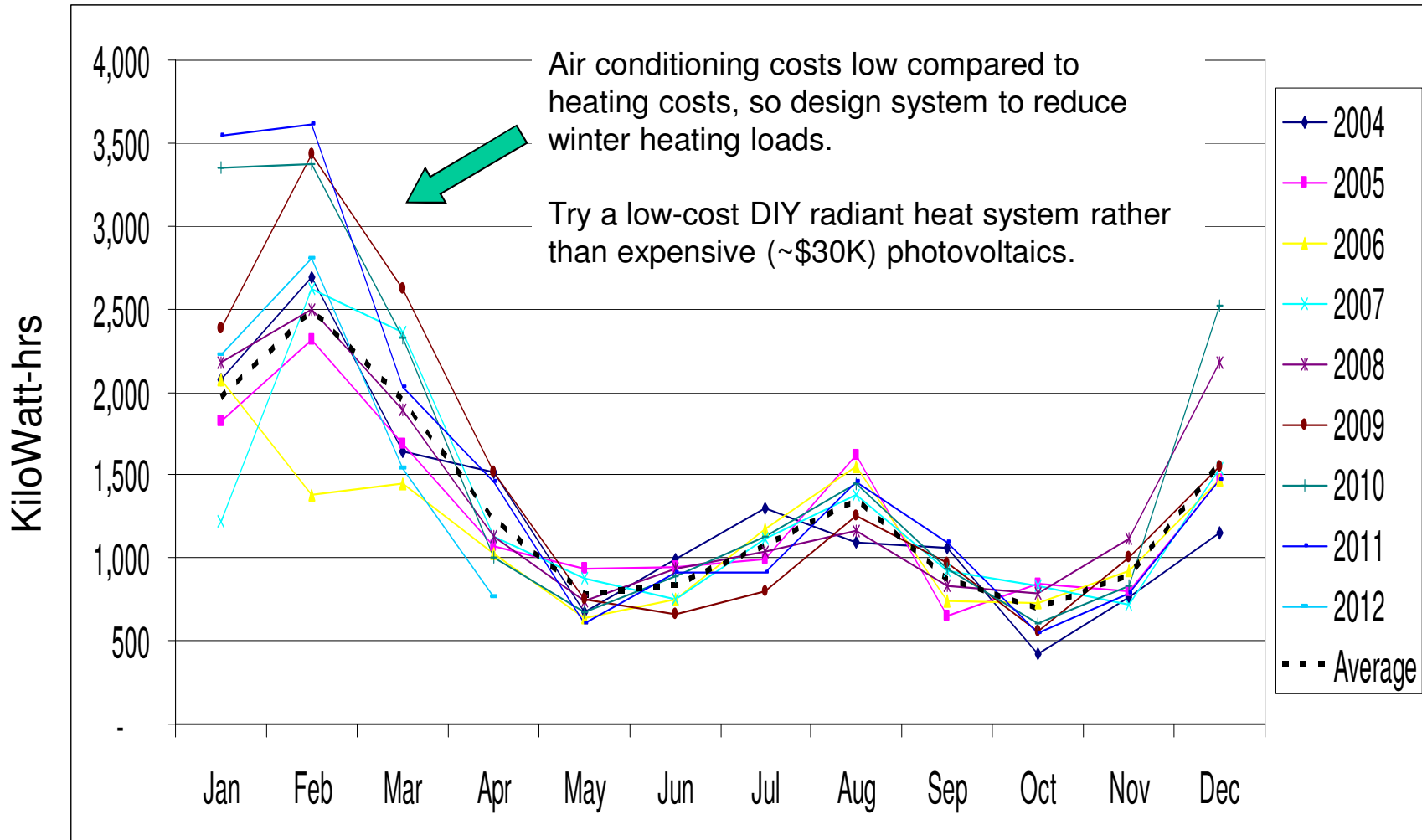# Do-it-yourself Solar Thermal Heating Project- Poquoson, VA
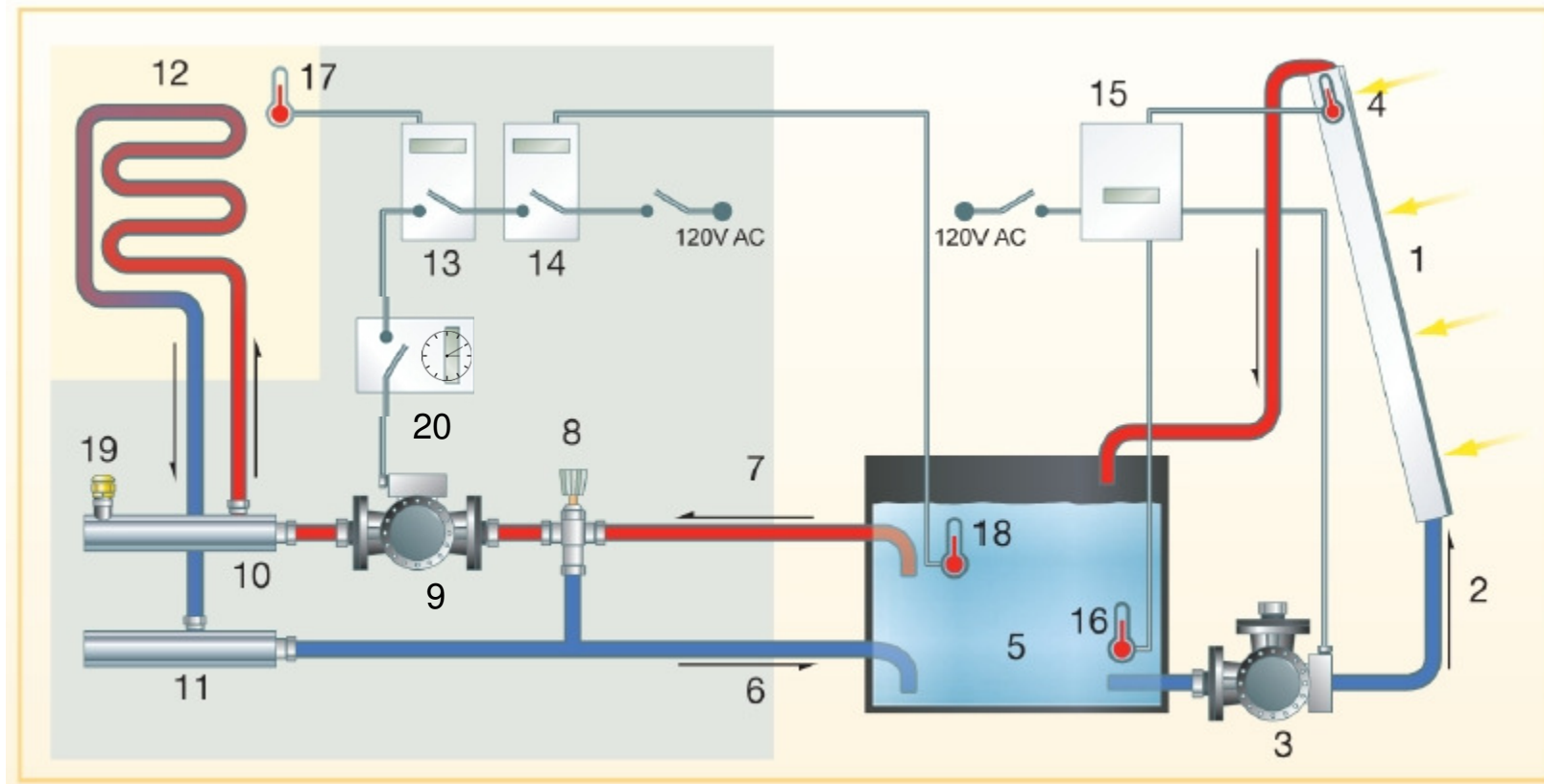
July 2011 – April 2012

Motivation for Project

1. Explore solar technology, benefit from tax incentives
2. Exercise my engineering skills
3. Be productive rather than watching TV
4. Improve comfort while watching TV, etc.

Electric Power Consumption

Air conditioning costs low compared to heating costs, so design system to reduce winter heating loads.

Try a low-cost DIY radiant heat system rather than expensive (~$30K) photovoltaics.

Y-axis: KiloWatt-hrs (4,000; 3,500; 3,000; 2,500; 2,000; 1,500; 1,000; 500; -)

X-axis: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec

Legend: 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, Average

System Block Diagram*
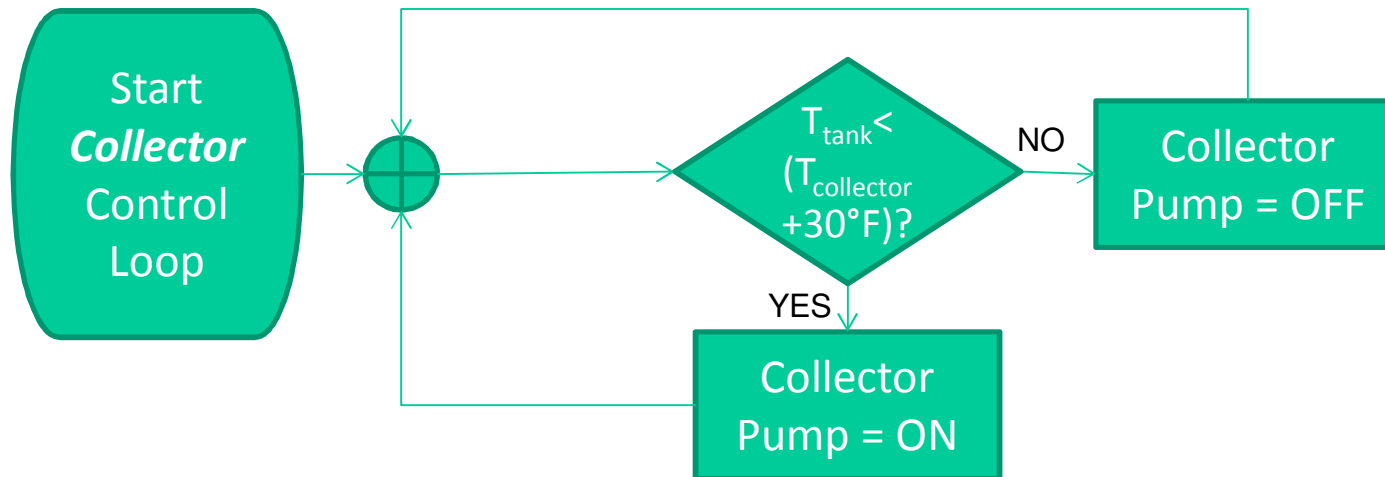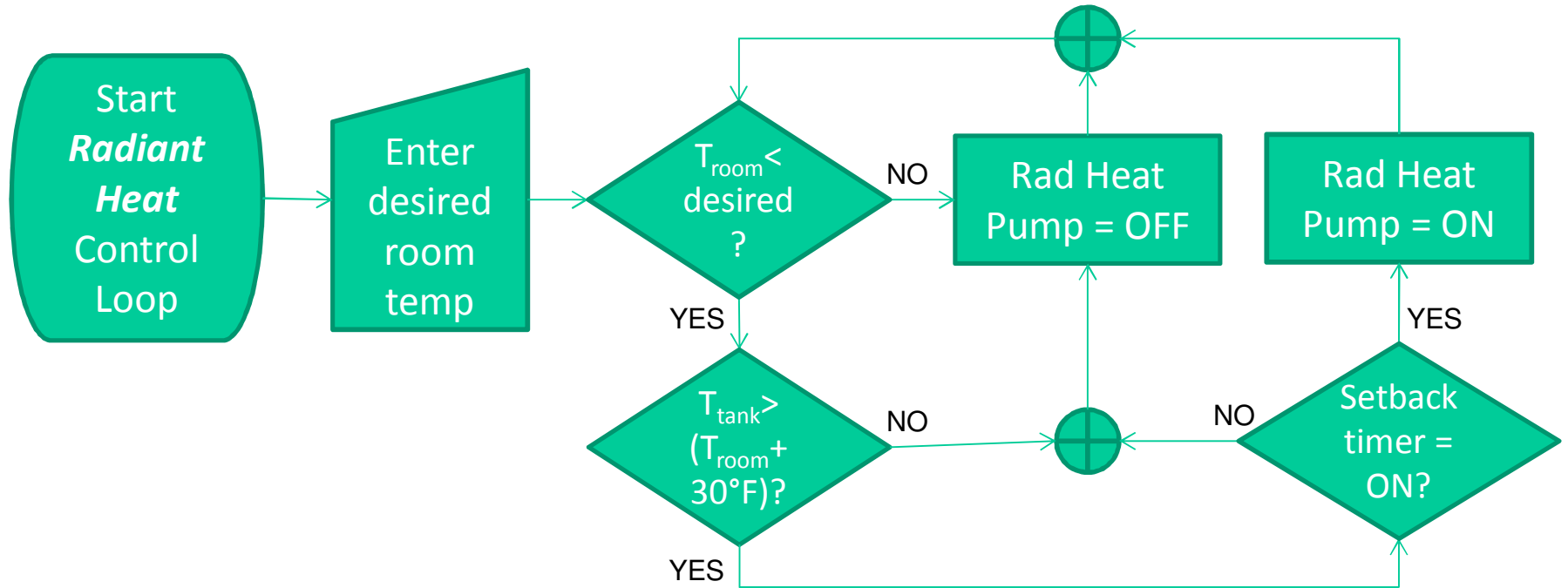

Radiant Heat System**   Thermal Reservoir   Solar Collector System

*Design from www.BuildItSolar.com. See part list at end of charts.
** Analyzed using Uponor Advanced Design Software

Theory of Control

Start *Radiant Heat* Control Loop → Enter desired room temp → $T_{room} <$ desired ?

- NO → Rad Heat Pump = OFF
- YES → $T_{tank} > (T_{room} + 30°F)$?
  - NO → Setback timer = ON?
    - YES → Rad Heat Pump = ON
    - NO → Rad Heat Pump = OFF
  - YES → Rad Heat Pump = ON

Start *Collector* Control Loop → $T_{tank} < (T_{collector} + 30°F)$?

- NO → Collector Pump = OFF
- YES → Collector Pump = ON

3D CAD Model-

Google SketchUp

Radiant Heat Circuits-
family room, kitchen, laundry room, ½ bath
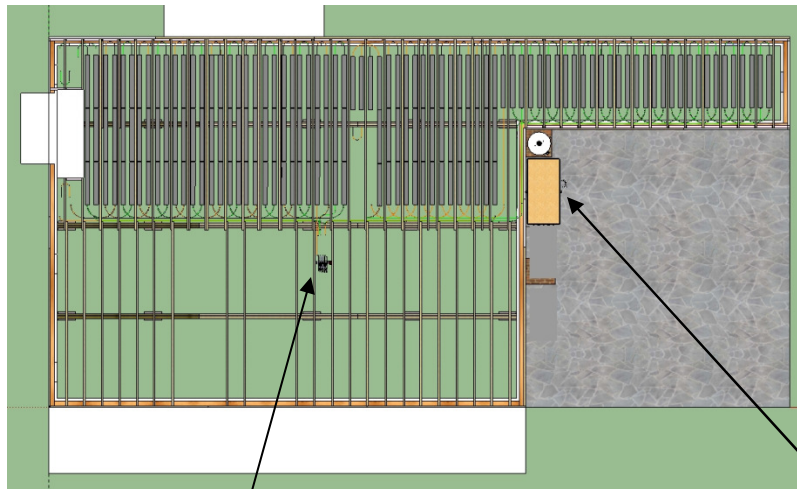
Collector Panels

Radiant Heat Manifold

Reservoir, Circulators & Controllers
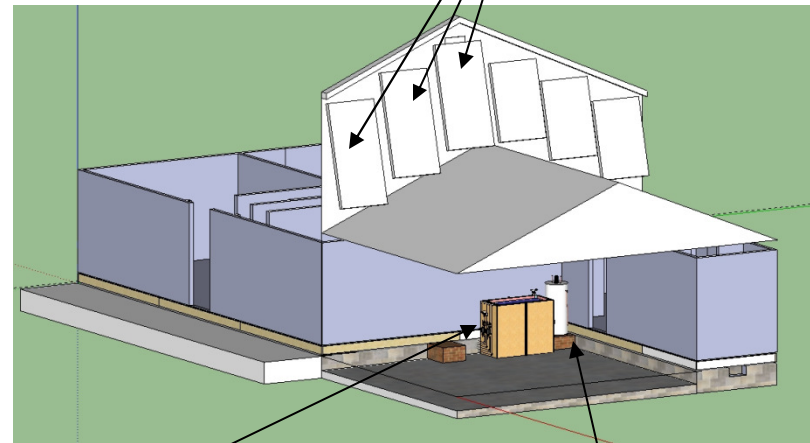
Hot Water Heater (ref only)

Solar Collector Installation-

15° East of True South, 15° Elevation* from Horizontal

Before

After

*vertical orientation maximizes collection in winter, minimizes in summer when unused

Reservoir Installation in Garage

- 250 gal of tap water
- Vented to atmosphere

Before

After

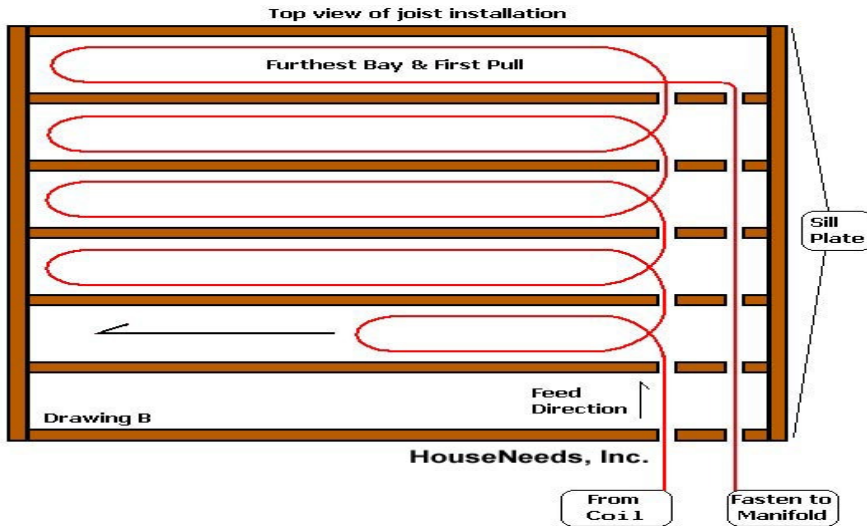# Radiant Heat Distribution Manifold Installation in Coat Closet

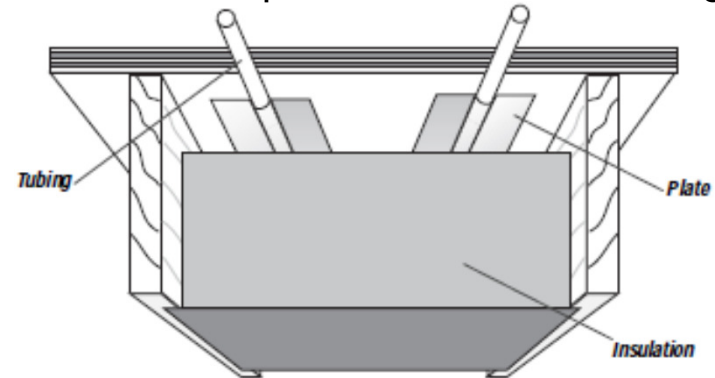Manifold Shutoff Valves, 2 places

Circuit Flow Adjustors

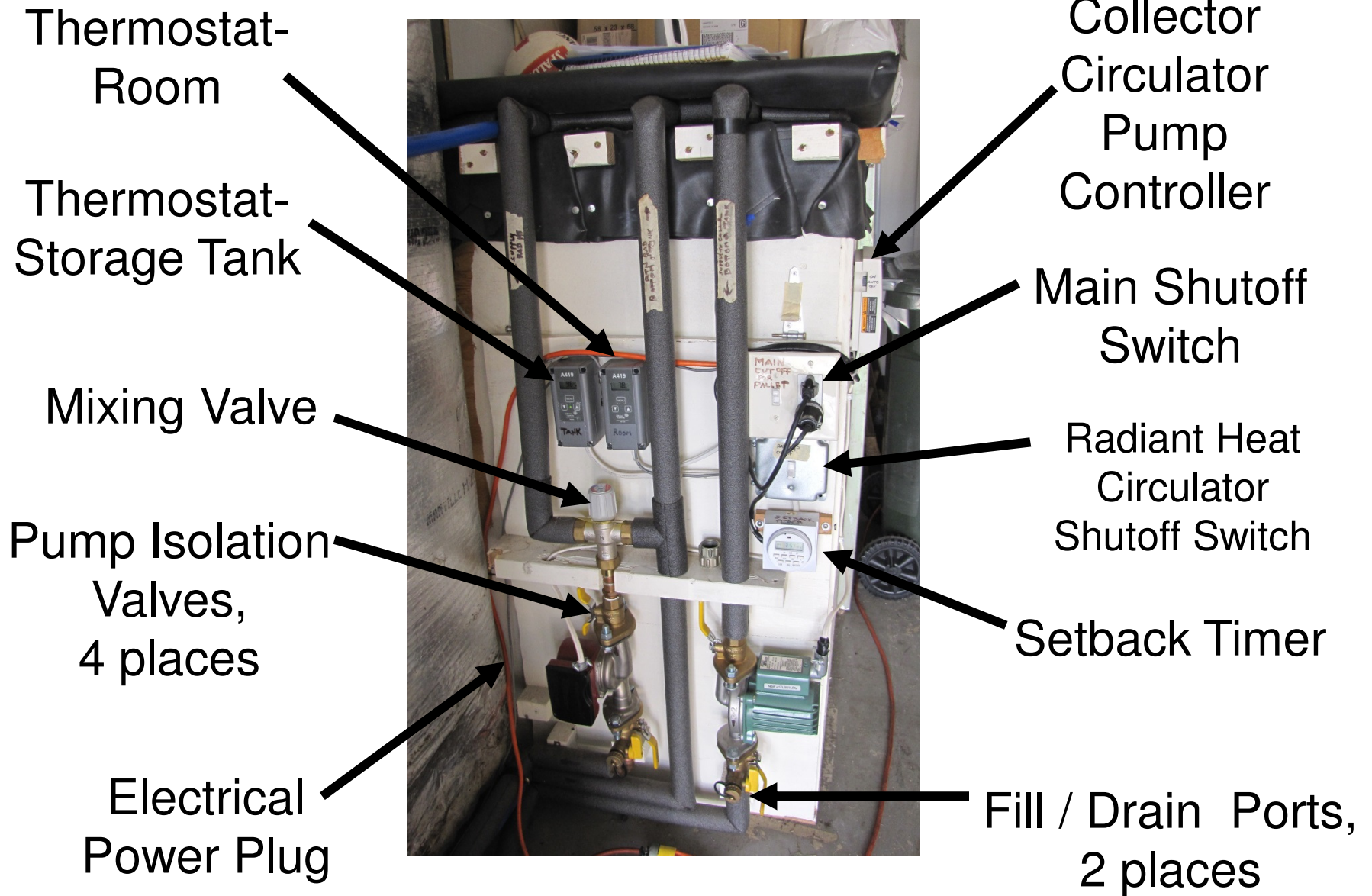Pressure Pump for initial leak check only

Radiant Heat Installation:

610 sq ft: 2 Loops in Family Room, 1 in Kitchen, 1 in laundry room / bathroom

Top view of joist installation

Furthest Bay & First Pull

Sill Plate

Feed Direction

Drawing B

HouseNeeds, Inc.

From Coil

Fasten to Manifold

Joist Trak plates for ½" PEX tubing

Tubing

Plate

Insulation

Operator Interfaces

Thermostat-Room

Thermostat-Storage Tank

Mixing Valve

Pump Isolation Valves, 4 places

Electrical Power Plug

Collector Circulator Pump Controller

Main Shutoff Switch

Radiant Heat Circulator Shutoff Switch

Setback Timer
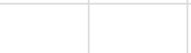
Fill / Drain Ports, 2 places

Project Management

- 9 month duration
- $6,565 material costs
- 288 man-hours,
  - Essentially by a single worker
  - Online research time was significant, but is not included

Timeline of Project

Task description	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12
Go ahead decision	▲										
Install Radiant Heat System		███	███	███	███	███					
rmv underfloor insulation. Instl band joist insul, diffuser plates, pex pipe, manifold, 6" underfloor insul											
Fab & Install H20 Reservoir in garage						███					
Fab copper pipe grid assys for collectors							███				
Fab circulator panel assy, instl lines to Rad Heat manifold								███			
Fab collector assys											
Instl collectors, lines to reservoir									███	███	
1st water thru Collectors & Rad Heat Sys										▲ ▲	
Insulate collector lines. Instl lid on reservoir											▲

Cost of Materials = $6,565

Consumables, $289.84

Floor Insulation (incl labor), $937.48

Circulator Sys-Collectors, $865.12

Solar Collector Instl Hdwr, $218.83

Solar Collectors Assys, qty=3, $1,230.35

Tubing/ Joist Track Instl, $1,862.50

Reservoir, 250 gal, $513.22

Circulator Instl-Rad Heat Sys, $647.83
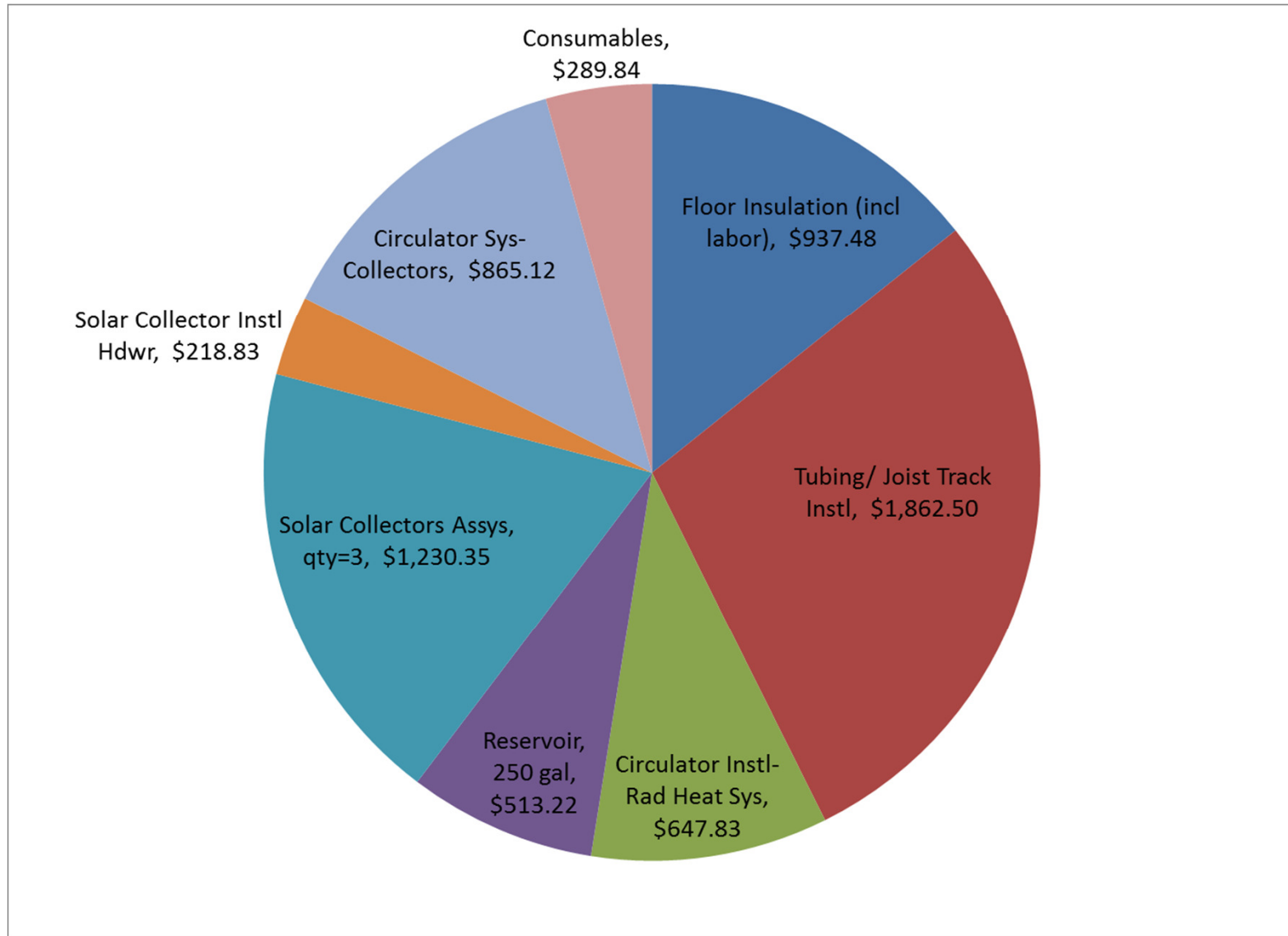
Manhours

- 4 hrs / day worked, over 73 work days, by a single workman
- Band joist insul = 12.0 hrs for 95.5 linear ft = 8 linear ft / hr
- Rad heat instl = 73.9 hrs for 610 sq ft = 8.3 sq ft / hr
- Instl Manifold Feed Lines = 13.0 hrs
- Fab collector assemblies = 59.2 hrs = 19.7 hrs / assy
- Installation collector assemblies = 35.8 hrs = 11.9 hrs / instl
- Fab Reservoir = 20.7 hrs
- Fab Circulator Pallet = 42.0 hrs
- Collector Plumbing = 19.1 hrs

Total labor = 288 man-hrs

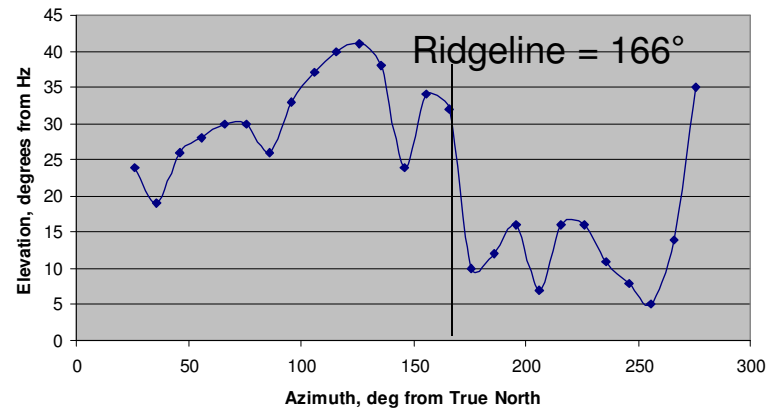# Performance of System:

- Predicted performance of Collectors and Radiant Heat System
- Data collection
- Analysis
  - Collection efficiency: overall, seasonal
  - Heating of house
  - Cost recovery
  - Reliability and Maintainability

Solar Obscuration Measurements

June 2011, 5' above ridgeline of garage roof, x = 4' out from 2nd story wall
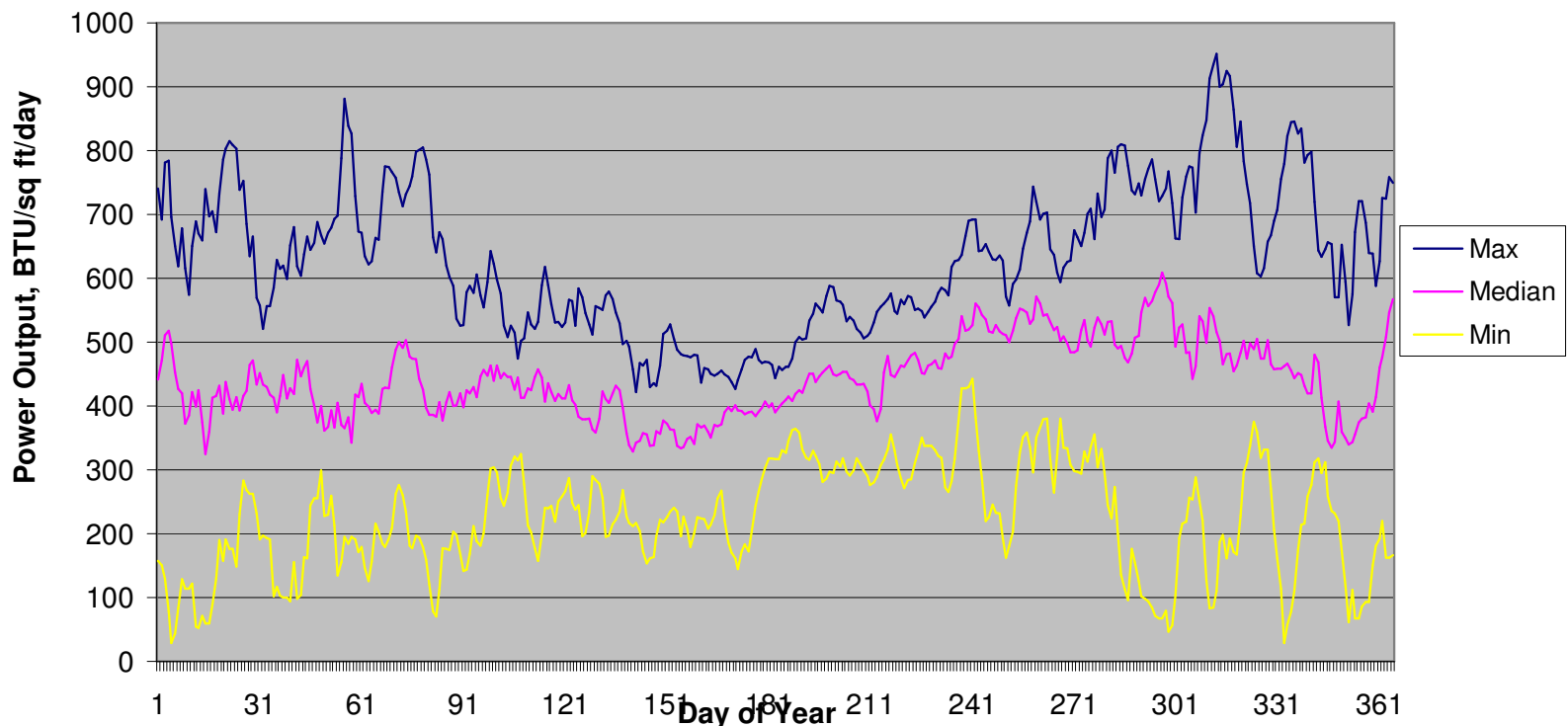

Trees on Property Line

Our Trees

Neighbor's Tree

Predicted Energy Gathering

from comparable commercial collector

Norfolk Intl Airport, Viessman Vitosol 200F Power Output vs. Season
Moving Average of Previous 10 days,
T in=113F, T out=122F, Collector Az=-15 deg, Collector Elev=75deg,
1991-2005 Average = 442 BTU/sq ft/day

For three 4'x8' collectors = 42,432 BTU/day

Predicted Heating Performance

- Calculated using free Advanced Design Suite software from Uponor
  - 68°F room temp, 24°F outdoor temp, 23 mph wind
  - 630 sq ft, average construction, Tin-Tout≤10°
  - 7,540 BTU/hr required = 1.8 gal/min @ 109°F
- Given predicted collector performance of 42,432 BTU/day, we'll get 5.6 hrs of 68°F room temp each day.
- Existing heat pump runs in parallel.
  - Solar heat setpoint 2° above heat pump to draw from solar first
  - Degree of interaction unknown

Data Acquisition System

- Solely for initial testing, the removed
- Arduino based data logger
  - Real Time Clock for time stamping
  - SD Card Reader module for data storage
  - Cost approximately $60
- Dataset includes
  - Temp of room
  - Temp of H20 in Reservoir
  - Outdoor Temp
  - Temp in Garage
  - Insolation on Collectors
  - Radiant Heat Status (ON/OFF)
  - Time of day

Design Flaw = Freeze Up

Burst, 3 places

Flawed Design

Corrected Design 7-28-2013

Drain back level

Trap precludes breaking siphon, therefore NO DRAIN BACK!
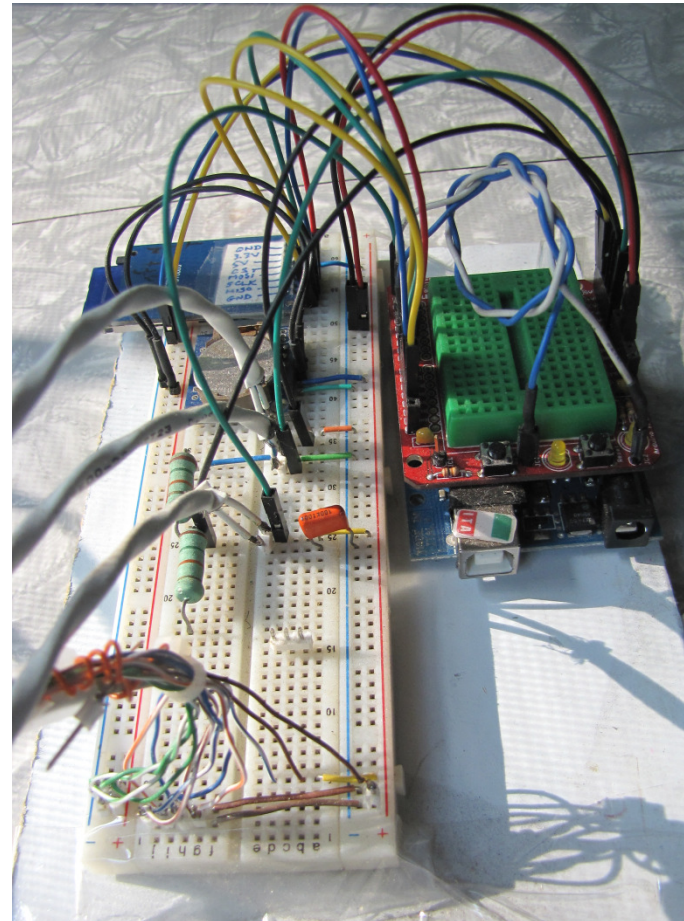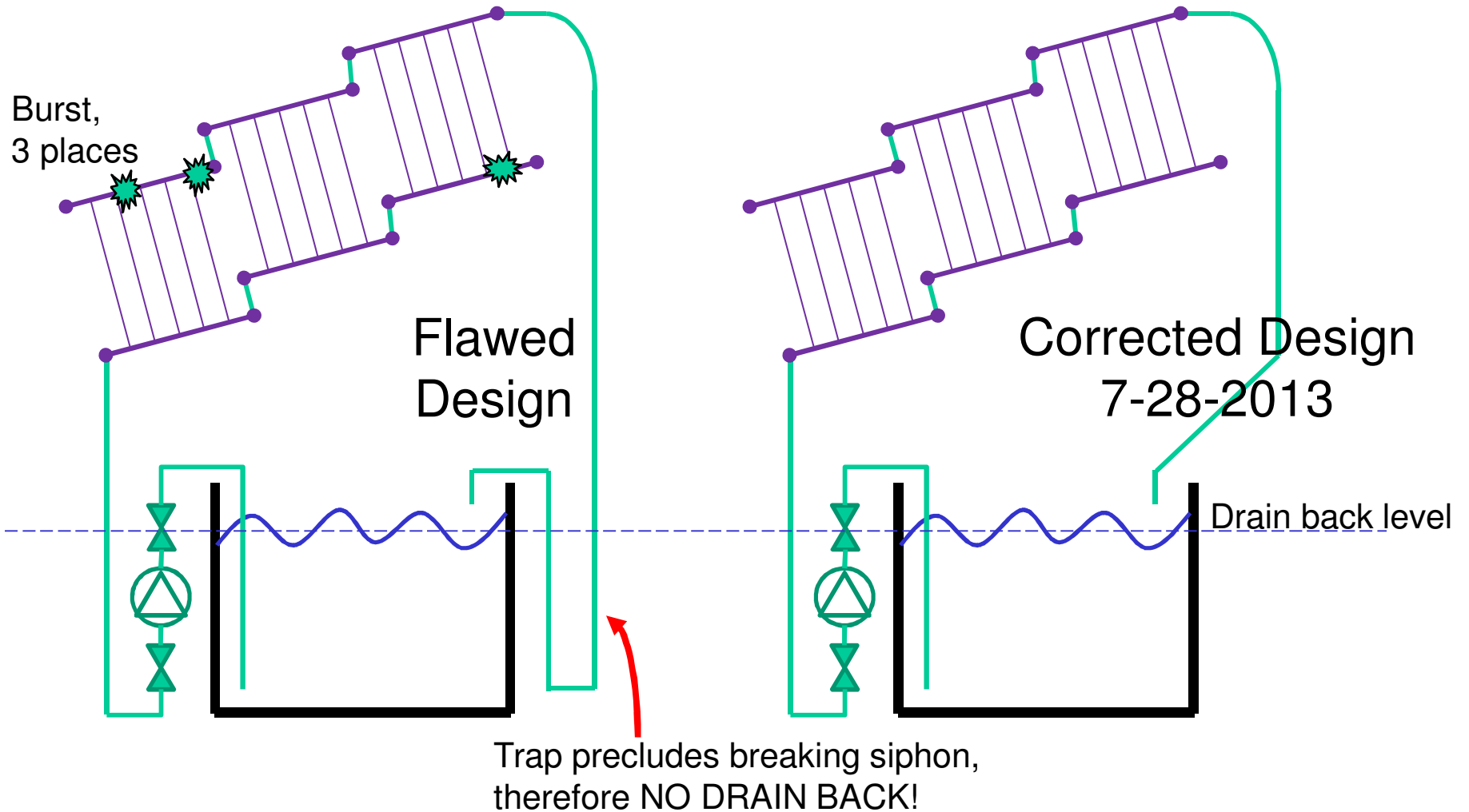
- 23 Jan 2013 Overnight temp = 18 deg F
- Eastern & western collectors froze & split pipes. No leak in center collector.
- Pumped tank dry

Measured Collector Performance

- No heat draw from Reservoir (Rad ht OFF)

- Measure on cloudless days, no leaves on trees

- Heat gain = (Temp rise of tank) x (vol tank) x (density water) x (heat capacity of water)

12 March 2012:
Heat Gain = (100°-74°)x(250 gal)x(62 lb/cu ft)x(1 BTU/lb/°F)
            =48,360 BTUs / day = **504 BTU / sq ft / day**

9 Nov 2012: 510 BTU / sq ft / day

vs. predicted avg of 450 BTU / sq ft / day. *Pretty Good!*

Measured Heating Performance

- Works well in spring and fall- no heat pump at all!

- Unclear about winter. Interaction w/ heat pump unclear, still figuring out ramp-up / down times

- Added set-back timer to heat rooms only in afternoon & evening

- With reservoir temp around 120°F, looses ~6° / night with unheated garage @ 50°

Was Project Successful?

1. *Explore solar technology, benefit from tax incentives*
   - Learned much about solar technology, only got minimal tax break for insulating floor
2. *Exercise my engineering skills*
   - YES! Design / build / test of plumbing, electrical, carpentry, controls, data logging
3. *Be productive rather than watching TV*
   - Yes. Watched little TV during the project
4. *Improve comfort while watching TV, etc.*
   - Yes. Den / kitchen was 60-62°F in winter, now 66-68°F

Items in Block Diagram

Item #	Description	Make	Model	Cost
1	Solar Collector	self	self	$ 483.00
2	Tubing	PEX	3/4 diam	$ 0.46
3	Pump, Collector	Taco	009-SF5	$ 326.00
4	Sensor, Coll'r Temp	incl w/ Steca	-	-
5	Water	God	Tap	-
6	Tubing	PEX	3/4 diam	$ 0.46
7	Tubing	PEX	3/4 diam	$ 0.46
8	Valve, Mixing	Honeywell	AM101-US-1	$ 75.00
9	Pump Rad Ht	Grundfos	UP15-29SF	$ 164.00
10	Manifold, Supply	RHT	FN5-4-90	$ 129.00
11	Manifold, Return	incl w/ supply mfld	-	-
12	Rad Ht Loop	PEX & Joist Track	1/2 diam	$0.89 / ft
13	T'stat, Tank	Johnson Controls	A419ABC-1C	$ 56.75
14	T'stat, Room	Johnson Controls	A419ABC-1C	$ 56.75
15	Controller, Collector	Steca/Solene	TR 0301 U	$ 187.00
16	Sensor, Tank Temp	incl w/ Steca	-	-
17	Sensor, Room Temp	?	RTD, 1000Ω	$ 10.00
18	Sensor, Tank Temp	?	RTD, 1000Ω	$ 10.00
19	Valve, Flow Cntl	incl w/ supply mfld	-	-
20	Timer, Temp Setback	Amazon.com	7 day	$ 20.00