS FLASHING TAPE OVER WINDOW FLANGES

R-13 DENSE PACK CELLULOSE INSULATION BLOWN INTO WALLS (R-20 AT GROUND FLOOR 2X6 WALLS)



BUILDING SECTION 1998 REHABILITATION

The Thousand Home Challenge did not exist when we started in 1998 but we would have adopted its goals if it had

We want you to look at our case study in the context of meeting the THC energy use reduction goal

Meeting the Thousand Home Challenge (THC)

- This home's customized threshold to meet or exceed is 6,231 kWh/yr (Threshold Allowance OPTION B, fuel heating)
  - OPTION B is not relative to previous use; inputs include weather, house size, number of occupant and type of fuel used for heating
- This household has officially met the THC as verified by utility bills documenting a year of household energy use of 4,675 kWh (net total site household energy)

Thousand Home Challenge Threshold Compared with Our Usage/Production

THC Option B: 6,231 kWh/Yr (Equiv.)

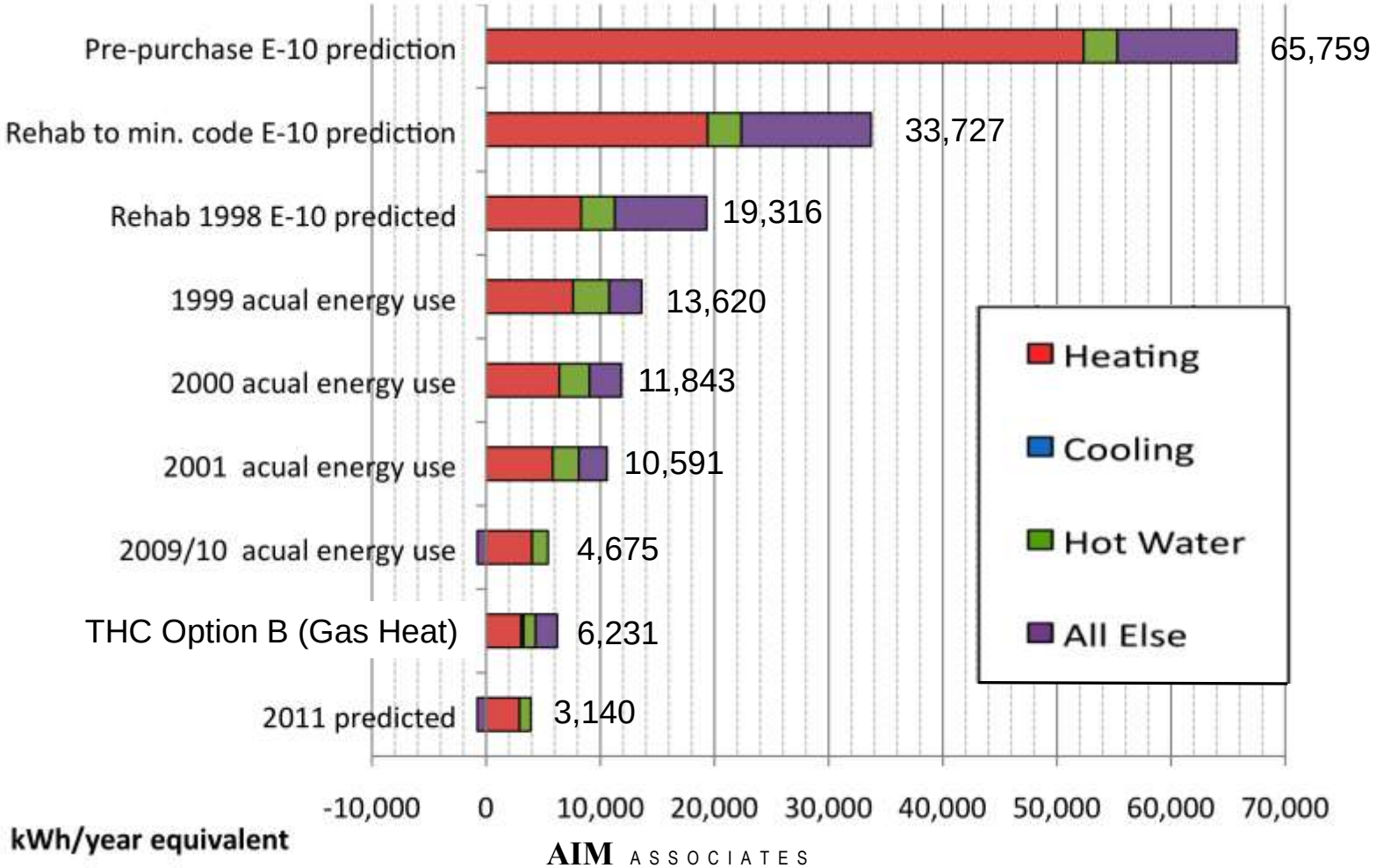
Actual Usage 2009-10: 4,675 kWh/Yr (Equiv.)

Energy Source	Annual Use	MMBtu	kWh
Nat Gas – therms	185	18.5	5,422
Electricity – kWh	-747		-747
TOTALS		**18.5**	**4,675**

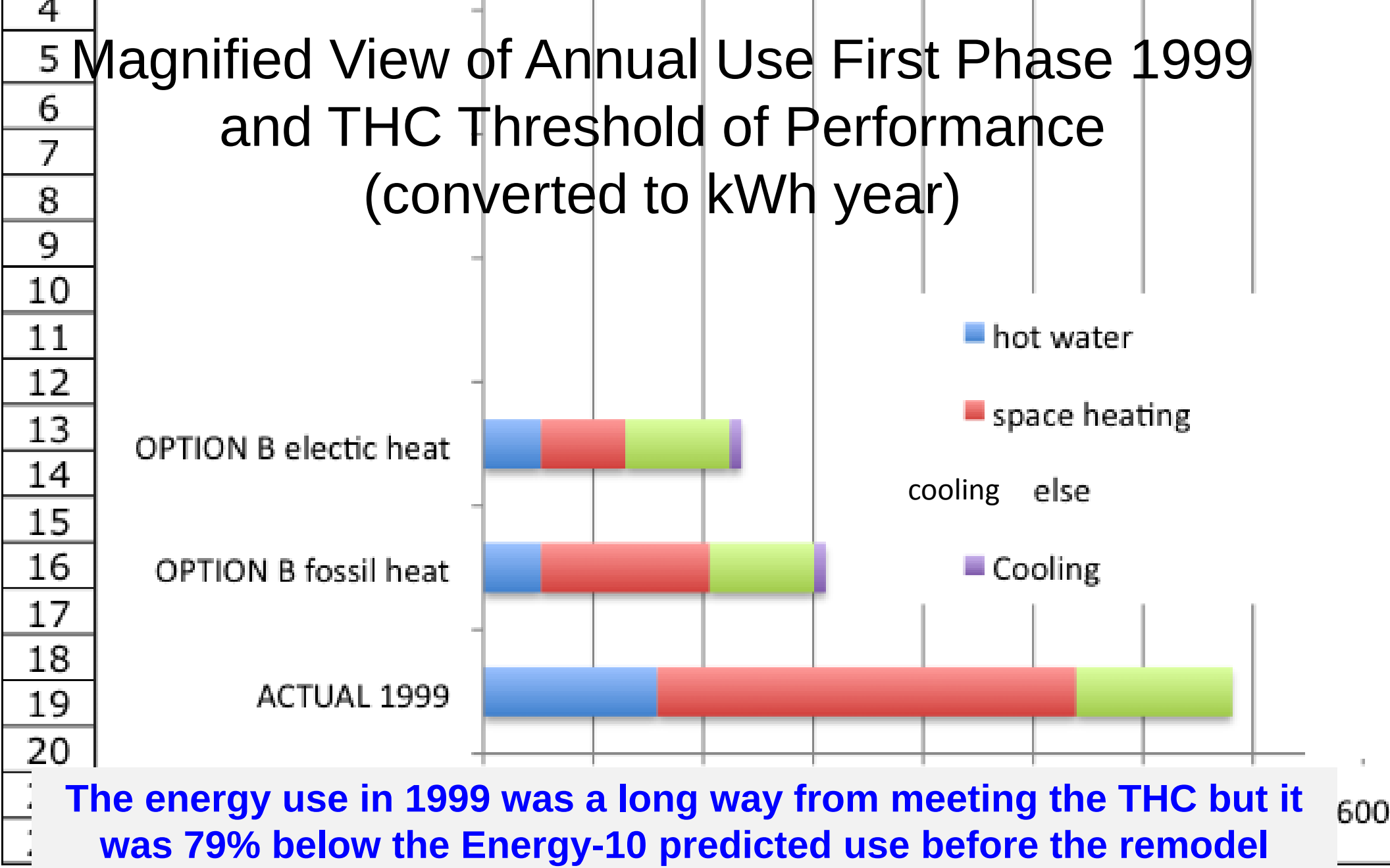
[1] **Option B Assumptions:** 2,791 HDD, 2 occupants, fossil heat, 2,500 ft² finished floor area

For more information on the Threshold Allowance: www.ThousandHomeChallenge.org

Thousand Home Challenge Threshold Compared with Usage/Production (kWh/yr by use)

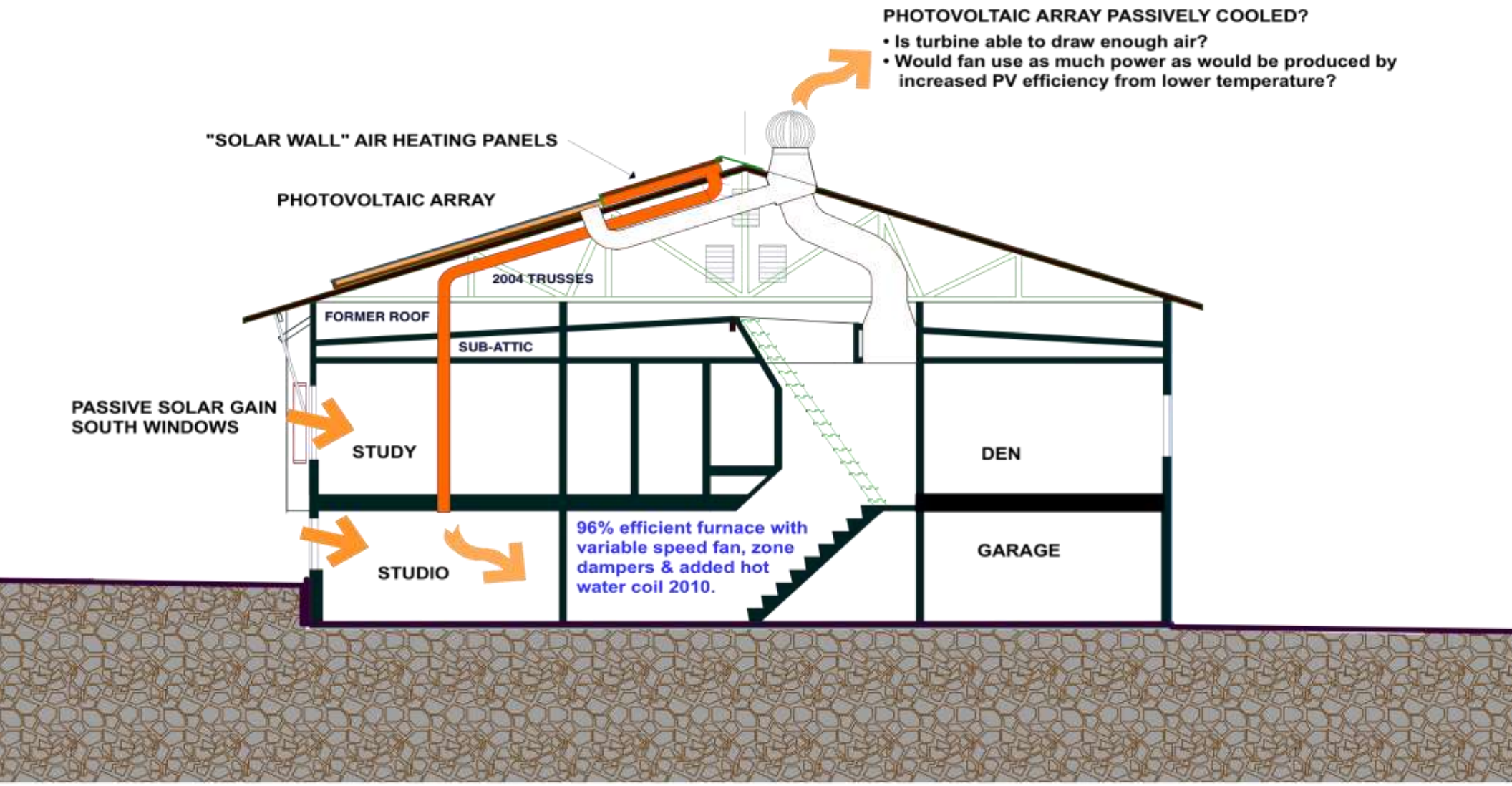


Magnified View of Annual Use First Phase 1999 and THC Threshold of Performance (converted to kWh year)

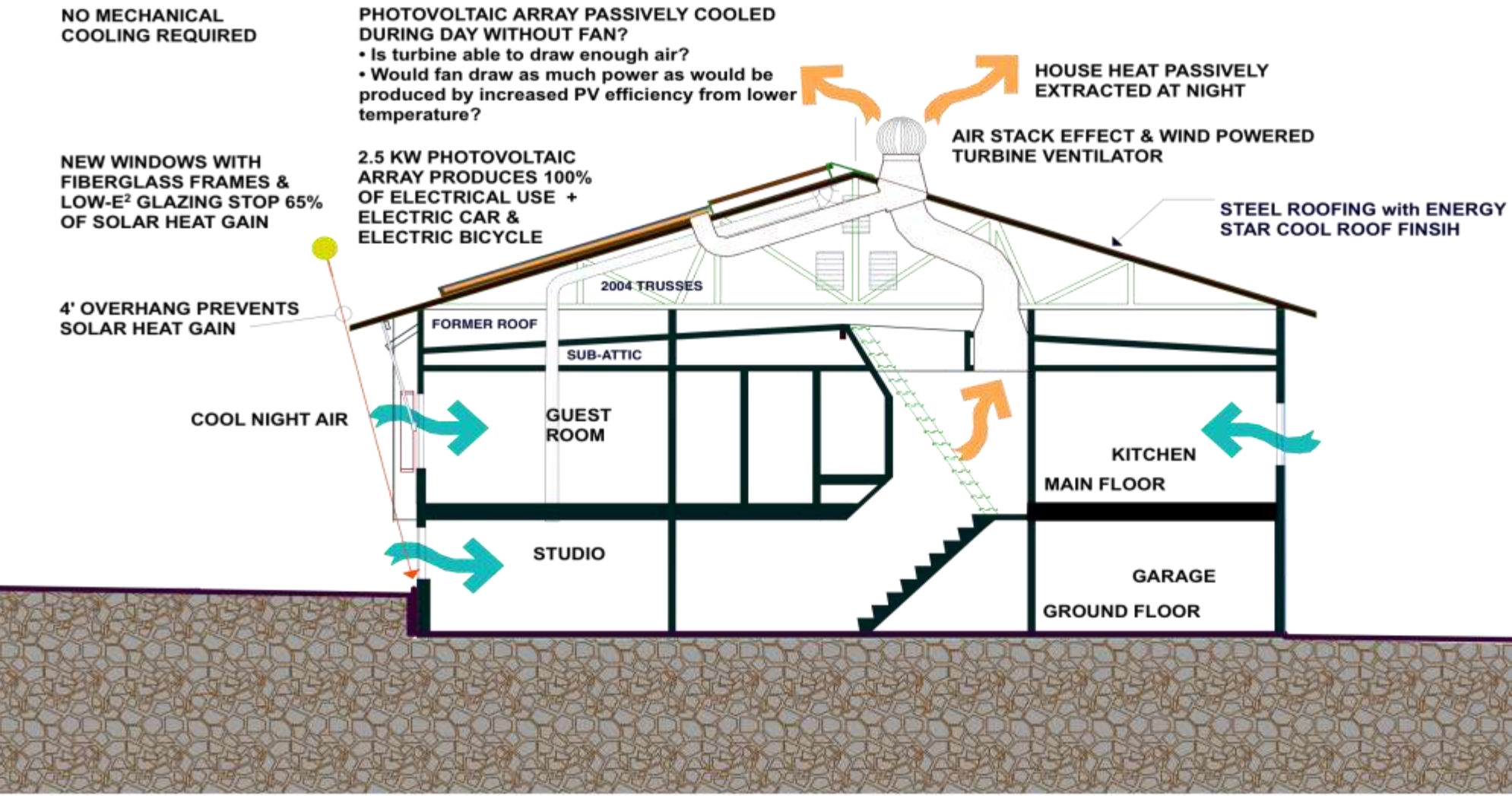


The energy use in 1999 was a long way from meeting the THC but it was 79% below the Energy-10 predicted use before the remodel

SECOND PHASE - 2005 REMODEL



WINTER FEATURES • BUILDING SECTION



SUMMER FEATURES • BUILDING SECTION

ALTERNATIVE ENERGY SYSTEMS

Turbine ventilator uses wind to draw air out of living areas for passive ventilation & night cooling

- 24” throat diameter
- It draws 2,000 cfm during 5 mph breeze
- A neoprene gasketed duct damper prevents air leakage common with whole house fans

Solar air heating is provided by 200 ft^2 of Solar Wall brand transpiring panels

2,500 watt photovoltaic array provides all live/work building electricity plus electric bicycle & future electric car

DUCTS UNDER TURBINE VENTILATOR

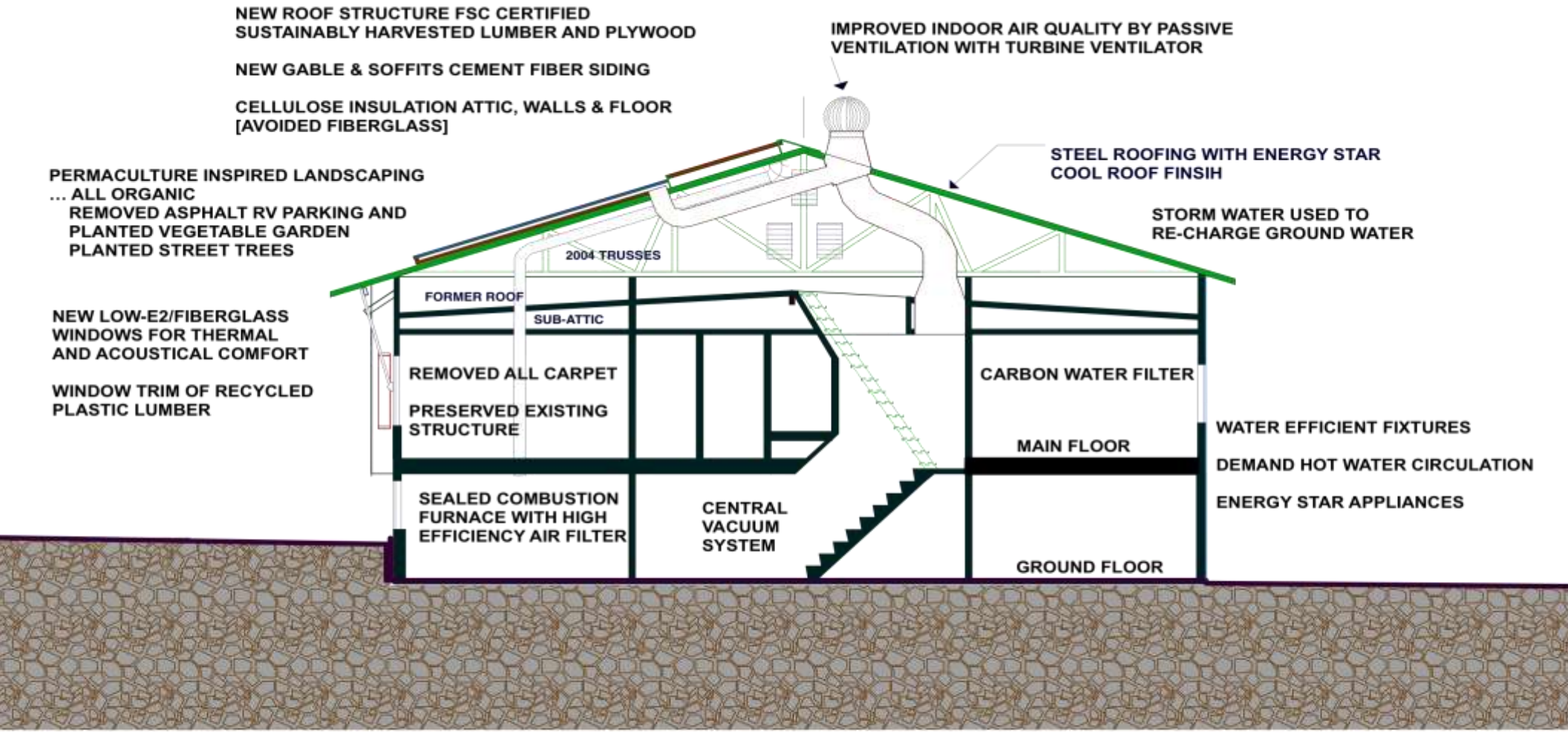
SOUTHEAST ELEVATION
AFTER 2005 RENEWABLE ENERGY REMODEL

In the first phase, all existing windows were replaced with high-performance windows, except this living room window because it was too expensive (unusual shape). That is why the R-4, three-layer honeycomb interior shade is needed

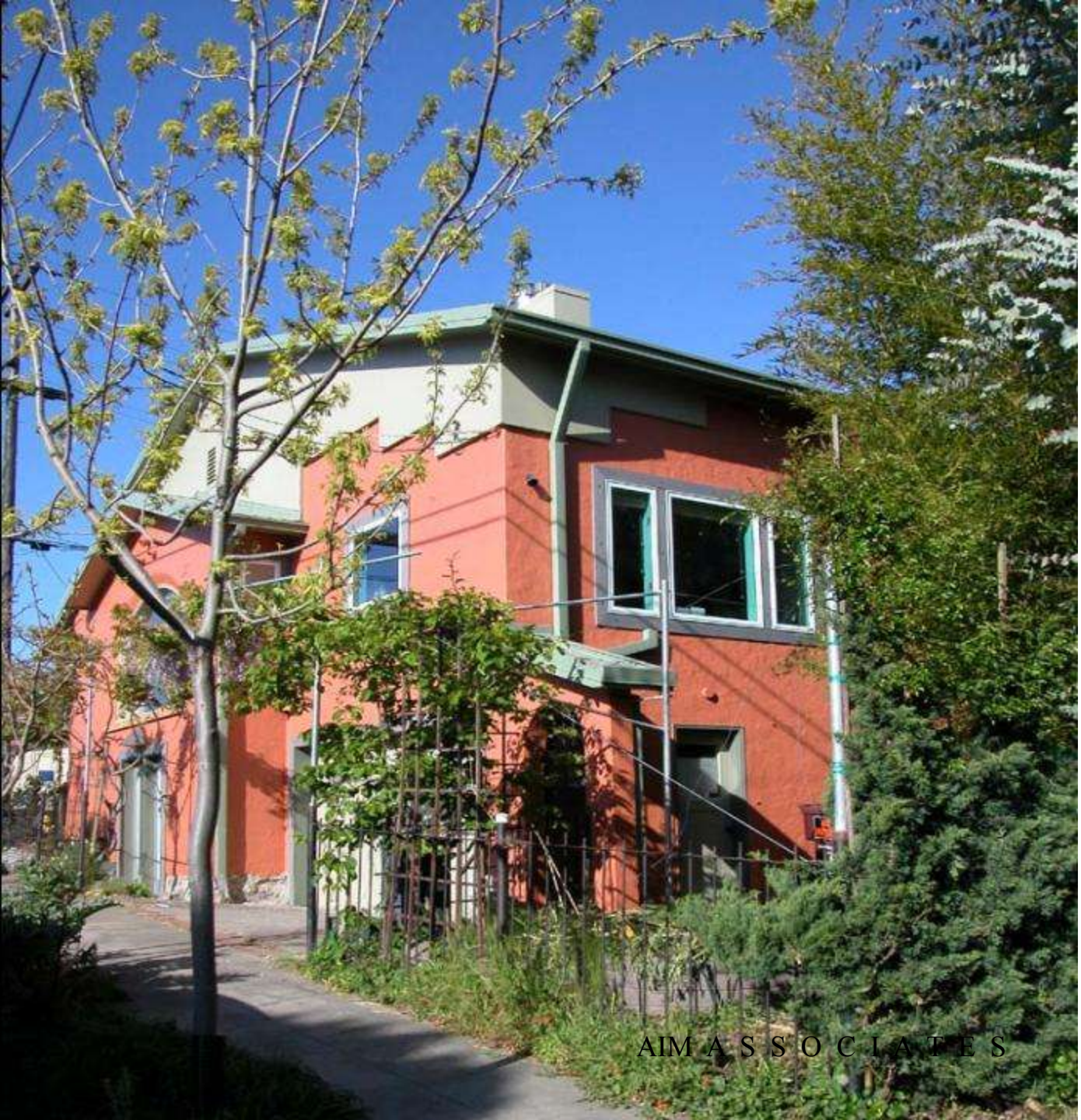
However, it is difficult to keep cold air from flowing out from around the edges of the shade

Cable trellis was modified, so vines shade office glass door but do not shade living room window

**DIRECT GAIN SOLAR HEATING WHEN THE SHADE IS RAISED.
THIS ALSO PROVIDES A DELIGHTFUL PLACE TO KNIT!**



GREEN, INDOOR AIR QUALITY, COMFORT, & HEALTH FEATURES



Northeast corner of lot planting, starting from the left:

- **Pecan tree**
- **Kiwi vine on cable trellis**
- **Raised vegetable bed of recycled plastic bender board**
- **Bamboo grove**

We open window & dump vegetable washing water into this gray water scupper
The scupper is piped to rainwater downspout that discharges into the underground perforated pipe, under vegetable bed, that recharges ground water

SECOND PHASE: 2005 REMODEL

Added renewable energy with the goal to achieve zero-net energy use.
We planned to generate enough electricity for 100% of our electrical use plus enough excess electricity fed into the utility grid to compensate for the natural gas we burn for heating, hot water, & clothes drying.

This is zero-net energy use because the utility will not have to burn that amount of natural gas for generation of electricity. We will not be paid by the utility for this excess electricity, but we have chosen to do this to be environmentally responsible.

RENEWABLE ENERGY

- **Photovoltaic system (2.5 KW)**
- **Solar Air Heating from 200 ft^2 of Solar Wall™ to reduce natural gas use by ~20%**
- **Passive solar heat gain captured by opening & closing window coverings**
- **Wind driven turbine ventilator to:**
  - **Enhance natural ventilation**
  - **Provide whole house night cooling**

RESOURCE EFFICIENCY

- FSC Certified sustainably harvested lumber & plywood
- Steel roofing because:
  - Recycled content
  - Never needs to be replaced if it is repainted about every 30 years
  - Ideal for future rainwater harvesting
  - Provide partial shielding of house from electromagnetic fields of adjacent power lines
- Storm water used to charge ground water
- Partial gray system for irrigation
- Cement fiber siding for new roof gables, etc.
- Lumber & siding waste:
  - Salvaged 75%
  - Used for birdhouses
- Best practices detailing for longevity & low maintenance

ADDITIONAL ENERGY EFFICIENCY FEATURES

- Add roof overhang over south facing windows for summer cooling
- No mechanical cooling needed
- LED house number

ENERGY PERFORMANCE PHASE TWO REMODEL FIRST YEAR

Electrical 0.0 kWh/year because of PV (excess produced 1,465 kWh first year)
(1,465 kWh x 3.34 national efficiency loss for site/source electricity[2] = 4,893 kWh x 0.879 lbs CO_2 per kWh CA average[1] = 4,301 #/CO2 saved from atmosphere)

Natural gas 167 therms/year = 6.68 kBtu/ft²/year (THC equivalent site 4,849 kWh)
(167 therms x 13.446 #/CO2/therm[1] source = 2,245 #/CO2)

EXCESS PV AS CARBON OFFSET FOR NATURAL GAS HEATING?

We propose that the excess electricity fed into the utility grid of 1,465 kWh/year more than compensated for the 167 therms/year of natural gas we consumed for space & water heating, etc. We propose that this be considered a carbon offset because our excess PV electricity saves more CO2 than our natural gas use released

However, our electricity and gas use gradually increased over the past few years

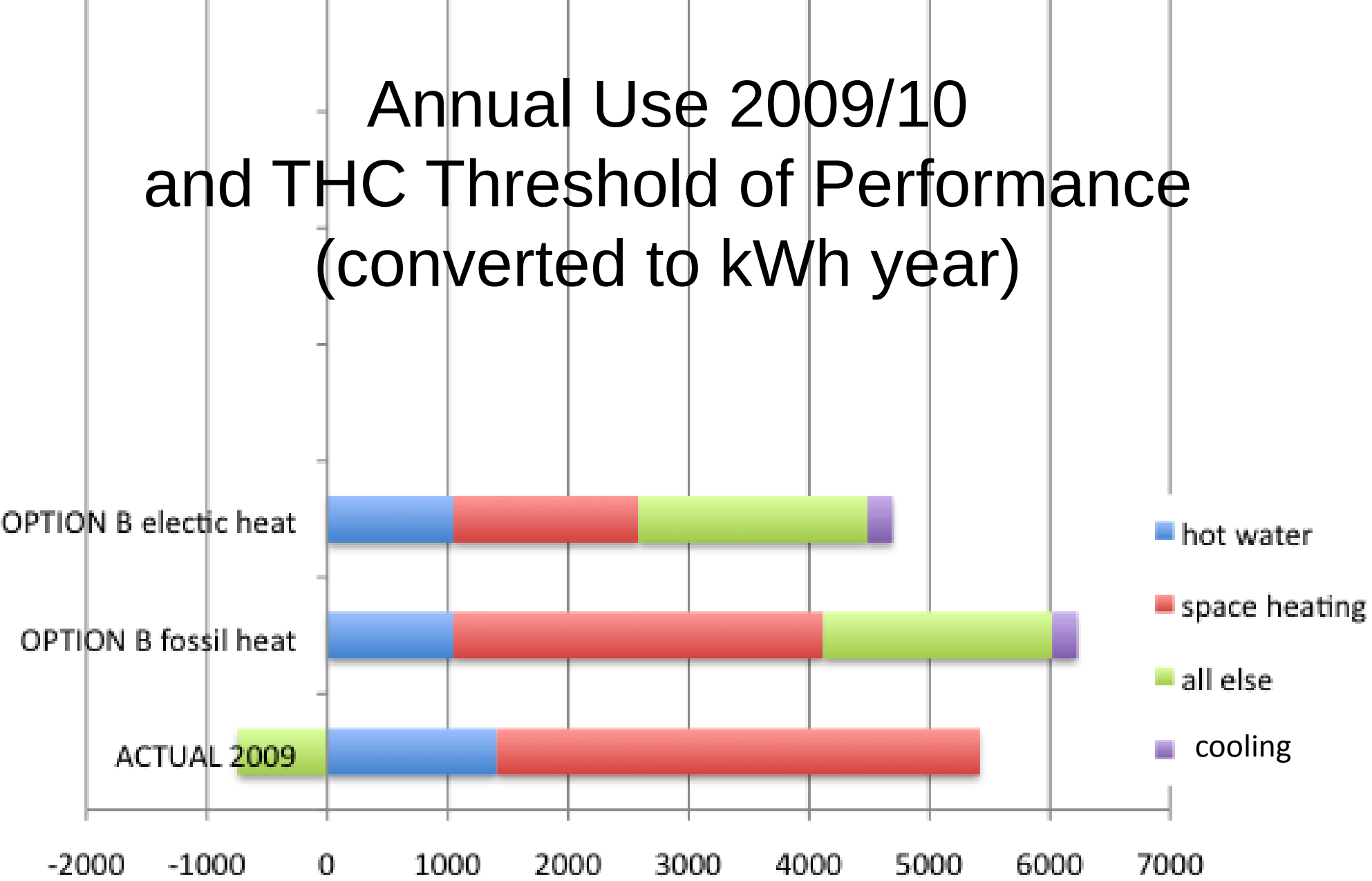
1 Per **Pacific Gas and Electric Company Carbon Footprint Calculator Assumptions**
http://www.pge.com/includes/docs/pdfs/about/environment/calculator/assumptions.pdf

2 **National average source to site electricity ratio is** 3.340 see table page 10, **ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy** Use see http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf

THIS LIVE/WORK BUILDING REHABILITATION IS VERY GREEN

This project includes many green features including resource efficiency, durability, healthy indoor environment, & permaculture-inspired landscaping

Annual Use 2009/10 and THC Threshold of Performance (converted to kWh year)



LESSONS LEARNED

Phase Two did not achieve lasting zero-net energy for natural gas use
This is because Ellen's fibromyalgia requires 70^{o} F air temperature, hot baths, & long showers for her to be comfortable

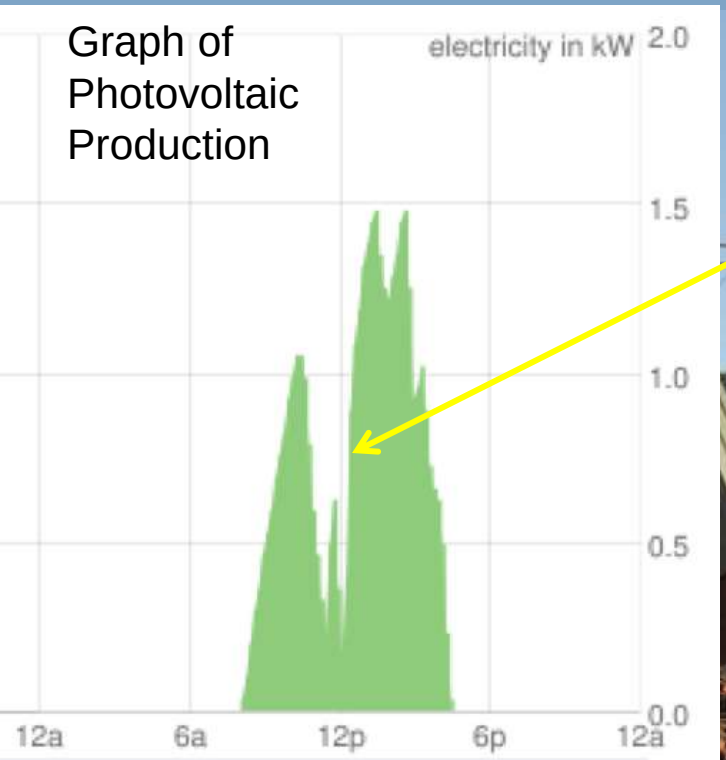
GOALS THIRD PHASE: 2010 REMODEL

- **Improve energy efficiency before adding more renewable energy with goal of soon achieving zero-net energy**
- **Create a "cocoon" room in den adjacent to kitchen for Ellen to provide comfort without heating the whole house to the same temperature**
- **Add solar air heating duct to den cocoon**
- **Areas disturbed by construction are being air sealed to reduce air infiltration**
- **Demolition revealed that attic insulation was installed unevenly during the remodel 12 years ago because of limited access**
- **Better access will now be provided & the attic insulation increased from R-30 to R-50**
- **Insulation was added to existing hot water piping when it was exposed**
- **Reinforce structure to survive major earthquake & severe wind storms**

MONITORING REVEALS PERFORMANCE PROBLEMS

Shadow from utility pole reduces output from photovoltaic system more than expected as documented on graph by Google PowerMeter from electrical circuit monitoring by Jeremy Fisher & Brennan Less

Graph of Photovoltaic Production



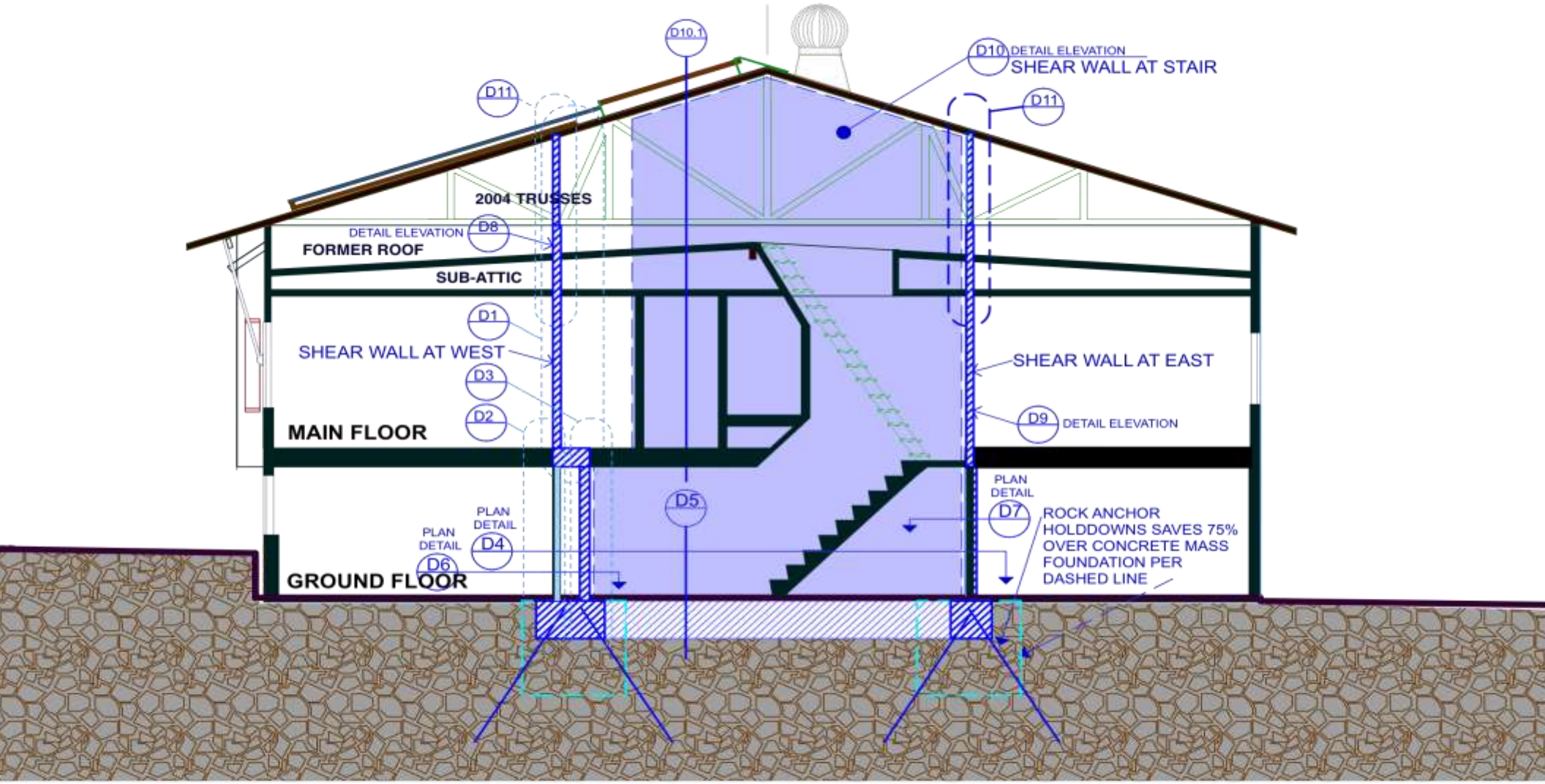
Thursday Dec 30
6.7 kW·h

REHABILITATION: MORE DIFFICULT THAN NEW CONSTRUCTION

Lots of wiring & pipes inside of walls

IMPROVE EARTHQUAKE & WIND RESISTANCE

- **Previous phases have dramatically improved earthquake & wind resistance following industry standards**
- **However, what most people do not realize is that, even with new buildings built to code, the goal is only for the occupants to get out safety, not to preserve the building**
- **The loss of a building's embodied resources during a natural disaster can usually be prevented with relatively little extra structural cost when the work is done during remodels adjacent to the structure**
- **Unfortunately, no green building program that I am aware of is addressing this issue**
- **This phase will reinforce the existing structure to approximate code requirements for essential buildings, like schools, for "maximum expected" earthquakes & windstorms**
- **This means that the building should be repairable after the "big one." Lateral strength of the building is improved with interior shear walls built on new concrete foundations with "rock anchors" and extending up to & connecting with the underside of the existing roof sheathing**
- **This is a good investment because now we feel that we do not need earthquake insurance which is expensive & has very high deductibles**



BUILDING SECTION SEISMIC RETROFIT

ROCK ANCHORS

Strong, but short interior shear walls need massive holddowns. These typically require large concrete foundations whose weight will hold them down

The engineer agreed to use rock anchors to save concrete

We tried this 3” diameter drill bit with a jackhammer

It took 1½ weeks to drill 12 holes

THE RIGHT EXPERIENCE & TOOLS GOT THE JOB DONE

Kent Williams, concrete repair journeyman of Durling Concrete, determined that core drilling was the appropriate technique even with the clay veins

The remaining 12 holes were drilled in one day!

KOREY GOSSELIN

Rock drilling was grueling & dusty work

JOHN HARRISON, ENGINEER, & DON FELKINS, BUILDER, REJOICE OVER FINDING PROPER TECHNIQUE FOR ROCK DRILLING

RESOURCE EFFICIENCY & DURABILITY

- The concrete used was reduced by about 75% by using drilled rock anchors instead of mass footings at holddowns (5.5 C.Y vs. 25 C.Y.)
- The soil was tested and found to be slightly corrosive, so the rock anchors were hot dip galvanized and protected by thicker than usual grout
- Concrete has 50% of Portland cement replaced with fly ash. This is not unusual for the greenest of buildings but, in this case, it is also for the exposed replacement slab areas, which is unusual & required very careful wet curing performed by the owner/architect
- The ultimate strength of the wood & plywood shear wall connections & mudsill connections to concrete footings was significantly improved by using construction adhesive
- A properly reinforced access panel opening & pre-placed water supply replacement piping anticipate plumbing repairs that could damage the shear wall
- Construction quality for the unusual structural detailing was ensured by an interested & diligent construction team as well as frequent site visits by the structural engineer & the architect
- The 40-year-old kitchen range had been repaired three times, but parts are now difficult to find. The Dacor replacement range was selected because of its high performance, durability, & repairability, & the fact that it is made in California
- “New” office lavatory & etched glass door are from a local salvage yard

RESOURCE EFFICIENCY & DURABILITY (CONT'D)

Water efficiency is improved by:

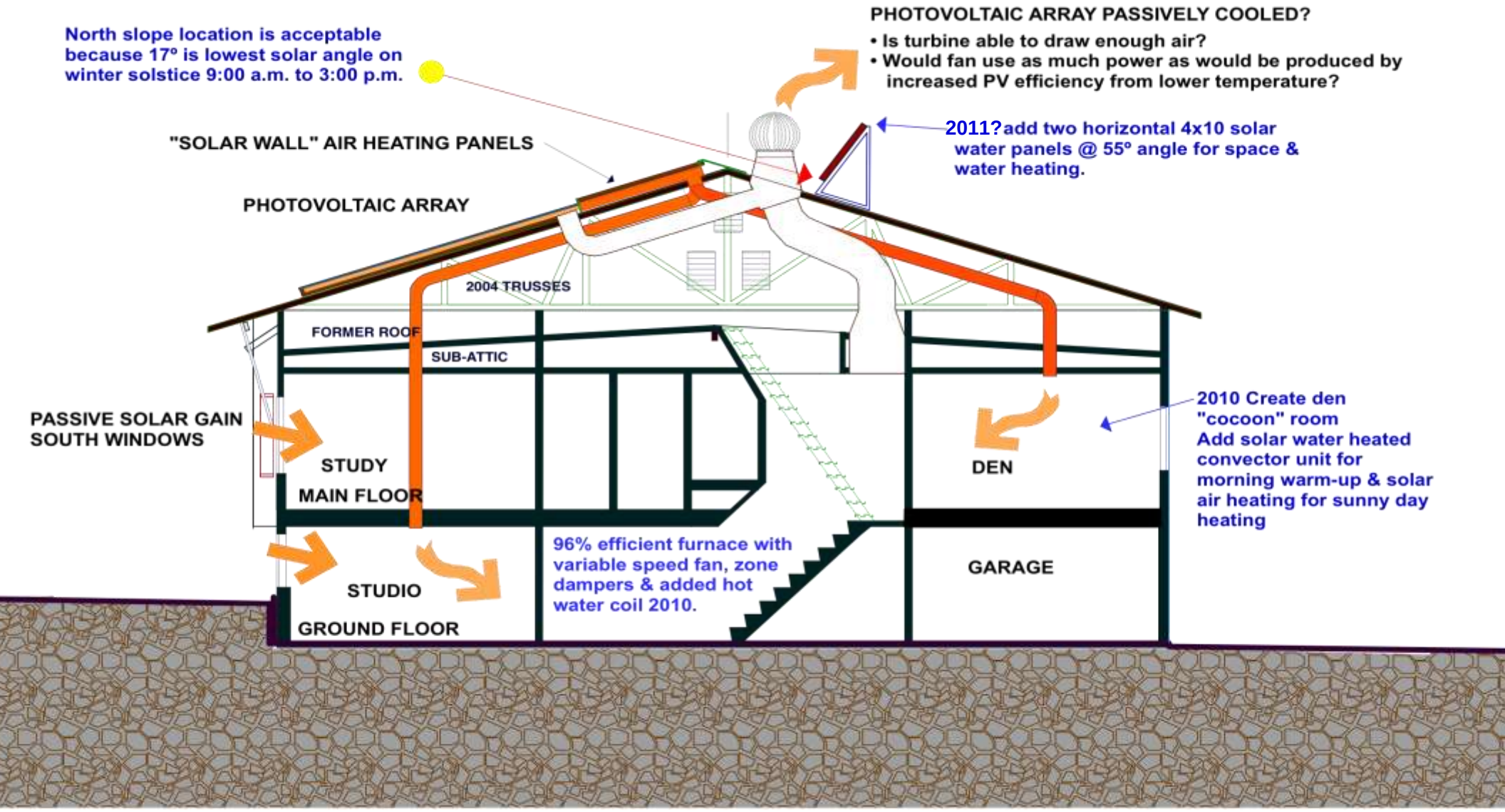
- **0.8-gallon flush Niagara Stealth™ toilet, with innovative technology that uses water pressure to create a vacuum in the waste pipe so that it pulls & pushes at the same time so it works even better than a power assist but without the noise**
- **New kitchen sink & bathroom faucets with separate valves for hot & cold because the way most people use single lever faucets is to push straight back, causing both hot & cold to flow even when they want only cold water**
- **Grey water diverter valve installed below shower & tub so that the system may be installed when the city reduces its restrictions**

Construction demolition debris was recycled to the full extent locally available

- **Small wood scraps & sawdust were composted**

OPPORTUNITIES LOST

- **The existing cellulose insulation that needed to be removed for working access could have been saved, but it got mixed in with demolition debris & had to be thrown away**
- **Using Zip Poles™ & Zippers™ would have saved a lot of plastic sheeting & finish repair damage from hanging dust protection plastic film with tape**



WINTER FEATURES • BUILDING SECTION 2010

HEALTH OF OCCUPANTS & BUILDERS

- The shear wall mudsills are borax pressure treated, which is a new nontoxic option
  - It is also more durable because the treatment penetrates the full thickness of the wood
  - As a result, drilled anchor holes & cut ends are not decay weak points
- All shear wall plywood is fastened with nails & construction adhesive. The very low VOC adhesive used is about 10x better than California requirements & 3x better than LEED requirements
- The furnace is being upgraded from a 1” air filter to a 4” MERV 10
- The areas not being worked on, registers, & opened ducts, were dust protected
- A much more effective range hood is added to the kitchen
  - It is top-capture & side-exhaust rather than the former down draft
  - It has a silencer for noise reduction & a variable speed control for much better energy efficiency
- The new kitchen sink has sloped stainless steel drain boards to avoid water pooling under the dish drain
- Opportunities lost:
  - Workers were diligent about wearing dust masks at first, until the head carpenter who insisted upon them left for another project
  - Unfortunately, hard hats were worn only by the sole union trained carpenter on the job, the structural engineer, & the architect

PLANNING FOR AN ELECTRIC CAR

We are going to buy an electric car, so we want to use our excess PV production to charge the car

- **Then we will not be able to count that amount of our excess PV as a carbon offset for our natural gas use**

- **However, our priority is to reduce our full lifestyle carbon footprint**

We recently installed a time of use meter (5-20-2010) so that our excess summer peak time PV electricity credit ($0.301) will have about a 5x multiplier for our off-peak, night charging of the car ($0.058 summer & $0.066 winter night rates)

- **Our Nissan Leaf electric car is predicted to average 4.167 miles per kilowatt hour (kWh)**

- **We have a credit of 612 kWh summer peak excess power x 30.1¢ credit / 6.2 ave. night charging rate = 2,971 kWh x 4.167 miles per kilowatt hour = 12,380 miles**

- **12,380 miles is significantly more that the 9,743 miles/yr. we drove last year**

ATTIC DUCTS & FEATURES

Roof hatch allows convenient access to roof hose bibb for rinsing dust off photovoltaic array

24” diameter from turbine ventilator down to air tight damper & grille above stairwell

Turbine ventilator provides passive night cooling for summer comfort

Former flat roof with urethane foam roofing

Roof trusses added in 2005
Local truss fabricator agreed to use FSC certified lumber

Pull-down stair allows convenient access to attic & to roof through roof hatch

BEFORE BLOWER DOOR TEST

Bruce Dichter & Mike Winter isolate the den to see if there is much difference in air infiltration compared to the rest of the main floor

Infiltration rate, entire main floor (1,800 CFM50 x 60 min./hr)/(17.2 x 1,540 ft^2 x 8' ceiling) = 0.51 air changes per hour natural

Infiltration rate, minus den & kitchen (1,065 CFM50 x 60 min./hr)/(17.2 x 1,018 ft^2 x 8' ceiling) = 0.46 air changes per hour natural

The results showed that the den's wall & ceiling wood paneling does not leak air nearly as bad as was suspected

AFTER BLOWER DOOR TEST

A blower door test was performed after more sealing was completed & more attic insulation was installed

Jeremy Fisher & Brennan Less operate a blower door to test the combined air leakage of the ground & main floors

The result was 2171 CFM50 = 5.6 ACH which is much higher than I had hoped

(5.6 ACH /17.2 = 0.33 air changes per hour natural)

DUCT & VENTILATION FAN TESTING

Jeremy Fisher & Brennan Less use a custom box to test the solar air heating fan

AESTHETICS OF SUSTAINABILITY

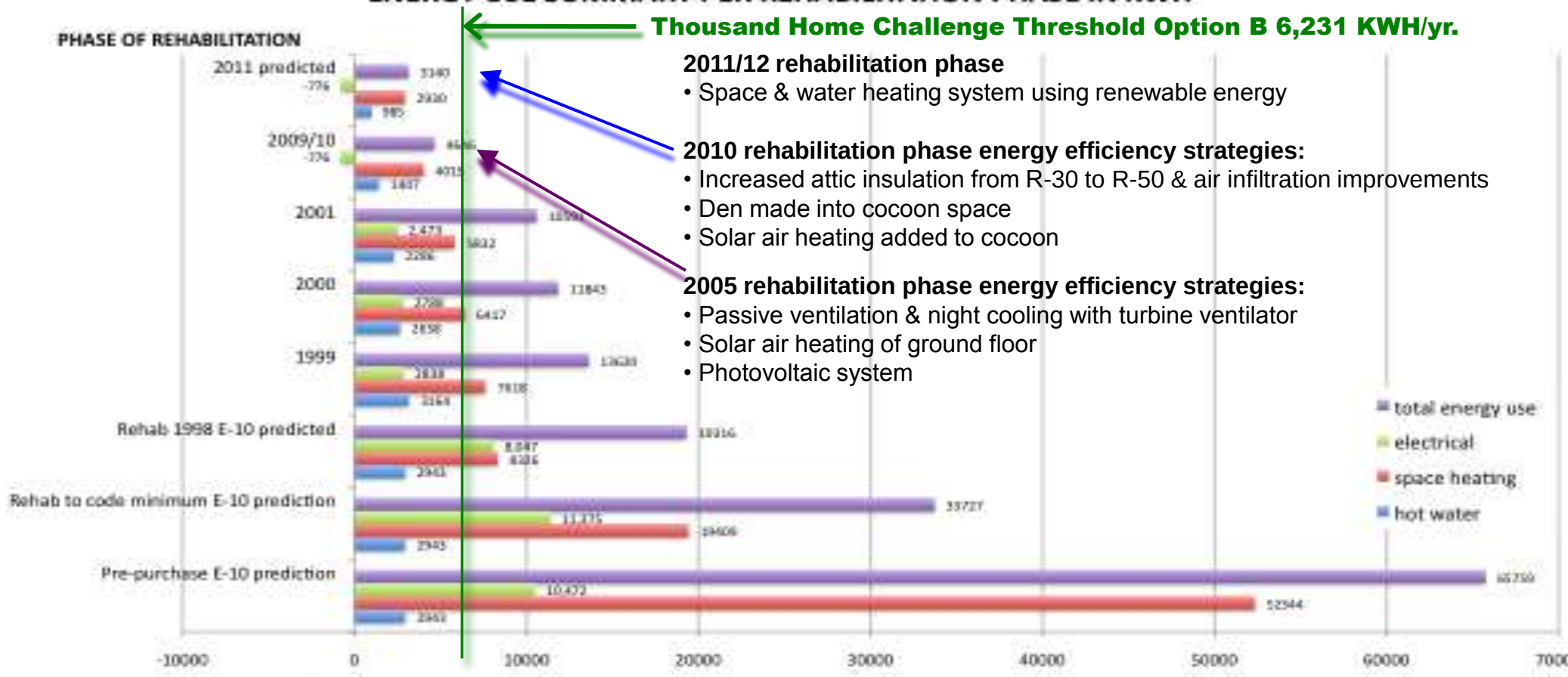
If a building is cherished by its occupants because of its beauty & functionality , it will be maintained & preserved.

Materialism can be reduced if we treasure fewer, well made, beautiful objects.

This vanity is made by master woodworker, Kevin Lee, Petaluma, CA. He says: "The vanity is made of both FSC approved woods and a variety of recycled materials and includes Cocobolo, fiddleback maple, mahogany and cherry as well as some gorgeous redwood which has a stunning flamed and striped figuring to it. The redwood is reclaimed and was purchased locally from Heritage Salvage in Petaluma, CA. Most of the other exotic species of wood are leftovers and remnants from a few instruments and other furniture pieces that I had accumulated over many years of custom woodworking and just couldn't bear to part with, hoping to one day use them in a project. I am happy they have found the perfect place in George and Ellen's home."

The story about the redwood by Michael "Bug" Deakin, Heritage Salvage, Petaluma: “The curly redwood boards were found in the attic of a small barn we took down on Stony Point Road. The old guy was trying to clean up the property so when his kids inherited it they would not have to worry about old structures, ‘including myself,’ he added. He was a woodworker in the 60's and had held on to them since then. I have been hoarding them for 5 years myself.”

ENERGY USE SUMMARY PER REHABILITATION PHASE IN KWH



Thousand Home Challenge Threshold Option B 6,231 KWH/yr.

2011/12 rehabilitation phase
- Space & water heating system using renewable energy

2010 rehabilitation phase energy efficiency strategies:
- Increased attic insulation from R-30 to R-50 & air infiltration improvements
- Den made into cocoon space
- Solar air heating added to cocoon

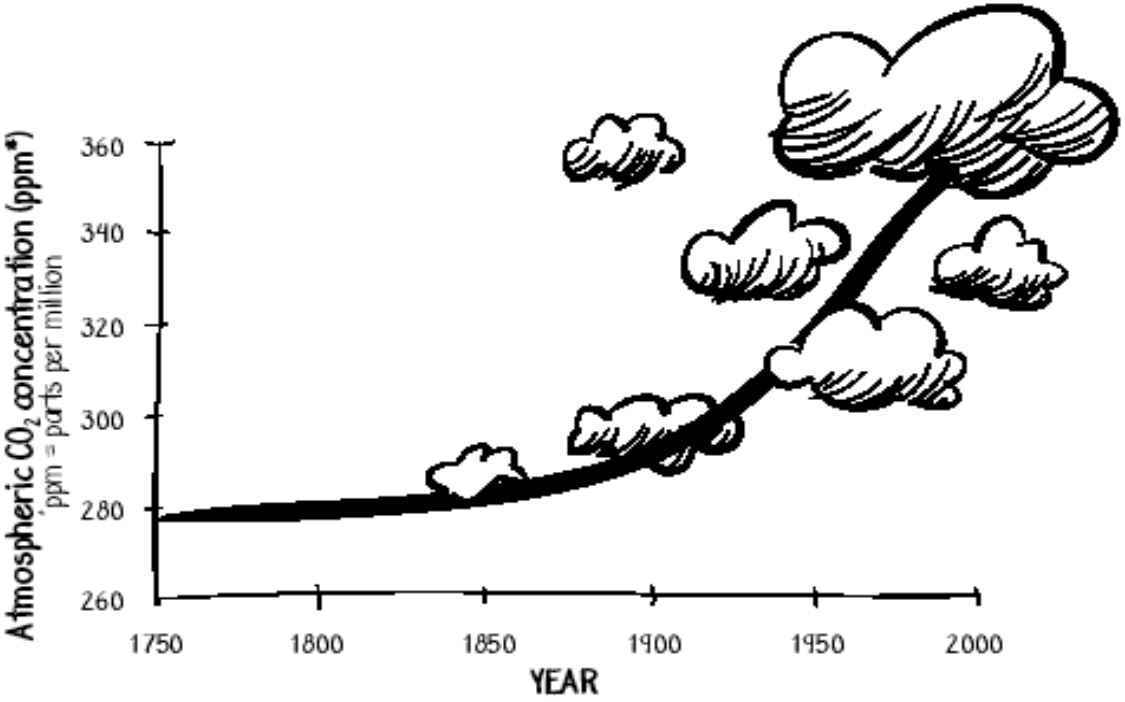
2005 rehabilitation phase energy efficiency strategies:
- Passive ventilation & night cooling with turbine ventilator
- Solar air heating of ground floor
- Photovoltaic system

	Pre-purchase E-10 prediction	Rehab to code minimum E-10 prediction	Rehab 1998 E-10 predicted	1999	2000	2001	2009/10	2011 predicted
total energy use	65759	33727	19316	13620	11843	10591	4646	3140
electrical	10,472	11,375	8,047	2838	2788	2,473	-776	-776
space heating	52344	19409	8326	7618	6417	5832	4015	2930
hot water	2943	2943	2943	3164	2638	2286	1407	985

LESSONS LEARNED

What I would do differently if I knew in 1998 what I know today:

- **I would have prepared a phased rehabilitation master plan (in 1998, I did not realize that global climate change was such a serious problem that my goal of 75% energy use reduction was not enough)**
  - **I therefore, did not realize that this was only the first phase of a series of improvements**
  - **I should have set phased goals to meet our new long-term goals of:**



The rise of carbon dioxide levels in the atmosphere

- **Zero-net electrical energy**
- **Carbon-neutral heating fuel**
- **Site-generated electricity to include electric car**
- **Improved long-term durability including beyond code resistance to major earthquakes & windstorms**

Chapter 4: Energy, Health, and the Environment

DISCUSSION: How energy choices affect our health and the environment http://www.energyforkeeps.org/preview.html

FORMULA FOR ZERO NET ENERGY BUILDINGS

The Contribution of Each Category May Vary Considerably

LESSONS LEARNED

What I would do differently if I knew in 1998 what I know today, continued:

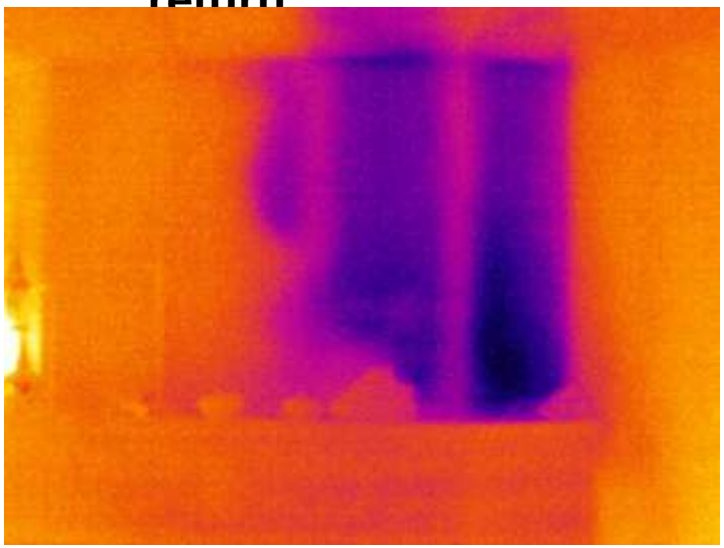
- Consider that major improvements in the building envelope may reduce heating & cooling loads so much that conventional heating system is not warranted
- In my case even at the level of envelope improvement of my first phase instead of investing in a very high-efficiency furnace & demand water heater, I could have better invested in a very high-efficiency water heater to use for space heating & domestic hot water (perhaps with convectors or radiators for space heating or zoned fan coil air system) (I do not use radiant floors anymore for multiple reasons)
  - The water heater could use carbon neutral heating fuel or be a very high-efficiency heat pump with additional photovoltaic panels
  - Solar water heating could be added

LESSONS LEARNED

What I would do differently if I knew in 1998 what I know today, continued:

I wish I would have had quality assurance testing done as work progressed:

- **Blower door testing for air infiltration**
- **Infrared imaging to locate thermal bridges & air infiltration to find problems like coved ceiling, chimney fire spacing at framing, & leakage to garage**
- **Duct pressure testing for air leakage & discover problems with ductless return**



Air infiltration from attic at fireplace chimney interior wall

Infrared photo by Jeremy, a graduate student researcher at Lawrence Berkeley National Laboratory

- **Carefully study alternative methods of envelope improvements to find most effective performance & cost options**
- **Look for options with multiple benefits such as:**
  - **Best access for air infiltration improvements**
  - **Best access for structural reinforcing & adding plywood from foundation to roof**

LESSONS LEARNED

What I would have done differently if I could have obtained additional financing:

- Add sloped roof in phase one so it would have allowed:
  - Major air infiltration work in attic
  - Better access to evenly add attic insulation to about R-50
- Cost benefit study of removing & replacing stucco siding which would have allowed:
  - Strengthen exterior walls for lateral loads of earthquake & wind storms for the maximum expected 200- to 500-year events
    - Add foundation reinforcement as necessary
    - Add plywood to exterior walls sealed to provide air infiltration barrier
    - Seal wall framing against air infiltration
    - Easy access to add insulation between studs at wood panel & ceramic tile walls
  - Install 2” polyisocyanate rigid insulation board (R-13) to raise total wall to relatively high insulation level of R-26 (2x code)

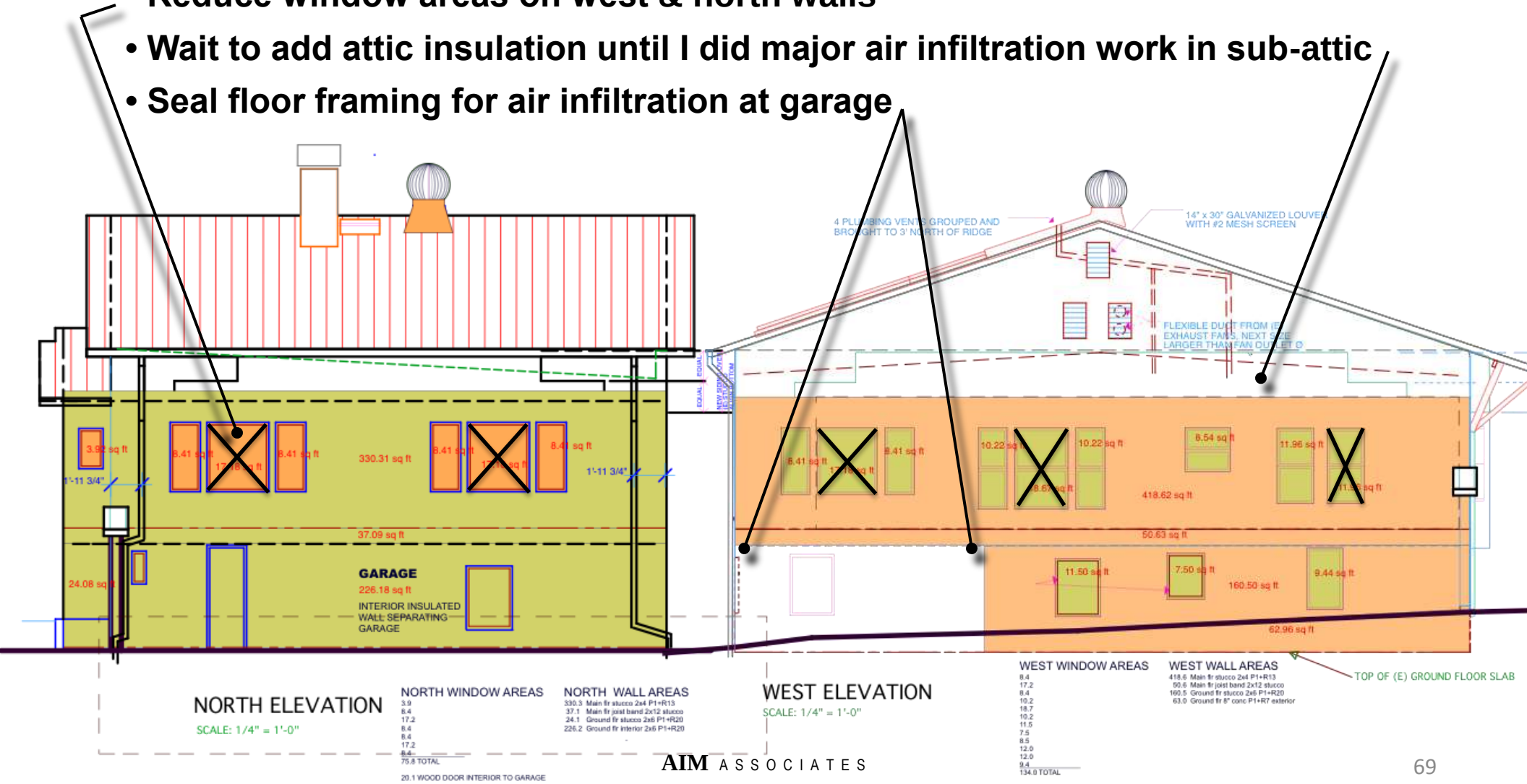
What I would change about our western society if I could:

- Mature into a world view that a stable climate, resources & energy must be shared with all life now and for endless future generations rather than our current attitude of entitlement without responsibility

LESSONS LEARNED

What I would do differently, continued:

- To further improve energy efficiency I would have:
  - Reduce window areas on west & north walls
  - Wait to add attic insulation until I did major air infiltration work in sub-attic
  - Seal floor framing for air infiltration at garage



LESSONS LEARNED

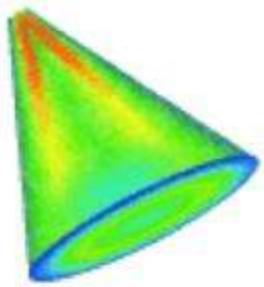
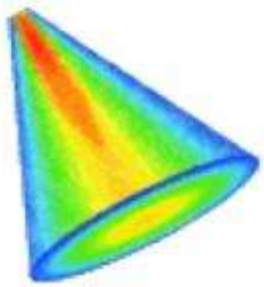
What I am especially glad that I did in earlier phases:

- **Building envelope energy improvements**
  - **Cellulose insulation blown into attic since it the lowest embodied energy of all available insulation types**
  - **Dense pack cellulose insulation blown into walls filled in nicely around plumbing & wiring**
  - **Installed windows better than code required for new buildings (fiberglass framed, Low E^2 argon filled)**
  - **These high quality windows provide excellent acoustical isolation from the noisy school across the street**
  - **Used best practice detailing to seal window flanges to stucco that greatly reduced air infiltration & improved long-term durability**
- **Durability**
  - **Used highest quality recycled plastic for exterior window trim that never needs painting & still looks new 12 years later (HDPE)**
  - **Replaced high maintenance flat roof with "permanent" sloped steel roof**

ELLEN NEEDS LONG, HOT SHOWERS TO RELIEVE FIBROMYAGLIA MUSCLE PAIN

"Delta Introduces Water-Efficient Showerhead with H_2OKinetic Technology Which Uses 36 Percent Less Water While Delivering a Great Shower Experience"

http://www.ebuild.com/articles/printArticle.hwx/Q/articleId.371904

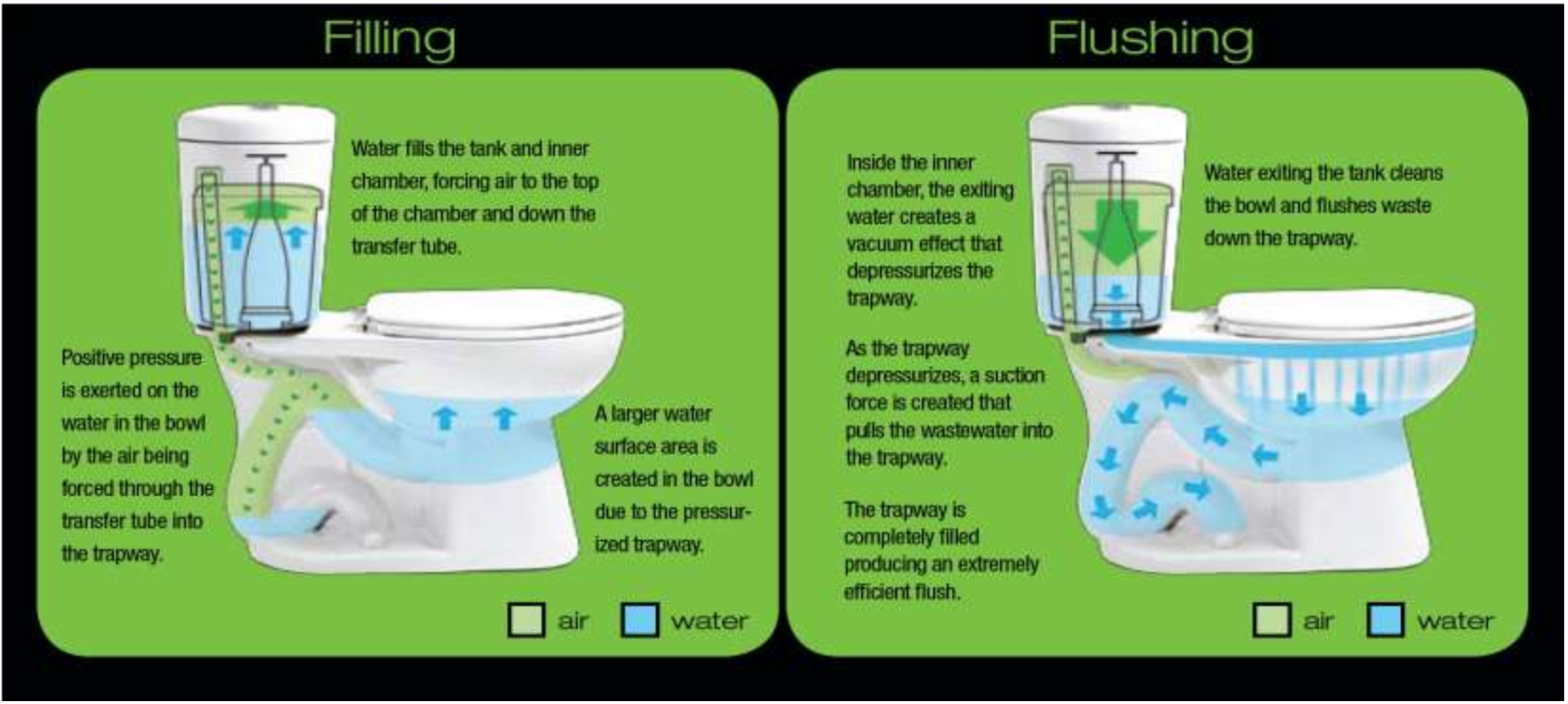
TYPICAL SHOWER	H2OKINETIC SHOWER	
		**Droplet Size:** Larger water droplets offer a more massaging shower experience.
		**Spray Coverage:** A dense shower spray offers a more drenching blanket of water coverage.
		**Thermal Dynamics:** Larger water drops and a dense spray pattern results in a warmer, more consistent showering experience.

LESSONS LEARNED

What I am especially glad that I did in earlier phases (continued):

- **Water efficiency features that have reduced our water use dramatically**
  - **Removed all turf & use existing shallow well for drip irrigation**
  - **On demand hot water circulation pump, low water toilets & shower that reduced our total water use of 75 gallons/day post-1998 to 50 gpd post-2005 to to 33 gpd post-2010 (average American water use is approx. 150 gpd per person)**

NIAGARA STEALTH **The world's first 0.8 GPF toilet using their new passive vacuum technology. This is one-half of our former 1.6 gallon low flush toilets!**



Our Petaluma water is from the Russian River which we share with the riparian wildlife: it is precious!

http://www.stealth-toilet.com

FORMULA FOR ZERO NET ENERGY BUILDINGS

The Contribution of Each Category May Vary Considerably

FOURTH PHASE: FUTURE REMODEL TO ACHIEVE ZNE HEATING

- Continue monitoring & improving energy efficiency performance
- Lifecycle cost analysis of space & water heating system upgrades with the renewable energy system needed

  This will include comparisons of:

  - Solar water heating for just domestic water or combined with space heating
  - High-efficiency heat pump options with addition to photovoltaic system
    - Air to air minisplit or
    - Air to water or water to water
  - High-efficiency combined space & domestic water heater using carbon neutral heating fuel (consider air pollution contribution & be non-agriculture intensive)

SHARING EXPERIENCES

Linda, Ellen, & Judy share their experiences with changing behavior to achieve deep energy reductions

Linda taught us about creating a "cocoon" room within a house that can be kept at a higher temperature, using much less energy than heating the whole house

Ellen has medical issues that can make low thermostat settings especially uncomfortable

We also talked about dressing to stay comfortable with low thermostat settings like people did in the "good old days" before central heating

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Director of Deep Energy Reduction Initiatives
Affordable Comfort, Inc.

Judy Roberson, jaroberson@mac.com
Residential Building Scientist
Energy Training Center, PG&E

ELLEN & GEORGE ARE CONGRATULATED BY LINDA FOR MEETING THE THOUSAND HOME CHALLENGE !

Ellen, George, & Linda join hands, pledging to help each other in spreading the word about how to achieve deep energy reduction in existing houses.

Setting performance goals early & making improvements in phases help make energy efficiency improvements more cost-effective & affordable

Monitoring results ensures that investment, efficiency, & behavior goals are achieved

George is always on the lookout for the latest innovations in best practice techniques that often cost very little more to implement but offer substantial performance improvements

The Thousand Home Challenge case studies tell the stories of what people have learned from their experiences

We discovered that we share the philosophy that we are not born with the entitlement of unlimited access to fossil fuels just because we live in a country that provides us with cheap access though subsidies. Rather, we each have the moral responsibility to use no more resources than the earth can sustainably provide for future generations

“Become the change you would like.”

Mahatma Gandhi

“Do all you can with what you have, in the time you have, in the place you are.”

Nkosi Johnson, *twelve-year-old Zulu boy, living with AIDS*

Presentation developed by **George Beeler, Principal Architect**

AIM ASSOCIATES

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