Passive Solar History

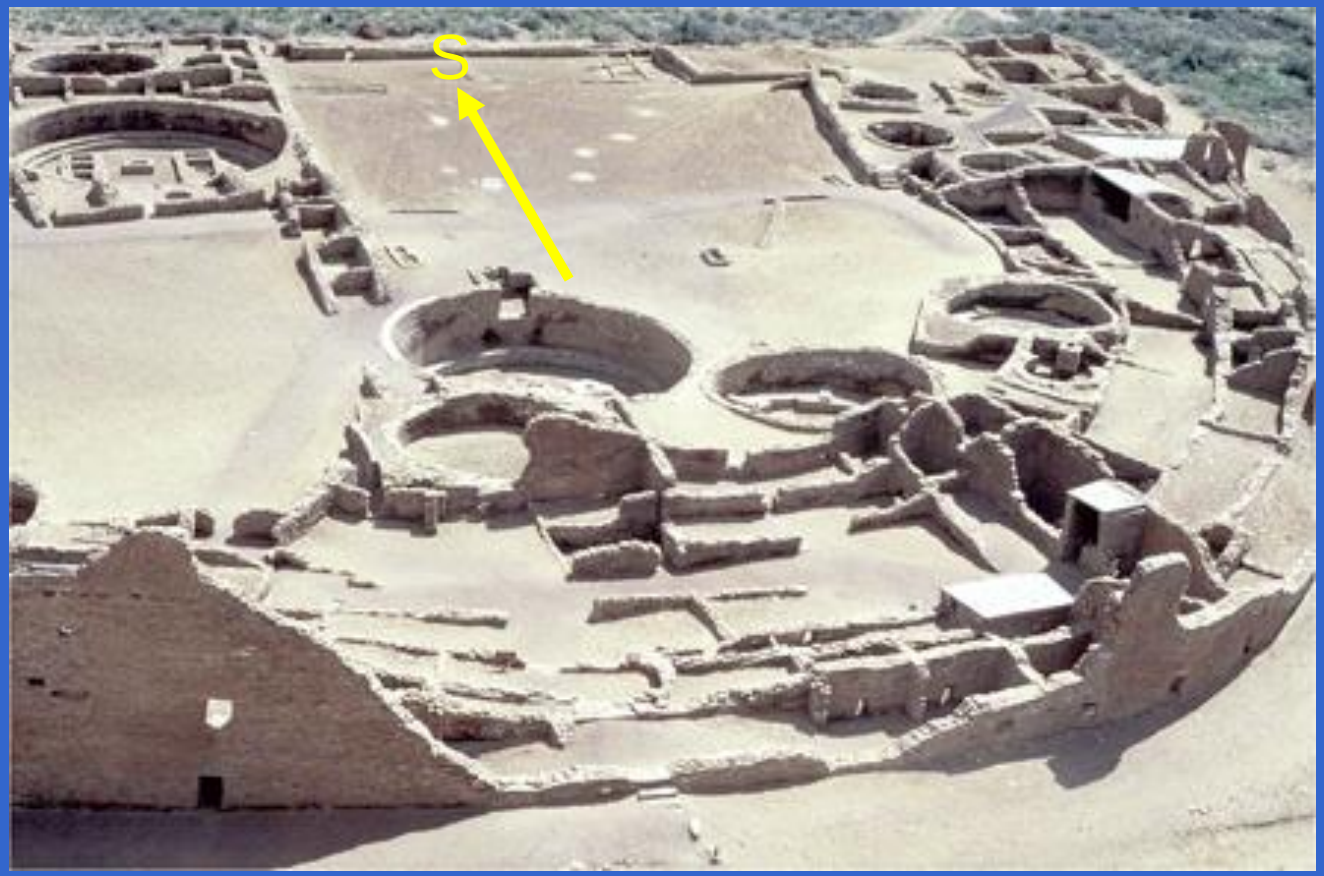
Heating, Cooling, Ventilation and Daylighting

David A. Bainbridge 2012

Prehistory

- We have used the sun and microclimates throughout history to stay comfortable
- The Anasazi used the sun to stay warmer in winter
- And solar control to stay cooler in summer

Pueblo Bonita - Solar Condominium



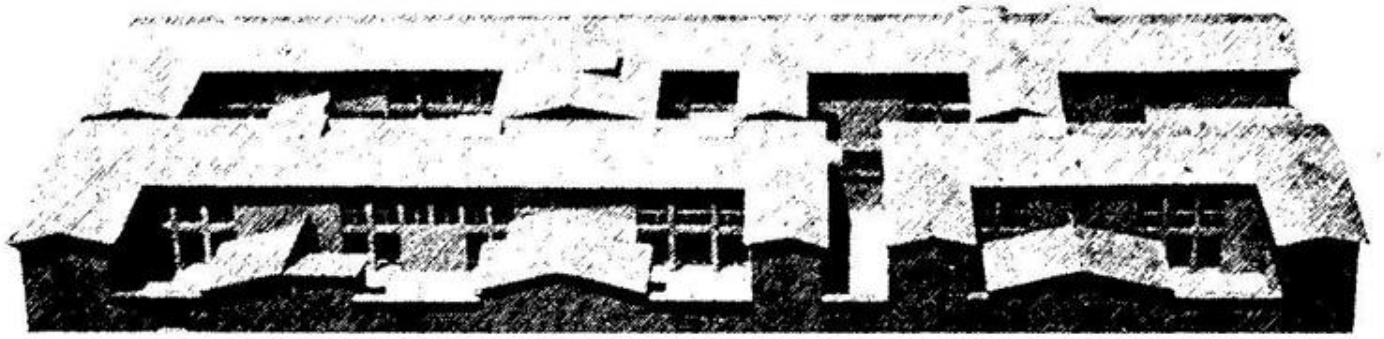
1200 AD Some buildings were quite impressive

Solar Homes and Cities

- The first written descriptions of passive solar architecture come from Greece
- Firewood shortages and rising charcoal prices led to widespread use of solar design
- As Aeschylus said of the barbarians, ***"they lacked knowledge of houses...turned to face the sun"***

Solar cities develop

- Street layout and building design in the Greek solar cities improved the quality of life
- Charcoal and fuel wood were increasingly costly
- Solar access was considered
- Solar control, ventilation and fountains improved comfort in summer



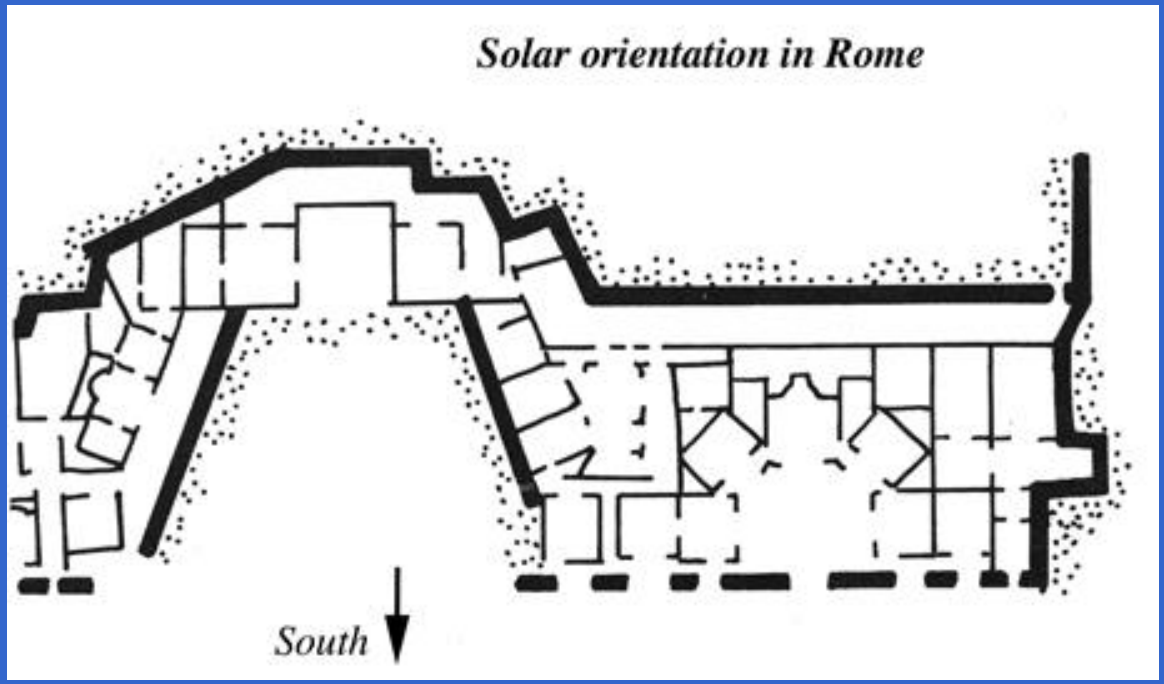
Adapted from Butti and Perlin, A Golden Thread

Rome

- Roman solar utilization was driven by the same desire for comfort
- Firewood and charcoal costs increased
- Solar energy was so important the first solar rights laws were passed to preserve access to the sun for winter heat

Passive Solar Architecture

If our designs are to be correct we must...take notice of the countries and climates in which they are built. Vitruvius



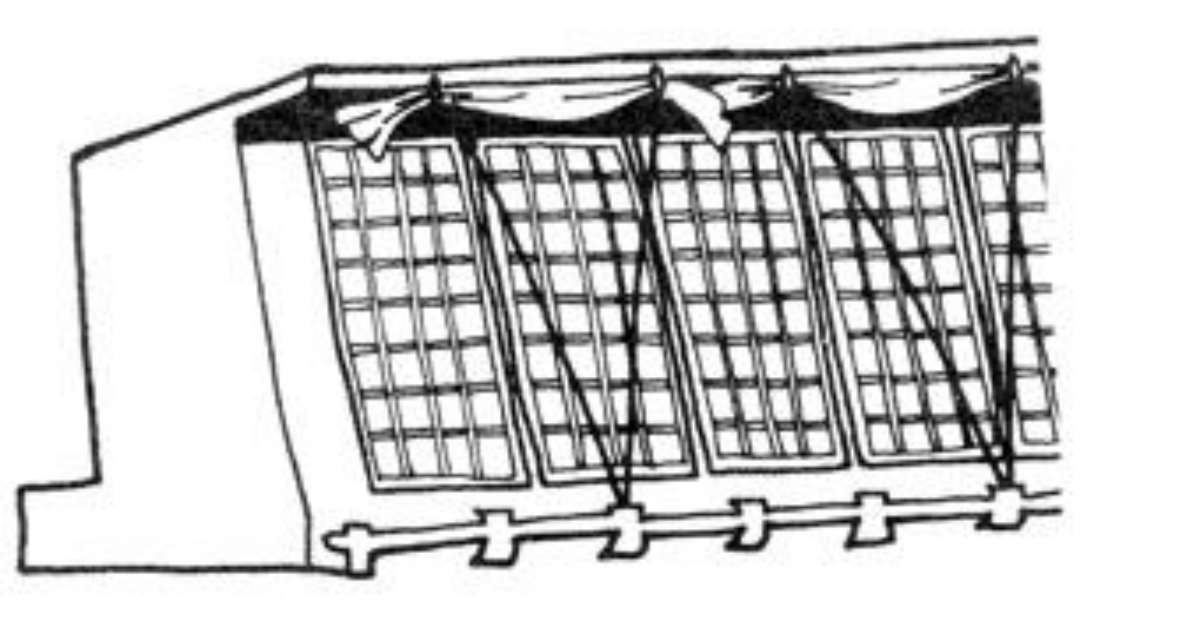
Summer cooling

- A well to do Roman family would have cool fountains and pools for summer

Ventilation

- Traditional designs also utilized stack and cross ventilation
- Buildings, wind catchers and wind towers provided cooling breezes
- Evaporative cooling from qanats and fountains added even more cooling

Solar Greenhouses



- In the 16th Century Dutch greenhouses began using glass and roll down covers to improved crop production
- By the mid-1700s these were sophisticated systems

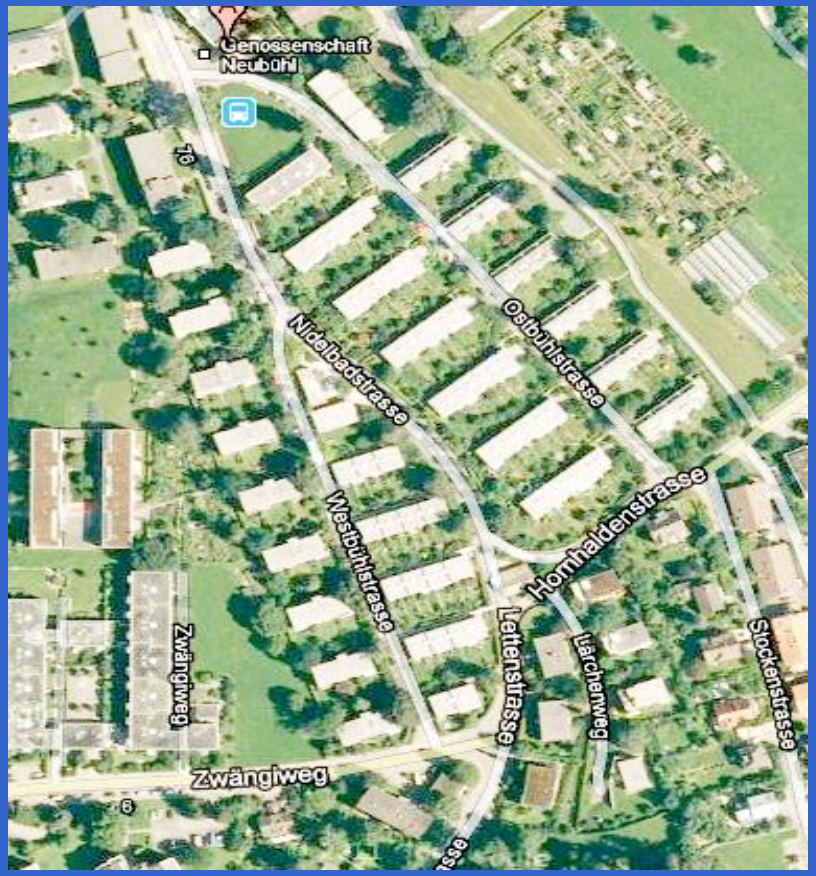
Passive solar buildings

- Passive solar heating was used for specialty food production and exotic plant collections in Europe and England -- here at Kew

1889 Solar community

- Port Sunlight Village was designed and built in England
- Solar access was for health and sanitation for worker houses, but also provided solar heating

1930s Swiss Solar Village



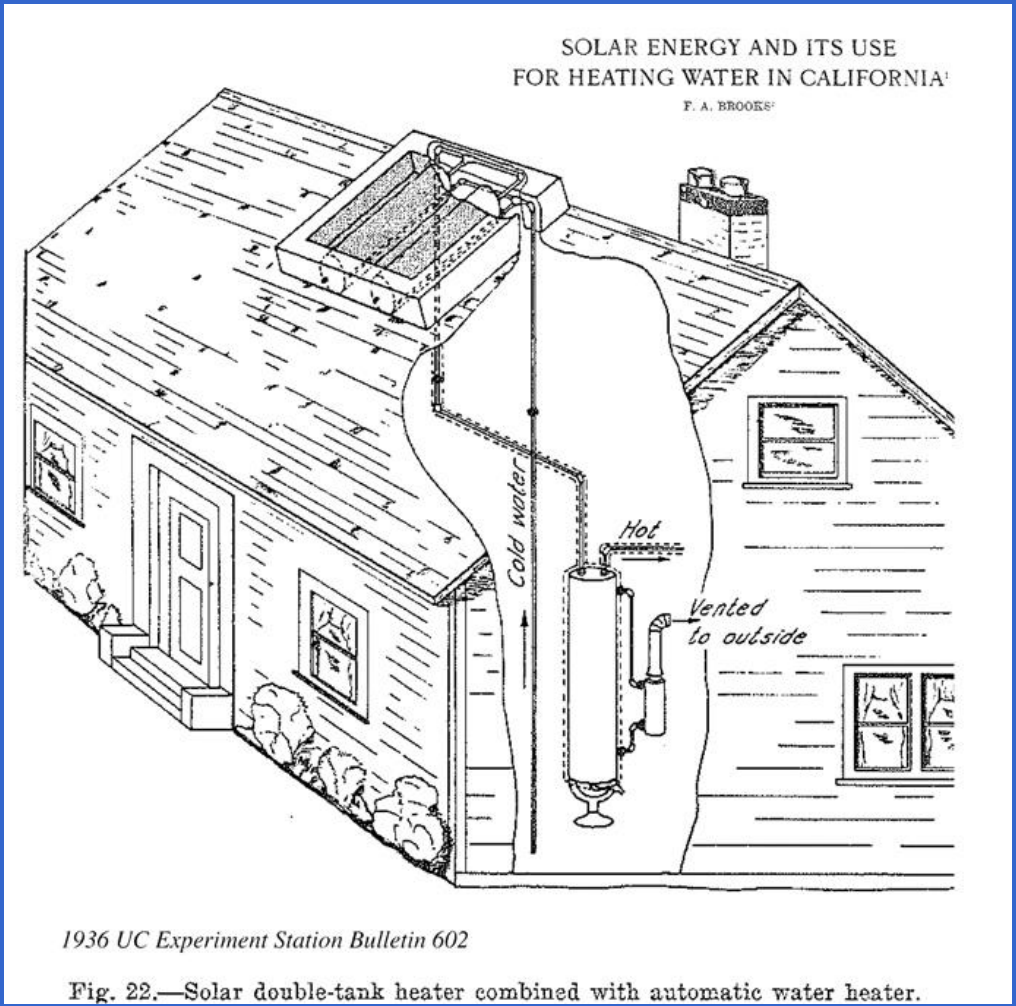
googleearth

- Fuel shortages and high costs after WWI led to solar utilization in Europe
- Neubuhl, near Zurich, was a cooperative solar village
- Passive solar designs are still working well today

1930s Passive Solar California

- This solar greenhouse retrofit in Bodie helped this family stay warm in this very cold mining town
- Firewood was in short supply and costly

1936 Passive Solar Hot Water



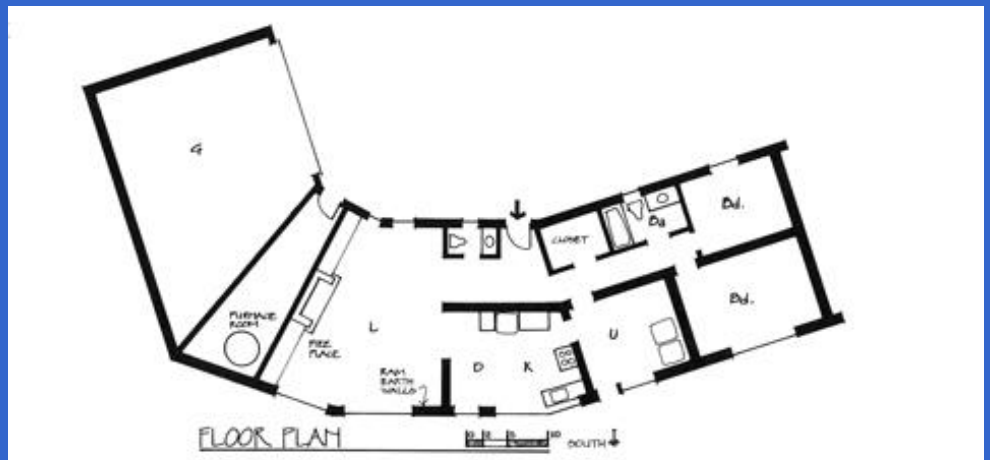
- F. A. Brooks tested solar hot water systems in California
- The integral type beat the flat plate
- This was the model for my first water heater and led to my 1981 book

1940s Solar USA

Adapted from Butti and Perlin, A Golden Thread

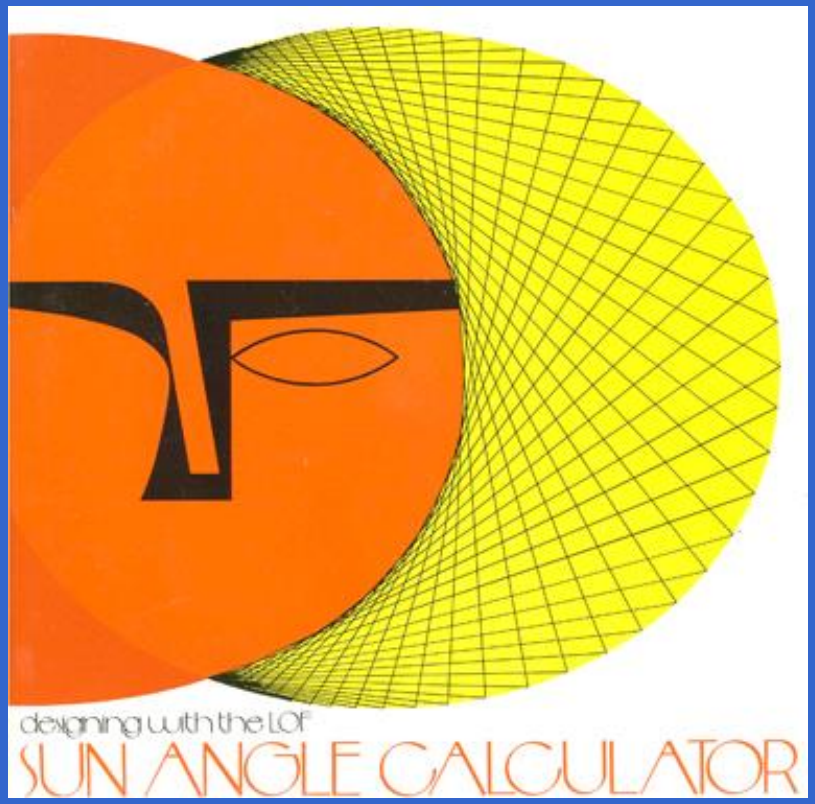
- George Fred Keck designs Solar Park homes for Howard Sloan in 1941
- Illinois was the home of Libby-Owens-Ford a double pane glass maker who supported solar development

1950 Solar Sustainable



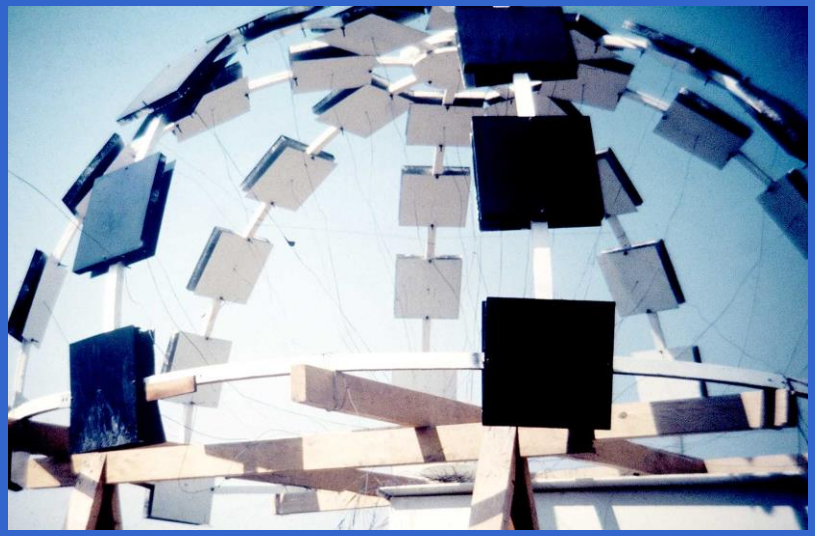
- A rammed earth passive solar home in Greeley was built in 1950 by David and Lydia Miller
- The owners and architect J Palmer Boggs were delighted with performance

1951 Solar Design Tools



- Architects in the 1950s had solar design tools for the first time
- Solar homes were built, primarily by architects for the well-to-do
- But subsidized electricity and low cost air conditioning soon killed solar design
- Homes were placed on “iron lungs”

Passive Solar Research



Radiant exchange with the sky dome

- Tod Neubauer began work on solar applications at UC Davis in 1950
- He studied both heating and cooling
- He continued until 1980 and was an excellent mentor

1956 Passive Solar France

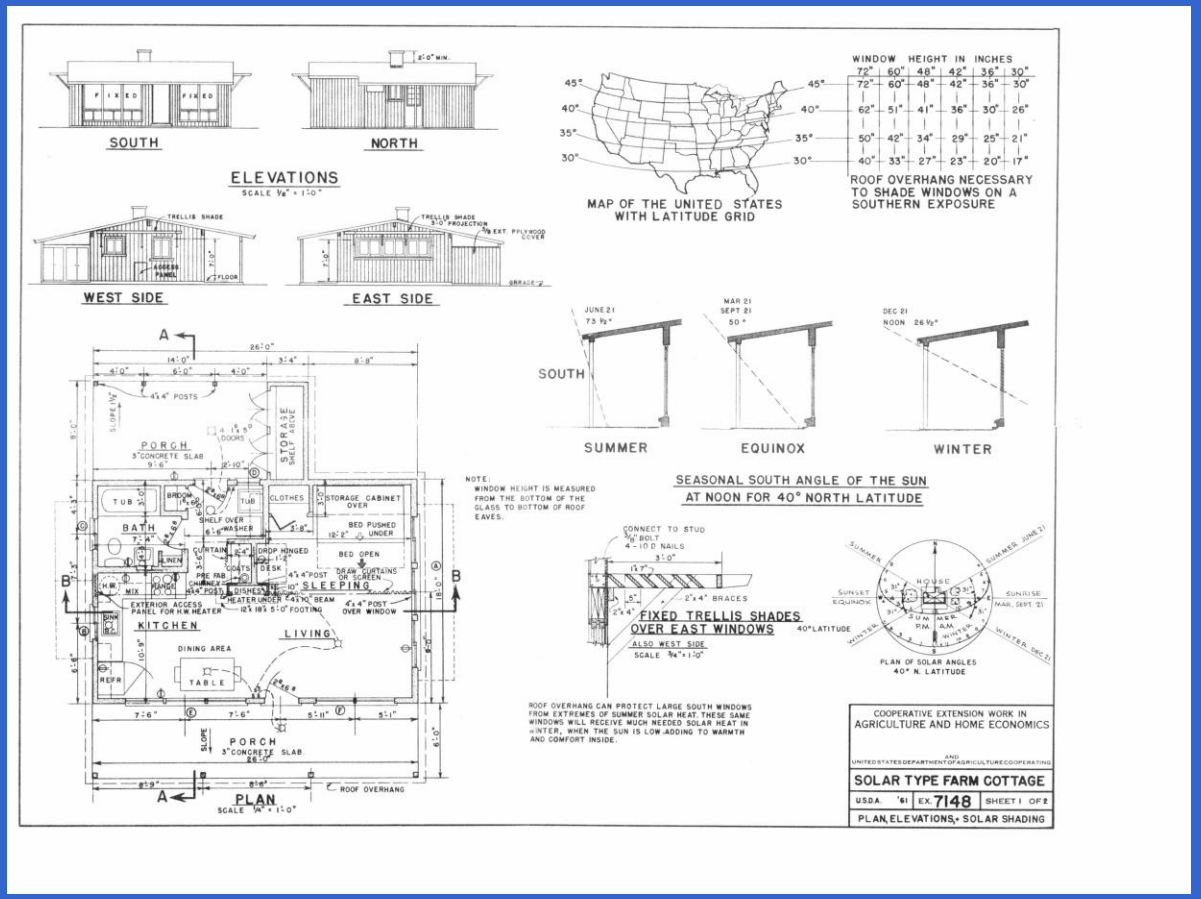
Trombe Wall Vancouver, BC

- A masonry wall provides thermal mass
- Glazing outside makes it an effective solar heater
- Best where cooling is not an issue
- First patented in the US in the 1890s
- Rediscovered and improved by Félix Trombe and Jacques Michel in France

Solar Rediscovered in New Mexico

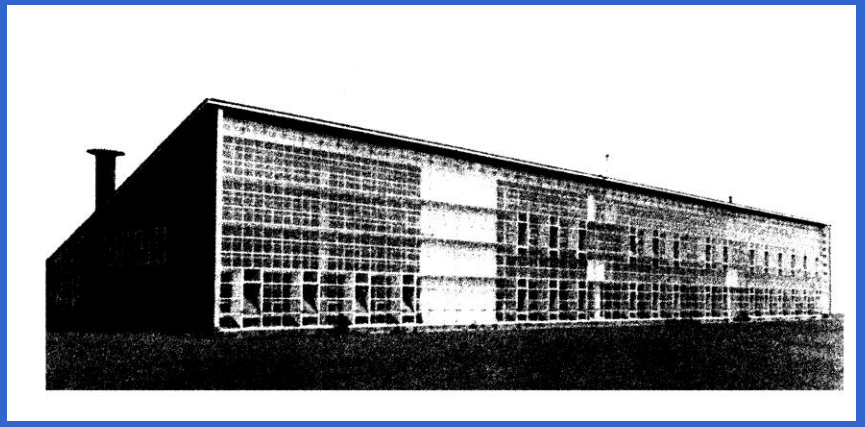
- Peter van Dresser was a pioneer (1940s) in passive solar design
- His Ghost Ranch project in the 1970s demonstrated practical passive solar use
- He was one of the first designers and planners to consider sustainability

1961 Passive solar USDA



- A passive solar home plan from extension, Tod Neubauer

1961 Passive Solar School



- Wallasey, England--Emslie Morgan, architect
- The first effective large passive solar design worked well for decades
- Double glazing, high mass with external insulation
- Students, sun and lights provided all the heat
- Sadly Mr. Morgan died soon after

1967 Heating and Cooling

Courtesy Tod Neubauer

- Harold Hay set up a test of his Skytherm system in Phoenix, AZ
- This system could provide comfort year round

Skytherm function

- The lids are opened in the day in winter for solar gain and closed at night
- In summer they are opened at night for night sky radiant cooling and closed during the day
- If the roof pond is open evaporation can add even more powerful cooling

1972 Water wall solar home

- Steve Baer built the first high performance water wall home in Corrales, New Mexico
- Exterior insulated reflective shutters improve performance
- His company, Zomeworks, is still active today
- He is one of the most innovative passive solar designers

Courtesy Steve Baer

1973 Hammond Water Wall

- Jonathan Hammond pioneered passive solar in California with this retrofit water wall
- With skylight, insulated shutters
- Adobe thermal mass

Water wall with drums

- The drums are not everyone's favorite but offer low cost
- Culverts, fiberglass tubes also used
- I favored rectangular steel tanks
- The waterbed in the water wall was a favorite spot for naps on warmer days

1973 Energy Crisis

- A solar resurgence began after oil cut-offs and rapid energy price rises
- I first became involved at UC Davis
- Tod Neubauer finally gets attention for his work over many decades
- Discussion of the first modern solar subdivision began

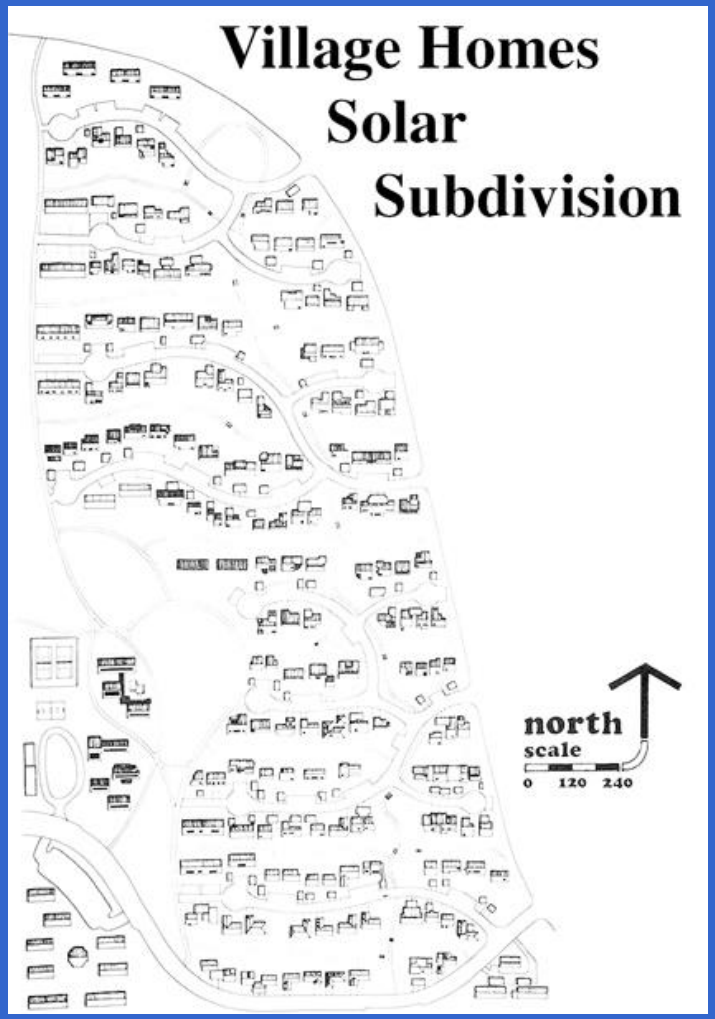
1974 Davis Building Code

- A climatically adapted building code was developed by Jon Hammond, Marshall Hunt, Tod Neubauer and Richard Cramer -- It was adopted by the City Council
- I helped teach builders how to comply
- They found it useful and not burdensome
- Much stronger than the state code that replaced it--dealing with cooling as well as heating

1975 Living Systems Office

- Jonathan Hammond designs and builds a water wall passive office building
- Living Systems provides solar design and research services for a wide range of clients

1975 Village Homes Subdivision



- Judy and Mike Corbett start a remarkable solar development in Davis, CA
- More than 200 units, designed for bikes, walking and community building
- Mixed use
- A delightful place

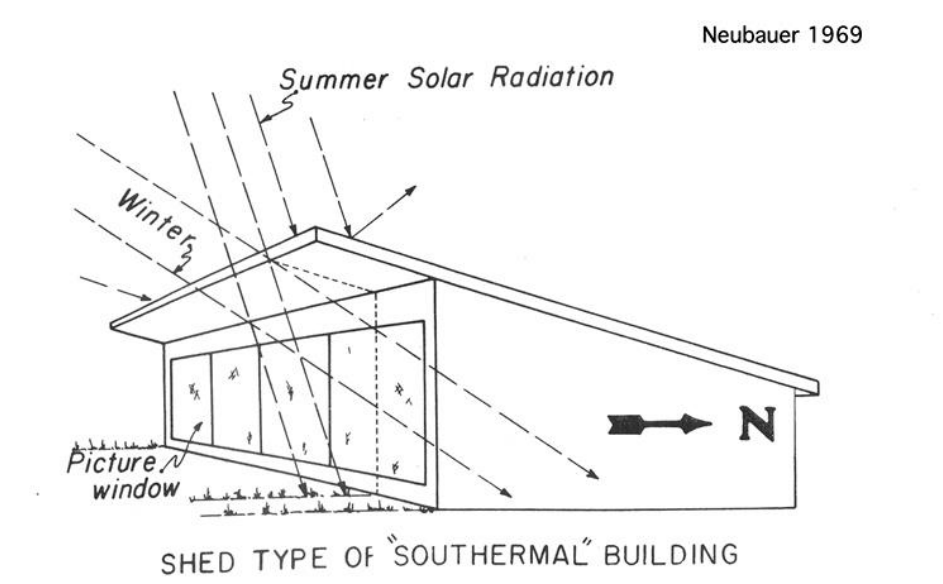
Village Homes

Chad Ankele

South

- All homes face south
- 50% less energy used than adjacent developments

What is a Passive Solar Home?



- The key is windows that face south for heating
- Solar control with overhangs and shading in summer
- Excellent insulation and a weathertight shell
- Thermal mass for heat or coolth storage
- Windows for cross and stack ventilation
- Use of night convective cooling, radiant night sky or evaporation for cooling

1975 Skytherm California

- Harold Hay, Ken Haggard and Phil Niles full scale Skytherm house
- 100% heating and cooling
- Sliding insulation panel system flawed

Passive Solar Gone Wrong

In most cases South windows should be 10-15% of floor area not 50-100%

- ***Solar brutal***
- *An early mistake was using too many windows*
- Not enough insulation, thermal mass, or solar control
- Common in New Mexico but this example is from Oregon

1975 Roof pond reflective lids

Courtesy J. Hammond

- Jonathan Hammond, Living Systems, designed this roof pond home
- Hydraulic rams lift lids on cool summer nights
- And on sunny winter days
- Hammond is still designing innovative passive solar buildings today

- Very energy efficient building shell with insulated window shutters
- A bicycle powered hydraulic pump backup could operate lids if the power went out
- House performed beautifully

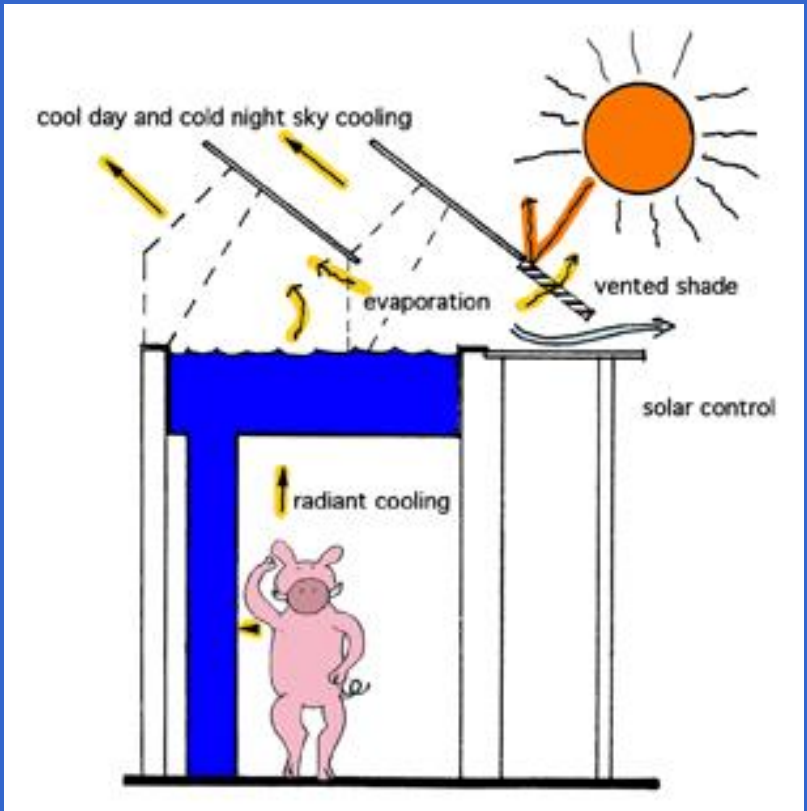
1976 Natural Heating and Cooling

- Jonathan Hammond and Marshall Hunt were the principals at Living Systems
- Greg Acker designed this culvert water wall home in 1976 for Marshall
- Night ventilation cooling
- Direct solar heating with a water wall
- 70% savings on energy use
- The integral solar water heater is still working today

1970s Cool towers

- The Environmental Research Lab in Tucson developed high performance downdraft evaporative cooling towers
- For homes and com'l applications

1970s Cool Pool Test Cell



Ken Haggard sketch

- Living Systems developed a fully shaded evaporating roof pond
- These can maintain comfort under extreme conditions
- Radiation to the cool sky adds to evaporation
- Performed very well in a very hot parking lot at the California State Fair

1977 my first solar home

- This water tank was the first rectangular water wall
- Also 3 tank ICS solar water heater
- Mass floor, solar orientation and overhangs for solar control reduced energy use 70%

Passive solar commercial

- I also worked on a wide range of other projects
- I liked the way this passive solar daylit medical office turned out

1975 240,000 sqft water wall!

- At Living Systems we designed a water wall passive solar office building design for the State Architects office
- Passive heating, cooling, ventilation and daylighting
- 88% energy reduction predicted, daylit, natural heating, cooling and ventilation
- General Services would not accept floating temperature even after we showed existing buildings were much worse

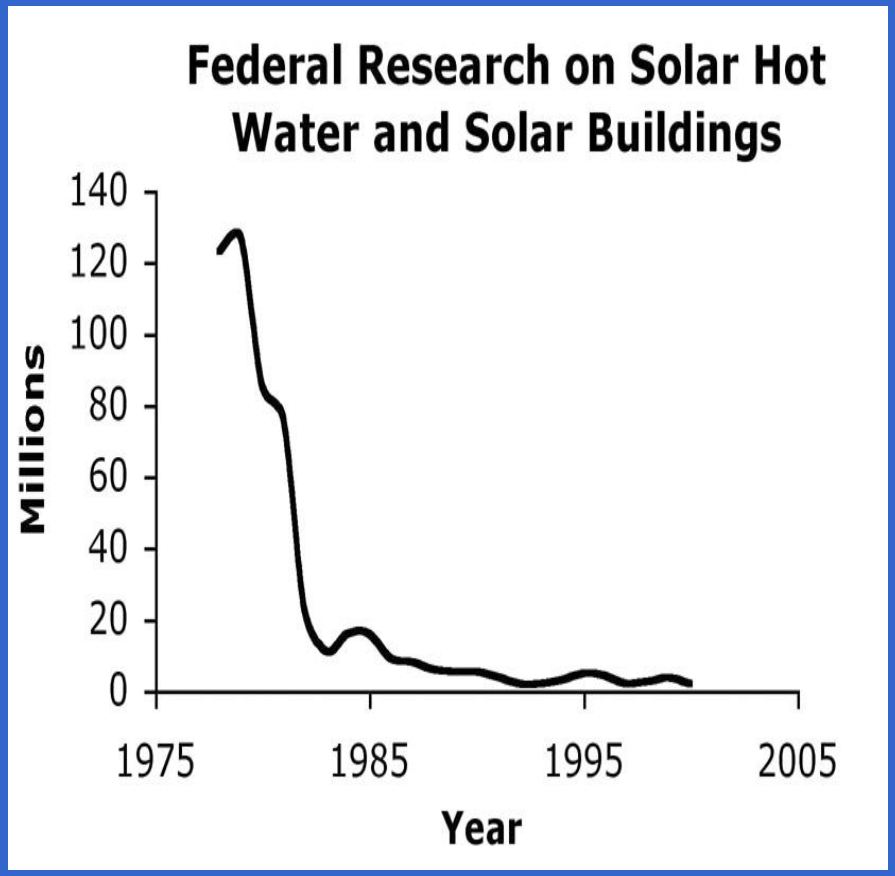
Passive Solar Tax Credits

- California and Federal Tax credits were passed in the 1970s to offset existing subsidies for fossil fuels and nukes
- Almost exclusively for active systems and PV
- I worked on the passive solar state tax credits - what a nightmare! The tax board was not concerned about performance or value
- We did finally get a reasonable approach approved but credits are a poor way to offset subsides for fossil fuels

1980 Passive Solar Handbook

- In 1980 the California Energy Commission released the first state handbook for passive solar design
- Ken Haggard and Phil Niles were the primary authors
- This and a state solar data handbook (1978) put useful tools together

Fossil fools



- Solar funding and development died with the election of Ronald Reagan
- Big coal, nuclear energy and global warming were in - solar was out
- Solar research funding encourages innovation
- It also helps students learn

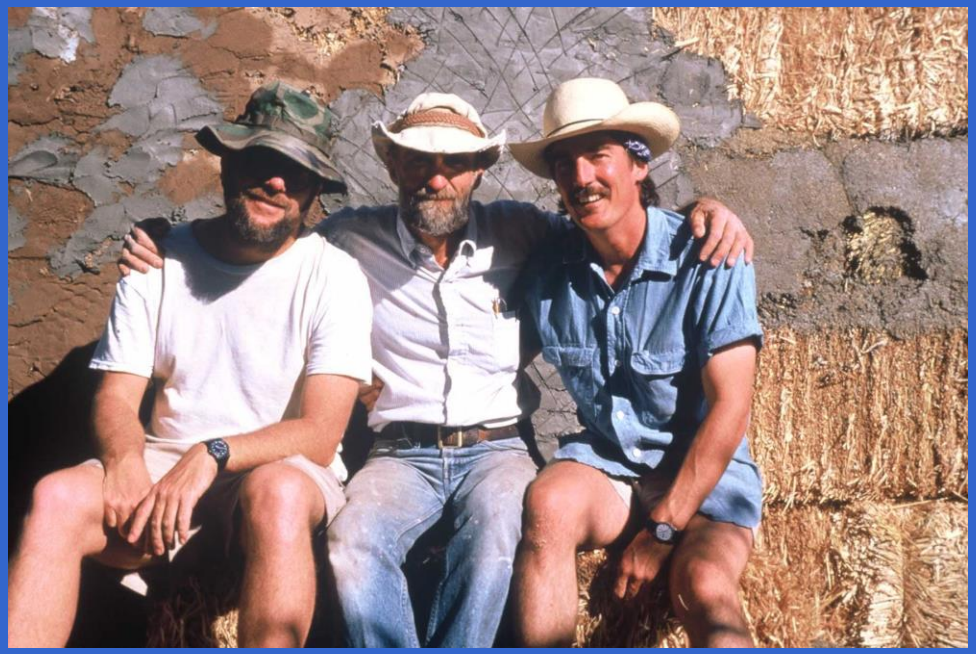
The challenge in 1980

- We now knew how to do very high performance buildings
- We had learned the value of super-insulation and sufficient effective thermal mass (water best)
- The challenge became finding a low cost way of building super-insulated buildings with high internal mass

1983 Bishop passive solar

- Good insulation with water wall passive design performs well
- David Bainbridge solar design with architect Brock Wagstaff
- The owners doubled the size of their living space and cut energy use in half
- This is a Factor Four gain with simple design
- With super-insulation the goal could be 90% saving -- Factor Ten

1980s The answer emerges



David Bainbridge, Matts Myhrman, Bill Steen

- A consulting job for a pig farmer led me to straw bale building
- Along with Matts Myhrman, Bill Steen and others we rediscovered America's historic straw bale buildings
- In 1989 we helped lead the first straw bale workshop near Oracle, AZ

1981 Straw bale simple passive

- Jonathan Hammond first wrote about straw bale building in the 1970's
- He built this lovely little studio to test ideas

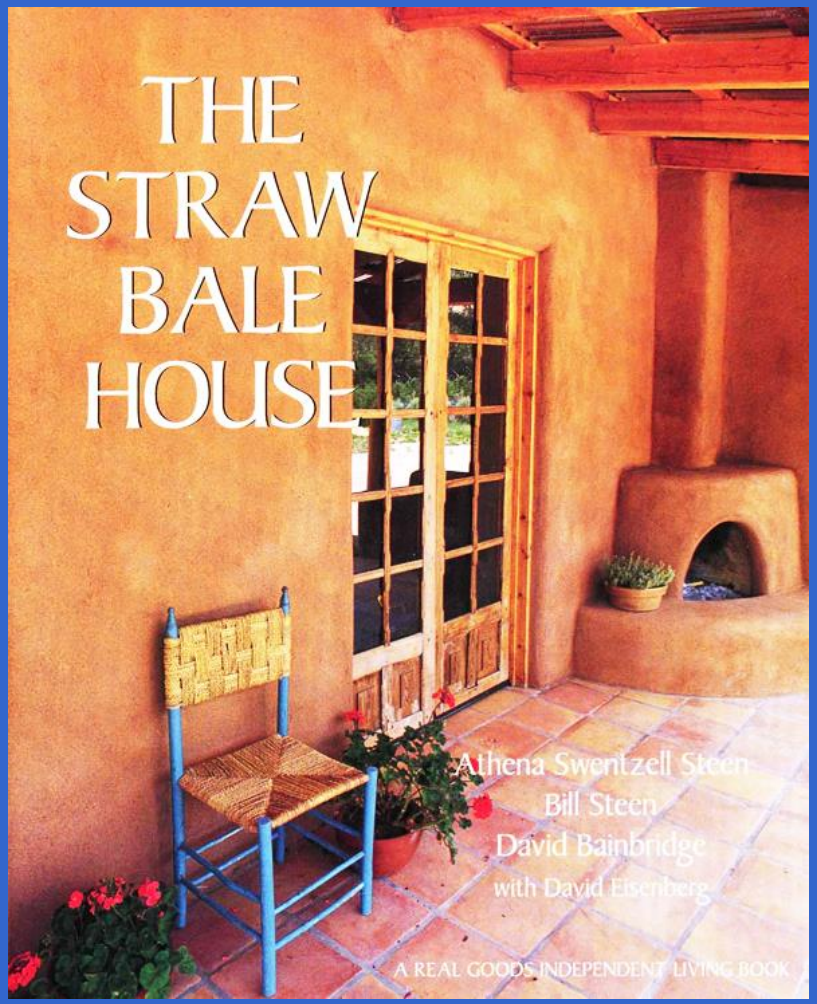
1981 Straw bale water wall

Shown with glazing removed

Courtesy Athena Steen

- At the same time Athena (to be Steen) was building a very low cost straw bale water wall in New Mexico
- It performed very well

1994 The Straw Bale House



- The Last Straw magazine with Matts and Judy Knox helped build SB interest and knowledge
- In 1994 I coauthored the straw bale house book with Bill and Athena Steen and David Eisenberg
- Now there are more than 20 sb books in many languages

1994 Straw bale passive solar

- Probably the first permitted straw bale in California
- Near Bishop, design by Ken Haggard and Polly Cooper with straw bale guidance by Pliny Fisk III
- Composting toilets and greywater biobeds
- Higher performance--modest price

Straw bale and passive solar

Building community as well as buildings

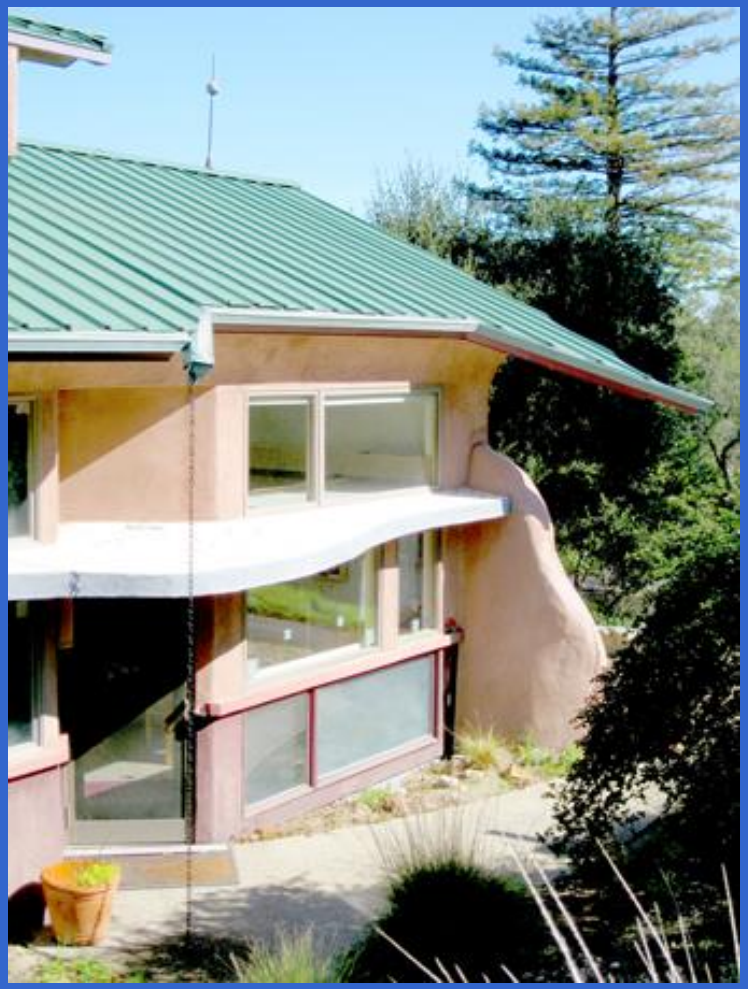
- Straw bale construction is now found worldwide
- In California hundreds of buildings are in use

China and Mongolia

Photo courtesy
ADRA

- Straw bale passive solar
- Thousands underway in China thanks to Kelly Lerner and other volunteers, ADRA
- In Mongolia energy use was cut 80%

1995 SLOSG Office



- Ken Haggard, Polly Cooper and their staff have designed more than 200 passive solar buildings since 1975
- This is their solar, straw bale off-grid office
- Waterwall for heating and cooling
- Daylit, natural ventilation

1996 Real Goods

Sim Van der Ryn,
David Arkin Project
Architect

- Large commercial passive solar straw bale building
- This retail store and education center is near Ukiah

2006 Congregation Beth David Synagogue, SLO

Design by Ken Haggard and Polly Cooper, San Luis Obispo Sustainability Group

- This naturally heated, cooled and ventilated building uses 91% less energy than California's energy code requires
- It uses water walls for thermal mass
- Straw bale walls
- Daylighting

2000s Passive School

Courtesy Nicolette Toussaint

- A series of straw bale buildings have been added to the Roaring Fork Waldorf school
- On-time, under-budget with many volunteer helpers
- Jeff Dickinson, Architect

2007 Passive solar straw bale

Courtesy Indigo Architecture

- Jonathan Hammond, Indigo Architecture
- Daylit, passive solar heating and cooling, daylit
- Sheriff substation
- Visalia, California

Passive Solar Straw Bale

- Costs have ranged from $4 sf to $400 square foot
- It depends what you want and how and where it is built
- Building with straw also sequesters carbon
- But the big reduction in GHG is from passive solar performance
- The thick interior plaster provides well distributed thermal mass
- Coupled with a water wall for added thermal mass performance is excellent
- Windows must be put in the right places with shading in summer

Passive solar obstacles

Anti-solar

Anti-social

Building

- Almost everyone involved has perverse incentives to do the wrong thing
- Key issues - subsidies, developer not client, tax code
- Result: sealed, unhealthy, unsustainable buildings
- Estimated lost productivity and medical costs $160 billion a year (Dept of Energy)

Additional problems

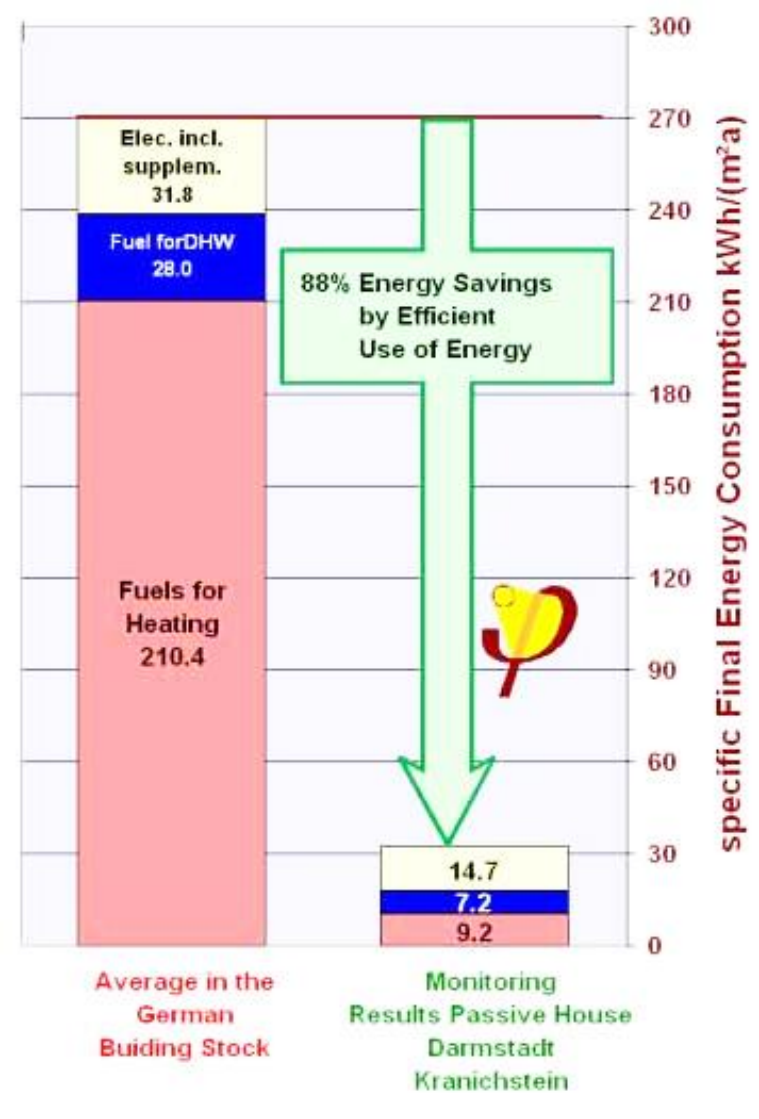
- Codes in effect are set by manufacturers (goal: sell lights, HVAC, electricity, etc)
- Award programs are often flawed as well - even LEED (insufficient knowledge of passive by developers - there was no provision for a building like the synagogue that had no HVAC system)
- Widespread ignorance hampers engineers and architects and renter/buyers
- Utilities have never had the vision to see the opportunity of passive solar -- thinking of providing wanted services of heat, cool, light rather than just electricity and gas

Passive Solar Europe

Courtesy Passivhaus Institut

- Germany and Scandinavia began passive solar home building in the 1990s
- Excellent resources and codes--but super tight homes require mechanical ventilation
- Typical 70-90% savings
- Driven by true cost pricing 30¢ up to 60¢ KWH peak periods

Passivhaus Performance



- 88% reduction realized in this German house
- Not unusual or difficult using passive techniques for heating, cooling and ventilation
- ***We have known how to do this since 1980!***

1987 BIG Passive Solar

- ING (NMB) bank building Amsterdam, 550,000 sf
- Daylit, natural ventilation
- Passive and active solar
- 90% energy use reduction no increase in cost
- Overcrowding led to changes in systems - mechanical added, reduced performance
- Operable windows did experience noise issues

1997 Passive Performance

- The Prisma building in Nuremberg
- Mixed use
- Daylit, passive heating, cooling and ventilation
- 140,000 square feet

Passive Solar Design Works

- The Greek and Roman architects and town planners understood how to do this
- This knowledge was regained in the 1970s and today a few architects continue to use integrated design to cut energy use 90%
- Sadly, solar expenditures are often for the most costly options instead of the most cost effective solution
- Lobbyists, congressional ineptitude and the power of the utilities and fossil fuel industry have won the struggle so far… but global warming may shift the balance

Cost Effectiveness USA

Clothesline	0.002 cents per kwh
Passive design HCVD	0-2 cents per kwh
Passive water heater	1-2 cents per kwh
Active water heater	2-7 cents per kwh
Photovoltaic	10-30 cents per kwh

What should we expect?

- **Health, comfort, joy and beauty!**
- 90% less energy needed for heating, cooling, and ventilation
- 75%+ daylighting
- Sustainable materials
- Comparable first cost

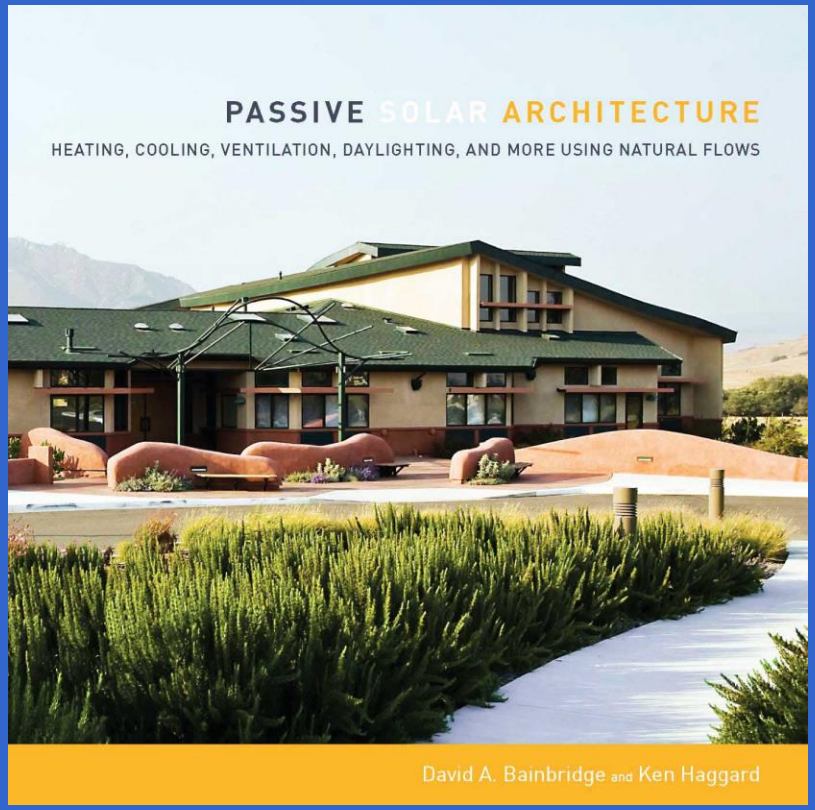
How?

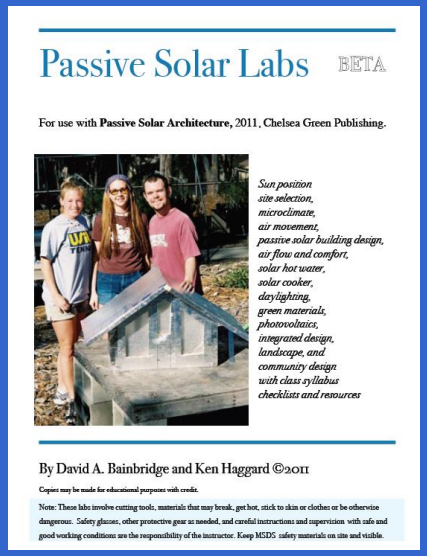
- Eliminate subsidies
- True cost accounting
- Integrated design
- Orientation, insulation thermal mass
- Modeling and calculation
- Research (just 0.02 percent of construction value today - versus 30% in dynamic industries)

Hull, England 2010

- “As an alternative to compulsory sustainable building standards, the study recommends that all new developments should consider passive solar design (PSD) at the planning stage. PSD involves optimising the use of solar heat, daylight and natural ventilation in developments.”

Resources





Passive Solar Labs BETA

For use with **Passive Solar Architecture,** 2011, Chelsea Green Publishing.

Sun position
site selection,
microclimate,
air movement,
passive solar building design,
air flow and comfort,
solar hot water,
solar cooker,
daylighting,
green materials,
photovoltaics,
integrated design,
landscape, and
community design
with class syllabus
checklists and resources

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Copies may be made for educational purposes with credit.

Note: These labs involve cutting tools, materials that may break, get hot, stick to skin or clothes or be otherwise dangerous. Safety glasses, other protective gear as needed, and careful instructions and supervision with safe and good working conditions are the responsibility of the instructor. Keep MSDS safety materials on site and visible.

RECOMMENDED READING

A Golden Thread K Butti and J Perlin

Passive Solar Architecture D A Bainbridge and K Haggard

Passive Solar Labs Manual D A Bainbridge and K Haggard

Village Homes' Solar House Designs - D A Bainbridge, J Hofacre and J Corbett

The Straw Bale House - D A Bainbridge, B & A Steen, D Eisenberg

Passive Solar House Basics - P van Dresser