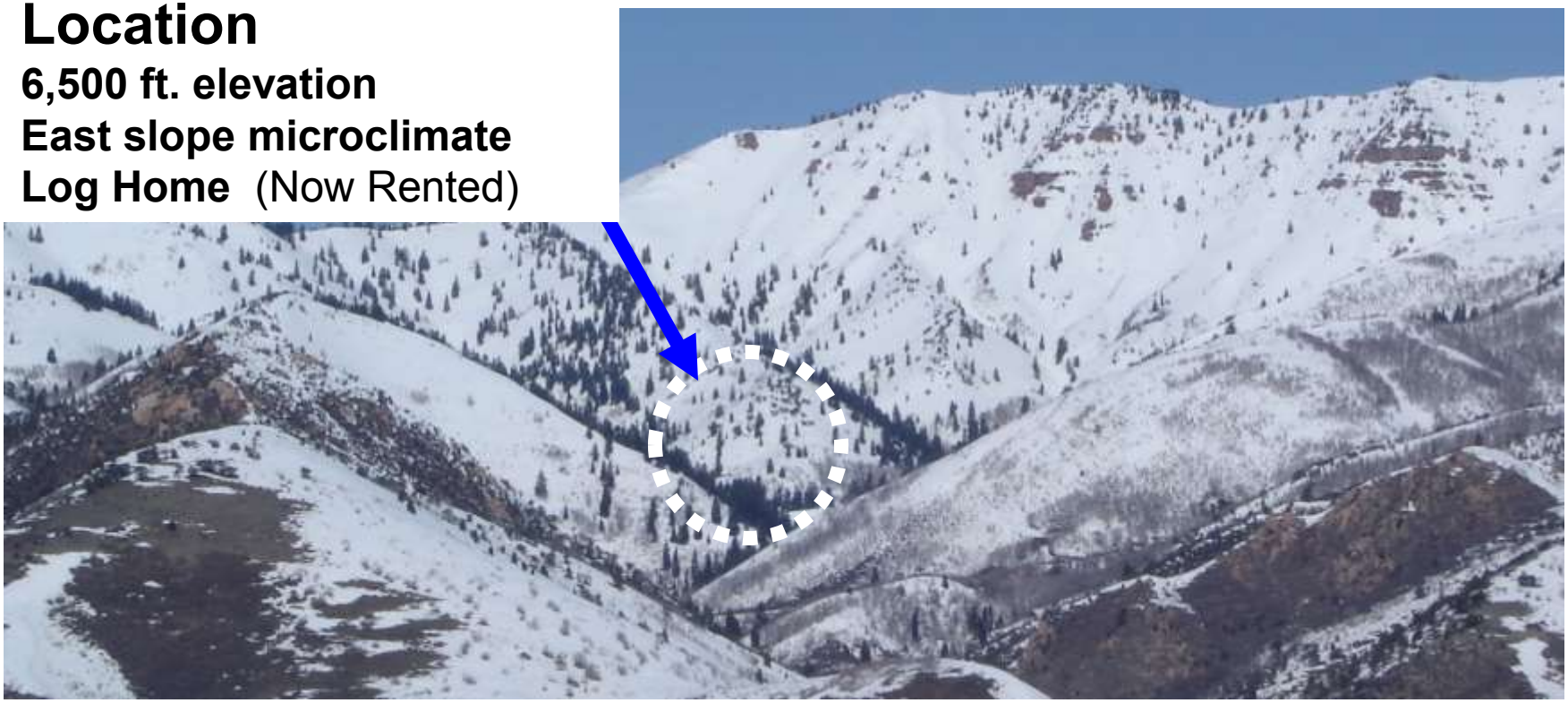
Thousand Home Challenge, ***Phased Retrofit*** Cold Climate Sustainability 3-12-15

Case Study By: W. Turner & K. Turner (70%? Reduction)

Year-round home, 800 ft^2, 8-9,000 degree days

Location
6,500 ft. elevation
East slope microclimate
Log Home (Now Rented)



Why Is This Relevant?

- Major reduced energy use, without re-skinning walls
- Vastly Improved comfort, IAQ, & health
- Long-term energy cost control
- Not that hard to do, reasonable internal rate of return on investment $$, & rewarding work

Natural Gas & Coal are plentiful; however, there are social & environmental "Costs" for energy.

Agenda

1. **Take a brief tour & Brainstorm 2 times**

2. **Look at what we did, why, & examine the most recent results**

3. **Discuss items to *"get over the hump"* to meet or exceed the *1000 Home Challenge Measured Energy Use Option B Benchmarks***

Learning Objectives

At the end of this session, participants will be able to:

1. Describe approaches to achieving a deep energy retrofit
2. List 4 opportunities to integrate a deep energy retrofit with a planned home renovation or typical repair opportunity
3. Identify 4 IAQ issues that can be addressed in the homes
4. Recognize the opportunity to simplify renovation strategies though a comprehensive planning, & following a logical sequencing of work to be performed

Typical Energy Reduction Options

- Reduce Air Leaks & Increase Insulation
- Address Basement / Crawl Space
- Control Ventilation & Humidity
- Doors & Window
- Domestic Hot Water & Heating/AC
- Lighting & Renewables
- Occupant Behavior
- **Also Consider:** (3 M's ☹)

Moisture, **M**old, Owner's **M**oney

Others?

Step 1.
Obvious Needs

Where did we begin?

Where we began in 2008:

Ceiling: Cathedral Ceiling & Loft Air Leakage

(T-111Paneling & no continuous air/vapor barrier)

Unfinished? Soffit: under East & West Overhangs (daylight is seen at the roof rake area)

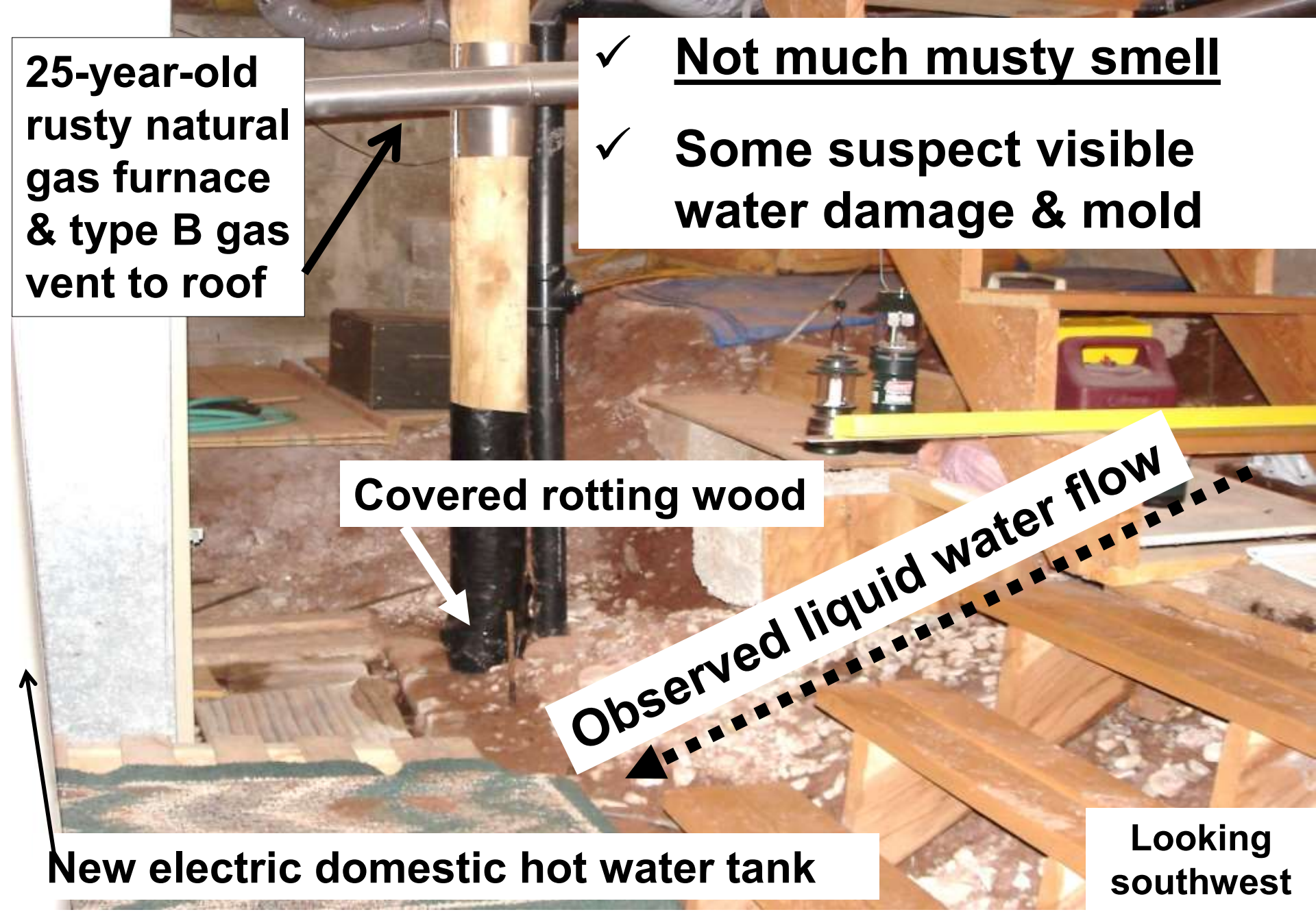
Windows: Functional aluminum 2-pane, non-thermally broken (double-hung, sliders, & two fixed unit picture windows)

Basement: *Dirt floor,* (2 egress windows & a door) washer & dryer (no vent outdoors), roughed in plumbing for a toilet, shower, & floor drain

Walls:
Uninsulated concrete

Floor: OSHA Type1, clay & rock, ledge?

Looking southeast



Pests

Cathedral Ceiling = Squirrel nesting

Basement Ceiling = Mice & spider nesting

Previous owner comment:

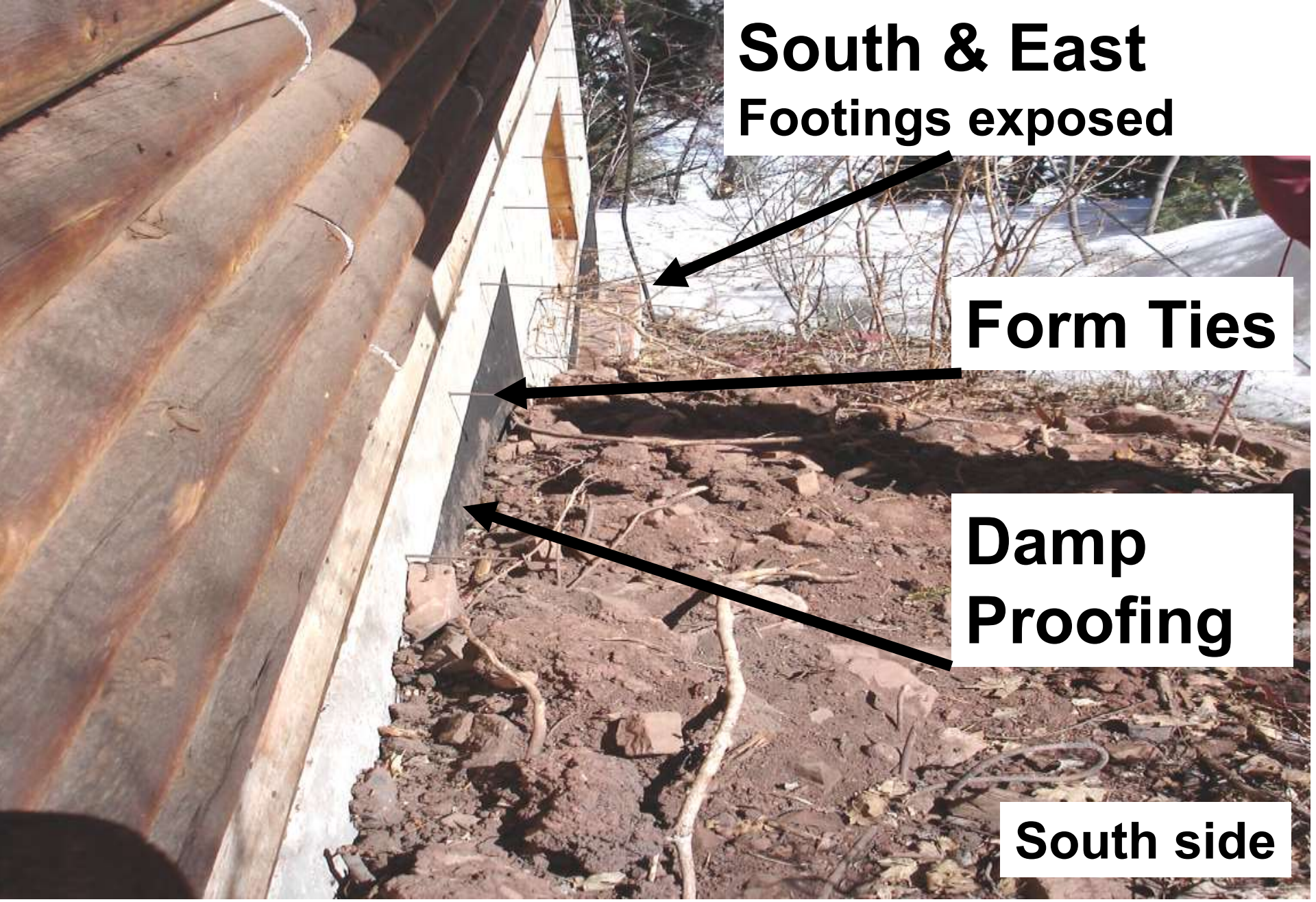
"We release chemical kill bombs every year & vacate the house for 2 days"

Bathroom: Some visible mold on ceiling & wall , no exhaust fans, operable window above bathtub

Outside:

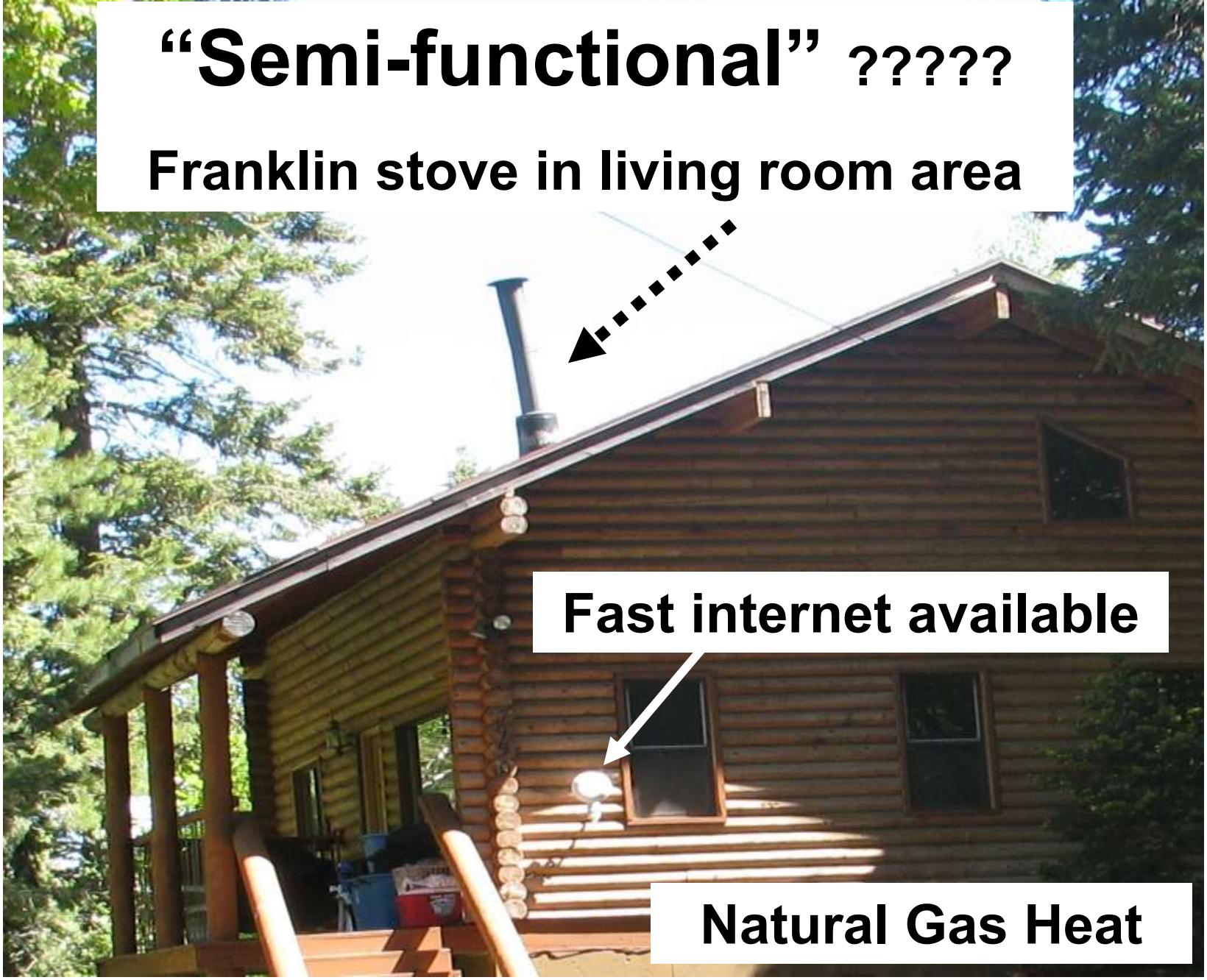
No uphill swale

All upslope water (600 vertical feet) drains toward the basement wall & into the basement



“Semi-functional” ?????

Franklin stove in living room area



Blower Door: 23 ACH_{50} (including basement)

5,400 CFM_{50} 152 $in.^2$ ELA

1.55 CFM_{50}/ft^2 (six-sided surface area)

Would You Purchase This Home?

- ✓ Elevation 6,500 ft., 10 + feet of snow a year
- ✓ 40 minutes to 5 very major ski areas
- ✓ 20 minutes to a major university & hospital
- ✓ 40 minutes to a very major city hub airport
- ✓ 0.15 acres of land & three parking spaces

Asking Price $300K

Thousand Home Challenge "10 steps"

www.1000HomeChallenge.org

1. **Assess Needs, Site, Goals, *& End Use of Space***
2. **Optimize Enclosure** (reduce heat & cooling load)
3. **Minimize Internal Loads** (lights, appliances, electronics)
4. **Provide Fresh Air**
5. **Control Humidity**
6. **Determine Cooling Needs**
7. **Integrate Hot Water with Other Loads**
8. **Determine Heating Needs**
9. **Integrate Renewables to Address Remaining Loads**
10. **Incorporate Verification, Feedback, & Evaluation**

Needs summary:

- Extremely *air leaky* log home (c.1980's)
- OK *double-pane windows*,
- *Roof shingles failing*, 6" FG batt atrium ceiling
- *Some mold on bathroom ceiling*, no exhaust fans
- *Pests*: Mice, some spiders, & squirrel
- *Dirt floor basement* & old natural gas furnace
- *radon< 2pCi,* red marine clay/rocky soil, no ledge?,
- Site water flows under the furnace (during any hard rain & spring thaw), foundation appears stable

Thousand Home Challenge "Tools"

available from: www.1000HomeChallenge.org

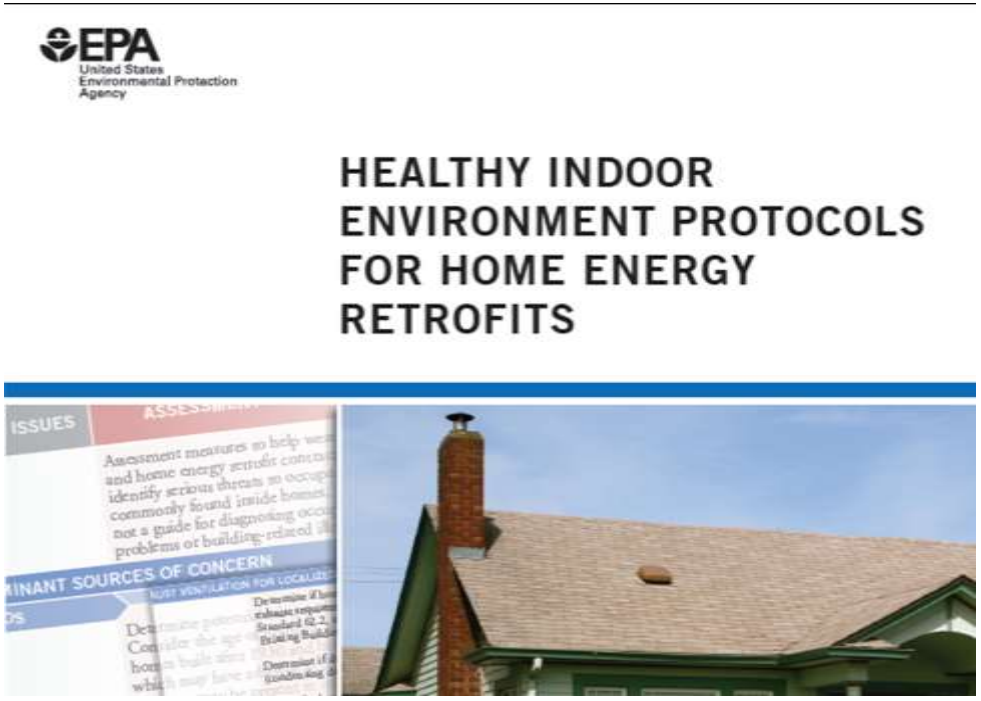
- **THC Ten Steps to Deep Energy Reductions**
- **THC Homeowner Priorities Worksheet (scope)**
- **THC Health, Safety, & Durability Plan**
- **THC Reduction Matrix**
- **THC Principles for Smart Staging**
- **THC Paths to Thermal Comfort**
- **Guiding Principles for Deep Energy Reductions**
- **Creative Financing Worksheet**

Homeowner's (Priorities) "Goals"

1. Warm, dry, & finished basement, no mold
2. 50% energy use reduction
3. New roof, no more ice dams or roofing water leaks
4. No more Pests, no kill bombs
5. Must be **occupied** during the renovation
6. Must still look like a log home, avoid re-skinning
7. Local jack-of-all trades labor available ($25/hr.)
8. Up to $60,000 home improvement loan available

Goal : Consider & Address US EPA Pollutants:

1. Asbestos, lead paint, radon/VOC's
2. Environmental tobacco smoke (ETS)
3. Moisture (mold & other biologicals)
4. Pests
5. Combustion safety
6. Ventilation
7. HVAC systems
8. Home safety
9. Worker safety
10. Sustainability



Brainstorming Session #1

Item	Options	Ballpark Costs
1. Basement/Moisture		
2. Roof/cathedral ceil.		
3. Bathroom mold		
4. Heat & DHW		
5. Exposed footings		
6. Windows / Walls		
7. Pests		
8. Others?		

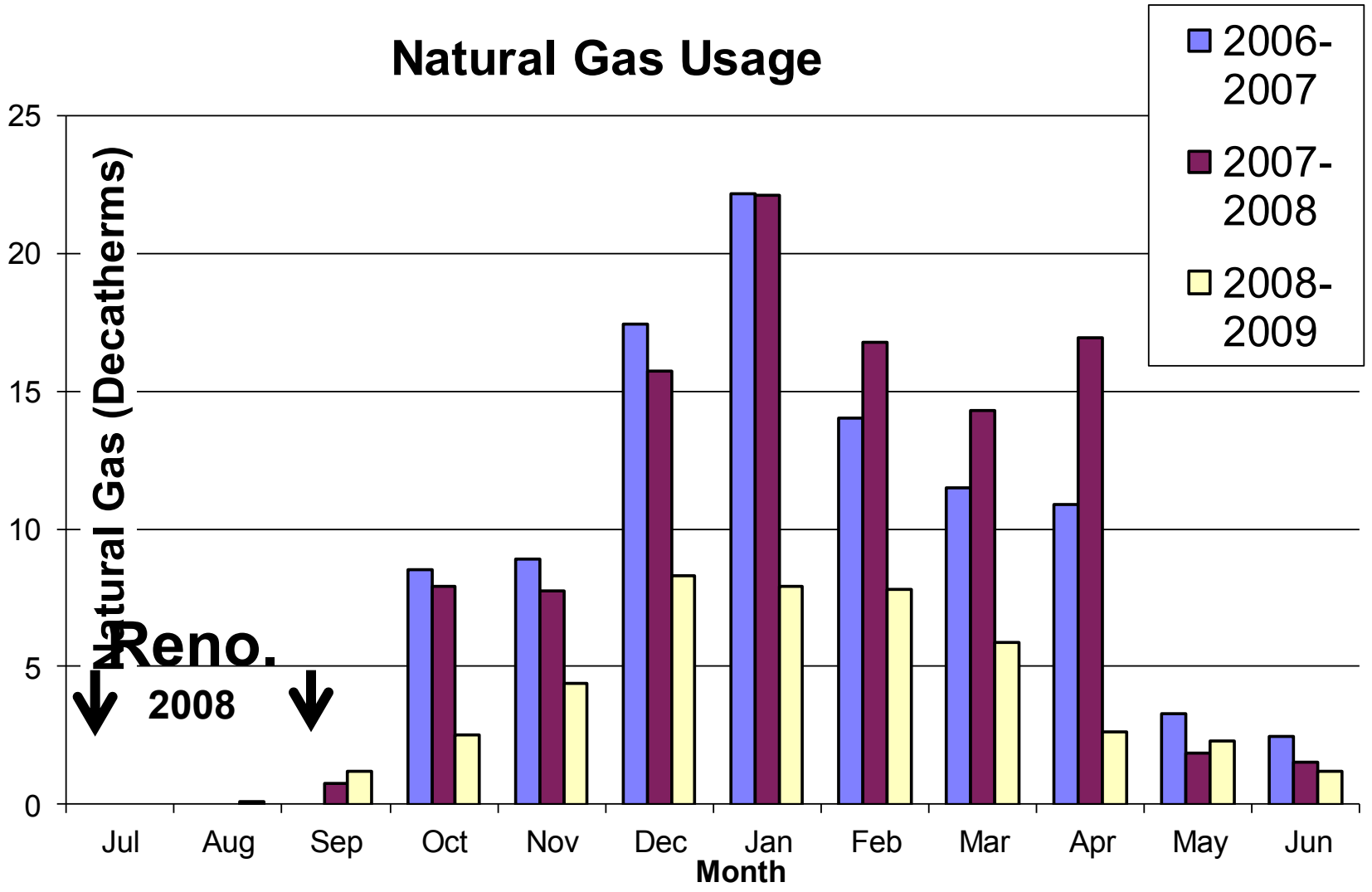
Energy/IAQ Renovation Estimate 2008:

1.	Basement	Excavate/finish	$ 20k
2.	Roof, cathedral ceil.	ext. foam, vented	$15.5k
3.	Bathroom mold	EOV & paint	$ .5k
4.	Heat & DHW	New gas high eff	$ 7k
5.	Exposed footings	Cover + storage	$ 5k
6.	Windows/walls	Air seal only	$ 1k
7.	Pests	Block & air seal	$ nc
8.	Others???		??
9.	(surprise) Septic & treat drinking water		$ 10k?
			$ 59k

Energy Performance: (First Round Results)

40% total energy use reduction (OOPs)???

> 70% energy use reduction per ft^2 of habitable space



What We Did:

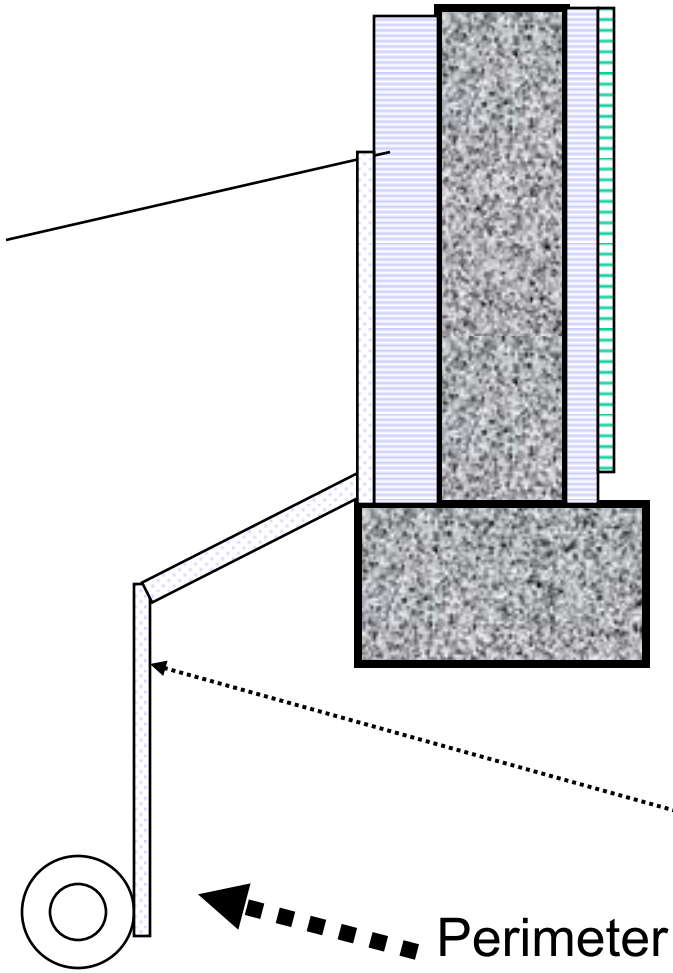
Step 2. "Optimize Enclosure"

"Want Warm & Dry Finished Basement", & Good IAQ

Site & Foundation Drainage and Insulation are critical.

Address upslope drainage

West Wall Drainage Basement Plan

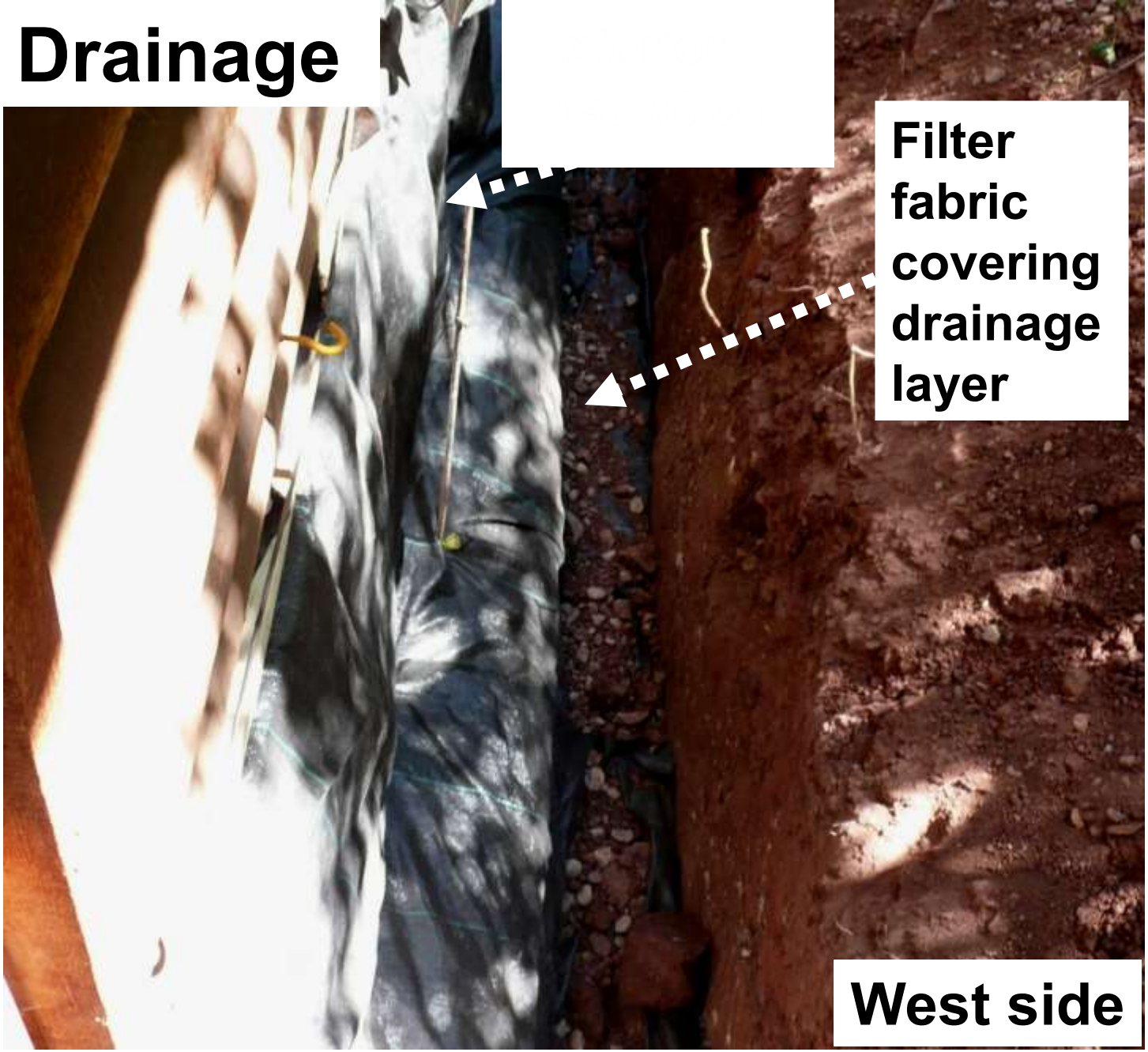


Intercept upslope water via perimeter drainage below footing & drainage mat to daylight drain, & re-grade surface with **swale**

Perimeter drain system to daylight

Drainage matting

What We Found: Were They Thinking…….?



South side, with drainage installed

Southeast corner

Finished Swale Uphill Side

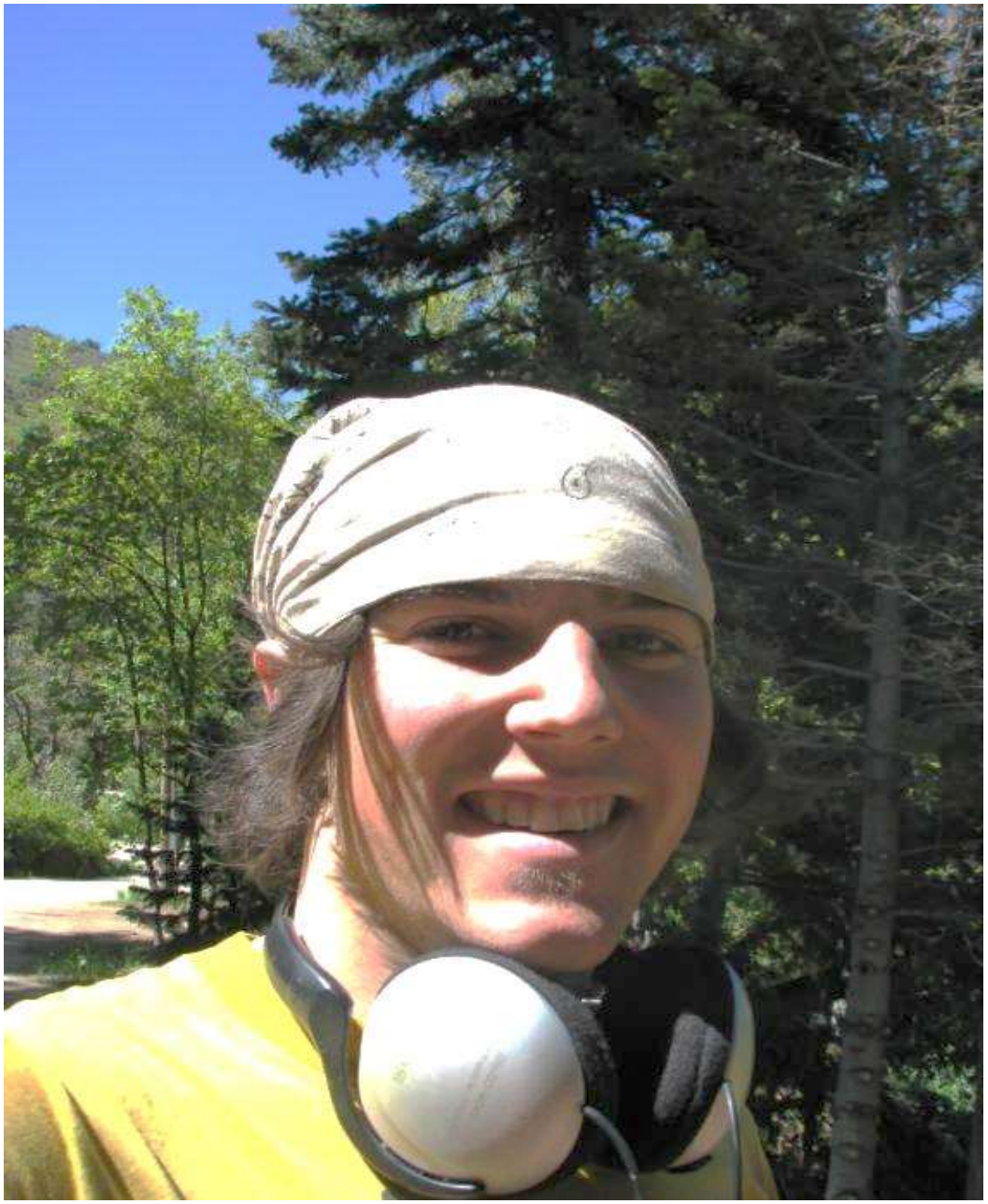
Finished Slope – South Side

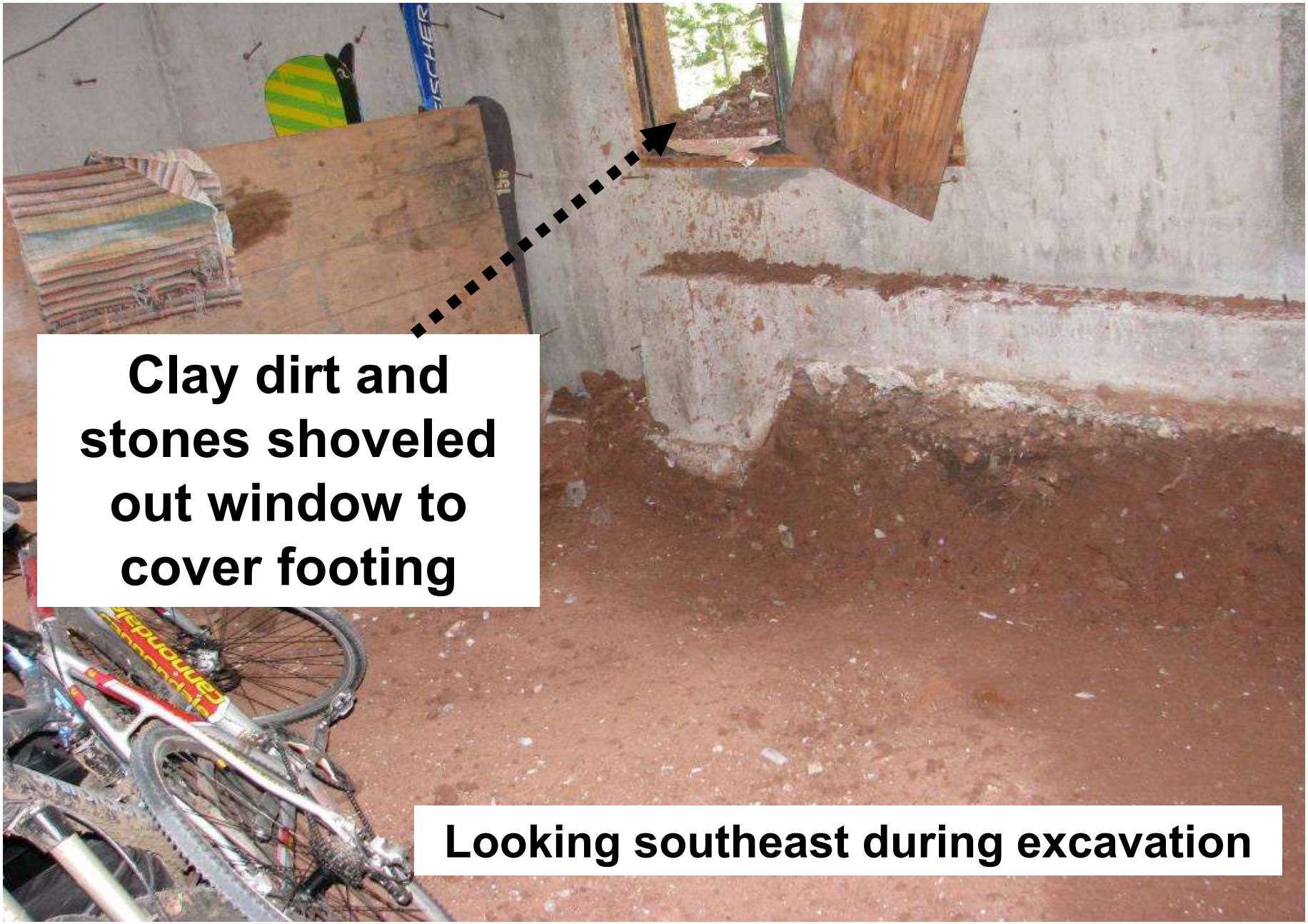
Basement:

Optimize Enclosure

(Cont'd)

Excavation by "Strong-Arms"

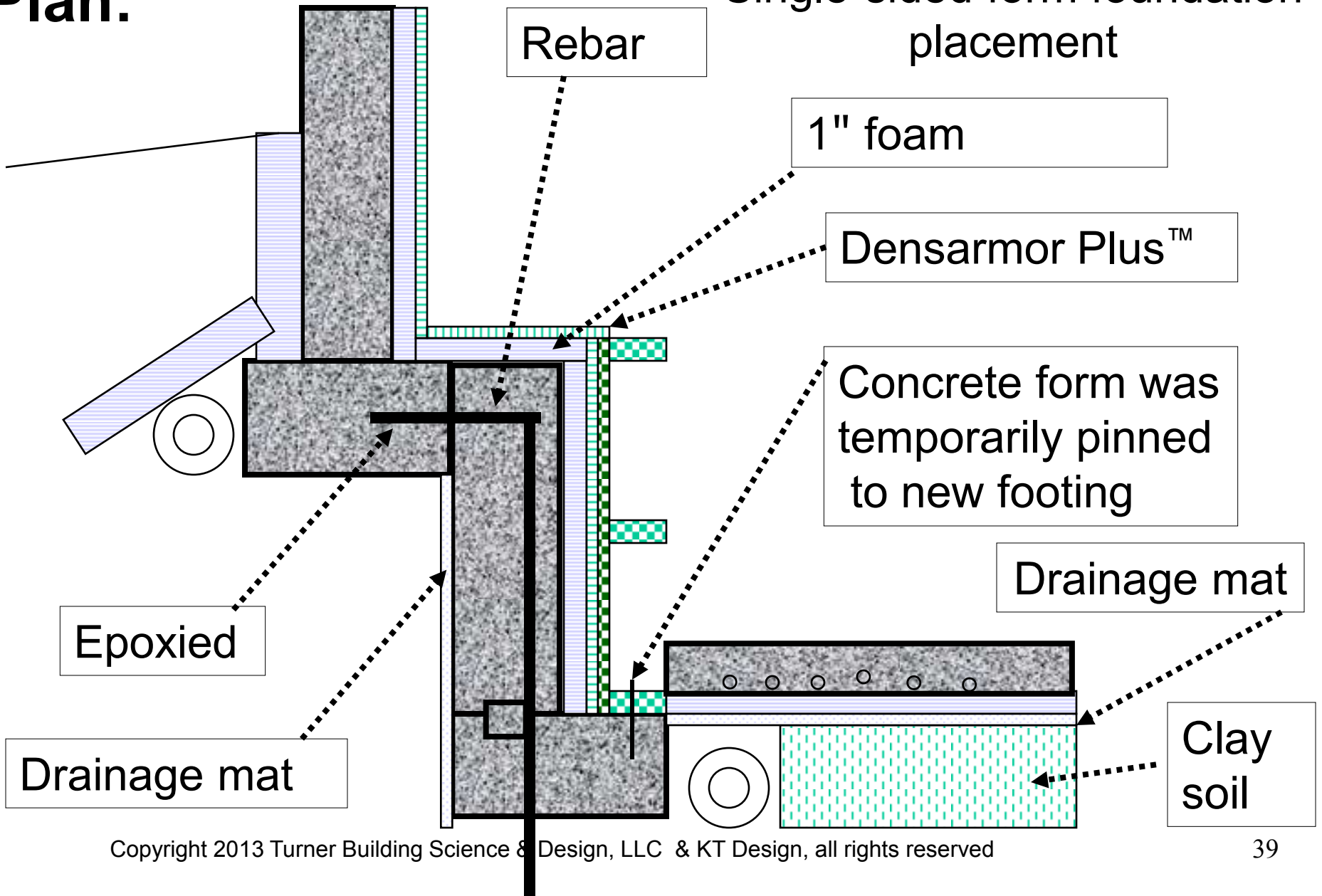




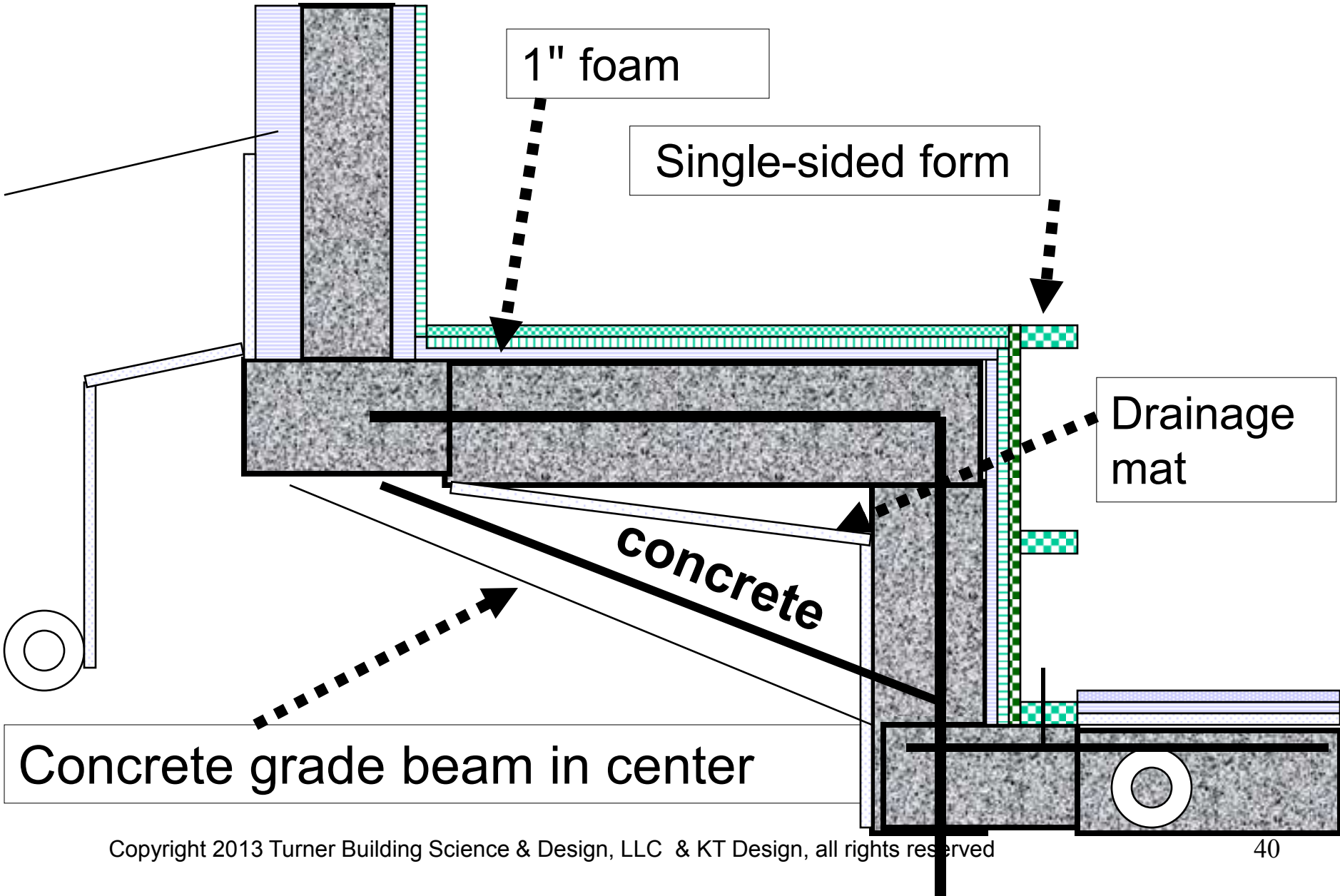
INSIDE Stepped Footing Plan:

North & South Walls

Single-sided form foundation placement



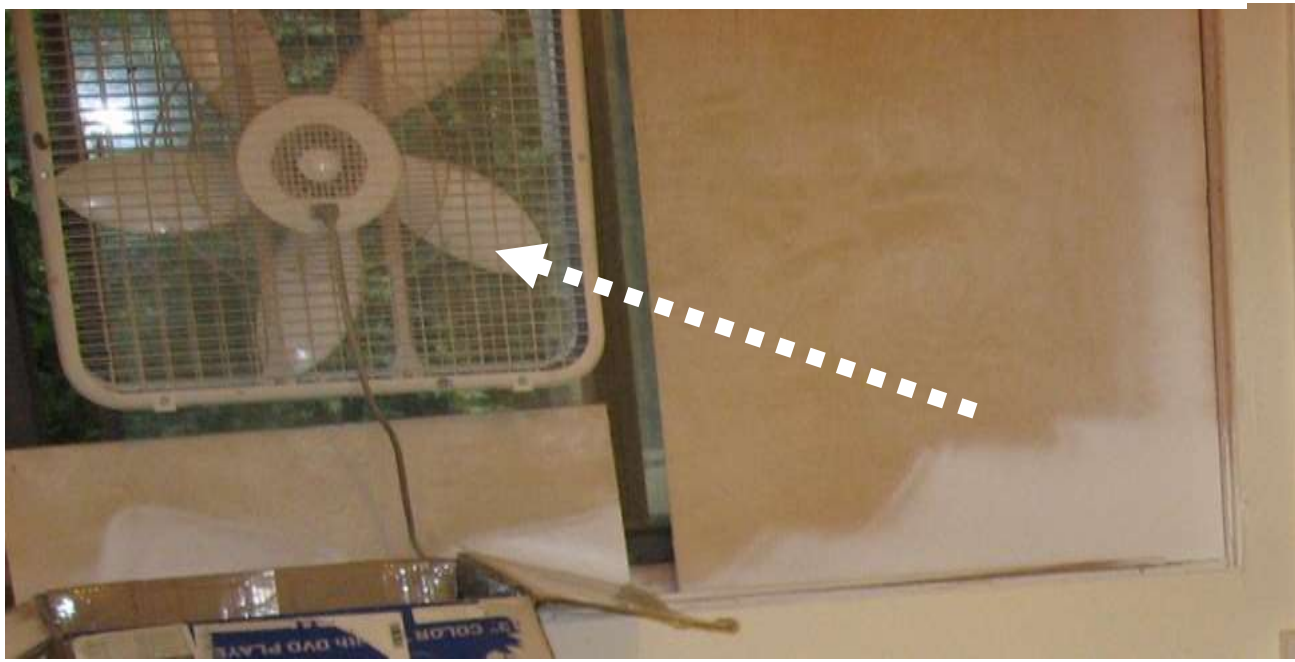
Up-slope West Wall Inside Basement Plan



Health & Safety:
Basement Neg. Air "Containment"

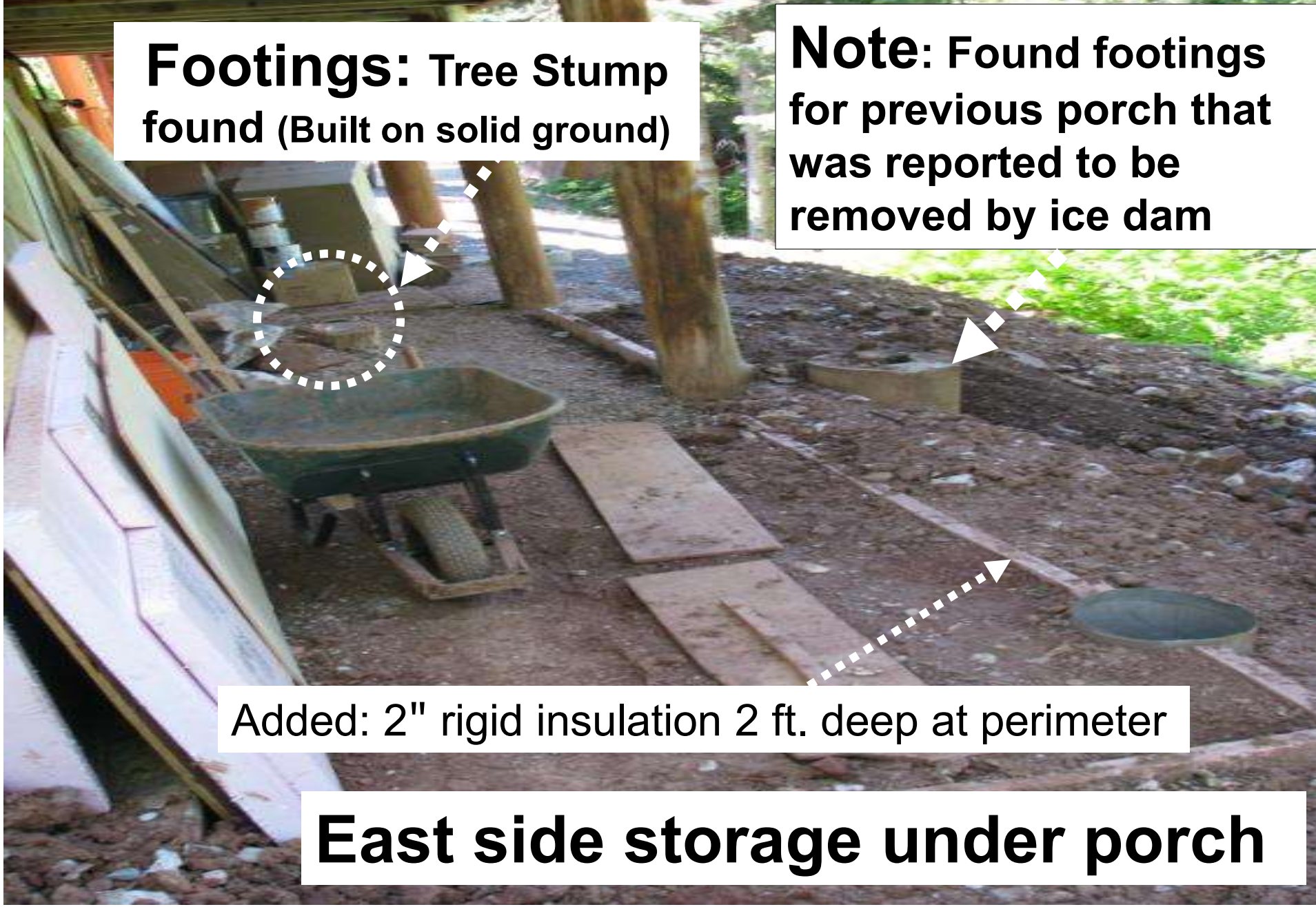
Created with

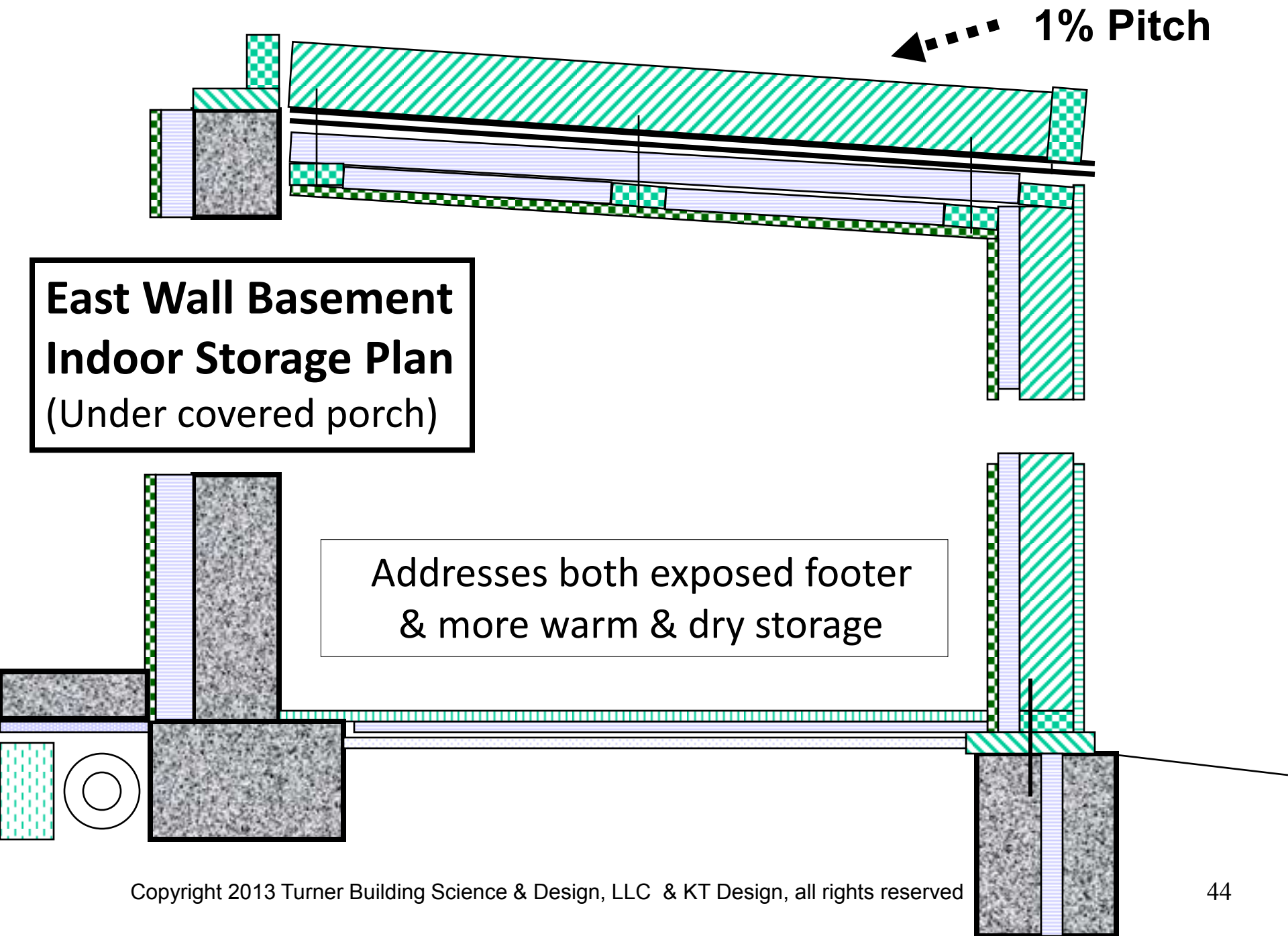
- ✓ **2 <u>exhaust</u> fans *sealed* in basement windows**
- ✓ **Upstairs windows partially open during all dust and odor generation**



- ✓ **Pests (worker & occupant safety)**
- ✓ **Field mouse nesting removed under *negative air containment*, droppings HEPA vacuumed**

Salvageable FG insulation reused in storage area walls without kraft paper





East Wall Basement Indoor Storage Plan
(Under covered porch)

Addresses both exposed footer & more warm & dry storage

Dry, Semi-conditioned, Space Under Porch

Capillary breaks used where ever wood meets concrete

Goal: Create "Water-managed" Assemblies

- ✓ Roofs, attics, & walls
- ✓ Basements, crawl spaces, & slabs

1. Keep out wind-driven rain
2. Manage water vapor
3. Allow assembly to dry if it gets wet
4. Use durable materials

Great Resource:

Energy Star & Indoor Air Plus Specs

(voluntary) www.epa.gov/indoorairplus/construction_specifications.html

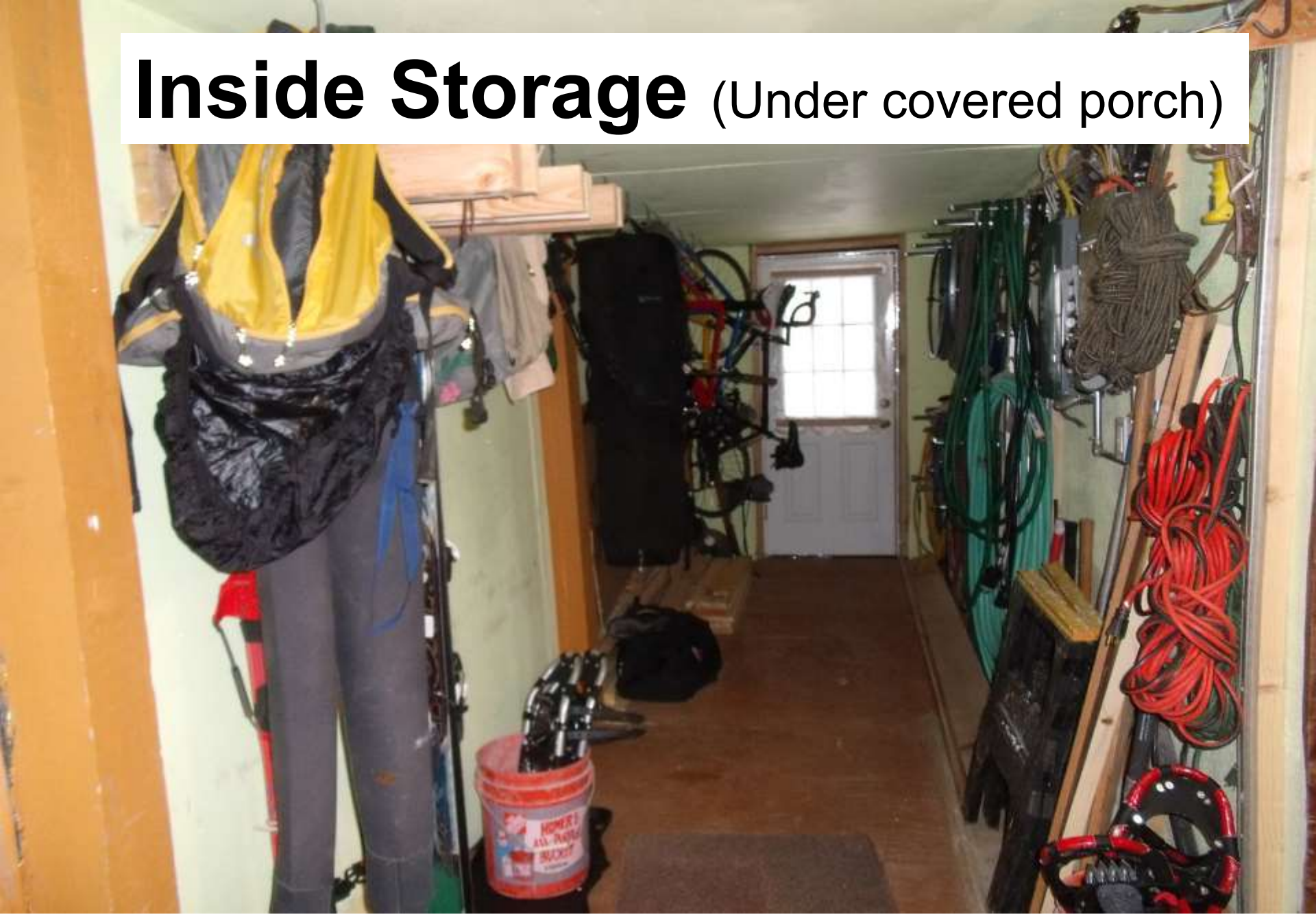
Moisture Control Technical Guidance

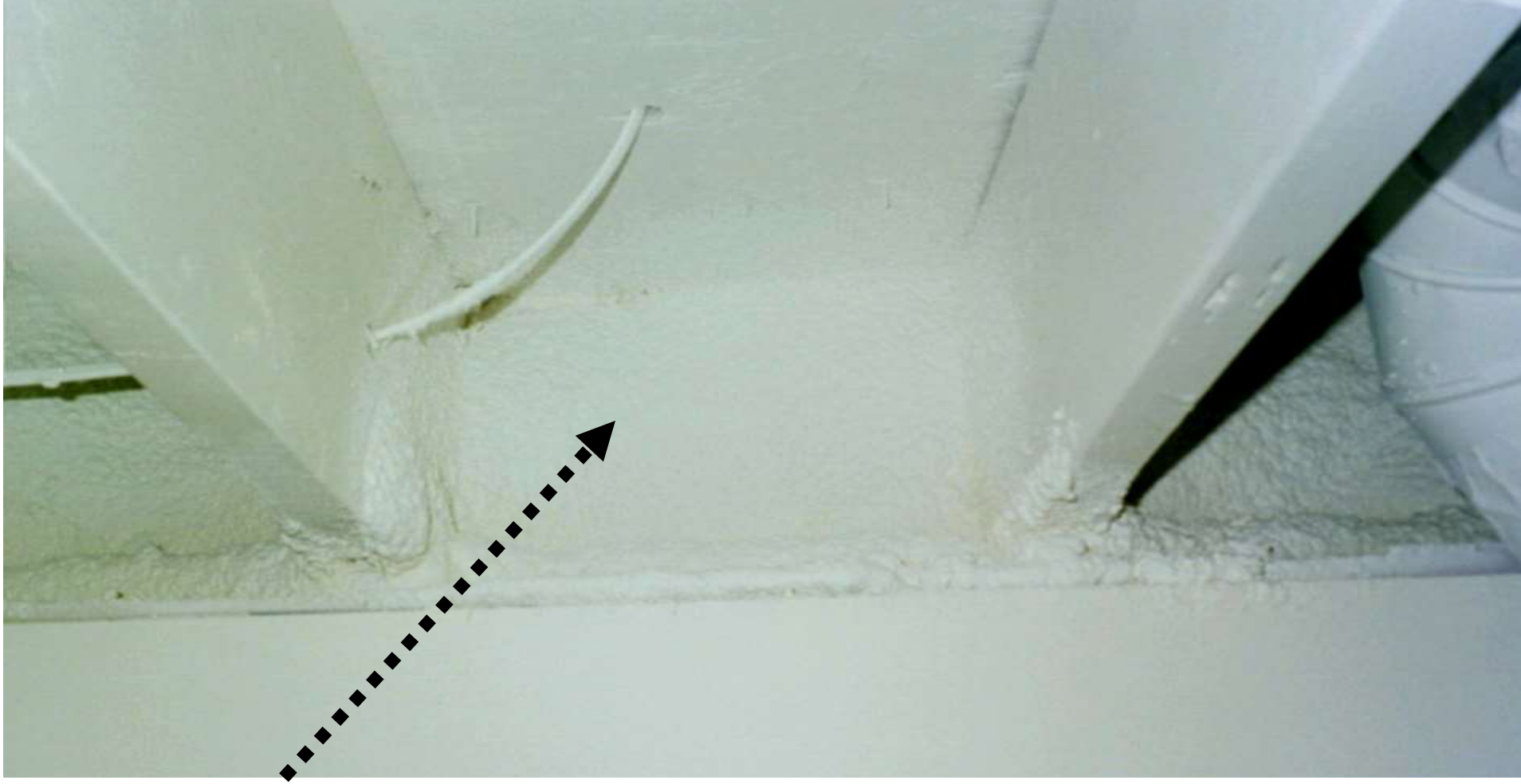
1. Water-managed Site & Foundation (Sec.1.1 - 1.4)
2. Water-managed Roof Assembly (Sec. 1.5 - 1.6)
3. Interior Water Management (Sec. 1.11 - 1.13)

HVAC Design (Sec 4.1 - 4.8)

Storage Outside View

Inside Storage (Under covered porch)





2-part kit spray foam used to insulate & air seal basement rim

NOTE: Many codes now require an ignition barrier.

Finished Basement TV Room Looking Southeast

New cabinets, tile, & radiant hydronic floor

Before

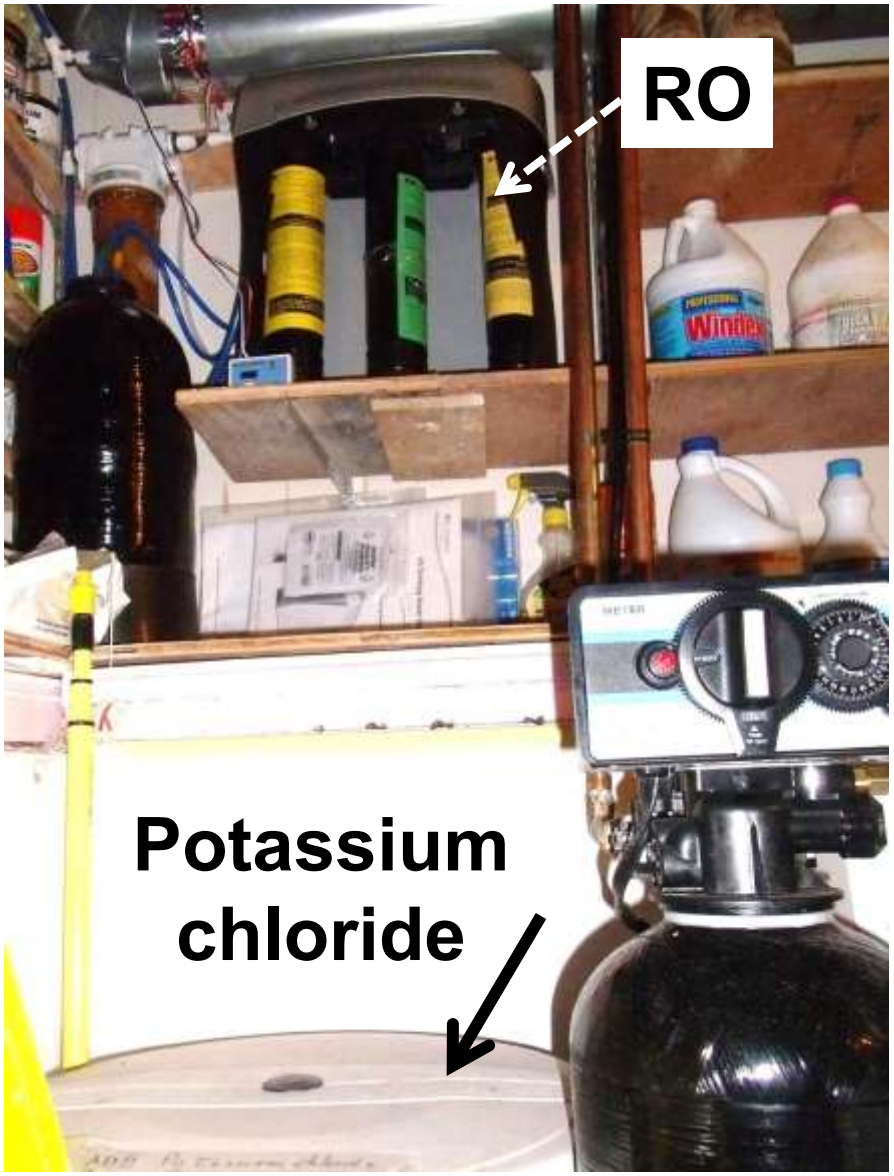
Basement Looking Northwest

Water Safety

Treat:

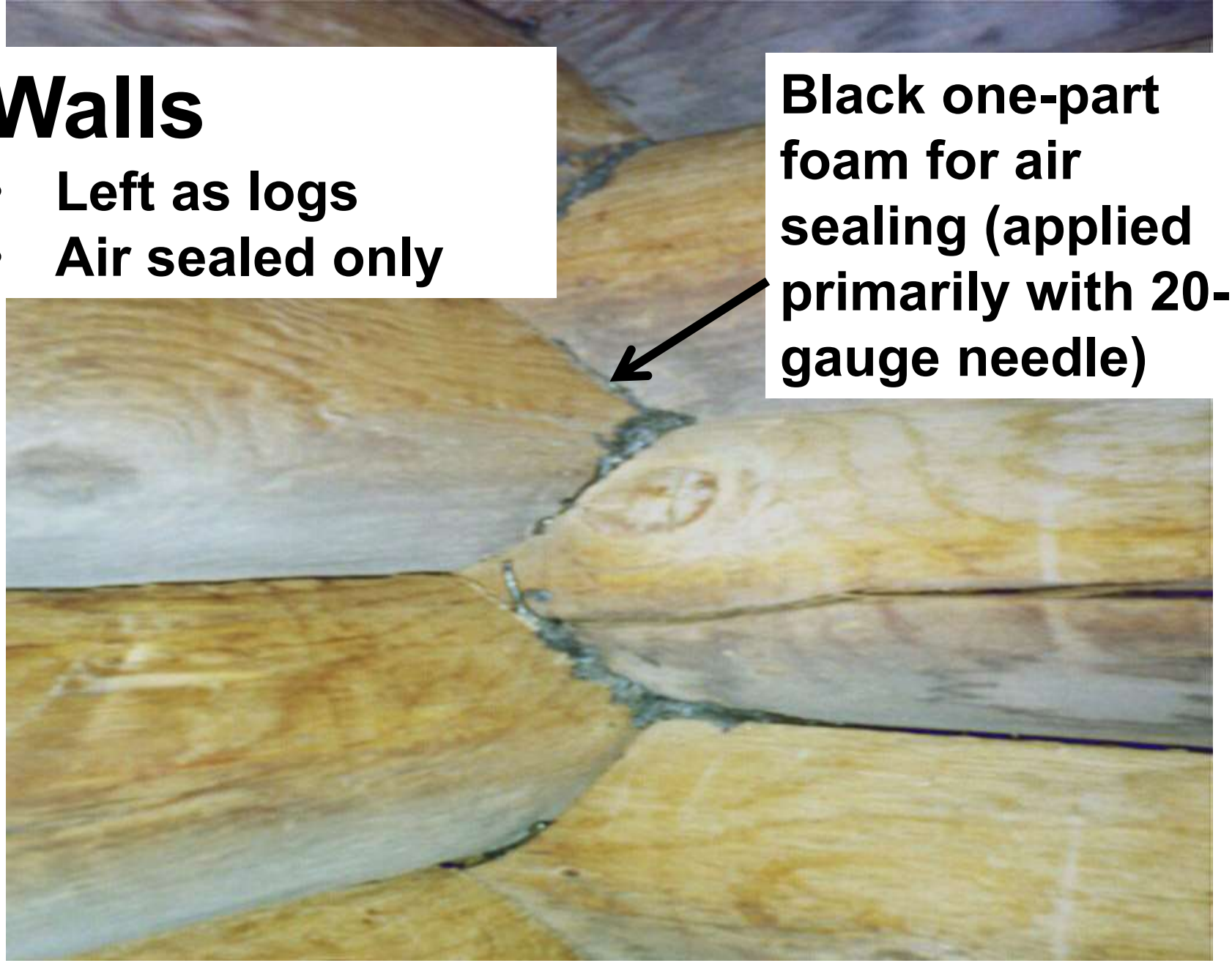
Remove iron & manganese via potassium chloride rechargeable media

Reverse Osmosis (RO) system to remove dissolved solids (salt) for drinking water



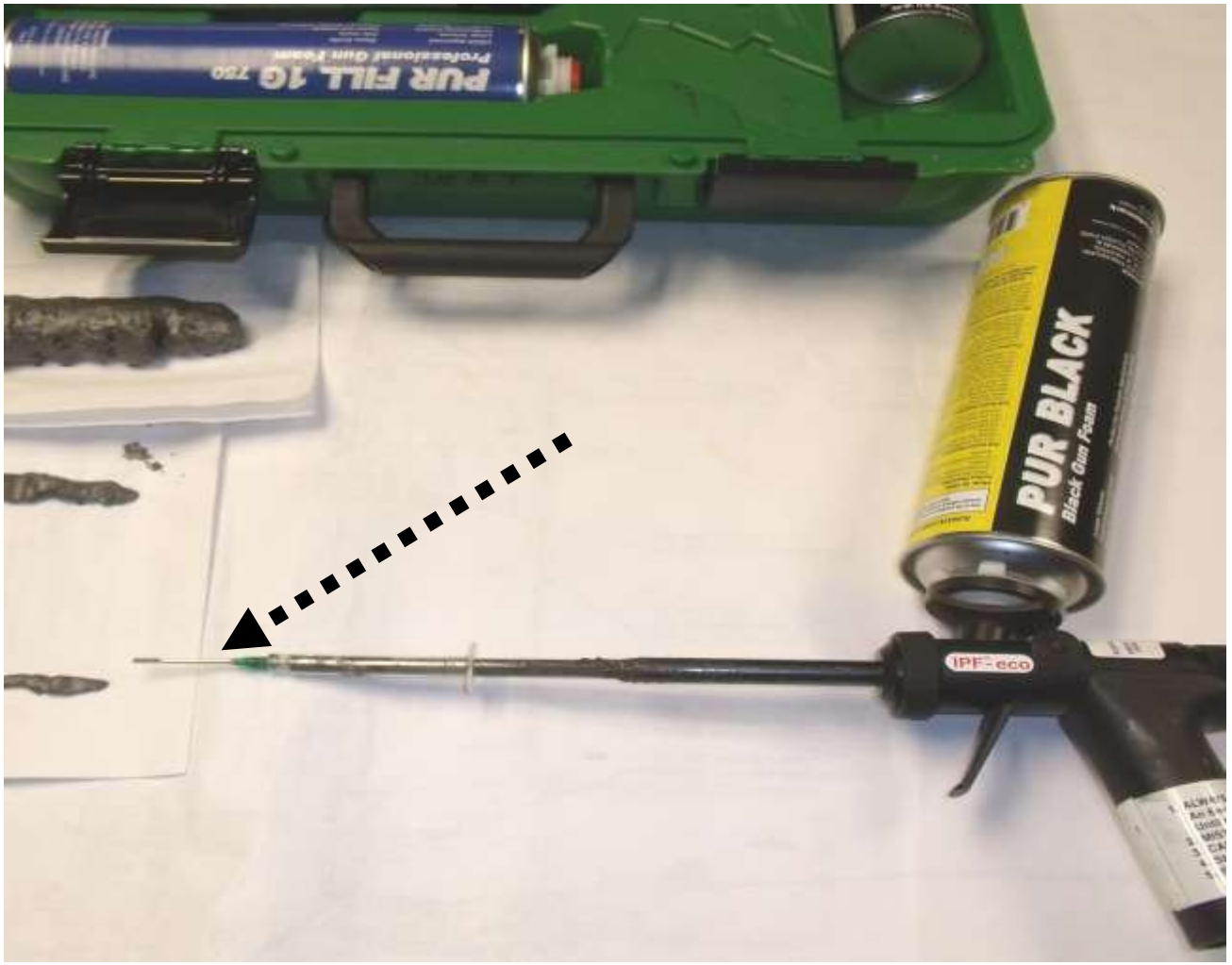
Walls

- Left as logs
- Air sealed only



One-part Foam

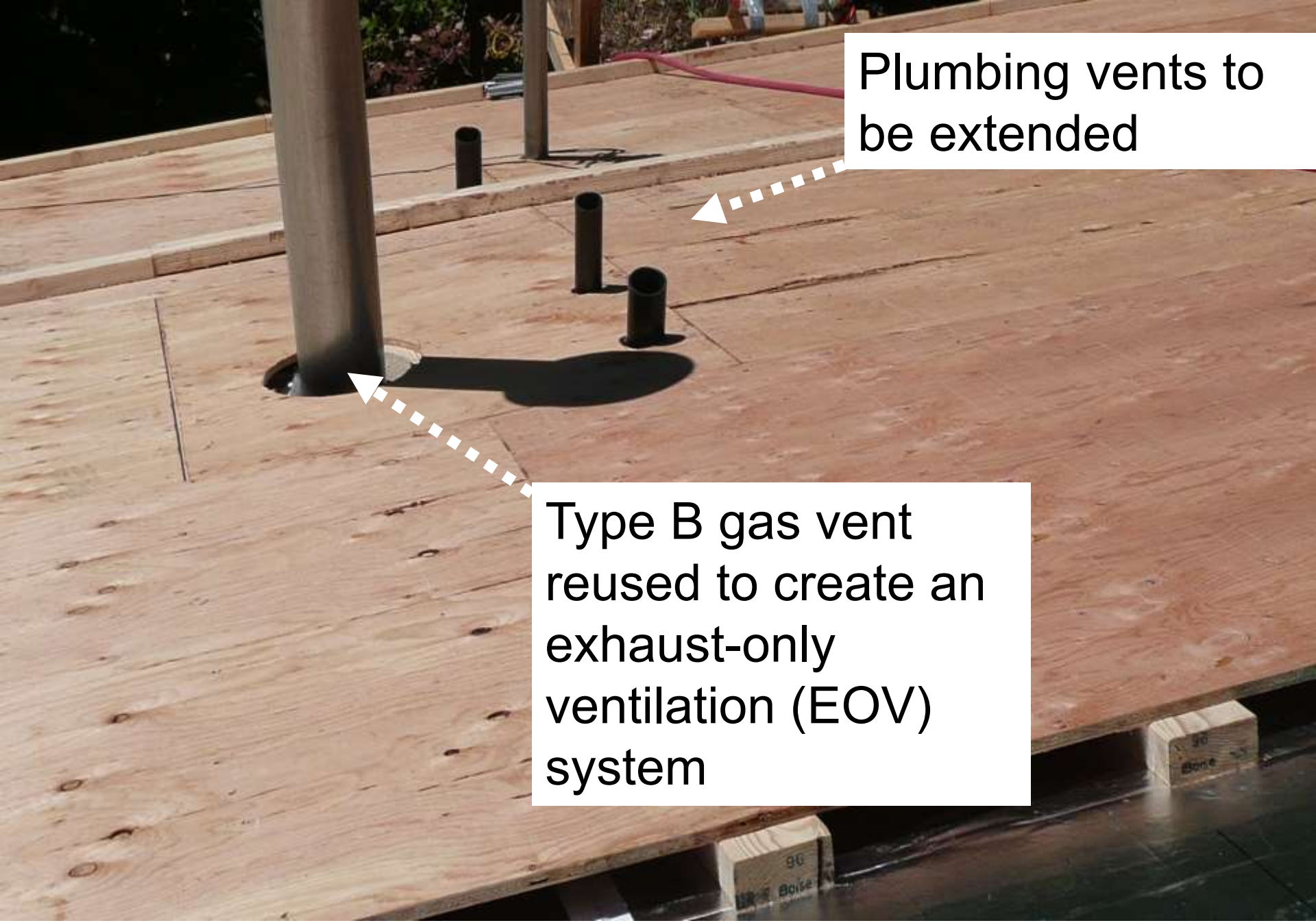
With 20-gauge needle for air sealing

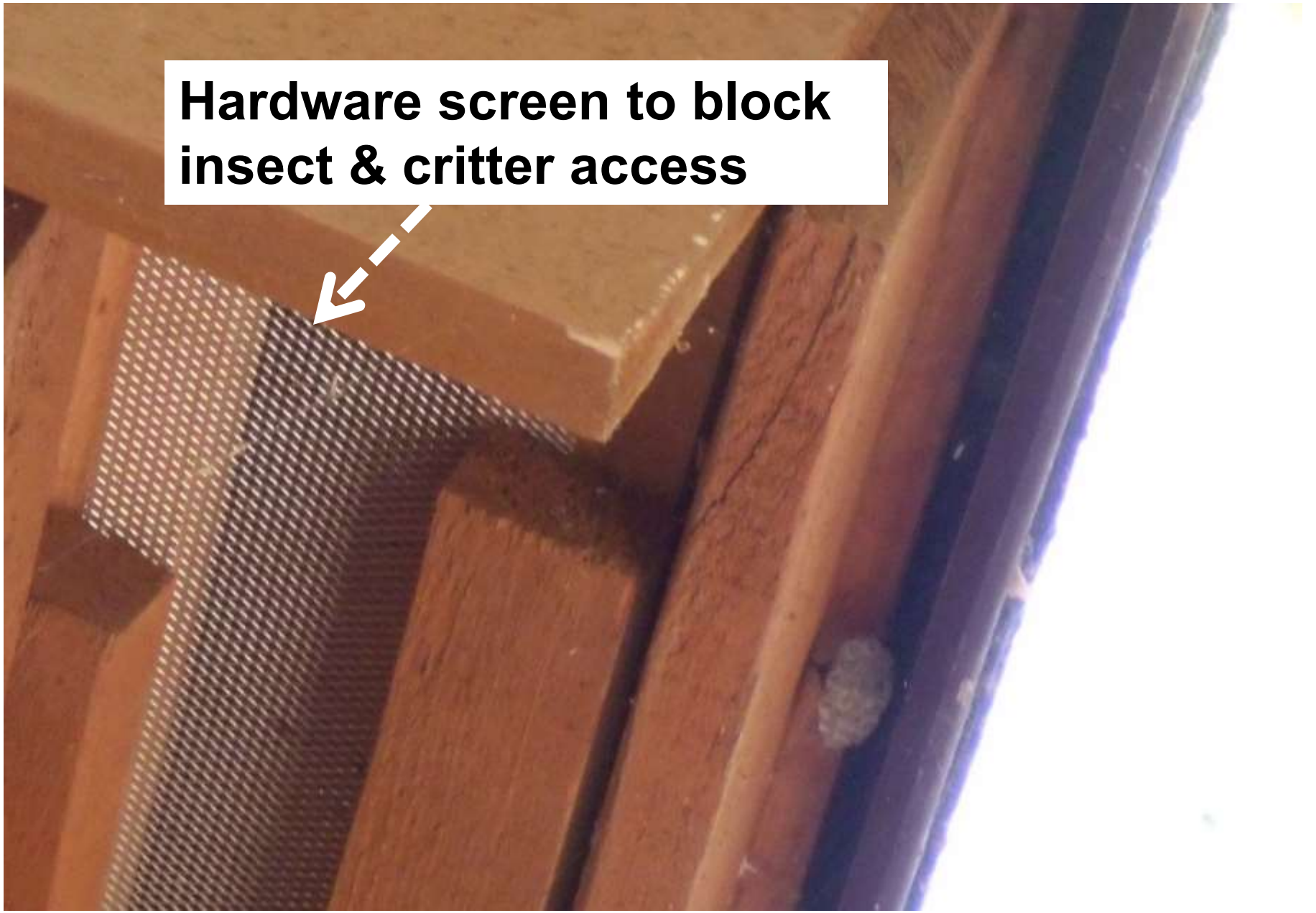


Roofing Upgrade "Re-skinned"

by "Rock-Climber"

Optimize Enclosure: 4.5" built-up rigid foam & vented roof cladding system

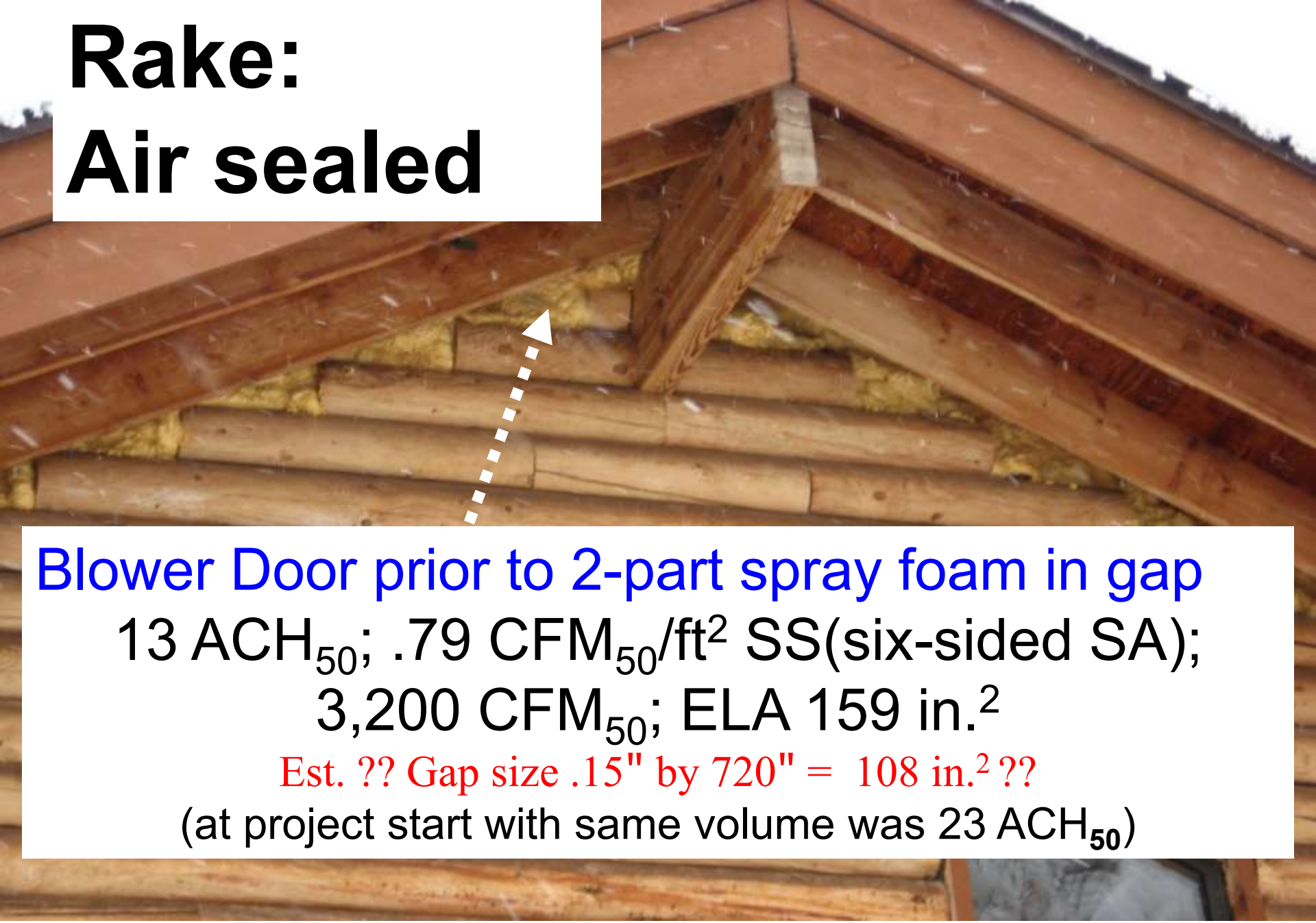




Elastomeric urethane caulk

Wood blocking & air sealing

Rake: Air sealed



Blower Door prior to 2-part spray foam in gap

13 ACH_{50}; .79 CFM_{50}/ft^2 SS(six-sided SA);

3,200 CFM_{50}; ELA 159 $in.^2$

Est. ?? Gap size .15" by 720" = 108 $in.^2$??

(at project start with same volume was 23 ACH_{50})

Blower Door Results After Air Sealing

6 ACH_{50};1,380 CFM_{50}; .34 CFM_{50}/ft^2 SS; ELA 69 $in.^2$

Still 10x Passive House

Heat loss via Logs 3x rest

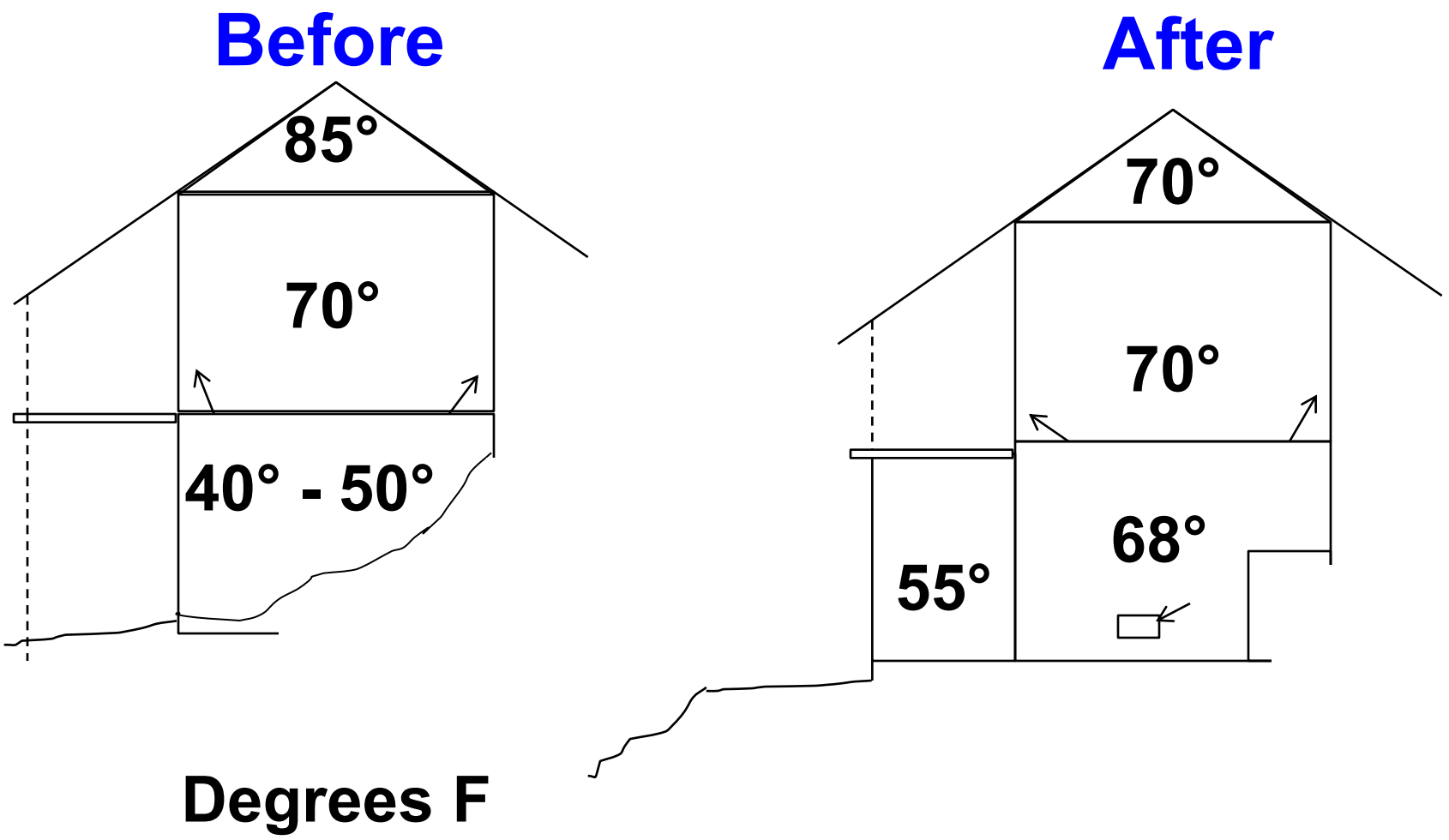
Roof (**R-40+**), basement (**R-15**)

8" log Walls air sealed & left as logs (**R-6**?)

Very dry, finished, conditioned basement

Now, 1,600 ft^2 finished floor area (FFA)

Comfort Improvement:
Now Even Temperature Distribution



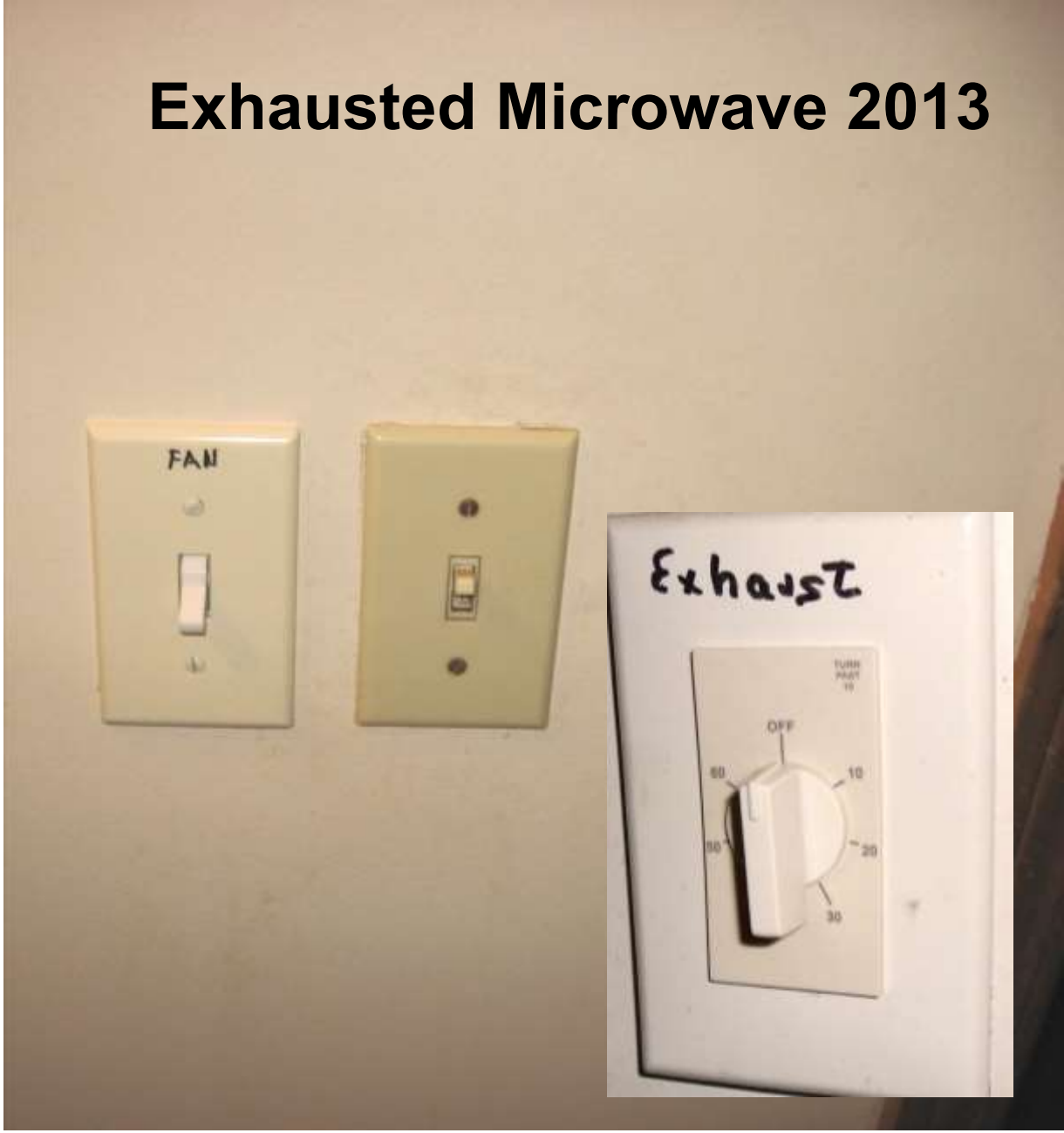
Ventilation/Mold Fix for Bathroom

Central Exhaust Only Ventilation

[redacted] switches

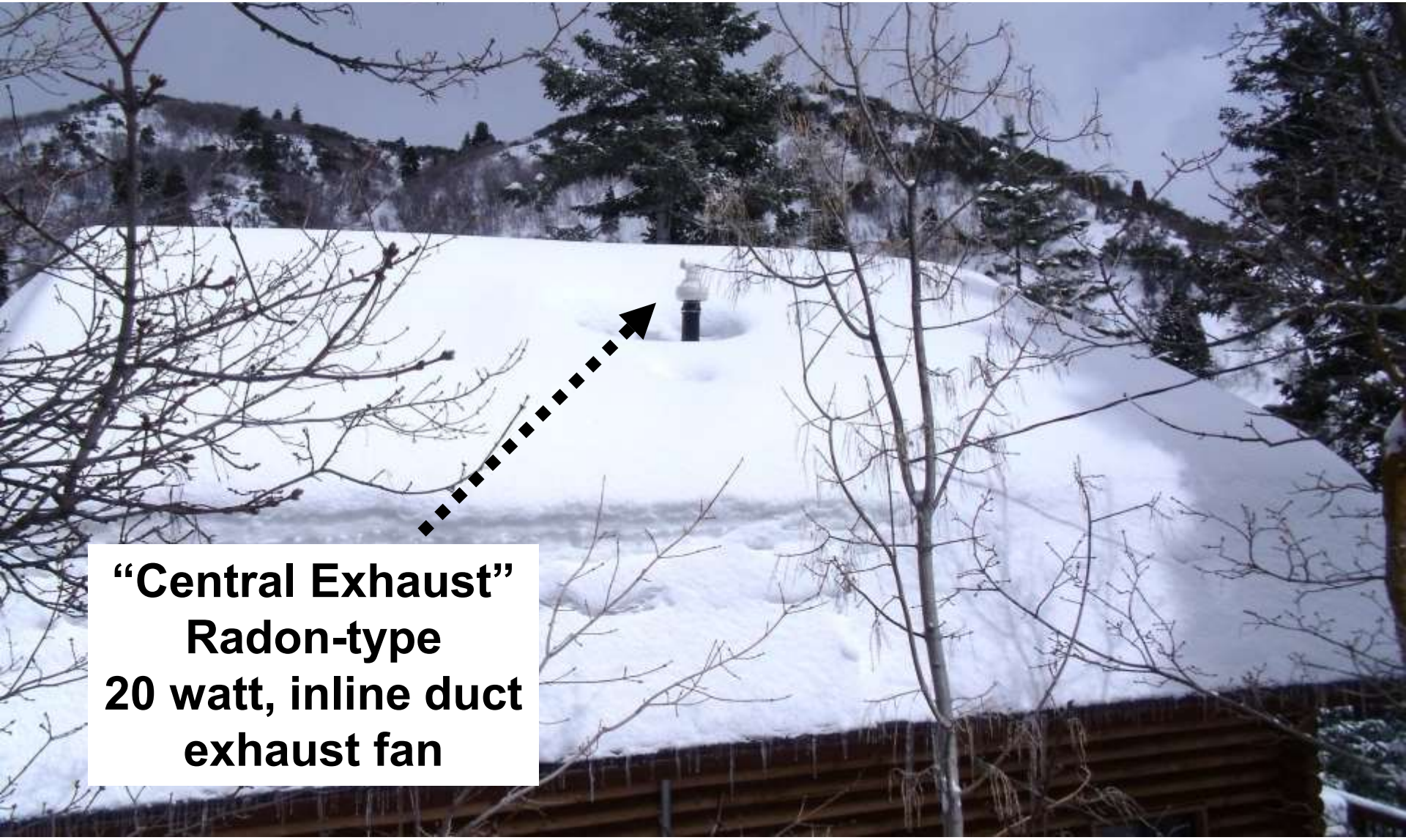
- Kitchen area
- 1st Flr Bathroom
- Basement bath

Changed 2012:
installed timers



B Gas Flue Reused for Central Exhaust Only (EOV)

Sealed combustion furnace & powered ex. hot water heater



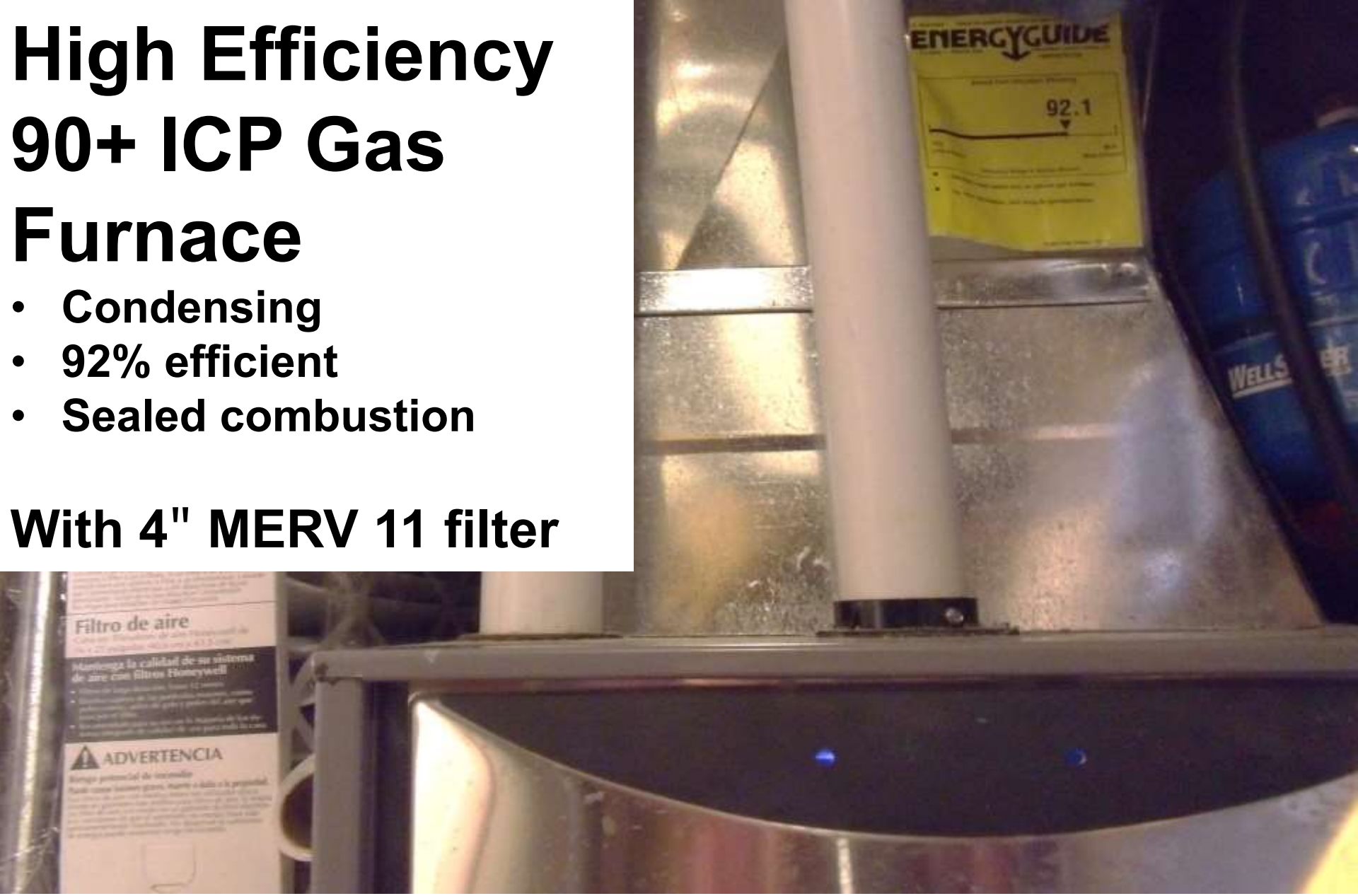
Combustion Safety:

Sealed combustion furnace, power vented hot water heater, currently no wood stove & some air leakage allows for exhaust only ventilation design

High Efficiency 90+ ICP Gas Furnace

- Condensing
- 92% efficient
- Sealed combustion

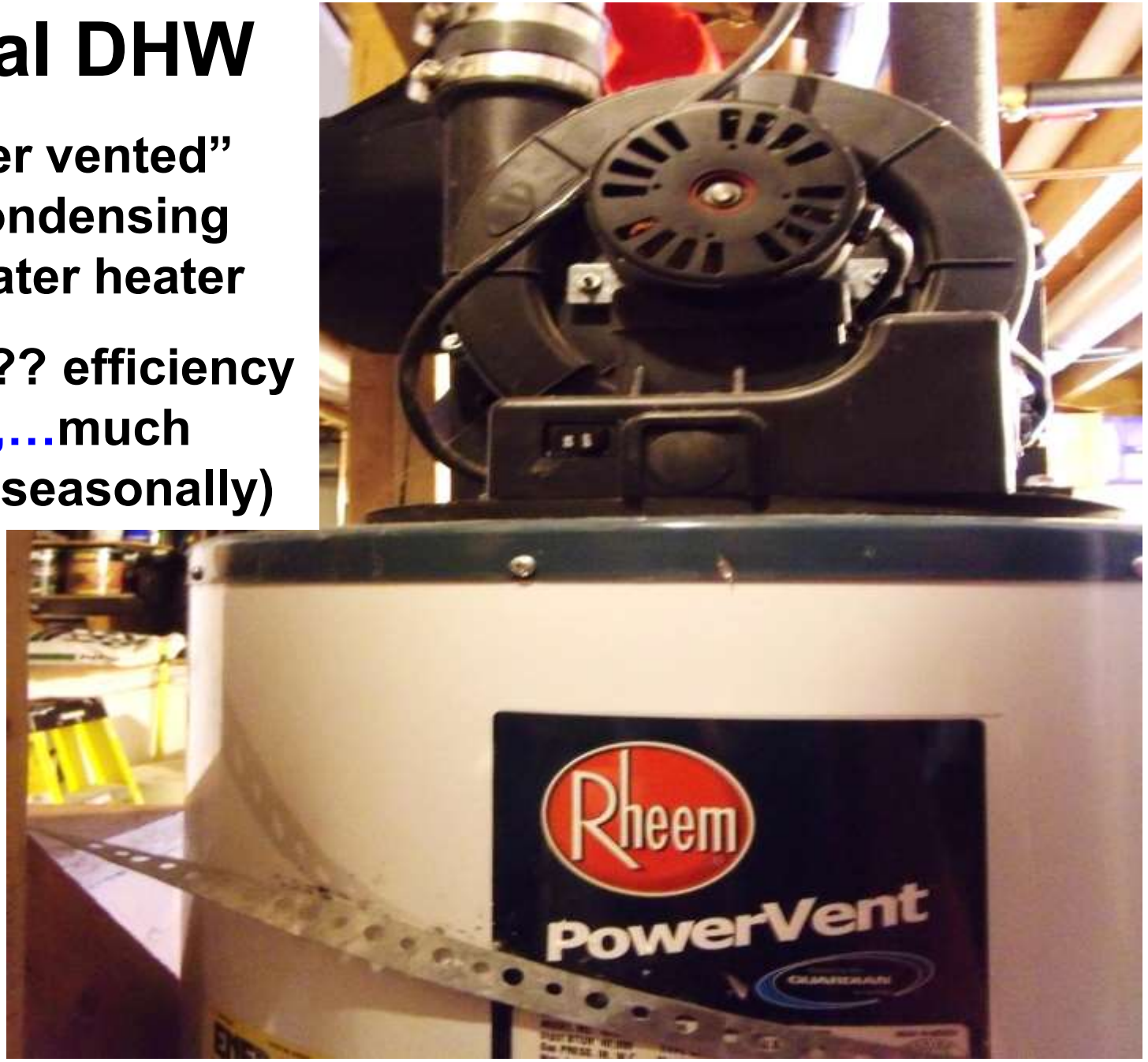
With 4" MERV 11 filter



Initial DHW

"Power vented" noncondensing hot water heater

65%??? efficiency (opps,…much lower seasonally)



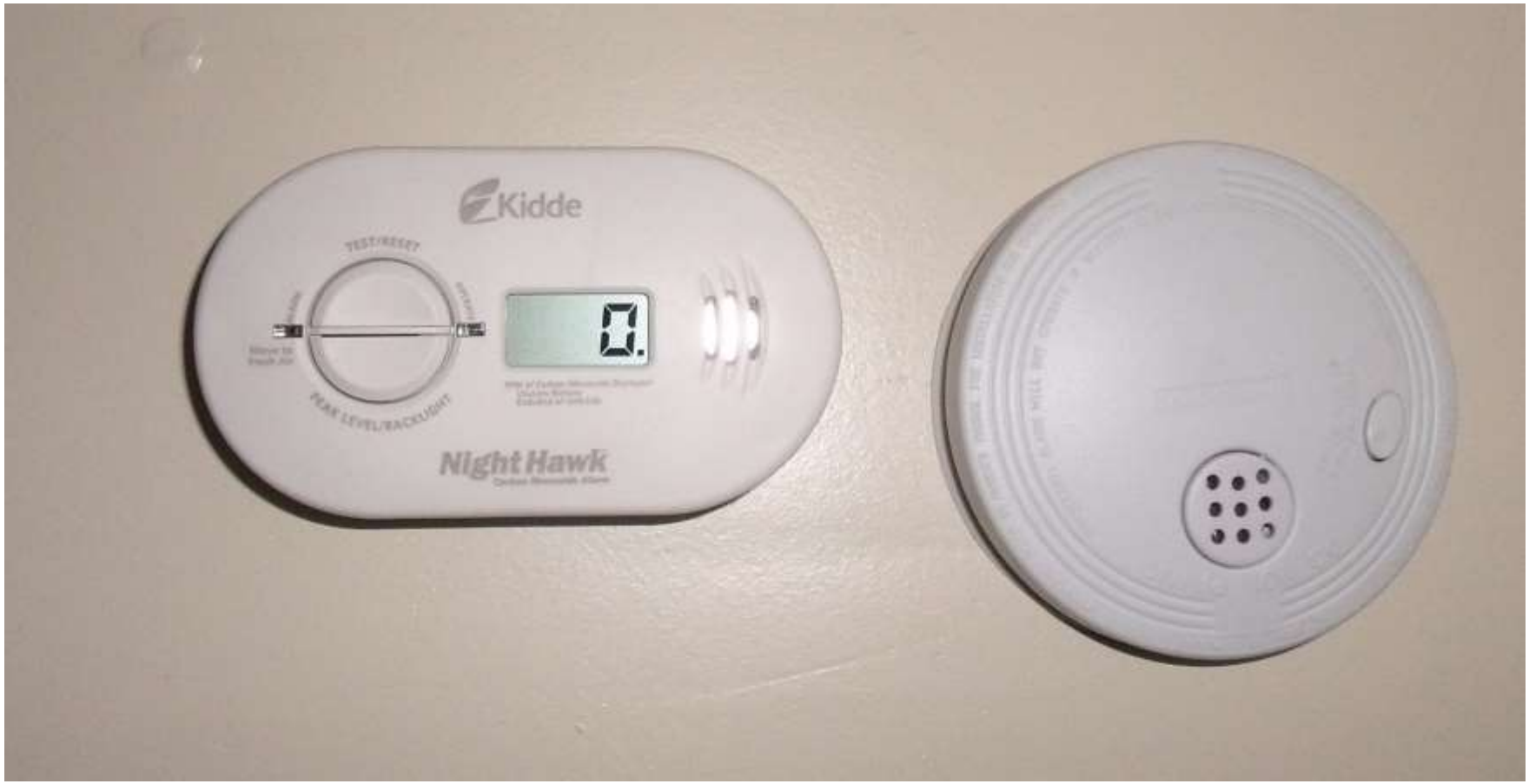
Part-time Basement Radiant Floor

Heat source domestic hot water & (in 2011) now passive solar storage assisted

Typically actively used 2-3 weeks/yr.

Lighting: Compact Fluorescent Everywhere (20)

Safety: Both CO & Smoke Detectors



“Surprise” Environmental SEPTIC SYSTEM UPGRADE & “Forced” Water Conservation

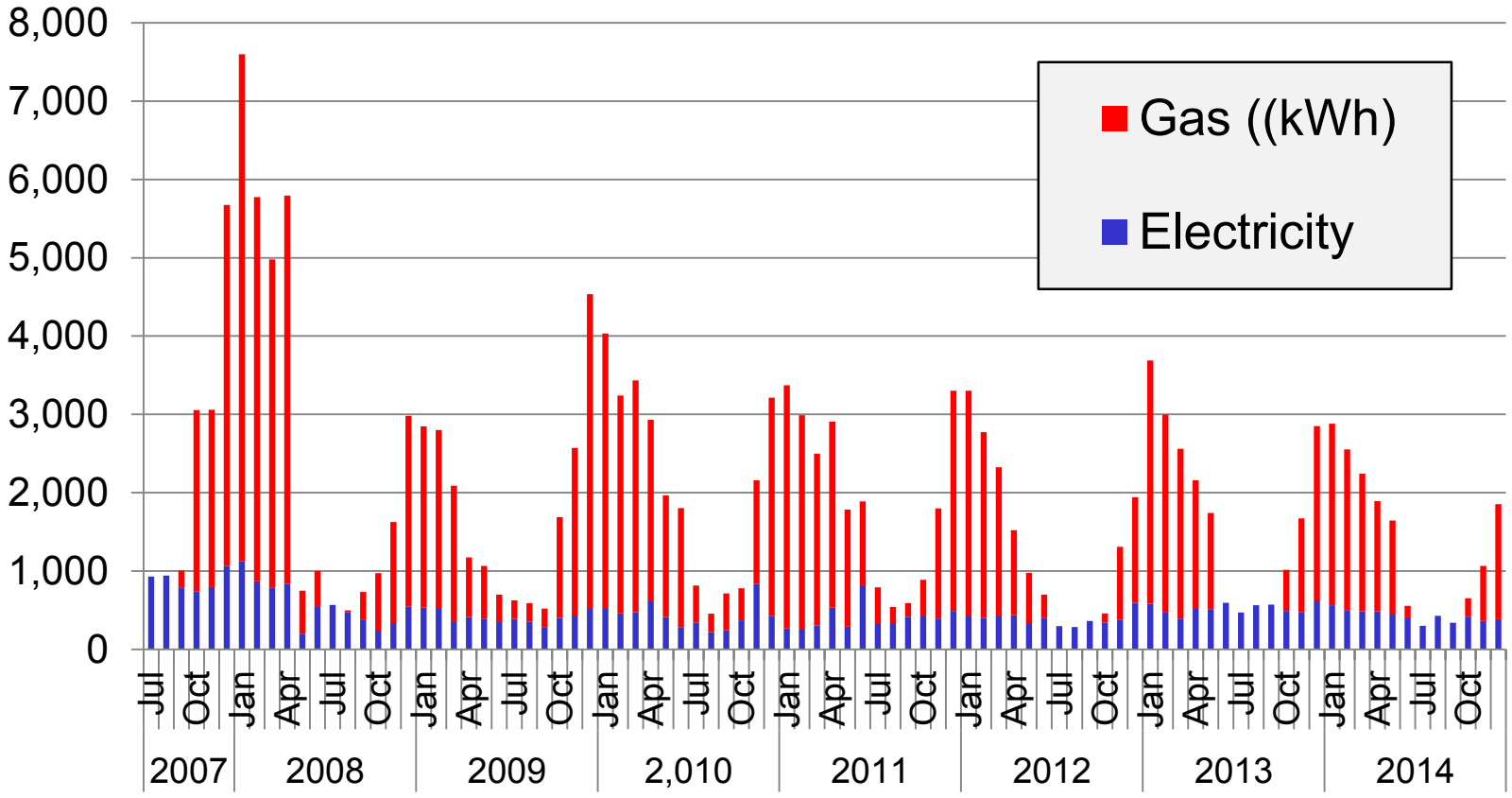
Waterless urinal, Purell, & 3,000 gallon separate blackwater holding tank added

1.28 gal. power flush Toilet fill water on solenoid valve controlled by bath light switch (pumped 1 time a year)

US EPA Healthy Home Summary: Addressed

1. _☺_ Asbestos (none noted, quarry tile kitchen floor)
2. _☺_ Environmental tobacco smoke (ETS) (banned)
3. _na_ Garage pollutants (snow blower & gas stored outdoors)
4. _☺_ Lead Paint (home is not pre-1978)
5. _☺_ Moisture (no mold & other biologicals)
6. _☺_ Pests & ☺_ Radon
7. _☺_ Other below ground contaminants (none)
8. _☺_ Combustion safety
9. _☺_ Ventilation
10. _☺_ Home safety
11. _☺_ Worker safety
12. _☺ **Sustainability & Resilience Objectives**, Meeting THC (further work in progress)

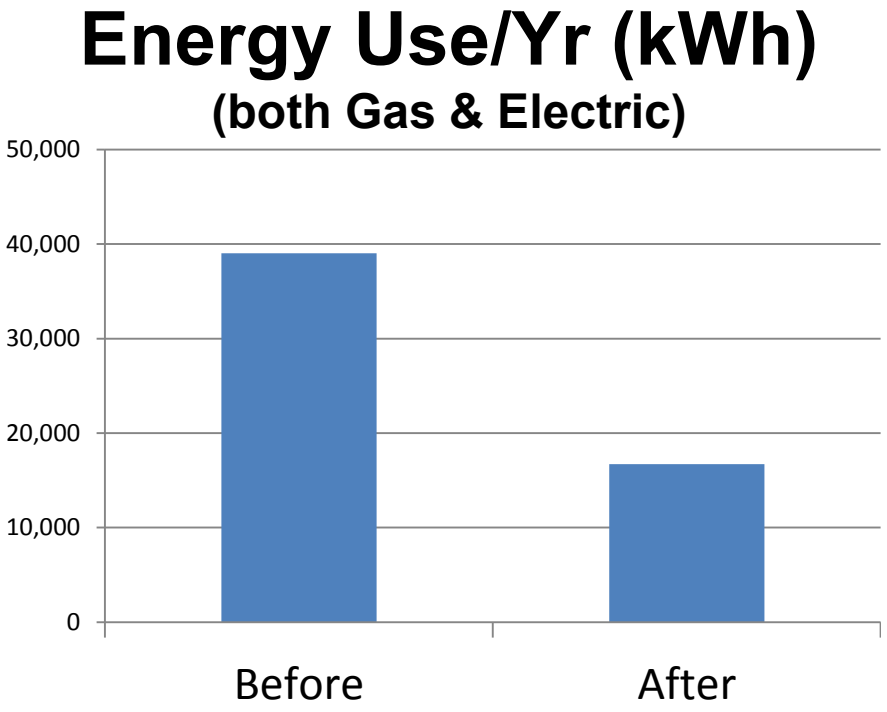
Where Are We Now Total Energy Use? (gas & electric converted to kWh)



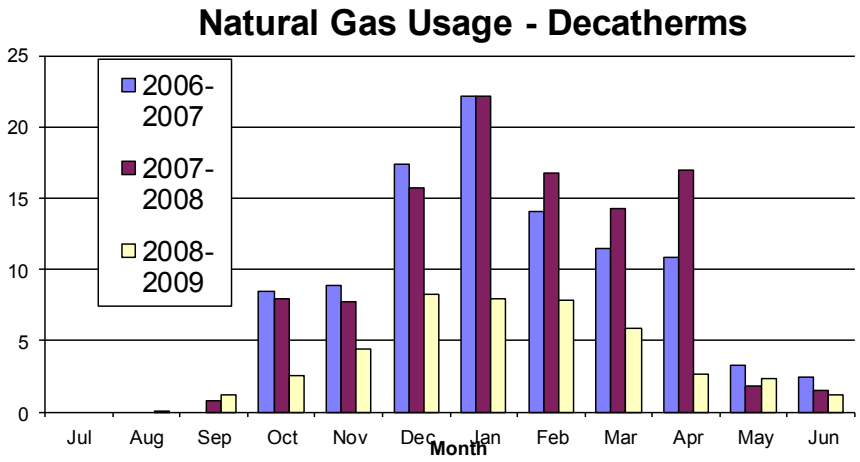
What Energy Metric?

Total Energy Use

~42% (includes added hot tub use, estimated at 2,500 kWh/yr.?)



39,020 kWh to 16,710 kWh

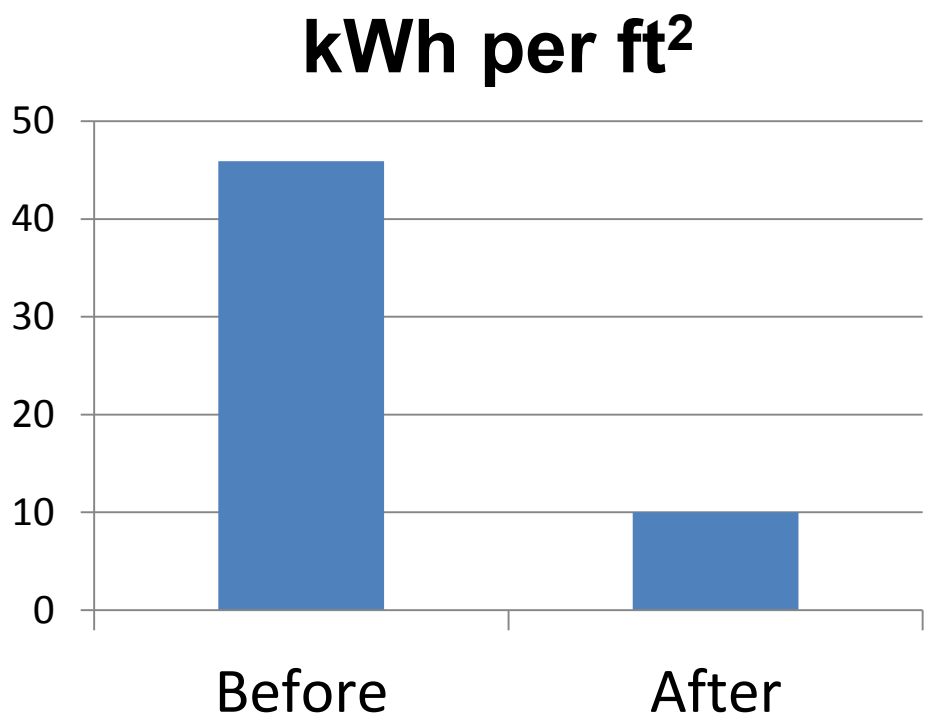


2" foam base, 3" spray foamed walls
8" cover, January electricity cost $10

What Energy Metric?

Per ft^2

78% reduction in energy use per ft^2 of habitable space?



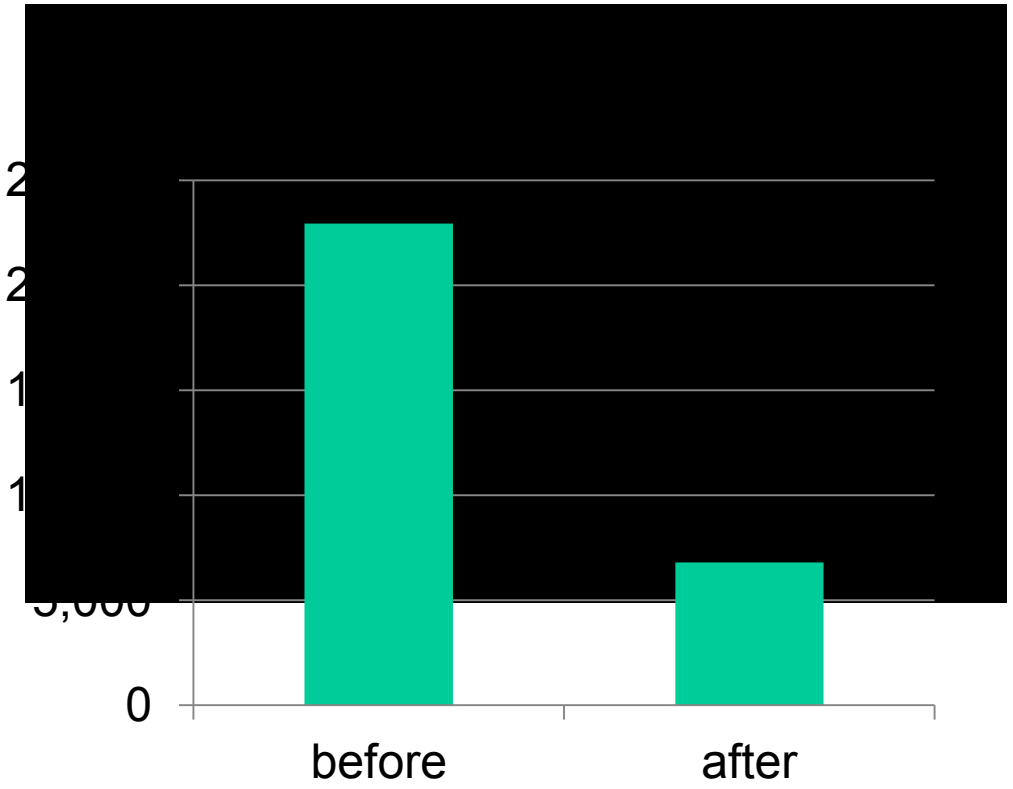
46 kWh/ft^2 to 10 kWh/ft^2

850 ft^2 to 1,637 ft^2

What Energy Metric?

Per Person

>70% reduction in energy use per person



22,953 kWh/per. to 6,803 kWh/per.

1.7 persons to 3.4 persons

Goal: To Meet THC: Determine Customized THC Allowance

OPTION A (75% reduction from previous use)

Based on verified immediate prior year;

Not applicable to a staged project.

OPTION B is absolute, not relative

Inputs

Weather: 8,876 heating degree days

House size: 1,637 ft^2 finished floor area

Number of occupants: 3.4

Heating source: fossil fuel

Attached or detached: detached

Meeting the Thousand Home Challenge

This household will officially met the THC when the application is completed & documentation provided to verify the annual household net site energy use is less than 12,221 kWh (2014 assumptions).

Staged, ongoing multi-year project? ***Great!***

Follow the Log cabin project updates

www.thousandhomechallenge.org

(Case Studies)

2014 OPTION B Inputs: **FFA: 1,637 Ft^2 ; 8,876 HDD; 6 months: 2 households, 4.5 occupants; 6 months: 1 household, 2.5 occupants**

Basis for Thousand Home Challenge OPTION B Must Meet Annual Site Energy Threshold (in kWh)

Allotment:

Heating: 7,389 kWh (if fossil/wood[1])

Cooling: 0 kWh

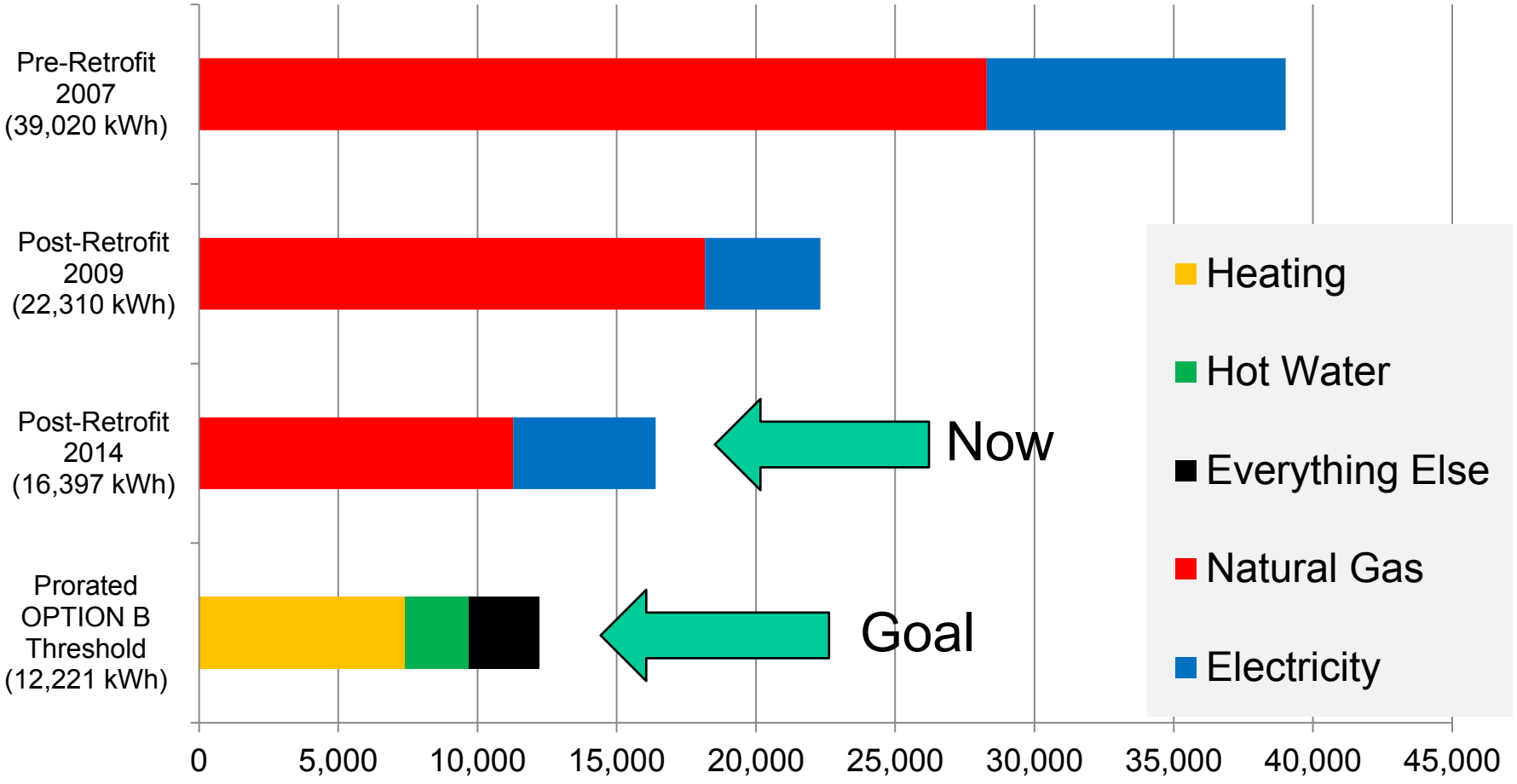
Hot Water: 2,305 kWh

Everything Else: 2,527 kWh

Total: 12,221 kWh/year

1. If electric heat – ½ of fossil/wood (3,694 kWh/yr.)

Comparing THC Threshold with Pre & Post Energy Use
(in kWh/year)



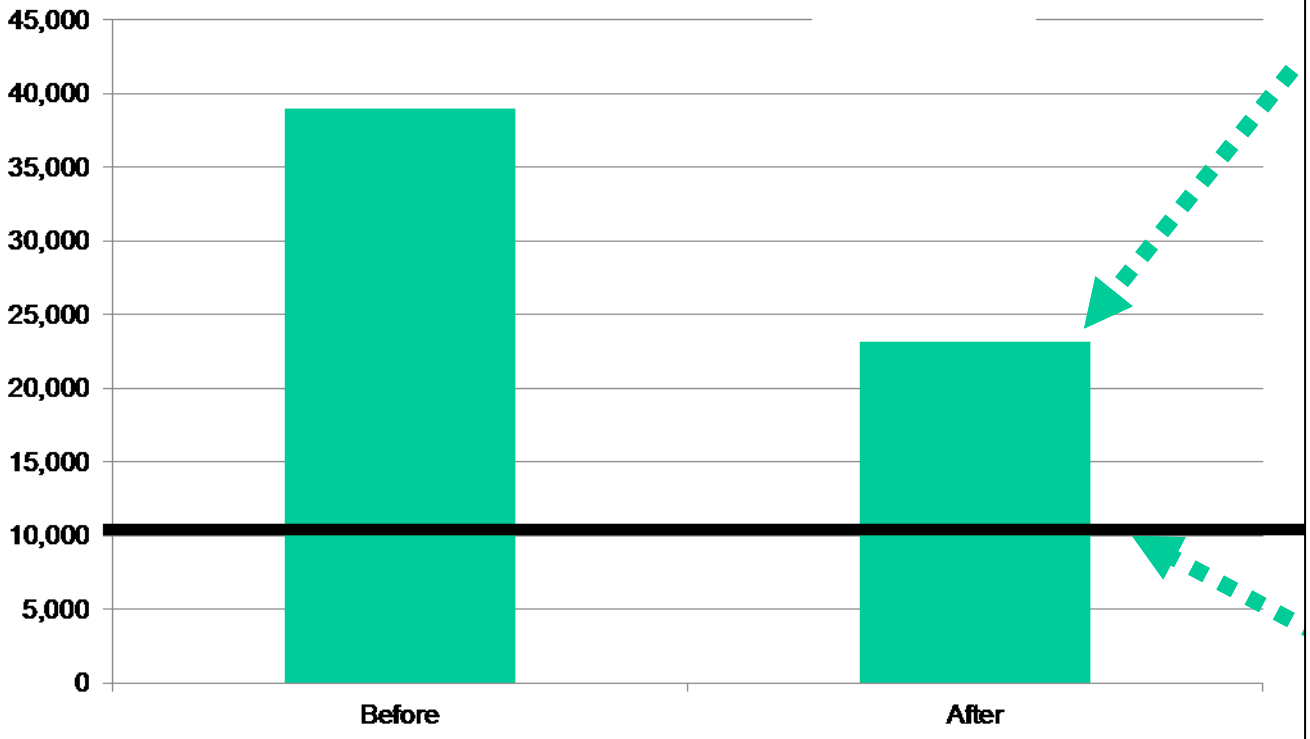
OPTION B Assumptions: FFA: 1,637 Ft^2 ; 8,876 HDD; 6 months: 2 households, 4.5 occupants; 6 months: 1 household, 2.5 occupants

How Are We Doing?

To Meet 1,000 Home Challenge

Option B = 12,221 kWh

Total Energy Use (in kWh/yr.)



Initially: Only About Halfway There 2009

STEP 10.

Further Evaluation & Steps Taken since 2009

Option B Continue to *Optimize Enclosure*

Tackle basement exposed north wall: add drainage, exterior insulation, & address window **Done 2011**

Renewables: Solar Thermal, PV?

100 gal. DHW tank & 3,000 lb sand bed floor storage, **Done 2011**

128 ft^2 southeast

Looking south

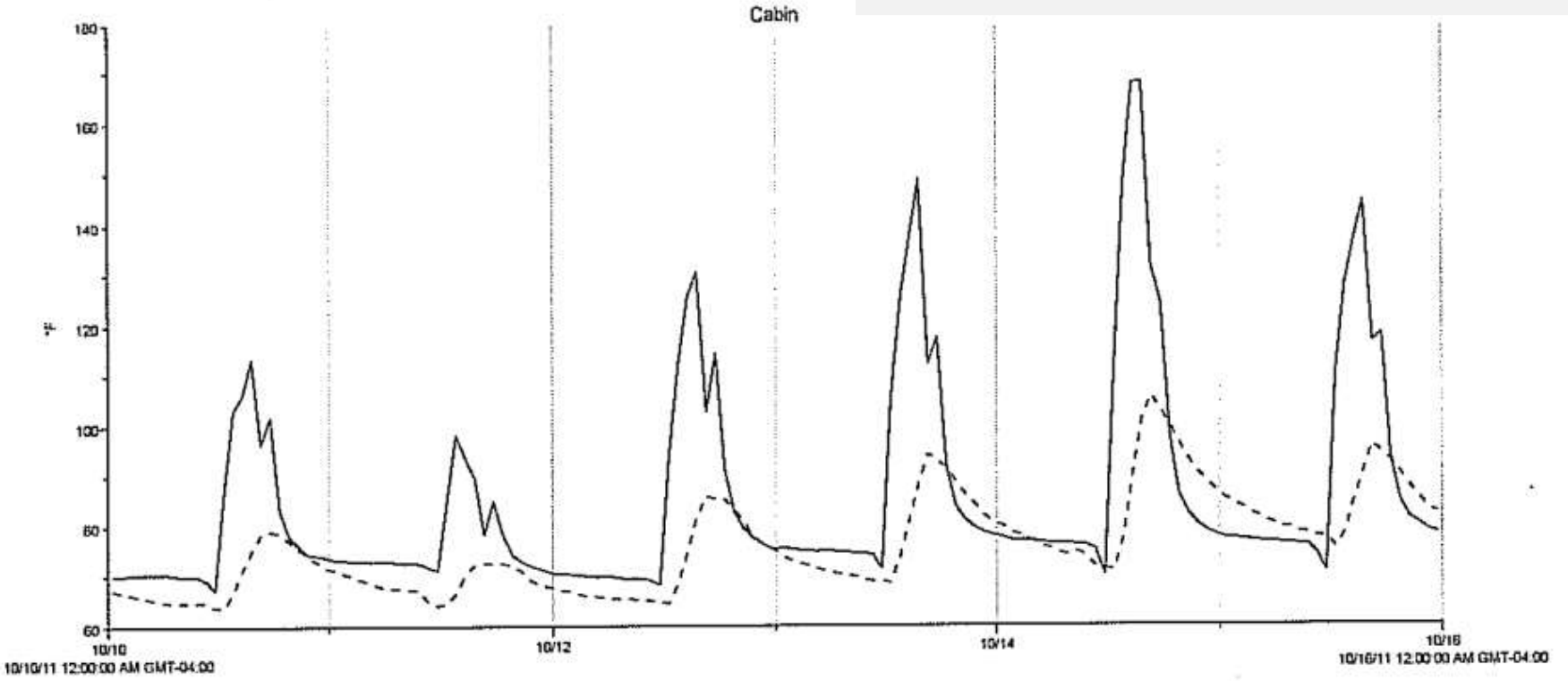
Solar Thermal Components

1. Four 32 ft^2 panels
2. 10-gal. drain back tank
3. 100-gal. Marathon tank
4. Heat exchanger for tank
5. 3,000 lb. sand bed floor storage for summer excess
6. Backup water heating???

(was existing GAS ????)

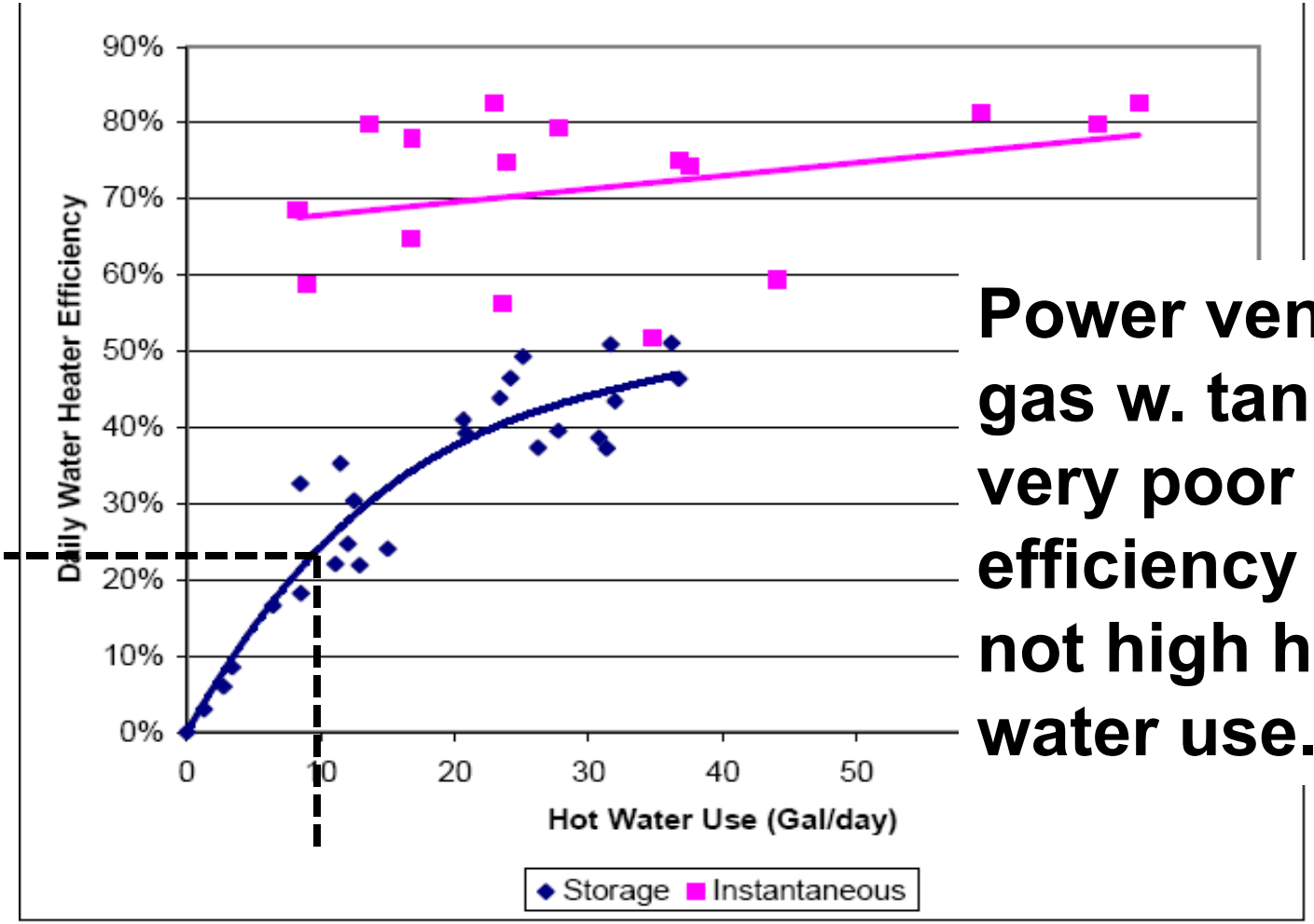
Solar Performance

Solid Line: ºF solar storage tank
Dotted Line: ºF sand bed



Note: Solar is working !! however, gas & electric bills remained the same for Oct., Nov., & Dec. 2011 ☹

?GAS DHW Efficiency? Vs. Water Use



Power vent gas w. tank very poor efficiency if not high hot water use.

Hoeschele, M., and Springer, D. "Field and Laboratory Testing of Gas Tankless Water Heater Performance" ASHRAE Transactions, vol. 114, pt. 2, 453-461, 2008.

Additional Energy Reduction Efforts for DHW & Hot Tub (done 2012)

1. *Seisco For solar backup DHW*
2. *Replace 4 amp solar pump w. 2 amp*
3. *Add solar loop to hot tub base (6 months)*
4. Tenant incentive, 70° occ. 60° unocc.

($100 monthly lower rental)

5. *Solar temp. indicator display in bathroom*

Solar DHW (tank)

Meters

Additional Logical Energy Efficiency Measures:

1. Add interior basement door between storage to create a vestibule entrance & insulate rest of wall
   Done 2012
2. Add instant electric solar back up & meters,
   Shut off gas DHW unit for 6 warmest months?
   Done 2012
3. Mostly cold water washing & use drying rack.
   Tenant agreed to 2012
4. Address some windows?
   Interior storms on 2 picture windows 2012
5. Structured plumbing? (further water reductions?)

Additional Energy Efficiency Measures?

Options:

6. Waste pipe HW energy recovery? *(4 ft Done 2013)*

7. Abandon Hot Tub (actual 1,500 KWH /yr) ☹?

   No-way ??????

8. Cut down or trim neighbor's big tree???? ☹

   Not possible

9. Buy Land tree is on. *Done 2014*

10. Tankless Gas or Electric DHW backup?,

    Electric *Done 2013*

Others? More air sealing Done 2013

Interior *Thermolite* Glass Low E Storms on Fixed Windows U =.25 (2012)

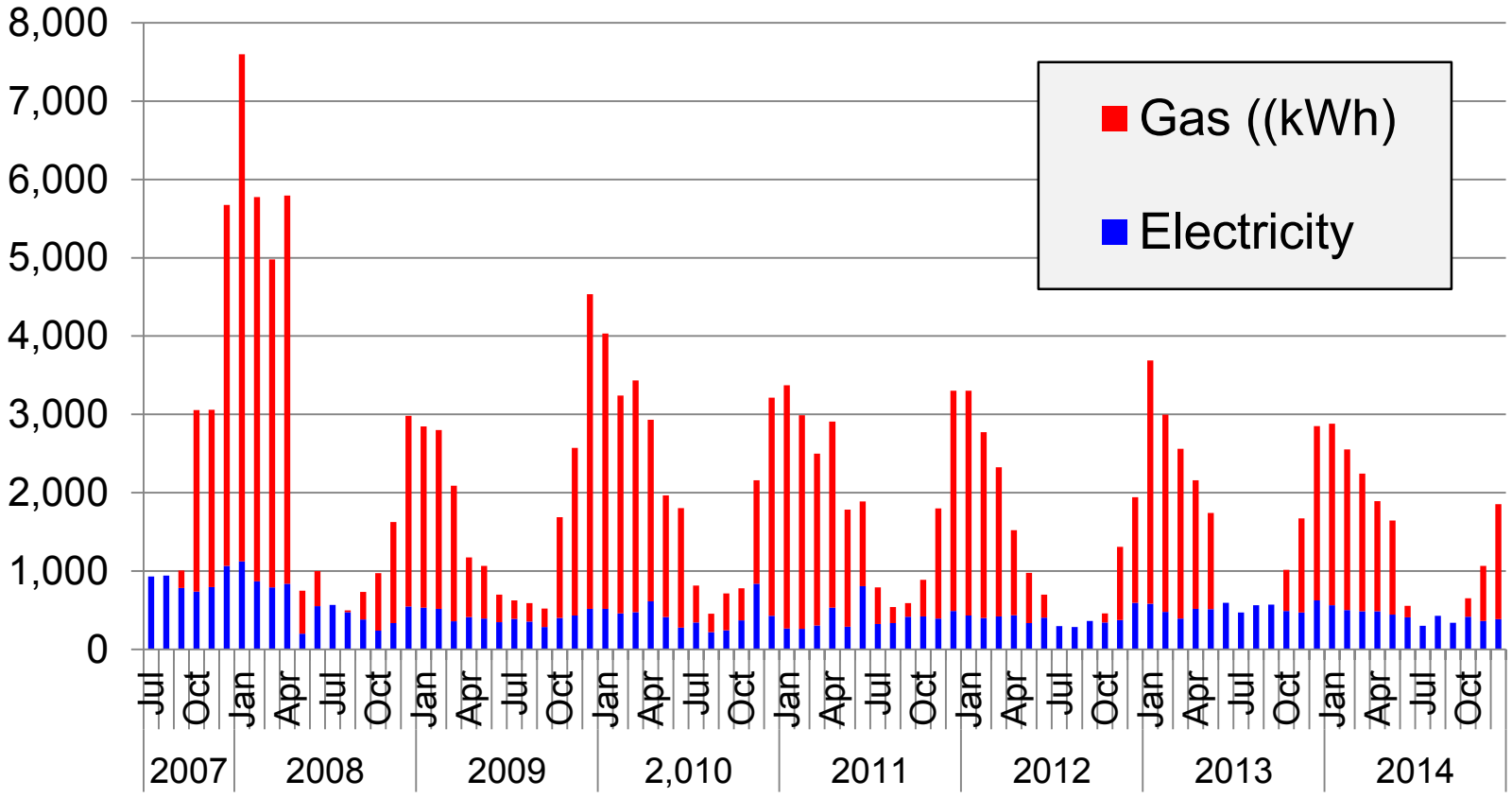
Further Air Sealing August 2012 & 13

Focused on Rake, log corner joints, & seams

Blower door results after air sealing ☹ ☹ ☹

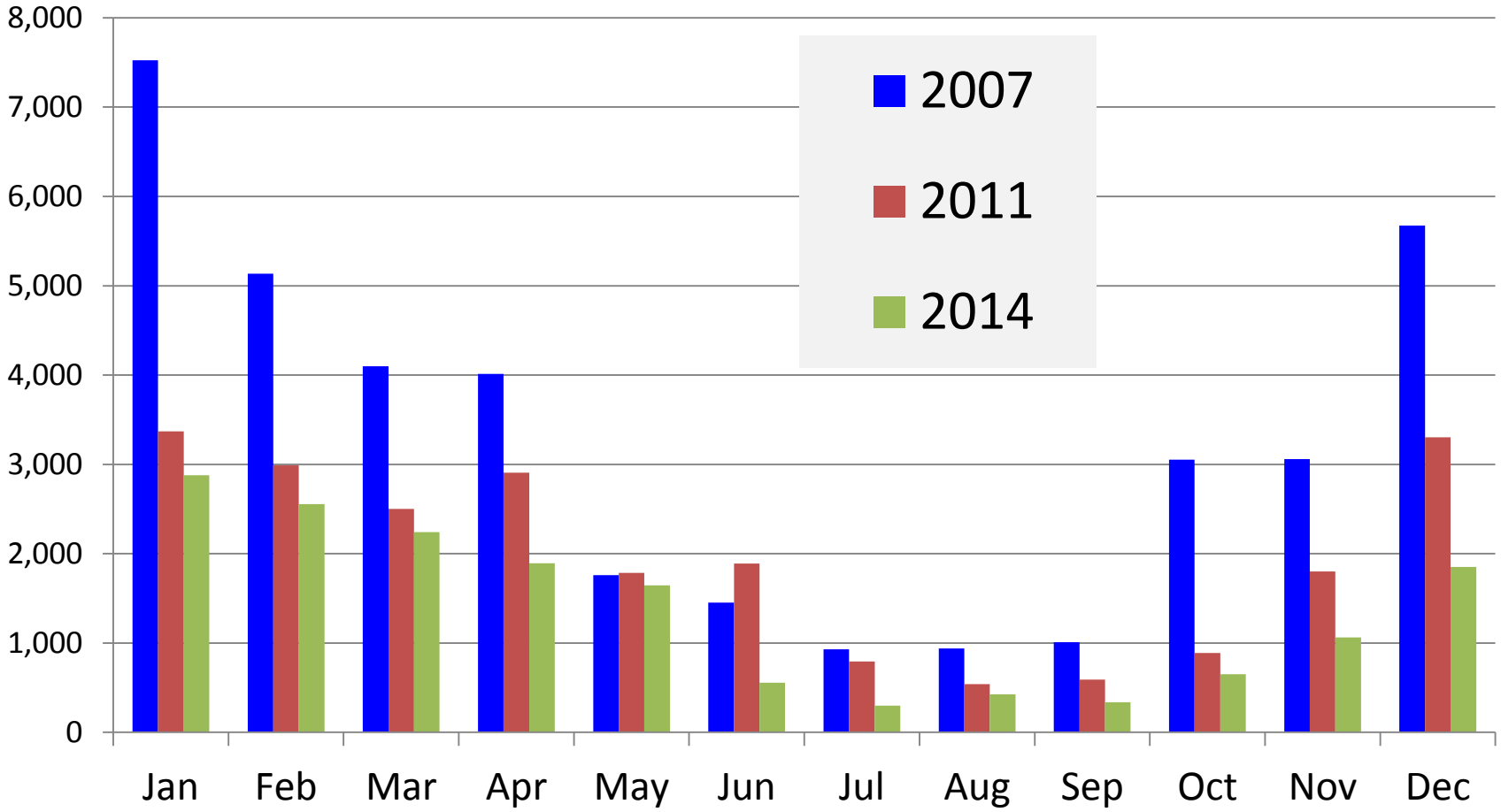
only 5% further reduction at 50 Pascals, 6 to 5? ACH_{50}

Where Are We Now Total Energy Use? (gas & electric converted to kWh)



Where Are We Now Monthly Energy Use?

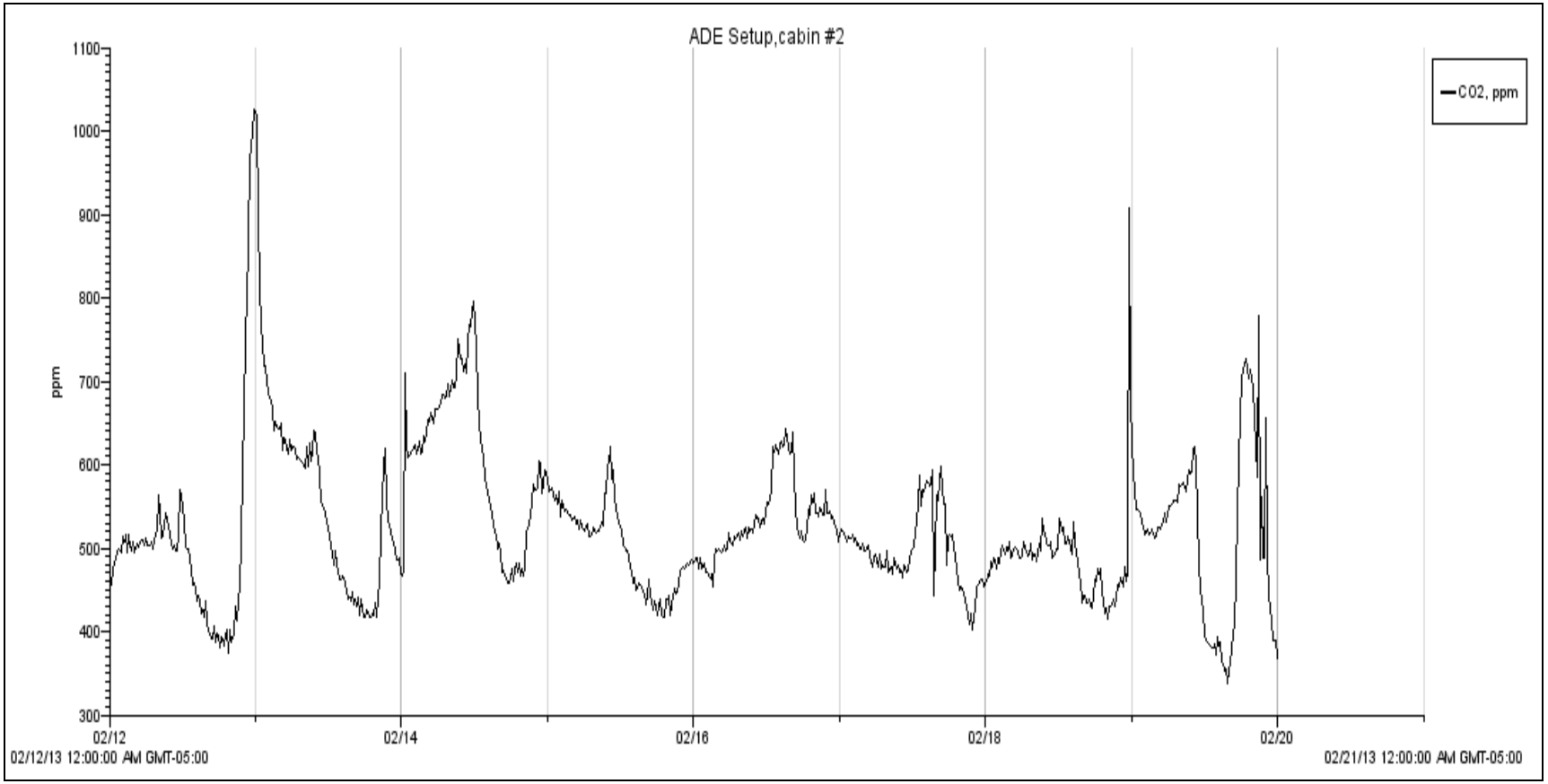
(converted to kWh)



Where Are We Now IAQ, Ventilation Rate?

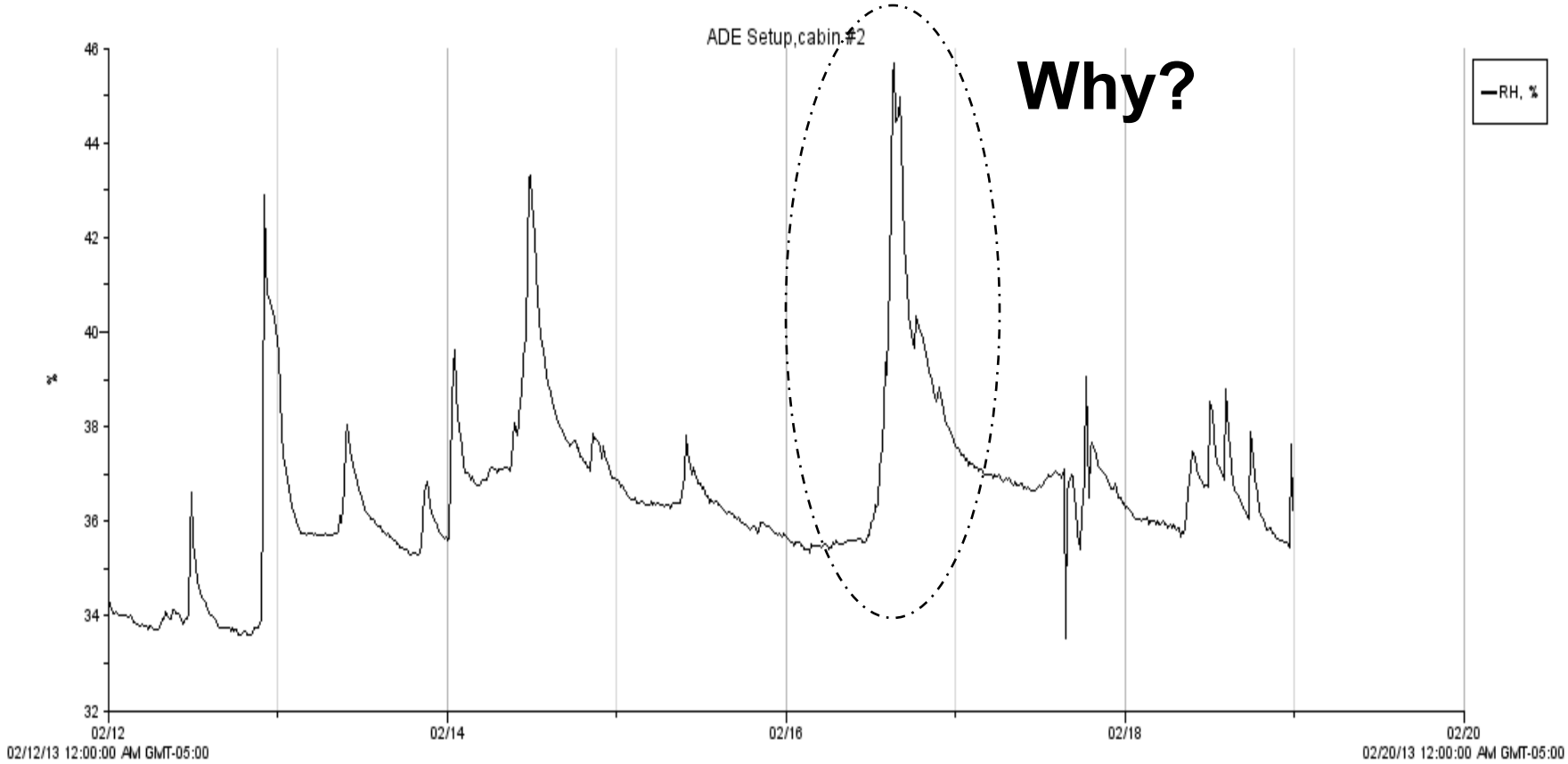
Check Carbon Dioxide 1 week Feb 12-19, 2013

Where Are We Now, Ventilation Rate? Carbon Dioxide 1 week Feb 12-19, 2013



Conclusion: currently over-ventilation in winter

Where Are We Now IAQ, Humidity ?
Relative Humidity 1 week Feb 12-19, 2013



Conclusion: (more air sealing likely ok, exhaust microwave?, ask about moisture on windows?, if tighter consider small HRV?)

To find more air leaks, do infrared imaging: done March 16, 2013

more air sealing work on a ladder Done Aug.2013

Also look at roof melt spot (not addressed yet)

Large transfer grills needed to relieve bathroom and bedroom pressures

Brainstorm:
How Do We Get Over the Hump?
3- 4,000?? kWh?

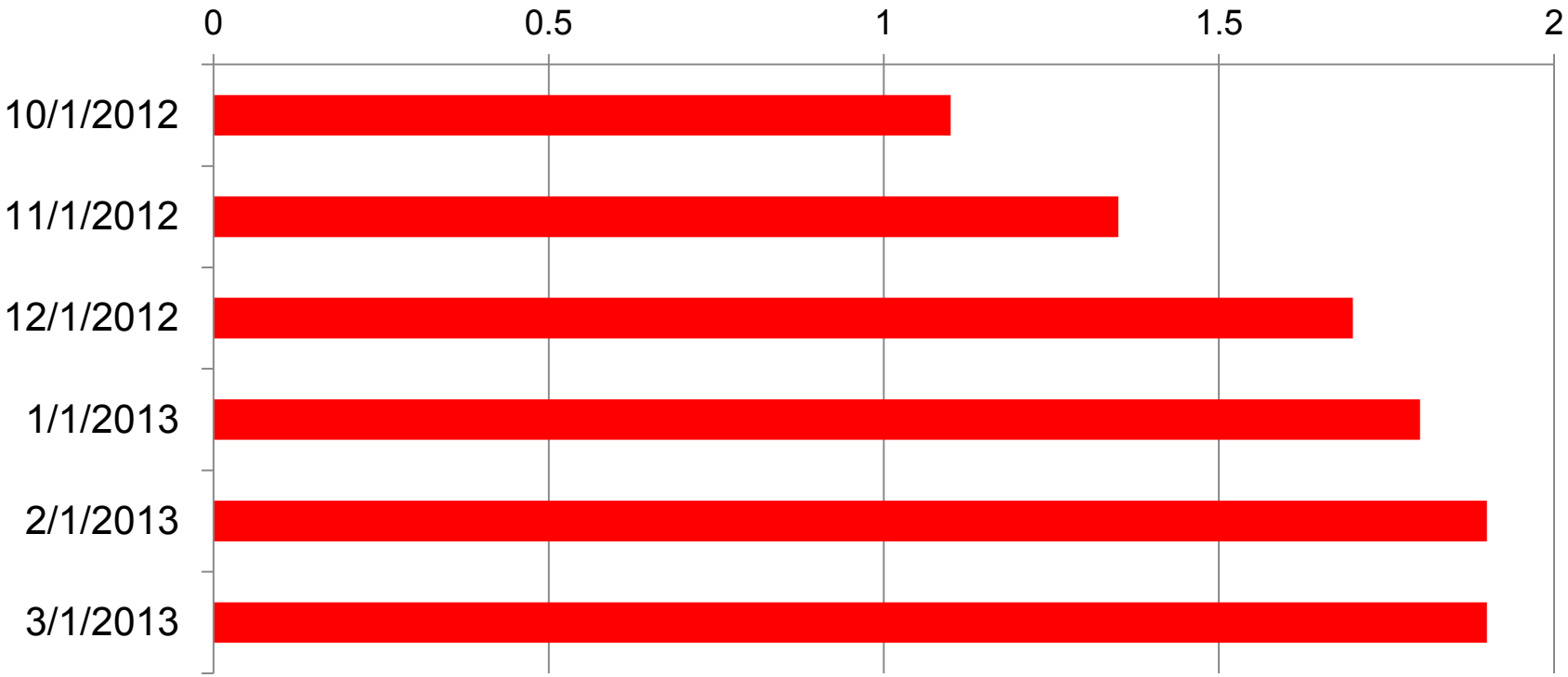
- High gas use Dec. 15 to Jan 15 due to very cold.
- 76% more heating degree days
- Average temp 8° outside vs. 32° F

Likely because of air leakage driven by Δ temp.

More air sealing could make appreciable difference.

Can we make option B without re-skinning???

Therms/HDD (65)



To Meet 1,000 Home Challenge Option B Step 10. "Further Evaluation" Consider:

1. More detailed "energy analysis" historic DD vs. Gas Use
2. Partial interior re-skinning, upper level north wall
   2" ? Interior foam & sheet rock or log siding?
3. Some more window modifications?
4. Doing additional air sealing efforts?
5. If lots tighter? small HRV?
6. After more air sealing, winter 2015-2016 monitor CO^2
7. Smart Thermostat ???? Done 2013

To Meet 1,000 Home Challenge Goals Step 10. "Further Evaluation"

Additional Considerations:

8. Higher efficiency laundry???
9. Some LED lights??????
10. Induction cooking?
11. Smart strips, timers, occupancy sensors? Additional behavioral choices?
12. Creative comfort to allow further temperature set-point reduction or set-back?
13. Community solutions?
14. Change hot tub operation, more foam in HT walls?

20/20 Hindsight

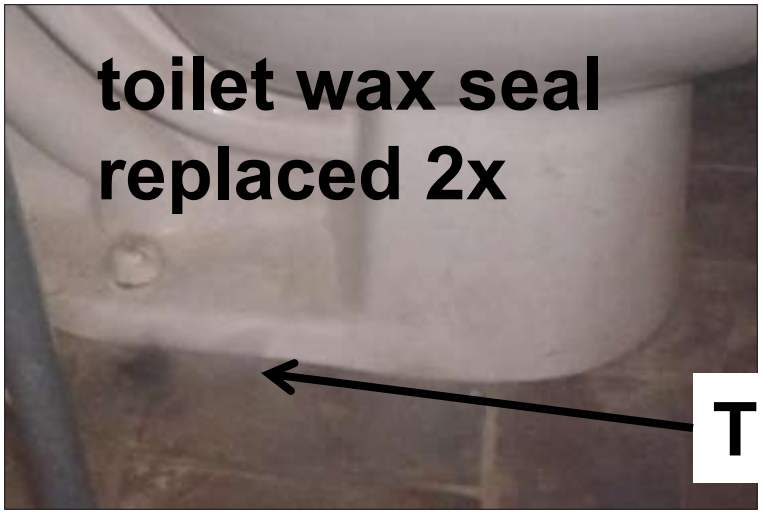
What could we have done differently if we were shooting for 1,000 Home Challenge energy goal from the very beginning in 2008?

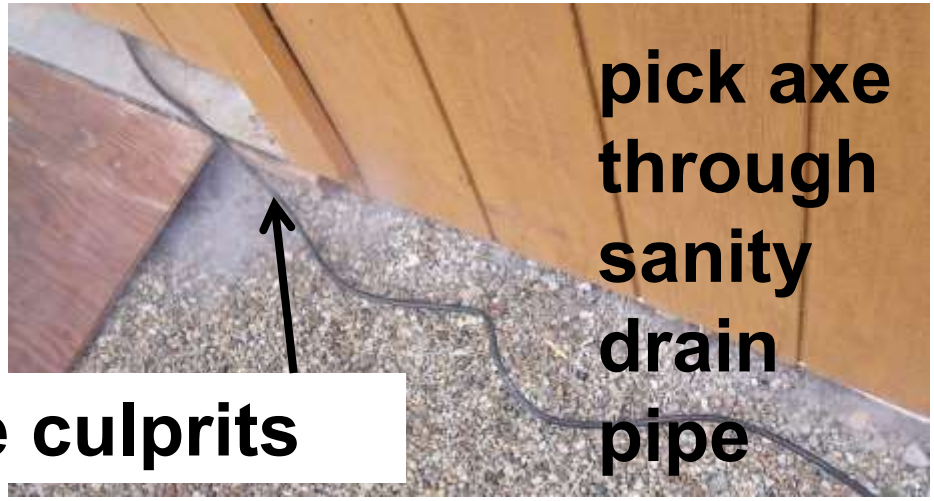
-

- Higher insulation levels in foundation floor?
- Higher insulation levels in vented cladding roof?
- Different space & water heating system?
- Further plumbing redesign to reduce water use, ¾ and ½ inch copper lines remain

Obnoxious Smell: Diagnostics & Repairs

Sewer Gas Smell: from Roof Vents? …not





The culprits

2012-2013 “Resilience” and Future Proof Goals Added

Cabin is in a very dry steep slope western climate, and had too much conifer undergrowth fuel wood surrounding it for the climate and further expected climate change issues.

- Summer 2013 contractor did some understory fuel wood reduction on neighboring land.
- Summer 2014 adjacent lot purchased and major understory fuel wood reduction accomplished on all adjacent lots with Kirk’s and neighbors help. Will be re-evaluated again in 2015 growth season.

View From Kitchen Window Looking North

Summary, Costs to date:

1.	Roof, cathedral ceil.	Ext. foam, vented	$ 15 k
2.	Walls/windows	Air seal, int. storms	$ 1.5k
3.	Basement	Excavate/finish	$ 20 k
4.	Bathroom Venting	Exhaust & paint	$ .5 k
5.	Heat & solar DHW	New gas fur & solar	$ 12 k
6.	Exposed footings	Cover, add storage	$ 6 k
7.	Siesco DHW, and Power Pipe		$ 2k
		Total	**$ 57 K = 20% of home value**

8. Black Water Holding Tank $10 K, fire fuel wood reduction $ 2K

Benefits: ***Doubled Space, Healthy Air, Significant Annual Energy Savings, Sustainability, & Peace of Mind …….***

Priceless……

ACKNOWLEDGEMENTS: Thank Yous!

To: THC, ACI, & Linda Wigington

Terry Brennan – Lifelong colleague

David Tobiason – Lifelong friend

Dan Boone Craig – Concrete & forming guru

My Tenants

& Kirk W. Turner – My son

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