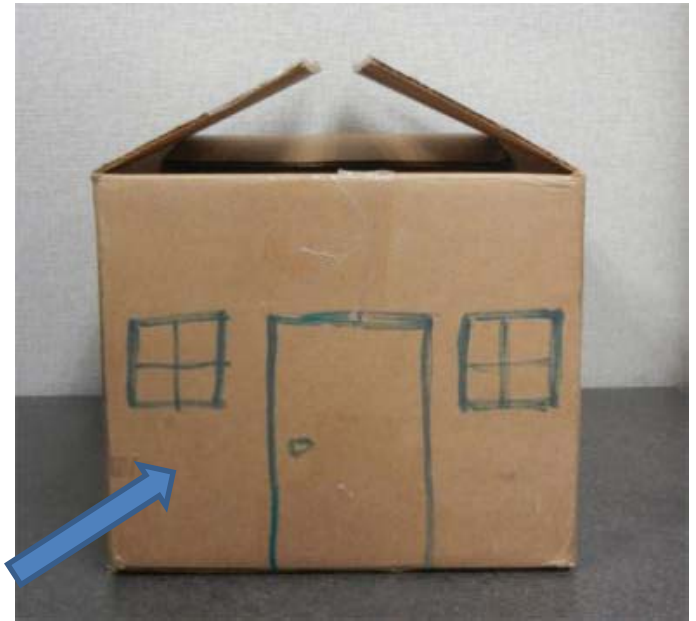


Think <sup>About</sup> ~~Outside~~ the Box



Better Building Design

Paul Westbrook May 2012

# Outline



- Why Is This Important?
- Efficiency First
- Building Design Factors
- Results/Data
- Renewable Generation
- Tips for Existing Homes

# Sustainability Diagram

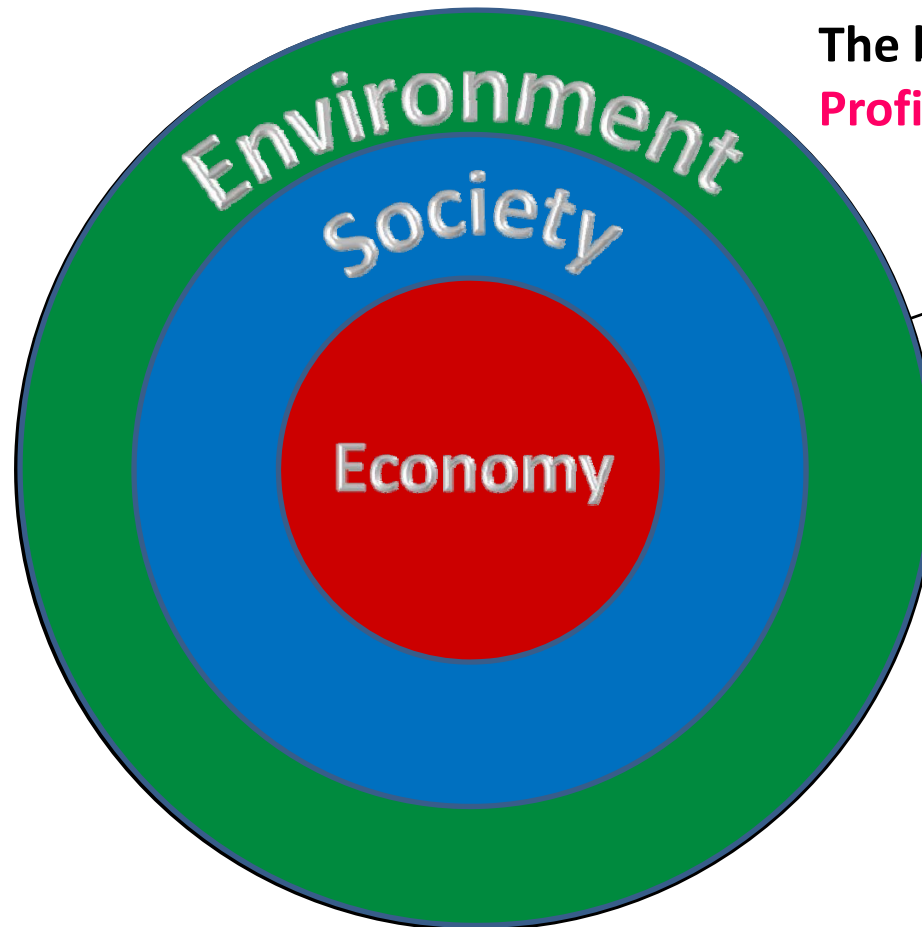


## Environmental Sustainability

Ecosystem Integrity  
Carrying Capacity  
Biodiversity

## Economic Sustainability

Growth  
Development  
Productivity



The balance of **People**,  
**Profit**, and the **Planet**

**Human Well-Being**

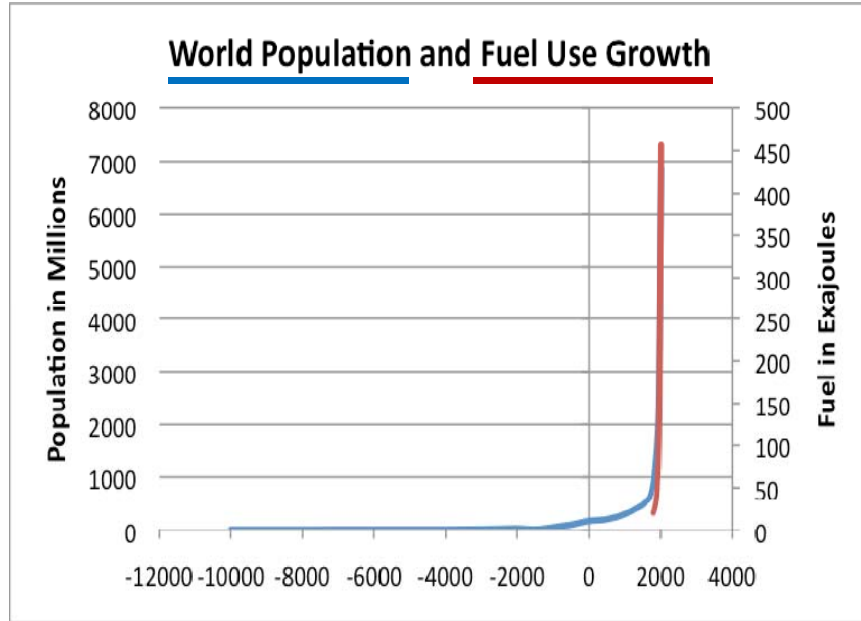
## Social

## Sustainability

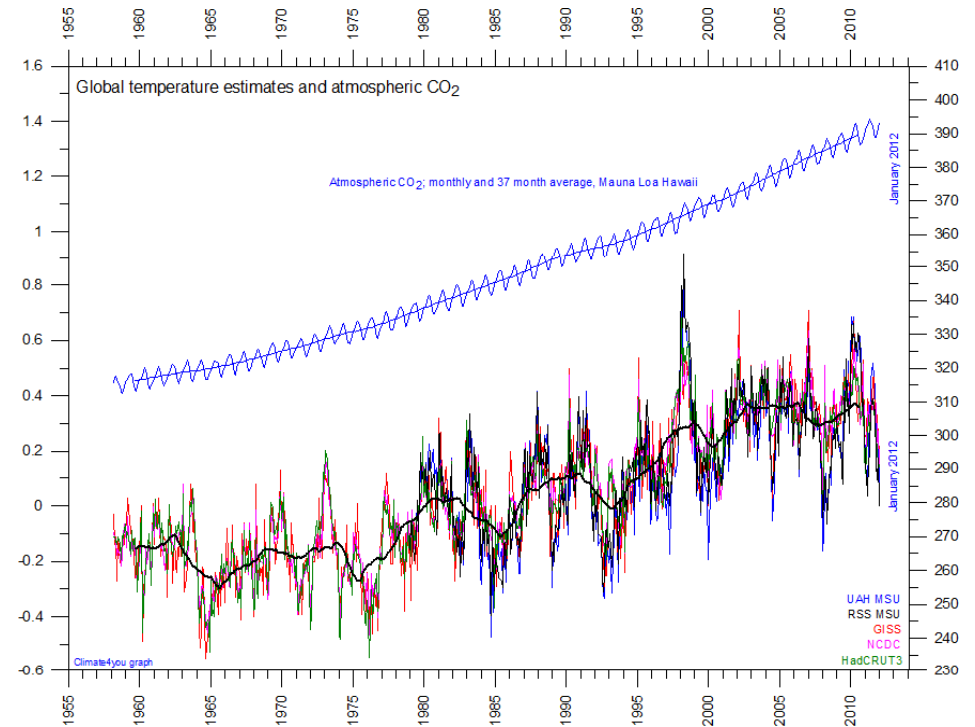
Cultural Identity  
Empowerment  
Accessibility  
Stability  
Equity

*A sustainable system delivers services without exhausting resources. It uses all resources efficiently both in an environmental and economic sense.*

# Why Should I Care?



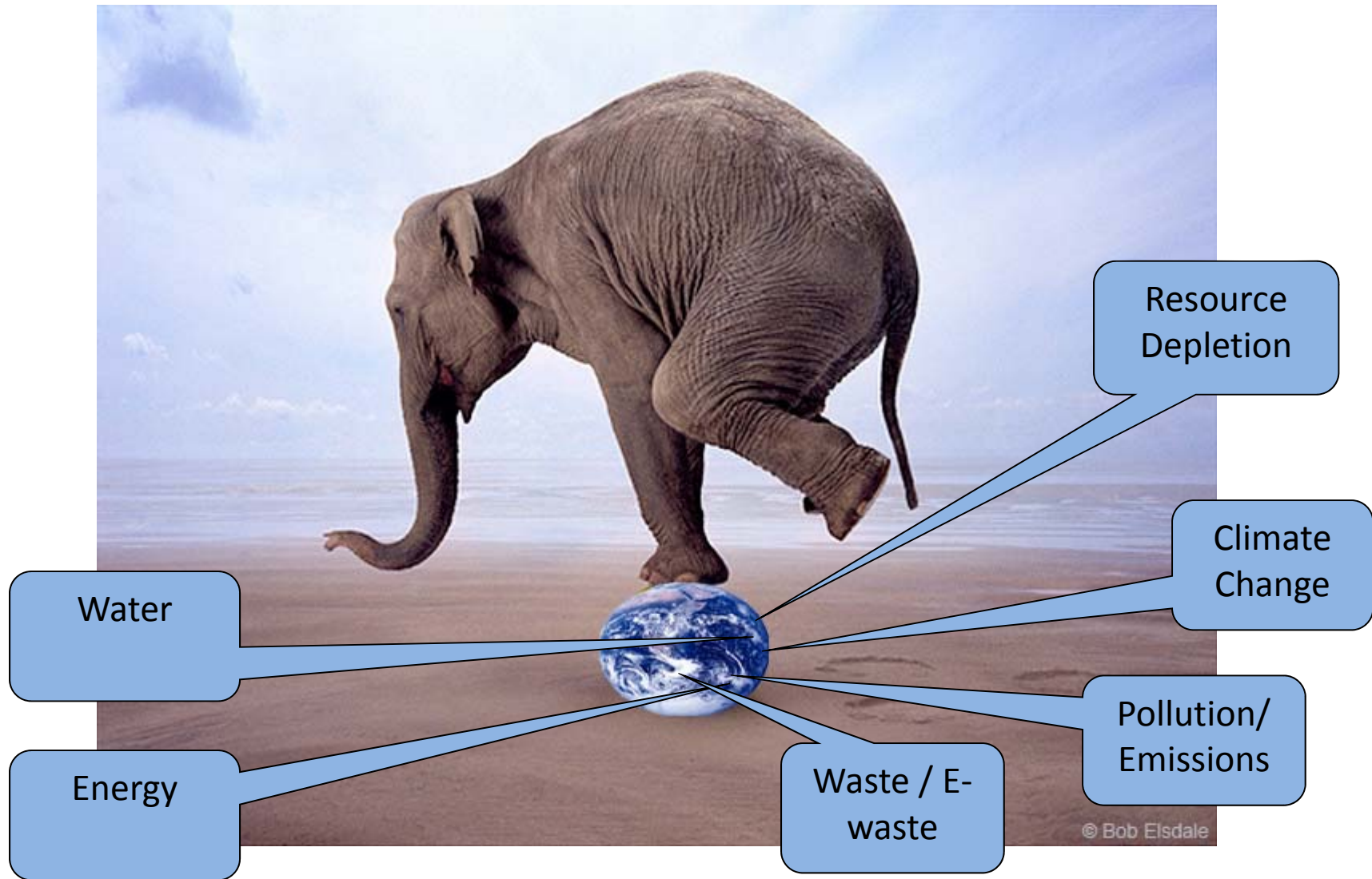
World population from US Census Bureau, overlaid with fossil fuel use (red) by Vaclav Smil from Energy Transitions: History, Requirements, Prospects



Motivation: Provide enough water, food, shelter, and energy to a growing population – including yourself.

“Motivation is what gets you started. Habit is what keeps you going.” – E. James Rohn

# Global Footprint Issues



# Efficiency - The Negawatt



**Negawatt** (n) - a measure of energy efficiency; a unit in watts of energy saved

Solar and wind may be sexy . . .

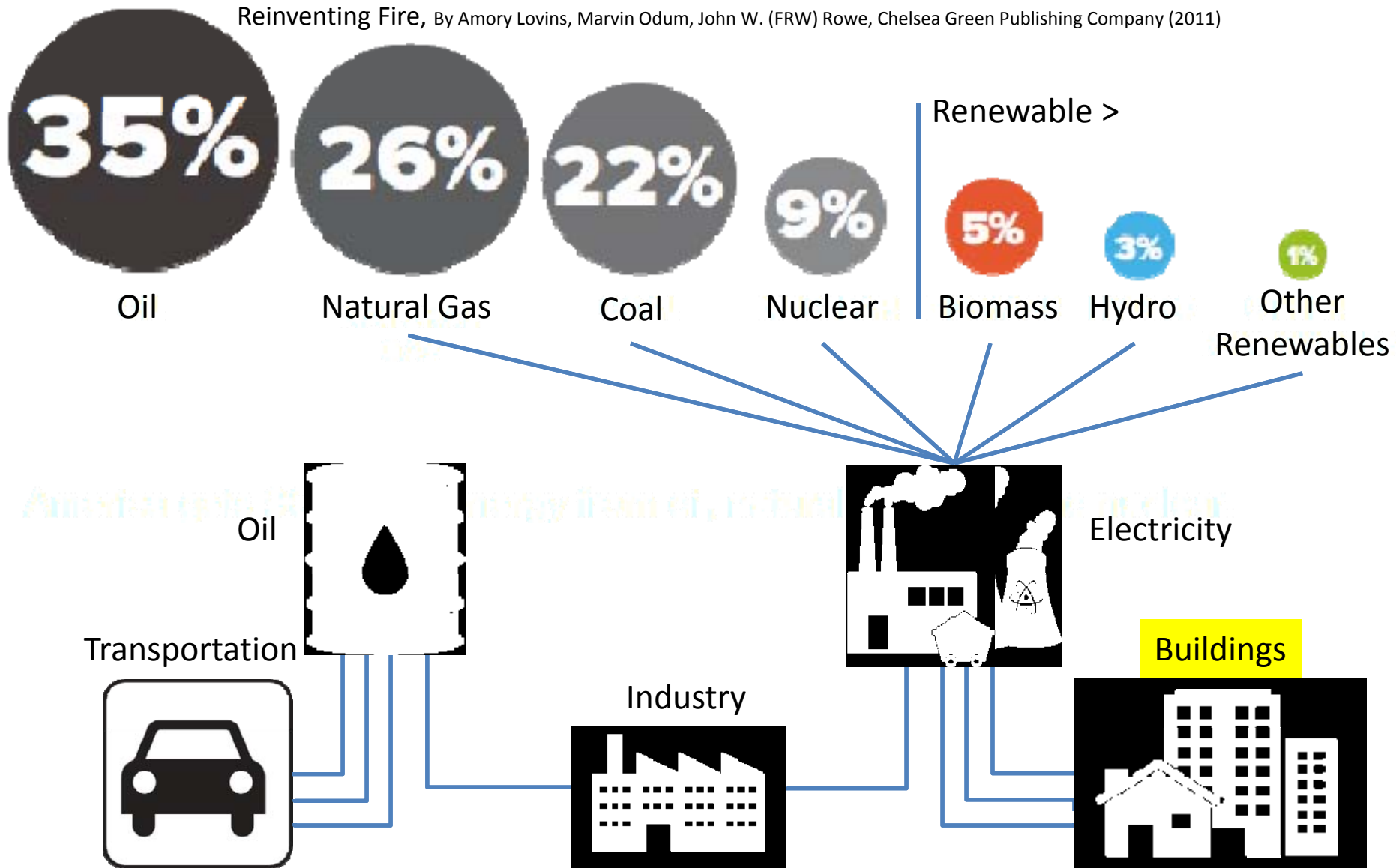


. . . but **efficiency** yields the best **financial** and **environmental** benefits



# US Energy Mix

Reinventing Fire, By Amory Lovins, Marvin Odum, John W. (FRW) Rowe, Chelsea Green Publishing Company (2011)



# The Box = A Building



- We spend 90% of our lives in buildings
- Buildings use 73 % of all electricity produced
- Buildings use 14 % of all water consumed
- Buildings use 40 % of all raw materials
- Buildings produce 38 % of all CO2 emissions







# Better Box Design Goals

- Energy, Water, and Resource Efficiency
- Low Environmental Impact (Sustainable)
  - Reduce – Reduce the need for utilities and materials
  - Reuse – Make use of “waste” for other purposes
  - Recycle – Use recycled products to close the loop
- Low Maintenance
- Affordable / Cost Effective



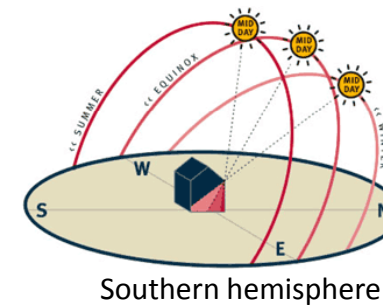
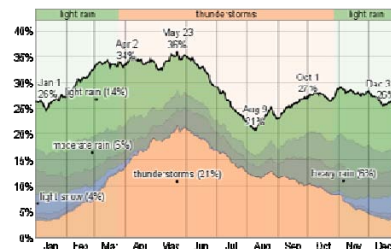
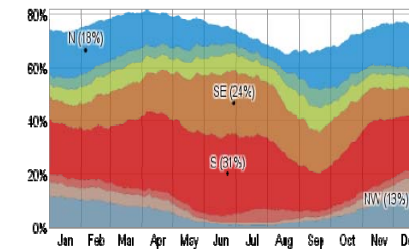
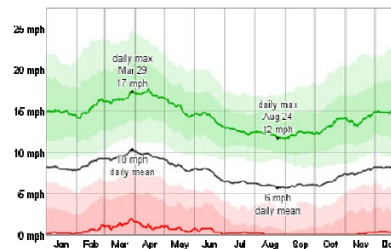
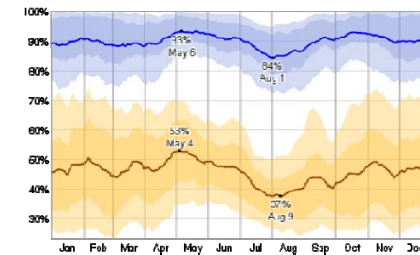
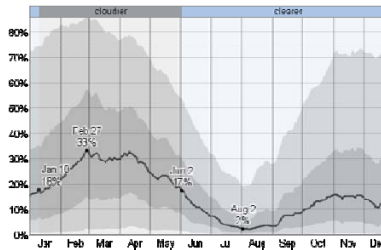
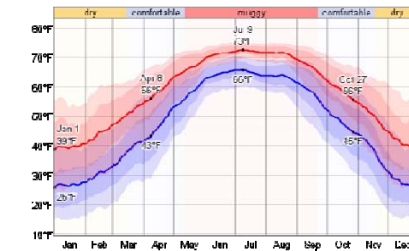
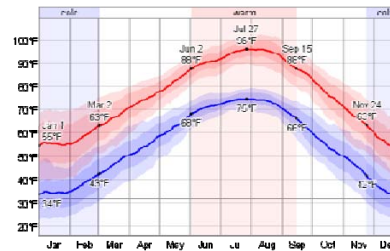
# Design Methodology

- Site Selection, Placement & Orientation
- Structure Size/Shape/Materials
- Window & Door Selection/Location/Placement
- Heating, Ventilation, and Air-Conditioning (HVAC)
- Water Heating / Water Efficiency
- All the Little Things
- Renewable Energy

# Location, Location, Location



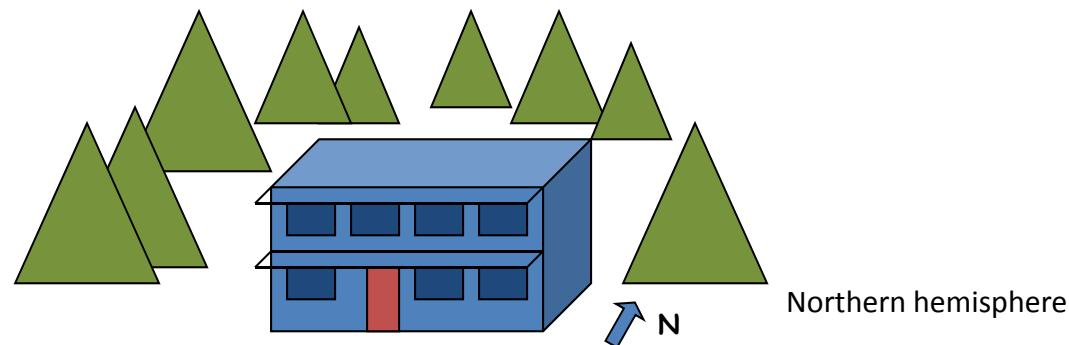
- Climate
  - Temperature
  - Humidity
  - Degree Days
  - Cloud Cover/Sun
  - Rain
  - Wind speed
  - Wind direction
  - Elevation
- Latitude
  - Sun path



# Site / Placement / Orientation

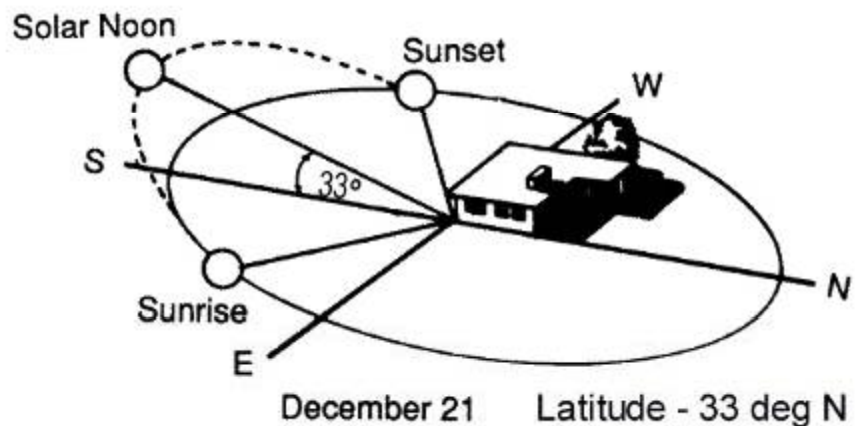


- Good southern exposure / evergreen trees to the north and west
- Preferably an east-west street (front of the building facing north or south)
- Long axis of the building running east-west
  - maximizes southern solar exposure
  - minimizes east and west solar exposure

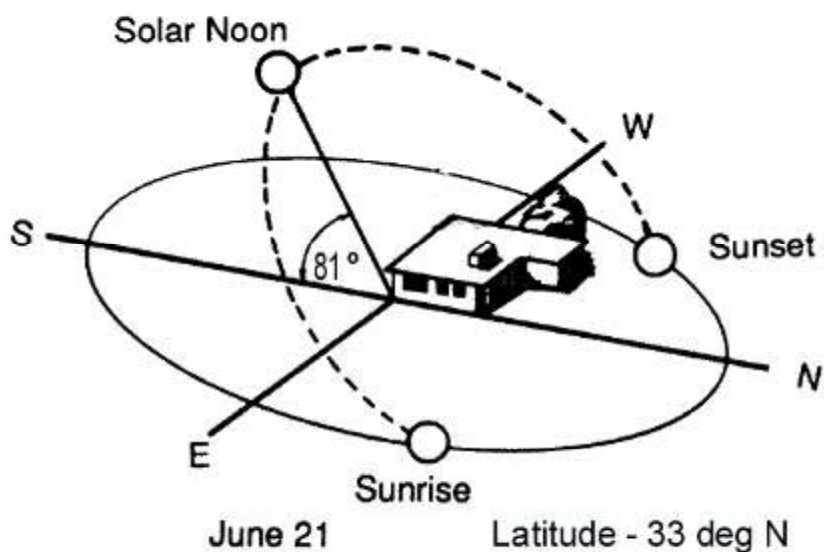




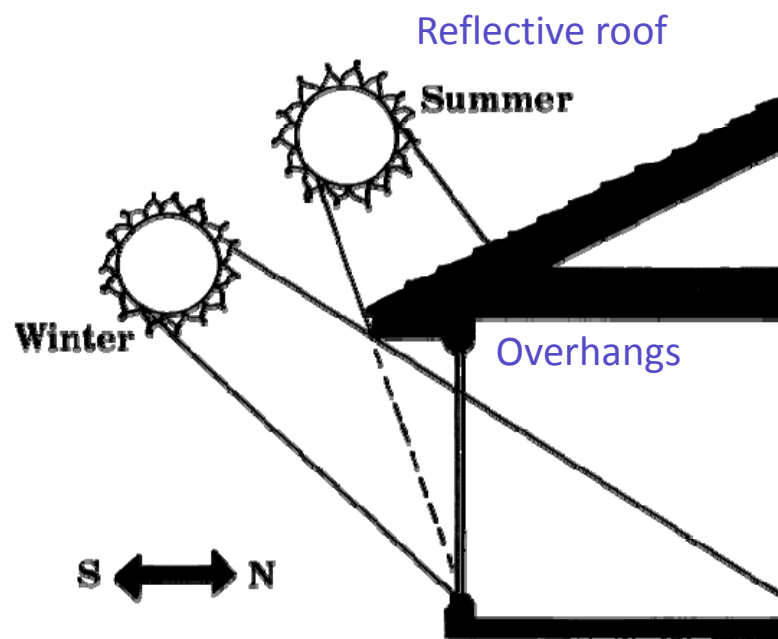
# Passive Solar



- ❖ Orientation
- ❖ Solar Control
- ❖ Mass and Insulation



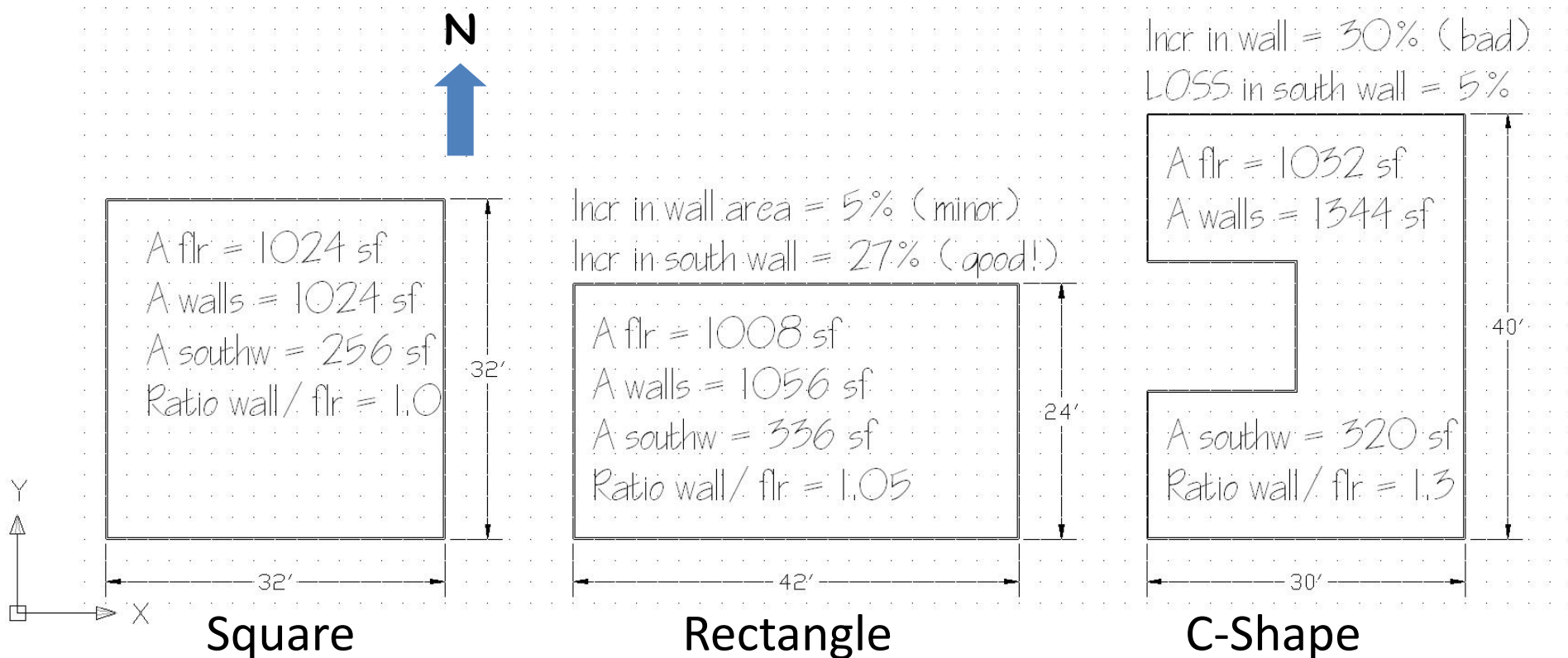
Minimize E & W windows





# Structure Shape Comparison

- The shape and orientation of the house can affect energy use by approximately 30%



# Structure Size/Shape/Material



- A 2-story rectangle is a space efficient and practical plan
- Structural Insulated Panels (SIPs) for the walls and roof offer several advantages
  - Very little air infiltration
  - Good, consistent insulation value
  - Thermal bridging is underestimated in stick built construction
  - Cost effective

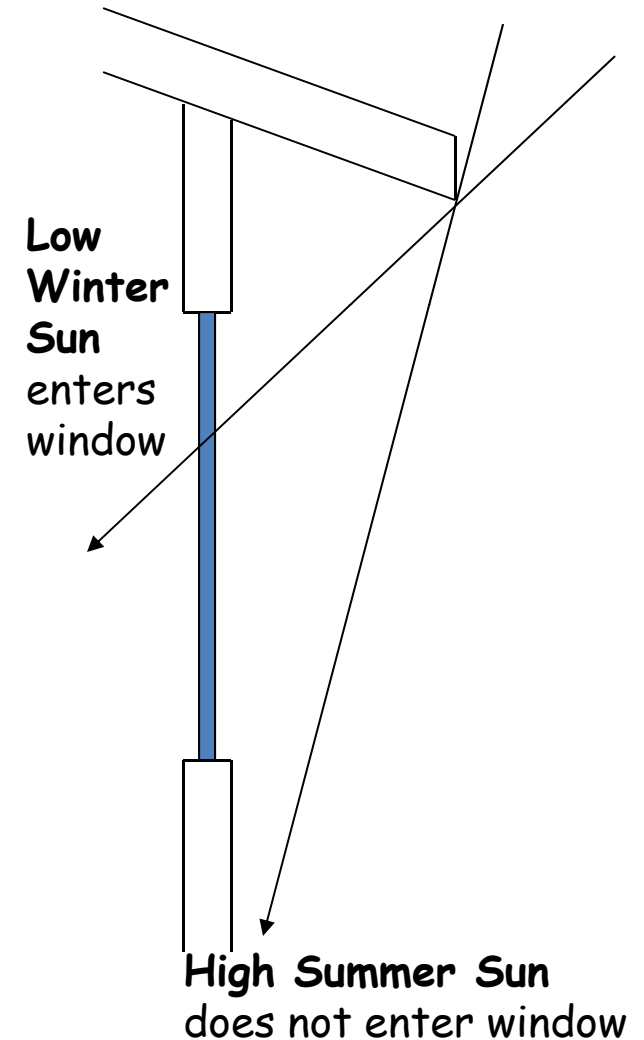
- ❖ 6" wall=R26,  
8" roof=R33
- ❖ Prefabricated in large sections off site, minimizing on-site erection time, crew size, and waste.



# Windows & Doors



- Use double-pane, argon-filled, low-E units (or better).
- I prefer vinyl for the low-maintenance and thermal performance. Fiberglass is best, but more expensive.
- The majority of the windows should be on the south (60%+), the next most on the north, with as few as possible on the E&W.
- Placement and overhang size are critical.







Photos at solar noon:



Winter solstice (left)

Equinox (lower left)

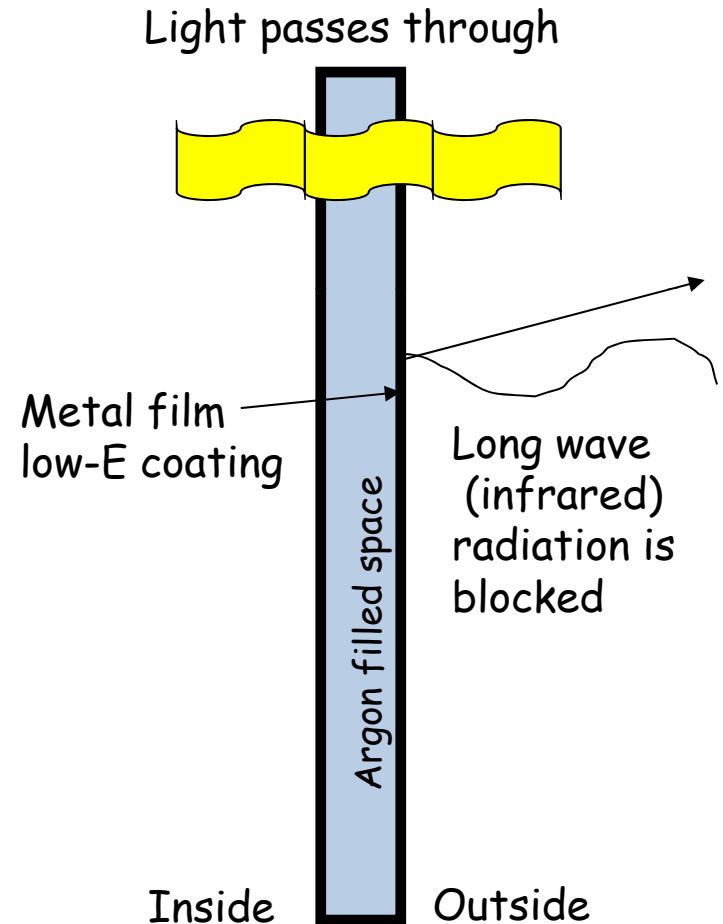
Summer solstice (below)



# Window Science



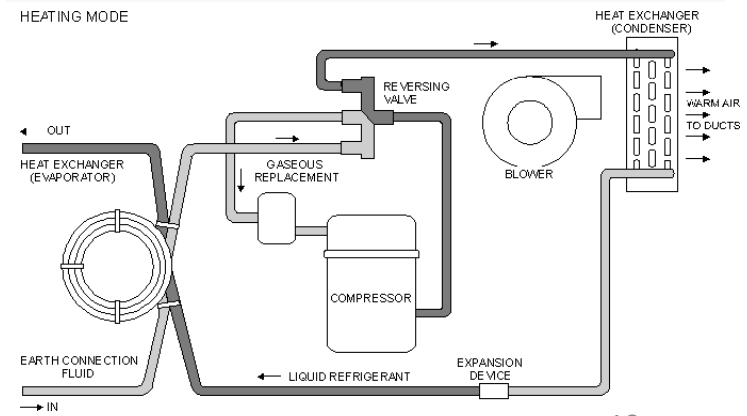
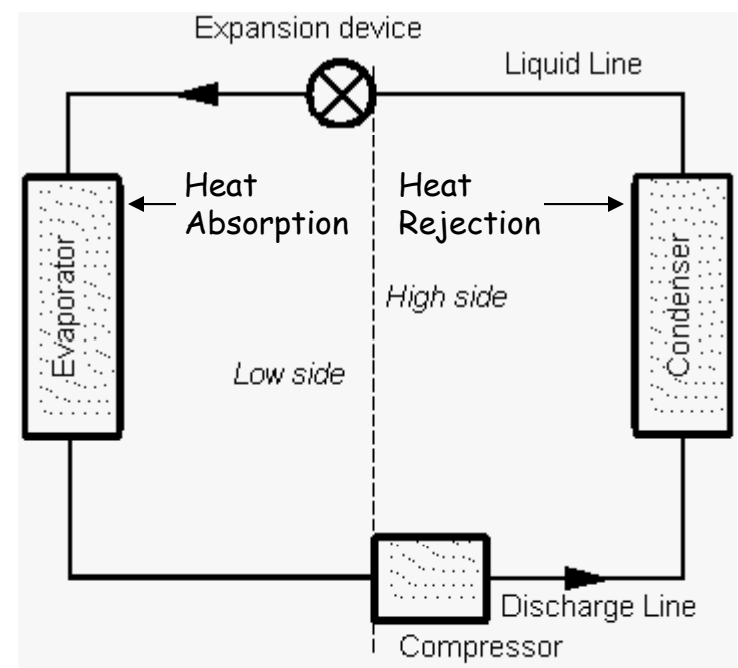
- Double pane provides an insulating air space
- Argon is denser than air (38% more), and does not conduct heat as readily (19% reduction)
- Low-E coatings block infrared (long wave) radiation and contribute to the comfort level of the home
- Radiation loss accounts for 2/3 of the losses by a window





# Heating / Cooling

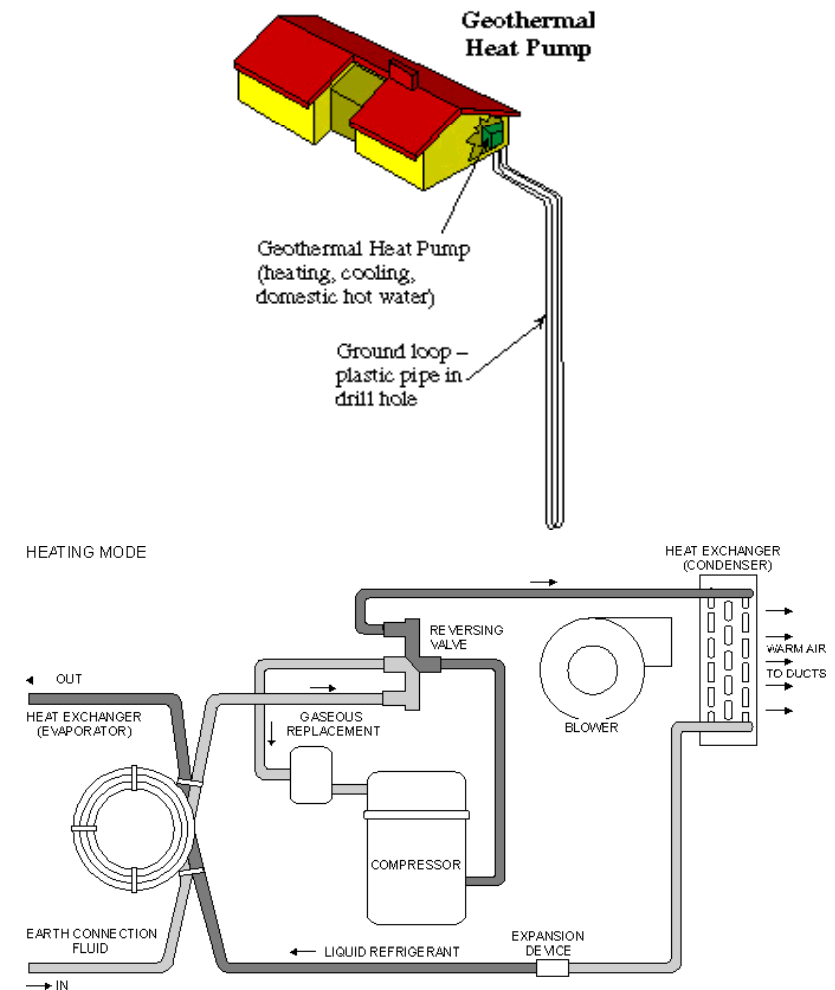
- Oversizing an HVAC system increases the initial cost and decreases the comfort. A short-cycling unit does not fully dehumidify.
- Two-speed units meet the variable loads more efficiently.
- Zoned duct is helpful in a two story home.
- Good design choices can greatly minimize the HVAC system size. The Westbrook House only needs 2 1/2 tons of cooling (2713 SF).



# Ground Source Heat Pump (GSHP)



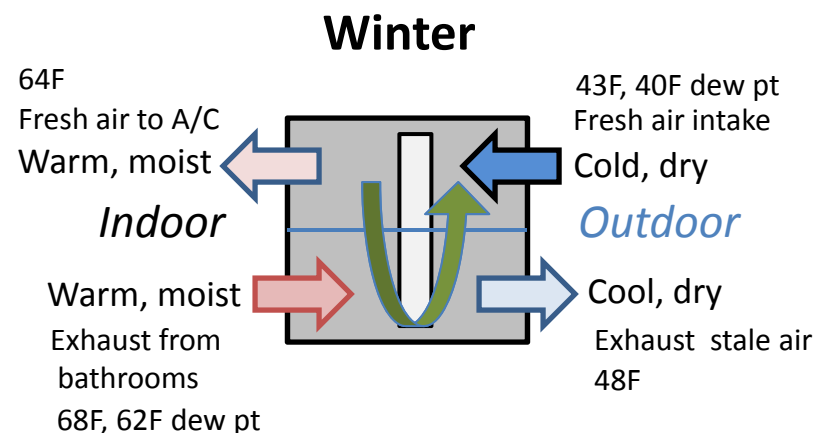
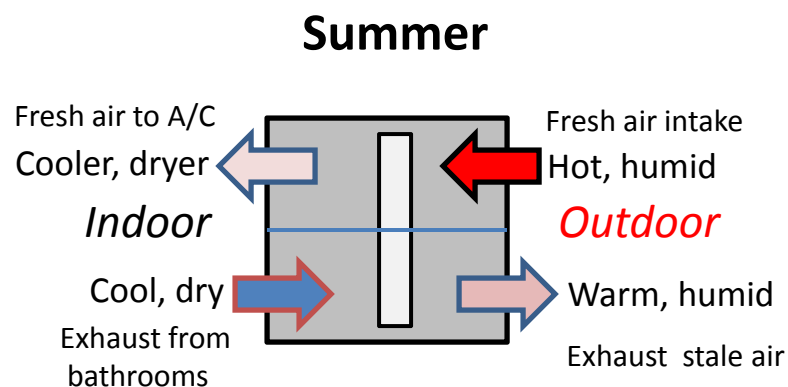
- The GSHP uses the relatively constant temperature of the earth as a heat sink or source.
- A GSHP can also be used as an efficient method of water heating.
- The minimum efficiency unit has a SEER of 13 (as of 2006). The Westbrook House GSHP has a SEER of 22.
- There is no noisy outdoor fan unit and we don't reject heat to the already overheated air.





# Energy Recovery Ventilator (ERV)

- The house is very air tight
  - GOOD: energy savings, minimal dust
  - BAD: not much fresh air
- An ERV brings in a steady stream of fresh air, but recovers much of the energy from the exhausted air
- Recovers over 70% of the total energy



# Efficient Lighting



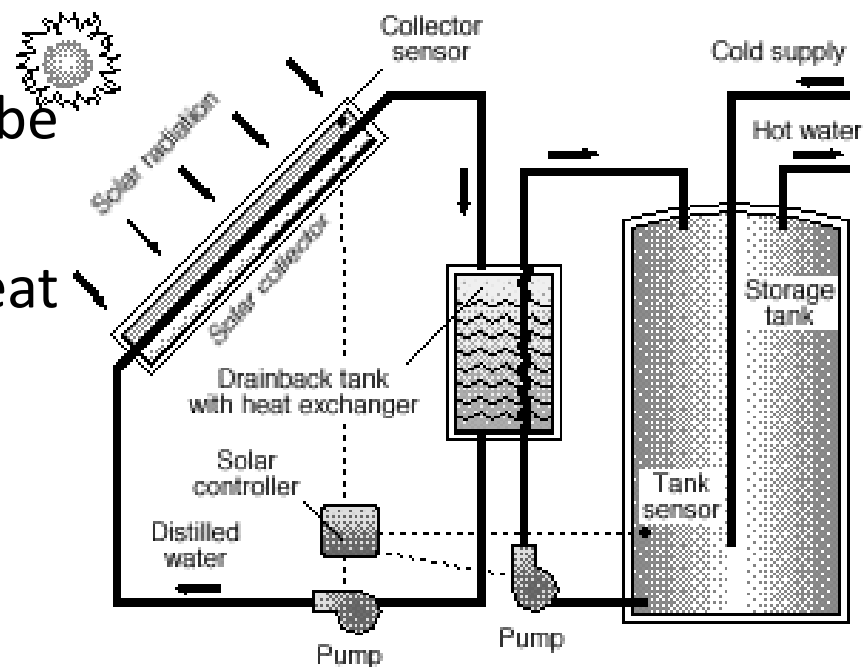
- Passive solar design can result in good natural lighting, decreasing the need for daytime artificial lighting.
- Compact fluorescent (CF) lighting uses only 1/4<sup>th</sup> the energy of incandescent bulbs.
- Incandescent bulbs and halogen lights convert >90% of the electric energy to heat, which increases your air conditioning load.
- Compact fluorescent lights last significantly longer than incandescent bulbs - each CF has a higher initial price, but the energy savings and long life give each bulb a net \$50 savings. LED is even better and dropping rapidly in price.



# Water Heating

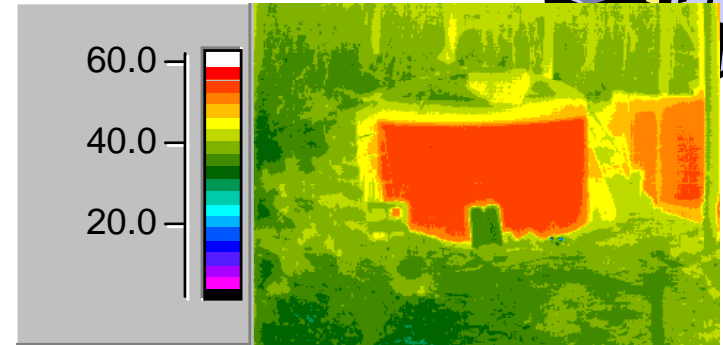


- Water heating can account for up to 30% of the electric use in a home.
- Solar Flat Plate water heating can be very cost effective.
- A side benefit of ground source heat pumps is a hot water recovery option which provides free hot water during the summer.
- R-25 polybutylene water heater / storage tank provides for long, hot storage.
- Heat pump water heaters are improving.



# Water Efficiency

- Rain water collection from the roof can be used to:
  - provide water for outdoor use.
  - reduce urban runoff.
  - lower your water bill.
- The first approach should be a native, low-maintenance lawn to reduce need.
- Rain water can also be used for human consumption.
- Our aerobic septic system uses our “waste” water to water the lawn.



1600 gallon rain water storage tank





# Water Efficiency



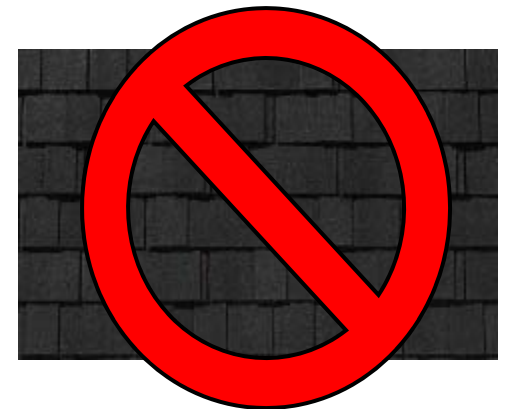
- House designed with all fixtures plumbed to a common water wall - no fixture is far from the water heater.
- Low flow fixtures - toilets, faucets, and shower heads all contribute.

*2009 North Texas Municipal Water District  
Water Genius Award Winner*

# Roof



- In hot climates, exterior colors should be light for reflectivity.
- The roof material is a major heat absorber and should be light colored. Look for a roof material with high reflectance and high emissivity.
- A Galvalume metal roof reflects heat, provides a clean surface for rain collection, and reduces homeowners insurance rates (hail resistance). It also has a 50year + life.
- A coated metal roof is an even better reflector



# All the Little Things



- Insulated hot water lines in the walls
- Earth bermed the west wall of the attached garage and insulated it. Lowest garage winter temperature = 51 degrees F
- Used 100% recycled polypropylene carpet from Image
- Motorized operators on clerestory windows for ventilation
- Efficient indoor appliances (refrigerator) to reduce heat load
- Wood stove and outside air intake for combustion air
- Horizontal axis washing machine for efficient water use
- Insulated the concrete slab foundation perimeter
- Ceiling fans in almost every room
- Recycled plastic / waste cedar shavings for deck board
- Low VOC paints for better indoor air quality

# Energy Efficiency/Best Investment



- Several items with large payback have little initial cost:
  - Design - orientation, window and overhang placement
  - Material color
- Some items pay back in other ways:
  - Well insulated shell reduces mechanical system size
  - Space efficient design reduces construction material cost
  - Metal roof reflects heat and provides a large discount on homeowners insurance (hail-resistant)

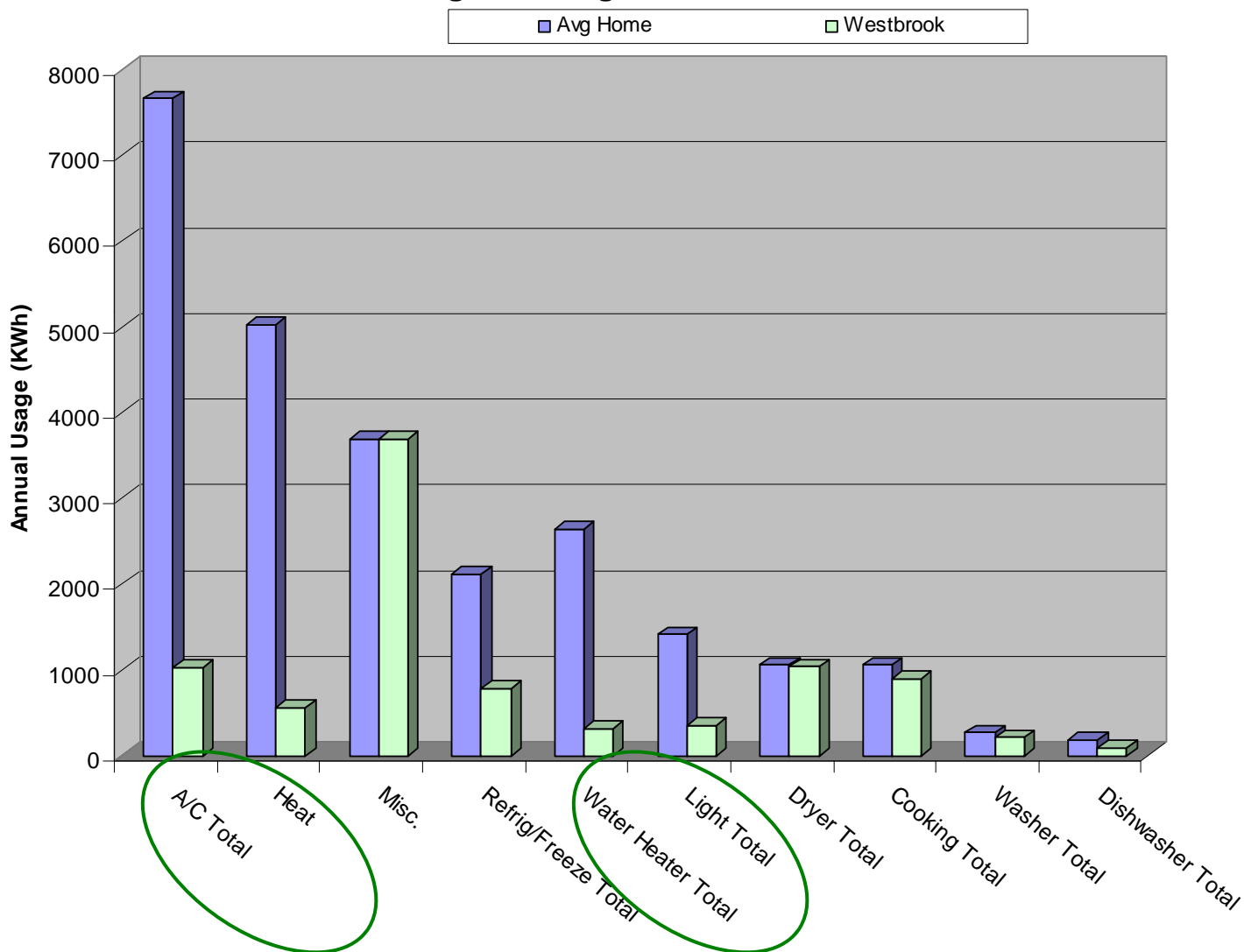
# Nice Looking and Nature Friendly





# Utility Usage Comparison

## Electric Usage - Average Home vs. The Westbrook House



# Annual Utility Costs

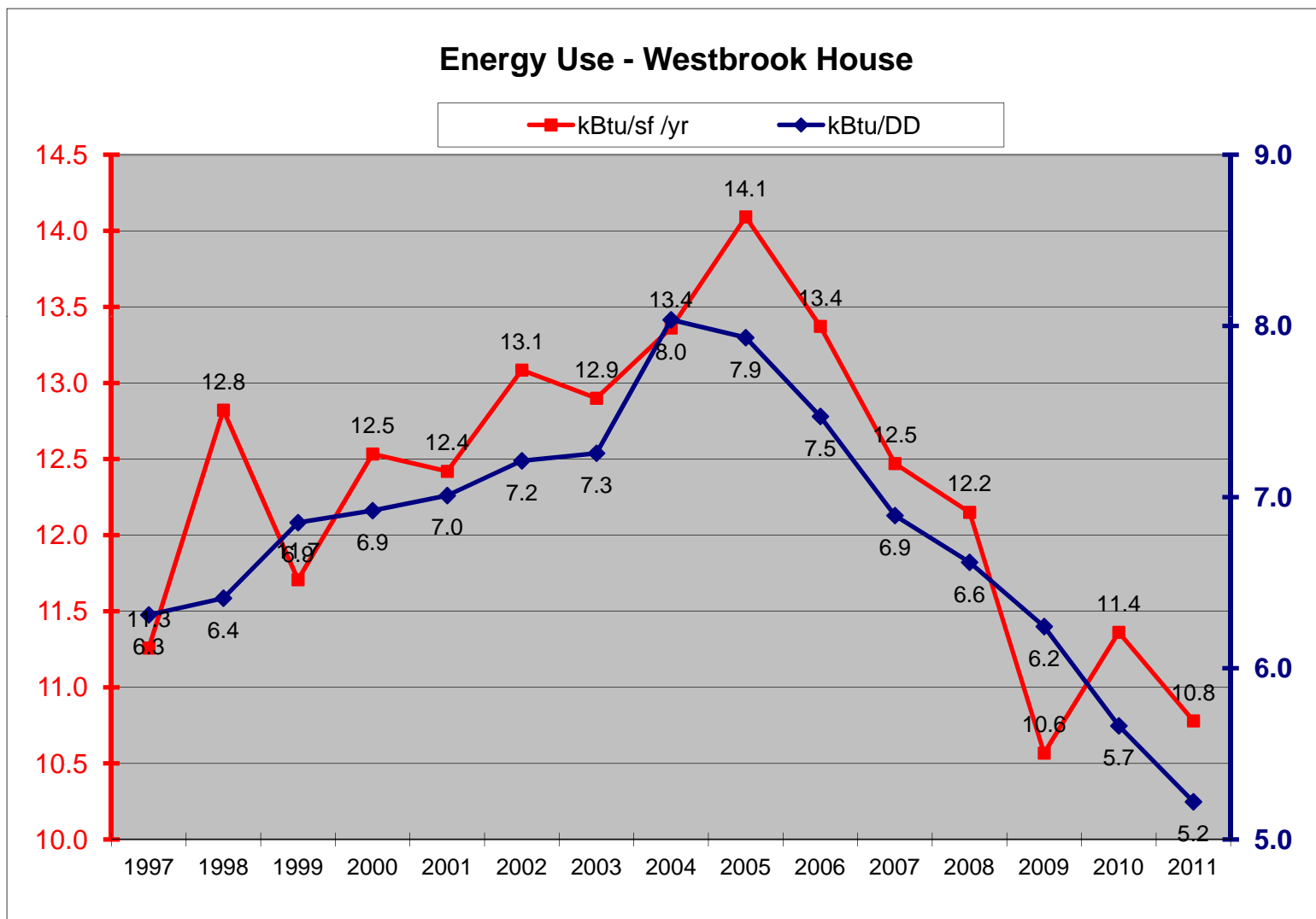
Texas average =  
40kBtu/sf



Westbrook House Annual Utility Data						2,713 sf, 3 people				
Year	kWh sum	kWh util	kWh wind	Cost/Yr	Average Cost/Mo	Elec Rate (\$/kWh)	kBtu/sf	kWh/sf/yr	kWh/DD	Water Use/Yr (gallons)
1997	8,952	8,952	0	\$ 739	\$ 61.55	\$ 0.083	11.3	3.3	1.8	34,700
1998	10,195	10,195	0	\$ 781	\$ 65.09	\$ 0.077	12.8	3.8	1.9	27,900
1999	9,309	9,309	0	\$ 644	\$ 53.63	\$ 0.069	11.7	3.4	2.0	45,500
2000	9,966	9,966	0	\$ 684	\$ 56.99	\$ 0.069	12.5	3.7	2.0	38,400
2001	9,875	9,875	0	\$ 753	\$ 62.79	\$ 0.076	12.4	3.6	2.1	36,000
2002	10,404	10,404	0	\$ 893	\$ 74.45	\$ 0.086	13.1	3.8	2.1	28,000
2003	10,257	10,257	0	\$ 934	\$ 77.87	\$ 0.091	12.9	3.8	2.1	38,000
2004	10,624	10,624	0	\$ 988	\$ 82.37	\$ 0.093	13.4	3.9	2.4	25,000
2005	11,205	11,205	0	\$ 1,177	\$ 98.08	\$ 0.105	14.1	4.1	2.3	37,000
2006	10,633	10,555	78	\$ 1,443	\$ 120.28	\$ 0.137	13.4	3.9	2.2	35,000
2007	9,916	9,770	146	\$ 1,305	\$ 108.79	\$ 0.134	12.5	3.7	2.0	28,000
2008	9,661	9,419	242	\$ 1,364	\$ 113.65	\$ 0.145	12.2	3.6	1.9	38,000
2009	8,403	8,118	285	\$ 1,247	\$ 103.92	\$ 0.154	10.6	3.1	1.8	29,000
2010	9,034	8,788	246	\$ 1,222	\$ 101.84	\$ 0.139	11.4	3.3	1.7	34,000
2011	8,571	8,238	333	\$ 1,137	\$ 94.73	\$ 0.138	10.8	3.2	1.5	42,000
Sums and Averages	kWh sum	kWh util	kWh wind	Cost		Elec Rate (\$/kWh)	kBtu/sf	kWh/sf/yr	kWh/DD	Water Use (gallons)
Total>	147,005	145,675	1330	\$ 15,313						440,500
Annual>	9,800	9,712		\$ 1,021		\$ 0.101	12.3	3.6	2.0	33,885
Monthly>	817	809		\$ 85.07						2,824



# Improvement Trend

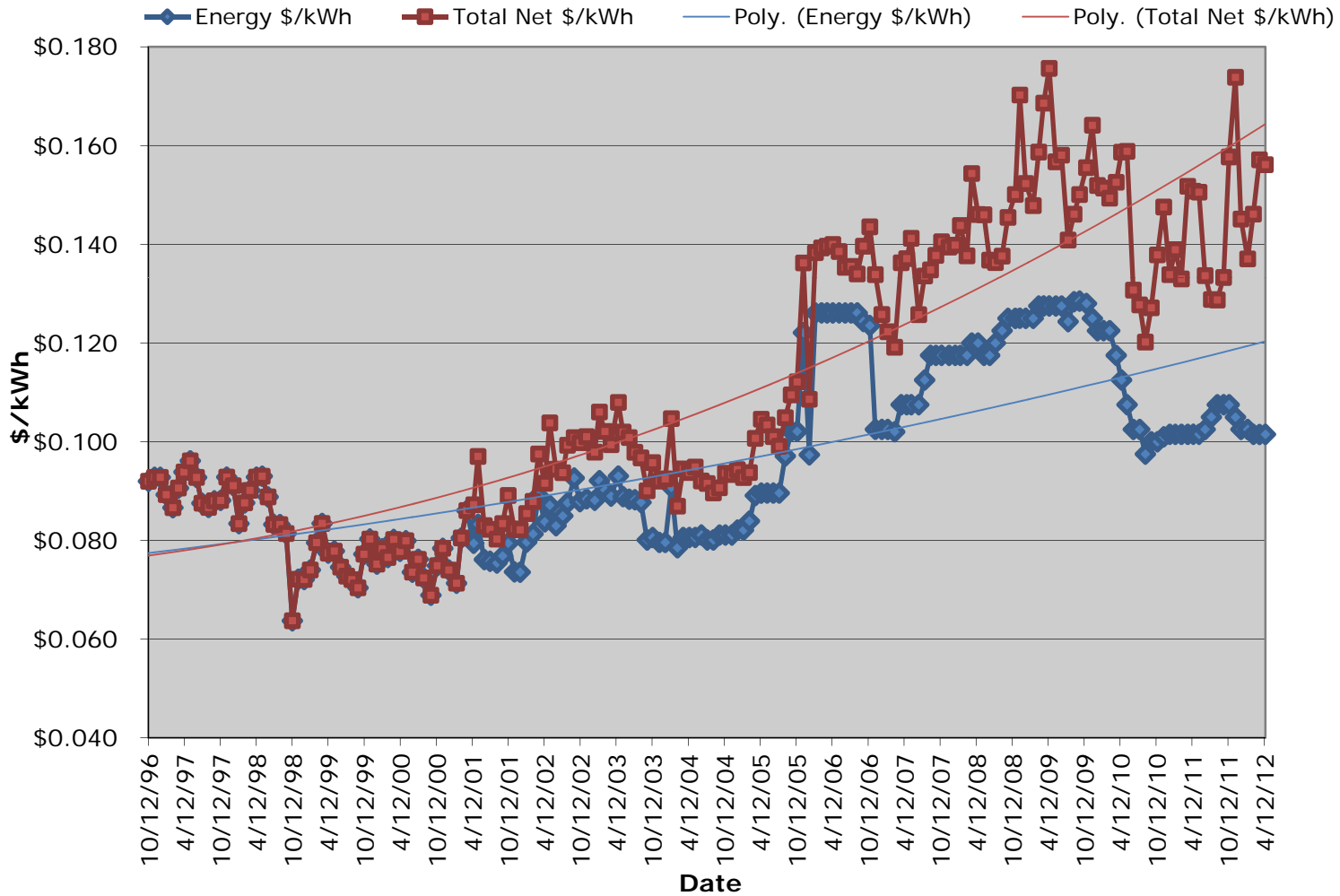




# Electric Rates



### Elec Rates - Grayson-Collin Coop





# Payback Information

Design Goals		
Energy Efficiency	Environmental Sensitivity	
Low Maintenance	Cost Effective Design / Construction	
Logistics		
Construction Time:	6.5 months	
Move In:	Sep-96	
Size (A/C):	2713 SF of A/C space	
Size (gross):	3312 SF under roof	
Electricity Savings (all electric home)		
Average Electric Bill:	\$85.00	avg use: 817 kWh/month
Highest Electric Bill:	\$170.71	Aug-06
Westbrook Electric Cost/Yr:	\$1,020.00	817kWh/mo * \$0.104/kWh over 15 year avg
Average Home Elec. Cost/Yr:	\$3,038.78	Avg use south: 10.77 kWh/sf/yr @ .104/kWh
Annual Savings:	\$2,018.78	
Monthly Savings:	\$168.23	
Payback		
Cost for Energy Efficiency Items:	\$ 13,000.00	Total cost of all energy efficiency upgrades
Added to a 15 year mortgage:	\$99.22	/mo @ 5.5% int + tax deduct on mortgage
Added to a 30 year mortgage:	\$74.94	/mo @ 6% int + tax deduct on mortgage
With a 15 year mortgage, you SAVE:	\$69.01	/month - but get full payback faster.
With a 30 year mortgage, you SAVE:	\$93.29	/month

After the mortgage is paid, you realize the full savings every month.

Note that mortgage interest is tax deductible.

Energy bills are not deductible. In fact, energy use is taxed.

Payback occurred in the first month when we paid more to the mortgage co. but less to the utility.

# What Would I Have Done Differently?



- More insulation (8" SIP Walls, 10-12" SIP Roof)
- A little less square footage
- Wood stove instead of fireplace (upgraded in 2009)



# What Would I Do Today?

- Passive House type structure
  - Extremely well insulated and airtight
    - Walls ~R-40, Roof ~R-60
- Top quality windows (>R-8 available)
- Integrate small A/C unit into energy recovery ventilator (ERV)
- Consider PV driven heat pump water heater instead of solar water heater

# Why Aren't Buildings Built Better?



- Buyer knowledge and demand missing
- Builder will build what they can sell – no incentive to change if buyers don't ask
- Codes
  - Still way below our capability
  - Some areas still use old codes
- Home design/build process is not integrated and optimized

# Efficiency First...Then Generation



- Since I have driven the consumption down I'm now investigating generation with solar and wind energy
- In 2006 I was selected by Southwest Windpower as a test location for their new Skystream 2.4kW wind generator

# Skystream 3.7 Wind Generator



- Developed with the National Renewable Energy Lab (NREL)
- Designed to be a simple, quiet, efficient, and clean power source for residences

# Skystream Wind Turbine







# Wind Turbine Performance

- I am in a modest wind zone (class 2+)
- I have too many tall trees close to the tower
  - Should have a 300 foot clear radius
- My tower is only 35 feet tall
  - My output is only about  $1/8^{\text{th}}$  what it should be
  - Wind power output is the cube of the wind speed
    - Small change in wind speed = large change in power output



# Tips for Existing Homes

- Consider an energy audit to help prioritize your efforts
- No Bulb Left Behind: Change all your light bulbs to compact fluorescent or LED
- The attic is usually a good place to start
  - Adequate insulation or sealed attic
  - Check ductwork for leaking connections and proper insulation
  - Provide good ventilation – exit AND intake
  - Radiant barrier



# Tips for Existing Homes

- Plug leaks in structure – caulk and weatherstrip
- Tune up your systems
  - Change the air conditioner filter
  - Clean the exterior coils
  - Insulate your water heater
- Appliances
  - Purchase Energy Star appliances
    - Tax free on Memorial Day weekend
  - Measure your appliances energy use
  - Put your energy “vampires” on a plug strip
  - Use timers and programmable thermostats
- Windows
  - Properly shaded or solar screens
  - Replace only after all other steps



# Efficiency in Everything



My car mileage – avg >53 mpg (for 8 years)



Even better



[www.enerjazz.com/prius](http://www.enerjazz.com/prius)



# A Few Final Thoughts

- Reduce the load first, then generate with renewable energy
- Optimize – don't compromise
- Everything is connected and related – recognize the connections
- Simple solutions are usually the best

Visit my web site for tips and links:

[www.enerjazz.com/house](http://www.enerjazz.com/house)