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

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

Year-round home, 800 ft², 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, Mold, Owner’s Money

Others?
Step 1.
Obvious Needs

Where did we begin?
“A large ice dam damaged the 1st front porch, so the house roof was extended to cover the porch.”

Dripping water.

Roof shingles in very poor shape

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Ceiling: Cathedral Ceiling & Loft Air Leakage
(T-111 Paneling & 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)

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

Floor: OSHA Type1, clay & rock, ledge?

Walls: Uninsulated concrete

Looking southeast
25-year-old rusty natural gas furnace & type B gas vent to roof

- Not much musty smell
- Some suspect visible water damage & mold

Covered rotting wood

Observed liquid water flow

New electric domestic hot water tank

Looking southwest
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

West side
“Semi-functional”
Franklin stove in living room area

Fast internet available

Natural Gas Heat
Blower Door: 23 ACH\textsubscript{50} (including basement)
5,400 CFM\textsubscript{50}  152 in.\textsuperscript{2} ELA
1.55 CFM\textsubscript{50}/ft\textsuperscript{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

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<thead>
<tr>
<th>Item</th>
<th>Options</th>
<th>Ballpark Costs</th>
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<tr>
<td>1. Basement/Moisture</td>
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<td>2. Roof/cathedral ceil.</td>
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<td>3. Bathroom mold</td>
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<td>5. Exposed footings</td>
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<td>6. Windows / Walls</td>
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<td>8. Others?</td>
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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

Natural Gas Usage

Reno. 2008
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 side
**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………?

Pipe & stone were directing surface water into the basement

West side
Drainage

Filter fabric covering drainage layer

West side
South side, with drainage installed
Southeast corner

Inner & outer footer drains joined to common daylight drain under footing
Finished Swale Uphill Side
Finished Slope – South Side

South side

Footing Covered
Basement: Optimize Enclosure (Cont’d)

Excavation by “Strong-Arms”
Looking southeast during excavation

Clay dirt and stones shoveled out window to cover footing
INSIDE Stepped Footing Plan:

Concrete form was temporarily pinned to new footing.

North & South Walls

Single-sided form foundation placement

- Rebar
- 1" foam
- Densarmor Plus™
- Concrete form was temporarily pinned to new footing
- Drainage mat

Epoxied

Drainage mat

Clay soil

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Up-slope West Wall Inside Basement Plan

Concrete grade beam in center

1" foam

Single-sided form

Drainage mat
Health & Safety: Basement Neg. Air “Containment”

Created with

- 2 exhaust 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
Footings: Tree Stump found (Built on solid ground)

Note: Found footings for previous porch that was reported to be removed by ice dam

Added: 2" rigid insulation 2 ft. deep at perimeter

East side storage under porch
East Wall Basement Indoor Storage Plan
(Under covered porch)

Addresses both exposed footer & more warm & dry storage

1% Pitch
Dry, Semi-conditioned, Space Under Porch

All materials:
- Drainable
- Moisture resistant

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

**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

East side
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 treatment

Athletic drying area
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

Black one-part foam for air sealing (applied primarily with 20-gauge needle)
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

2 x 4 Overhung for venting

Pre-drilled 2x4 & 8 inch roof screws
Rigid foam, all joints staggered & taped, “vented roof cladding”

Foam Layers
1.0” EPS
2.0” EPS
1.5” Iso & Foil
4.5”

$12/ft^2
materials & labor
2x6 on Ends

Existing ridge vent covered
New ridge vent added
Plumbing vents to be extended.

Type B gas vent reused to create an exhaust-only ventilation (EOV) system.
1.5" roof cladding venting space
Hardware screen to block insect & critter access
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

$6 \text{ ACH}_{50} \times 1,380 \text{ CFM}_{50} \times 0.34 \text{ CFM}_{50}/\text{ft}^2 \text{ SS}; \text{ ELA 69 in.}^2$

Still 10x Passive House

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)

Heat loss via Logs 3x rest
Comfort Improvement: Now Even Temperature Distribution

Before

Degrees F

After
Ventilation/Mold Fix for Bathroom

Scrub off mold, use “gloss” paint on ceilings

Added bath exhaust
Central Exhaust Only Ventilation

- 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

“Central Exhaust”
Radon-type
20 watt, inline duct exhaust fan
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.?)

Natural Gas Usage - Decatherms

Energy Use/Yr (kWh)
(both Gas & Electric)

Before
39,020 kWh to 16,710 kWh

After

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?

Before

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

After

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 ft² 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](http://www.thousandhomechallenge.org) (Case Studies)

2014 OPTION B Inputs: **FFA:** 1,637 Ft²; 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)

Pre-Retrofit 2007 (39,020 kWh)
Post-Retrofit 2009 (22,310 kWh)
Post-Retrofit 2014 (16,397 kWh)
Prorated OPTION B Threshold (12,221 kWh)

OPTION B Assumptions: FFA: 1,637 Ft²; 8,876 HDD; 6 months: 2 households, 4.5 occupants; 6 months: 1 household, 2.5 occupants
How Are We Doing?

Total Energy Use
(in kWh/yr.)

To Meet 1,000 Home Challenge

Option B = 12,221 kWh

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**

**Neighbors Tree**

128 ft² 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 ????)

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Solar Performance

Solid Line: °F solar storage tank
Dotted Line: °F 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.

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)
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:**


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)

![Energy Use Chart]

- **Gas ((kWh))**
- **Electricity**
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
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???
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

toilet wax seal replaced 2x

The culprits

pick axe through sanity drain pipe
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 $0.5 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 $2 k

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
          Graduated Western Washington University
          Industrial Design & Sustainability Program

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