

CH 7 PASSIVE SOLAR

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EGR343 Green Architectural Engineering
Lecture notes (Chapter 7)

↳ COLLECT, STORE, AND REDISTRIBUTE ENERGY WITHOUT FANS, PUMPS, OR COMPLEX CONTROLS

7.1, 2 HISTORY

A) WESTERN CIVILIZATION (MOSTLY EUROPE)

i) ANCIENT GREEKS (~600 BC TO ~30 BC)

- PEOPLE:**
- MOSTLY PEACEFUL AND PHILOSOPHICAL (SOCRATES)
 - FIRST OLYMPICS
 - INTRODUCED PROPORTION
 - FIRST IN SCULPTURE
 - THEN IN ARCHITECTURE

ARCHITECTURE

- SOUTH-FACING HOUSES WITH OVERHANGS
- LARGE WINDOWS → LIGHT SHINES ON THICK WALLS AND FLOORS (I.E., THERMAL MASS) TO STORE HEAT FOR NIGHTTIME HEATING OF HOUSE

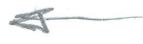
ii) ROMAN EMPIRE (~700 BC TO ~500 BC)

- PEOPLE:**
- GREAT ARCHITECTS AND ENGINEERS
 - IMPERIALISTIC
 - REPUBLIC

ARCHITECTURE

- FIRST GLASS WINDOWS (50 AD) → GREENHOUSE EFFECT
- SUN ROOMS → FRUITS + VEGETABLES ALL YEAR
- PUBLIC BATHS → FACED SOUTHWEST FOR SUN → PLUMBING
- "SUN RIGHTS" → LAWS TO ENSURE INDIVIDUALS HAD ACCESS TO SUNLIGHT VIA HOMES AND PUBLIC BUILDINGS

GOOGLE: "ROMAN EMPIRE MAP"



GOOGLE IMAGE: "ROMAN BATHS"



iii) DARK AGES IN WESTERN CIVILIZATION (~500AD TO ~1400AD)

PEOPLE

- "FALL OF ROMAN EMPIRE"
- BREAK-DOWN OF CIVILIZATION
- FEUDAL SOCIETIES

→ PEOPLE LIVED WITHIN WALLED CITIES AND CASTLES RULED BY WEALTHY POWER WITH A PRIVATE ARMY

ARCHITECTURE AND URBAN DESIGN

- ORGANIC VENEZULAR GROWTH OF BUILDINGS AND CITIES

→ IRONICALLY, BEAUTIFUL CROOKED COBBLE-STONE STREETS AND SOME ARCHITECTURE BEAUTIFUL WITHOUT "DESIGN" (FORMAL)

→ IRONICALLY, HIGH-DENSITY CITIES DURING THIS TIME RESULTED IN BETTER MASS TRANSIT LATER ON (I.E. NOW)

→ PEOPLE NOT SPREAD OUT LIKE IN U.S. AND OTHER MORE RECENTLY DEVELOPED PLACES.

→ CARS ↑ → DENSITY ↓

GOOGLE IMAGE "BELGIUM CASTLES" ETC.

GOOGLE IMAGE "ITALIAN CITY-STATES" ETC.

GOOGLE MAP "MONS, BELGIUM" ETC.

GOOGLE MAP "LOS ANGELOS" ETC.

iv) RENAISSANCE (~1400AD TO 1600AD) ← "RE-BIRTH"

PEOPLE

- CIVILIZATION!
- ART, SCIENCE, ETC.

ARCHITECTURE

- FIRST, BIG CHURCHES (CATHEDRALS)
- CONSERVATORIES (LARGE GREEN HOUSES)
- SUMMER ROOMS ON NORTH SIDE
- WINTER ROOMS ON SOUTH SIDE
-
-
-

↑ MORE ON THIS LATER

GO TO DR. W. HOMEPAGE, SEE ALL ITALY PICTURES

B) INDIGENOUS OLD WESTERN CIVILIZATIONS (NOT DEVELOPED)
OF AMERICAS

- AZTECS (MEXICO) "SUN"
- INCA (PERU) "SUN"
- CHanneled SUNLIGHT

→ U.S. AMERICAN INDIANS IN SOUTHWEST

- ★ → THICK WALLS (THERMAL MASS)
- ★ → ORIENTED HOUSES = f (SUN ANGLES & PATHS) AND CITIES

Google Images
"PUEBLO BONITO"
ARCHITECTURE

C) NON-WESTERN CIVILIZATIONS

- MESOPOTAMIA (~5000 BC FIRST CITY) "CRADLE OF CIVILIZATION" → LOW IRAC
- CHINA (FOR 1000'S OF YEARS) (NO DARK AGES)
- ★ → TURN HOUSES TOWARD SOUTH

→ ANCIENT EGYPT (~3000 BC to ~300 BC)

- ★ → THERMAL MASS'S TO COMPENSATE LARGE ΔT FROM DESERT RADIATIONAL COOLING (SEE CH 3)

→ BLACK POOLS OF WATER HEATED DURING DAY.

- WATER DRAINED THROUGH PIPES IN FLOOR TO HEAT PALACE AT NIGHT

Google Image
"MESOPATAMIA"

D) USA
↳ MODERN TIMES

★
EARLY 1900'S

FRANK LLOYD WRIGHT (1867 to 1959)
→ U.S.A.

GOOGLE IMAGES:
"FRANK LLOYD WRIGHT SOLAR"

- ★ → OPTIMIZED OVERHANGS
- ★ → CURVED BUILDINGS TO MATCH SUN PATHS "SOLAR HEMICIRCLE"

→ AN ARTS & CRAFTS AND VICTORIAN ERA ARCHITECT WHO VISITED JAPAN AND WAS INFLUENCED

GOOGLE IMAGES
"PRAIRIE STYLE"

→ INVENTED PRAIRIE STYLE

GOOGLE IMAGE
"WALTER GROPIUS SOLAR"

ALSO SEE WALTER GROPIUS
→ CAME TO U.S.

LEONARD SCHAUB (1895 - 1980)

→ SEE DR. W. "MANSIONS" PPT ON HIS WEBSITE

1800'S, 1900'S MOSTLY

THIS LECTURE ALSO HAS SOME ARCHITECTURAL FUNDAMENTALS

7.4



PASSIVE ADVANTAGES OVER

ACTIVE
SOLAR

- ① LESS INITIAL COST
- ② LESS MAINTENANCE
- ③ MORE RELIABLE
 - PREDICTABLE
 - LONGER LIFE
- ④ ~~YIELDS~~ BETTER OVERALL ARCHITECTURE
 - ESTHETICS
 - VENACULAR
 - LOCAL MATERIALS
 - LOCAL STYLES
 - COMPLIMENTS SURROUNDINGS
 - HUMAN SCALE
 - YIELDS TO NATURE
- ⑤ LESS "ENABLING" OF OUR EVER INCREASING RELIANCE ON TECHNOLOGY



★ All

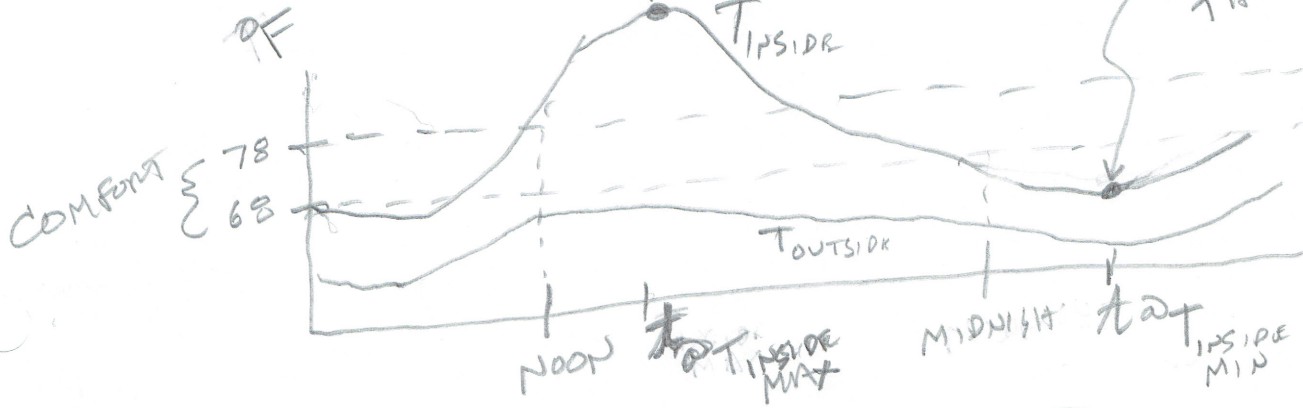
7.6-11 DIRECT-GAIN SYSTEMS (INCLUDING TROMBE WALL)

~~~~~ = SHORT WAVE SUNLIGHT  
 ~~~~~ = LONG WAVE HEAT  
 ~~~~~ = INSULATION

JUST FOR GRAPHICAL PURPOSES HERE

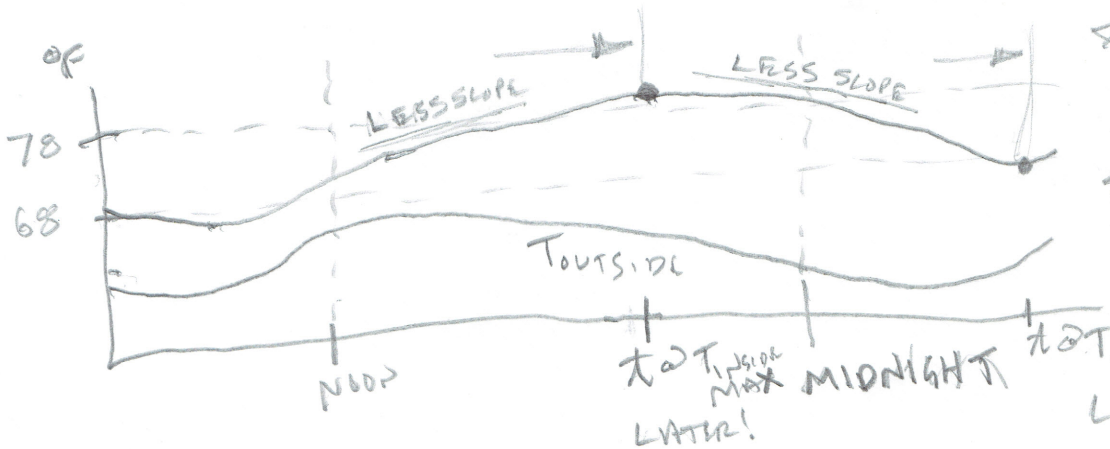
(I.E., NO PHYSICS SIGNIFICANCE)

## LOW-MASS FLOORS + WALLS:



TOO BIG A  $\Delta T$

## HIGH-MASS FLOORS + WALLS



★  $\Delta T$  INSIDE AND  $\frac{dT_{INSIDE}}{dt}$  COMFORT LATER!

# THERMAL MASS CHOICES

→ CONCRETE FLOORS AND WALLS (AND COLUMNS) GOOD,

→ FLOORS BEST CHOICE:

- ① ~~IT'S~~ MOST SUN DIRECTLY
- ② MOST COMFORTABLE AS HEAT RELEASED
- ③ EASIER TO CONSTRUCTION
- ④ EASIER TO PENETRATE & MAINTAIN STRUCTURAL ENGINEERING
- ⑤ EASIER TO SURFACE (PART OF BEST?)
- ⑥ MORE ESTHETIC

→ WATER OR WATER FOR THERMAL MASS:

NOT IN HUMID CLIMATES

- ① COLUMNS OF WATER INSIDE → LET LIGHT THROUGH
- ② POOLS INSIDE/OUTSIDE → BUT MAINTENANCE & SANITATION ISSUES → MAYBE A COY. POND

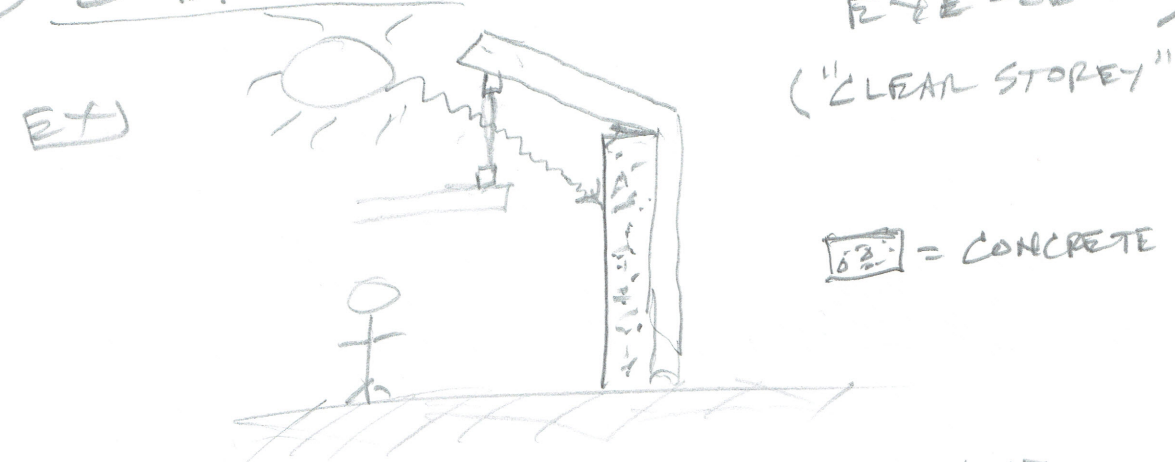
~ ③ EGYPTIAN TYPE BLACK POOL OUTSIDE, PUMP WATER IN AT NIGHT → SEMI PASSIVE / PASSIVE

~ ④ SOLAR COLLECTORS WITH PIPING AND PUMPS → BUT THIS IS NOT PASSIVE (SEE CH 3) "ACTIVE SOLAR"

GOOGLE IMAGE  
"THERMAL MASS WATER"

# MORE ELABORATE TECHNIQUES

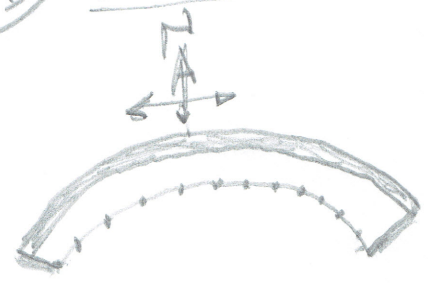
(A) CLERESTORY (HIGH WINDOW ABOVE EYE-LEVEL)  
("CLEAR STOREY")



ALSO GOOD FOR BRINGING IN LIGHT  
SEE ITALY, ROME PICTURE ON DRW  
WEBSITE BASILICA ST. PETER

→ HISTORICALLY CLERESTORY MEANT  
UPPER LEVEL (SECOND STOREY) OF  
A ROMAN BASILICA

(B) SOLAR HEMICYCLE BUILDING FOOTPRINT



GOOGLE IMAGE  
"SOLAR HEMICYCLE"



## ③ CHANNEL SUNLIGHT TO THERMAL MASSES

- HIGH-REFLECTANCE PAINTS
- POLISHED METAL
- MOVABLE REFLECTORS ON SKYLIGHTS =  $S(\theta_{ALT})$

## ④ TROMBE WALL ("THERMAL STORAGE WALL") AND DIP → USES "GREEN-HOUSE EFFECT"



"GAP" (1 in. MIN)

- PAINT WALL BLACK OVER GLASS
- OPERABLE SHUTTER FOR NIGHT IS GOOD
- BUT NOT PASSIVE

BOOKSAYS:  
→ AVOID CIRCULATING AIR FROM GAP  
~~FOR ADDED HEATING (OLD IDEA THAT DOESN'T WORK)~~

→ MORE RESEARCH NEEDED MAYBE

★ FALL

# DESIGN OF DIRECT GAIN SYSTEMS (INCLUDING TROMBE WALL)

- ★ (A) BUILDING MUST BE WELL INSULATED
- ★ (B) USE THERMAL DRAPES AT NIGHT IN COLD CLIMATES
- ★ (C) OPTIMUM SOUTH-FACING GLAZING (GLASS) (FROM TABLE 7.7A)

| U.S. CLIMATE REGION | GLAZING AREA % OF FLOOR AREA | HEATING LOAD CONTRIBUTED BY SOLAR (%) |                       |
|---------------------|------------------------------|---------------------------------------|-----------------------|
|                     |                              | NO NIGHT INSULATION                   | WITH NIGHT INSULATION |
| 3 (SOUTHEAST PA)    | 28                           | 21                                    | 60                    |
| 11 (PHOENIX, AZ)    | 12                           | 60                                    | 75                    |
| 16 (MIAMI, FL)      | 2                            | 48                                    | 54                    |

★ BIGGER THAN HOTTER PLACES

★ SURE, BIG NUMBERS BUT TOTAL HEATING LOAD IS LOW

- ★ (D) WINDOWS SHOULD BE HIGH-PERFORMANCE
  - DOUBLE GLAZED
  - MAYBE SPECIAL GAS BETWEEN GLAZINGS

## ★ (E) OPTIMUM THERMAL MASS SIZES (NOT TROMBE WALL)

| TYPE                             | THICKNESS* | SURFACE AREA / GLAZING AREA | ★ FLOOR / MOST WALLS |
|----------------------------------|------------|-----------------------------|----------------------|
| CONCRETE OR MASONRY (DIRECT SUN) | 4-6 in     | 3                           | ★ FLOOR!             |
| " (REFLECTED SUN)                | 2-4 in     | 6                           |                      |
| WATER                            | 6 in       | 1/2                         | ★ BEST               |

\* ADDED THICKNESS;  $\Delta T_{INSIDE}$  ↓, COMFORT ↑

- ★ (F) USE DARK COLORS FOR THERMAL MASSES
- ★ (G) USE LIGHT COLORS FOR ALL ELSE TO REFLECT LIGHT TO MASSES

★ (H) OPTIMAL THERMAL MASS FOR TROMBE WALL

| TYPE                | THICKNESS* | SURFACE AREA / GLAZING AREA |
|---------------------|------------|-----------------------------|
| ADobe (DRY EARTH)   | 6-10 in    | 1                           |
| CONCRETE OR MASONRY | 10-16 in   | 1                           |
| WATER               | 8+         | 1                           |

\* THICKER YIELDS BETTER ALL-NIGHT HEAT

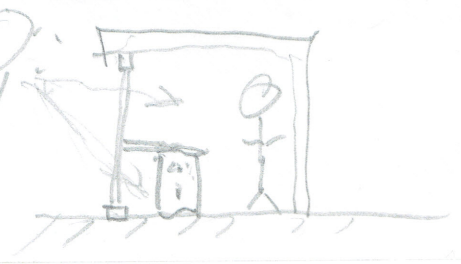
- ★ → WORKS BEST IN COMBINATION WITH OTHER THERMAL MASS SYSTEMS FOR OPTIMAL  $\Delta T$
- ①  $\Delta T$  INSIDE
  - ② VIEWS
  - ③ INTERIOR LIGHTING
  - ④ NO EXCESS OF SUN GLARE

★ MUCH BETTER THAN REGULAR WALL'S THERMAL MASS AND EVEN BETTER THAN CONCRETE FLOORS

★ → WATER CAN BE IN VERTICAL TUBES OF

- ① PLEXIGLASS
  - LETS LIGHT THROUGH!
  - MAYBE A FISH TANK? IF SMALL AND TOUGH FISH
- OR
- ② STEEL
  - PAINT SUN SIDE BLACK
  - PAINT INSIDE WHITE

★ → HALF-HEIGHT WALL COMBO-WINDOW + TROMBE



# \* 7.12-16 SUNSPACES ("SOLARIUM")

- CALLED "CONSERVATORIES" IN US, 1700'S, 1800'S
- CAN ACT AS GREENHOUSES (ROMANS DID THIS)
- " " " LIVING SPACE (BUT  $\Delta T_{AIR}$  TO BIG SOMETIMES)
- COLLECTS HEAT FOR HOUSE!
- ISOLATE IT AT STRATEGIC TIMES (ASSUME SUN)
  - NO HEATING OR COOLING (WILL OVERHEAT)
  - DOORS + OPERABLE WINDOWS AND FANS (BIG ONES)
- ACTS AS BUFFER TO COLD AT NIGHT (ONES)

- 7.14 → GLAZINGS USE THERMAL MASS'S
- PERPENDICULAR TO SUN DURING COLDEST MONTHS

- MAY CHOOSE VERTICAL
  - LESS LEAKY
  - BEST WHEN OVERHANG SHADING DESIGN CH 9

→ INCLUDE SOLAR MASS IF SPACE USED MOST OF YEAR

→ BUT IN VERY HOT OR COLD CLIMATES

→ USE TREES, REFLECTORS, AND OVERHANGS TO CONTROL LIGHT (CH 9, 13)

→ USE MOVABLE SHADES!

JUST USE FOR A WINTER USE SPACE

JUST USE AS ISOLATED HEAT COLLECTOR

GOULLE IMB "OPPELAND HOTEL"

→ ALMOST ALWAYS FACE GLAZING TO SOUTH

BUT) EXCEPTIONS:

① ART/ARCHITECTURAL STUDIOS WANT MOSTLY NORTHERN LIGHT

→ DESPITE WORSE THERMODYNAMICS, CONSISTANT ("COOL" AND CONTROLLED) LIGHT WITH NO GLARE IS MOST IMPORTANT

② "USES" FOR MOSTLY-MORNING

→ FACE SOUTHEAST

→ EX) SCHOOLS, RE

③ MICROCLIMATES WITH MUCH MORNING FOG OR CLOUDS

→ FACE SLIGHTLY WEST OF SOUTH

④ BREAKFAST ROOMS

→ FACE EAST FOR NICE MORNING LIGHT

# 7.17 HEAT STORAGE MATERIALS



- ① CONCRETE MASONRY VERY GOOD AND AS STRUCTURAL
- ② WATER ~~OR STEEL~~ (2X) AS GOOD

NEW ③ PCM BEST AND LET LIGHT THROUGH  
 (PHASE CHANGE MATERIALS) SOLID-LIQUID

- ① + ② STORE AS LATENT HEAT (SEE SCH3)
- PCM STORES AS SENSIBLE HEAT
- AS  $T \uparrow$ , WHEN  $T_{\text{MELTING}}$  REACHED, MATERIAL ABSORBS MUCH HEAT FOR LITTLE  $\Delta T$
- UNTIL ALL MATERIAL LIQUID

→ THEN AS  $T \downarrow$ , PCM SOLIDIFIES, HEAT RELEASED  
 → LOOK FOR IT EMBEDDED IN DRYWALL

~~EX~~

|                  | HEAT STORAGE<br>(KJoule/Kg·Kelvin) | COST |
|------------------|------------------------------------|------|
| <del>WATER</del> |                                    |      |
| <del>WATER</del> |                                    |      |
| <del>WATER</del> | 2                                  | 4    |

GOOGLE SCHOLAR:

"PHASE CHANGE MATERIAL PASSIVE SOLAR"

Google:

"SONNESCHIFF" SOLAR CITY

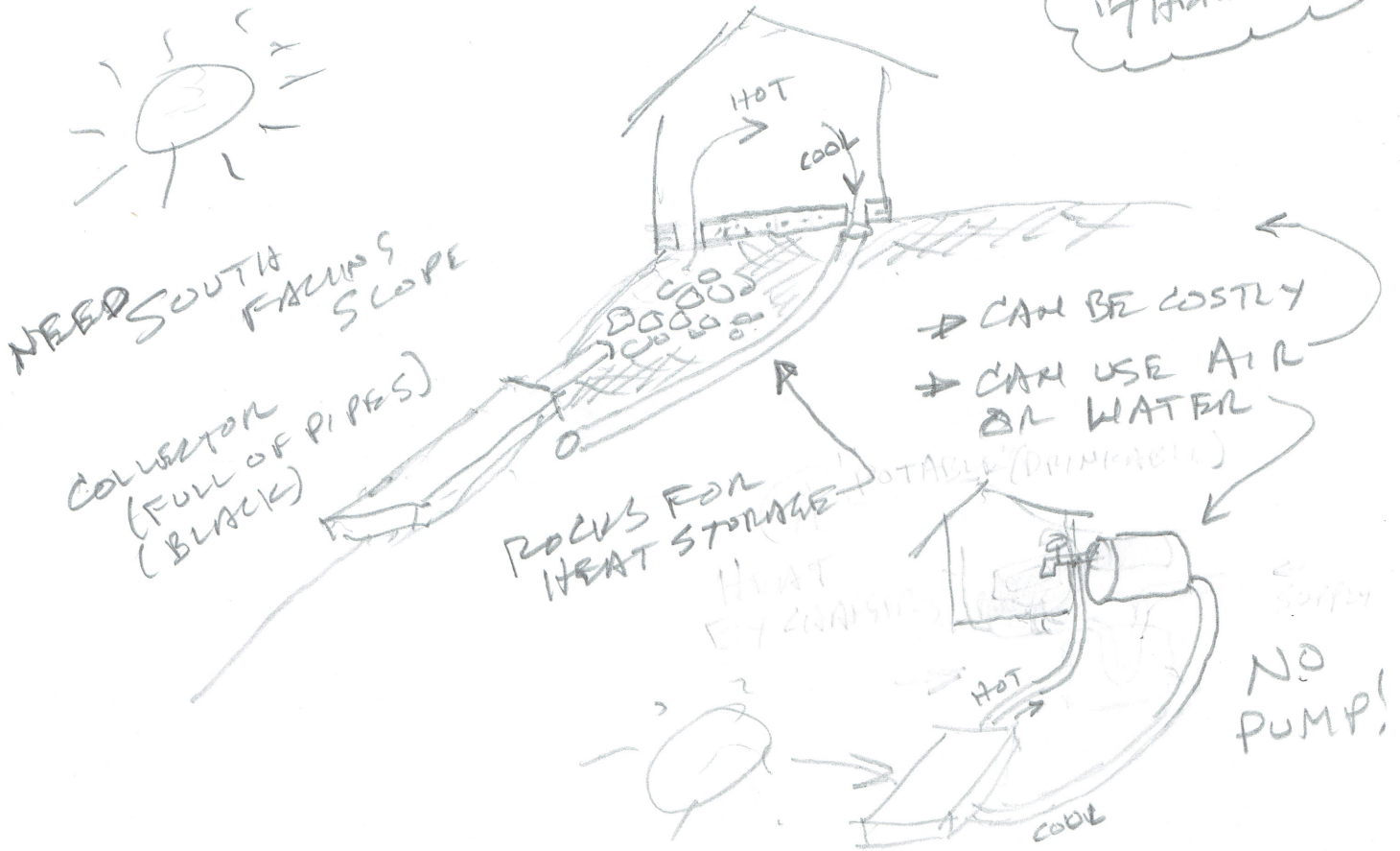
→ PCM'S

→ BETTER THAN NET-ZERO ENERGY  
 → PRODUCES 4X WHAT IT NEEDS

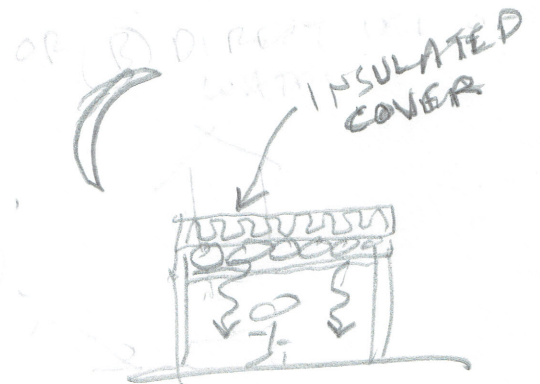
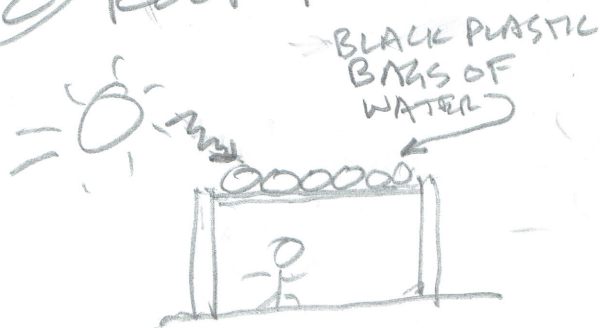
# 7.18 OTHER PASSIVE SOLAR

## ① THERMOSIPHON (CONVECTIVE-LOOP)

GOOGLE IMG  
THERMOSIPHON



## ② ROOF PONDS



### ③ ROOF RADIATION TRAP

