Gay Head Lighthouse Visitor's Center – Environmental Opportunities

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Beautiful site but what about utilities?

- Avoid the approach of the affluent
  - Somebody has to pay, for energy and environmental degradation
- Water may be scarce (as it is on Cape Cod)
- Please do not compartmentalize BT and Design

Things to think about

1. Warmth in spring and autumn
2. Comfortable indoor environment in summer
3. Human waste disposal without sewer or septic system
4. Water conservation
   a. greywater recycling for irrigation
   b. rainwater capture
5. Little or no need for off-site fuels
   a. Conservation
   b. On-site electricity and hot-water production using renewable source (maybe)
6. Responsible choice of materials

1. Warmth in cool weather

- Key factors
  - Insulation
  - Windows for solar energy
  - Heat-absorbing mass to regulate indoor temperature

Passive solar heating

- Direct gain
- Sunspace
- Trombe wall

A Simple Direct Gain System

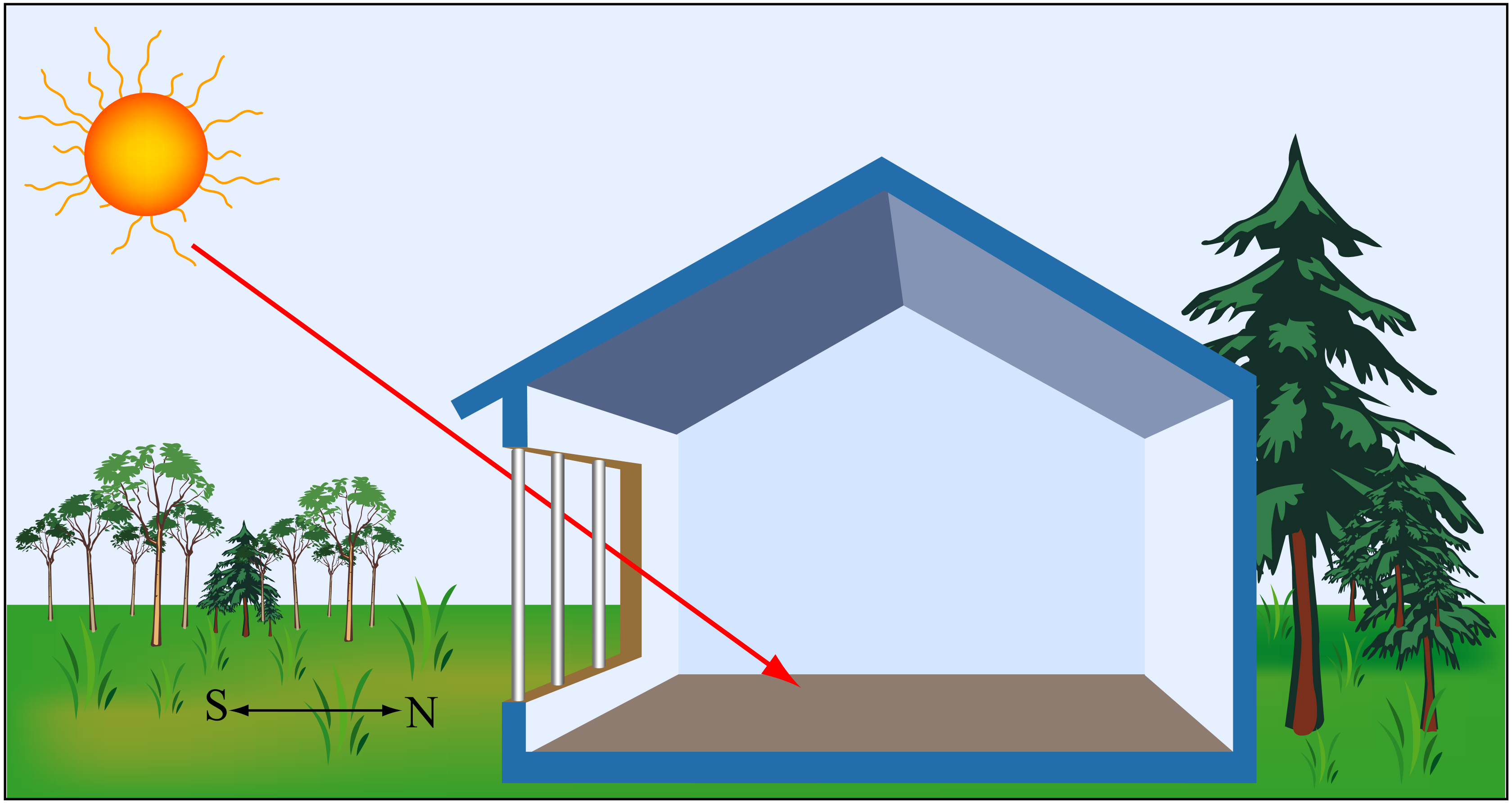


Figure by MIT OCW.

Clerestory – another form of direct-gain system

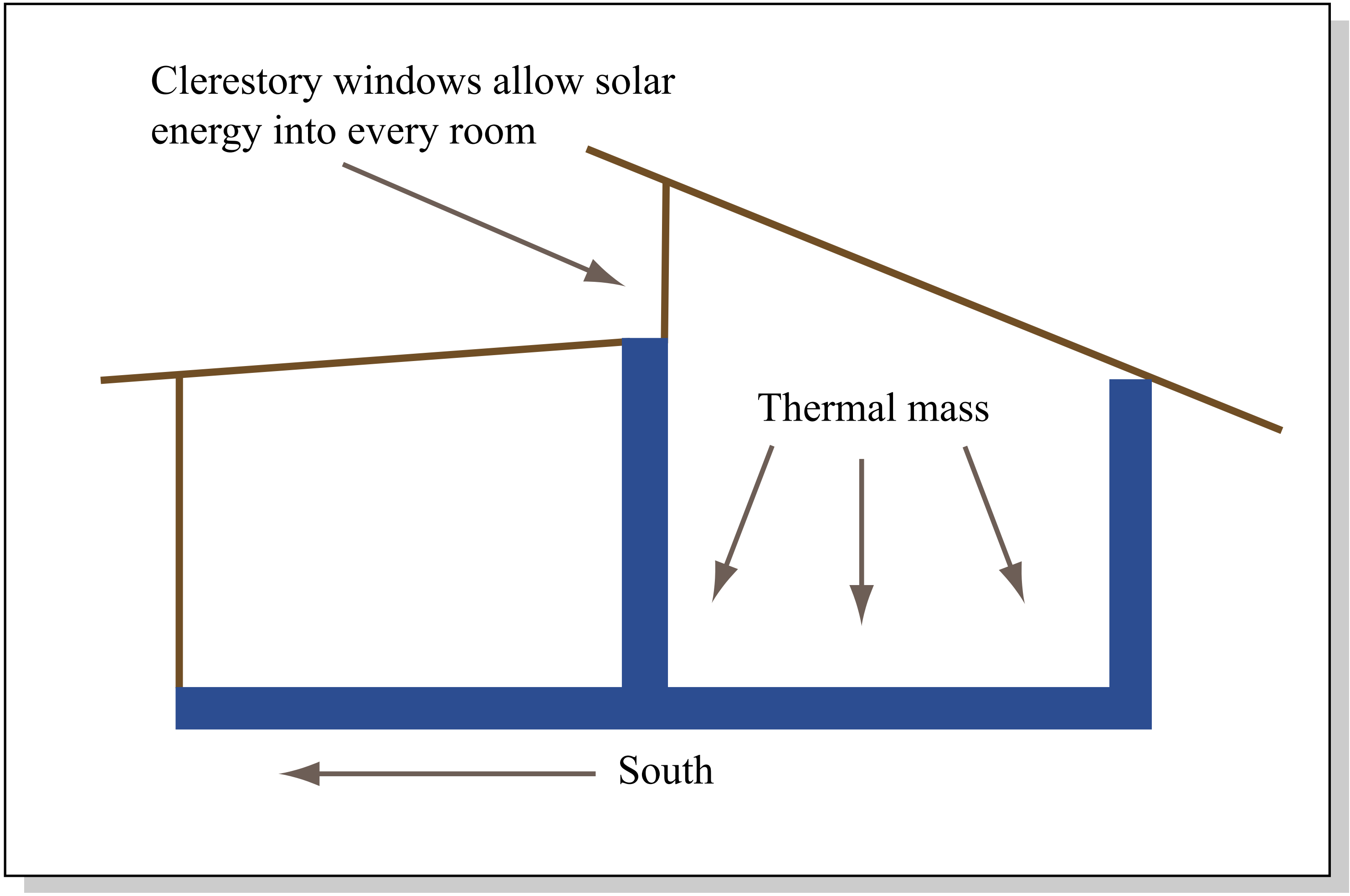


Figure by MIT OCW.

Sunspace with mass wall added

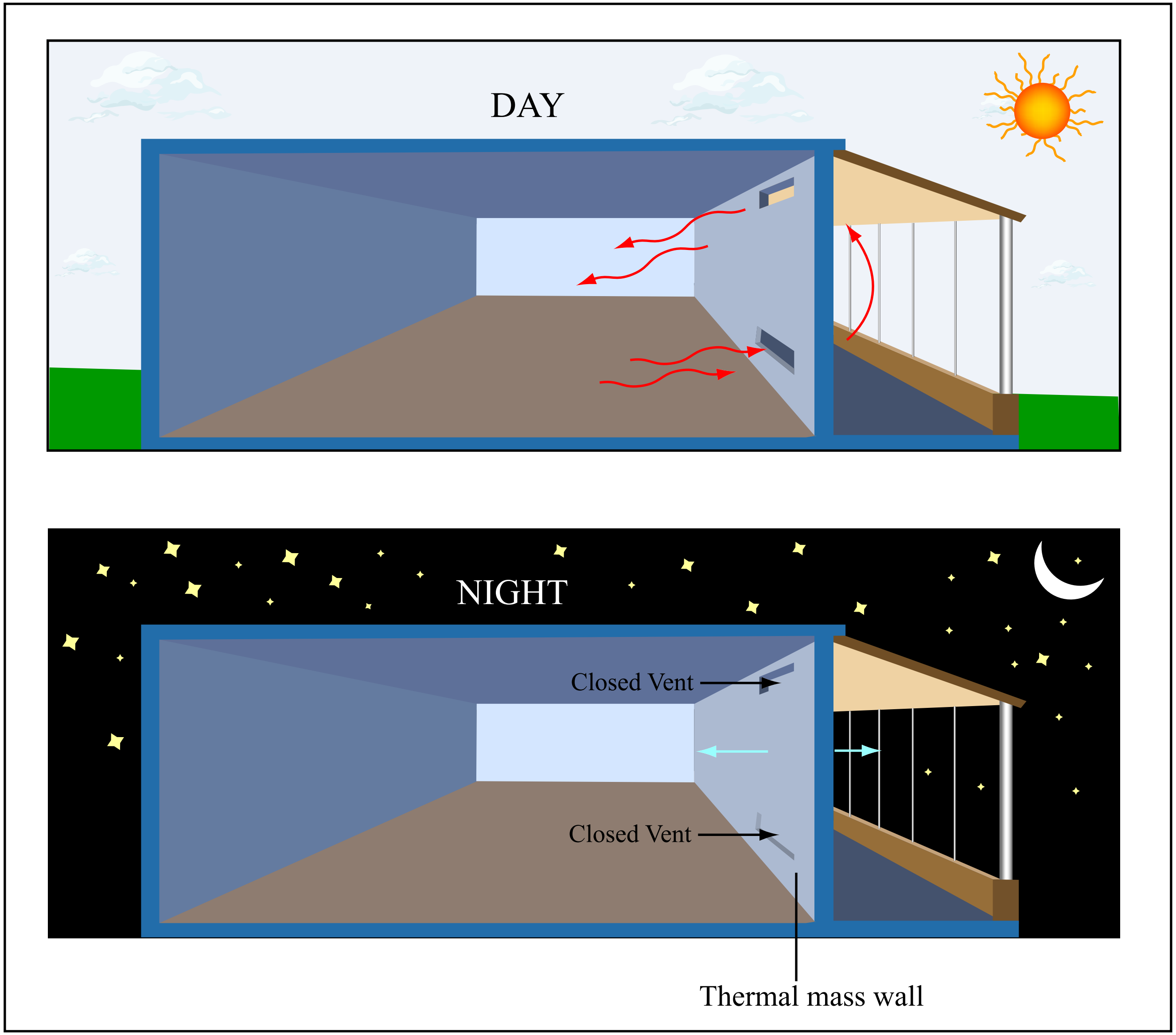


Figure by MIT OCW.

Trombe Wall Diagram

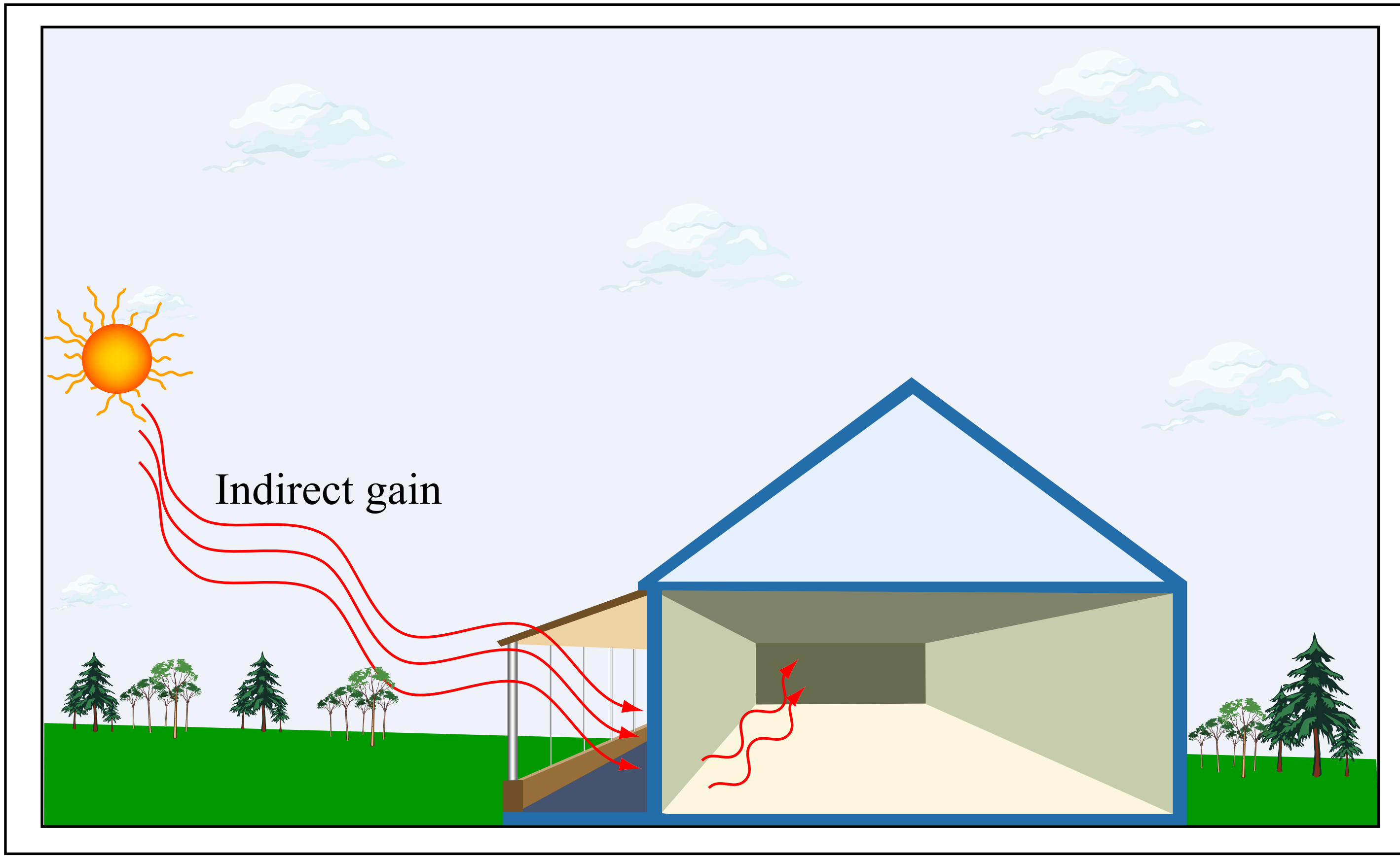


Figure by MIT OCW.

Trombe Wall with Vents

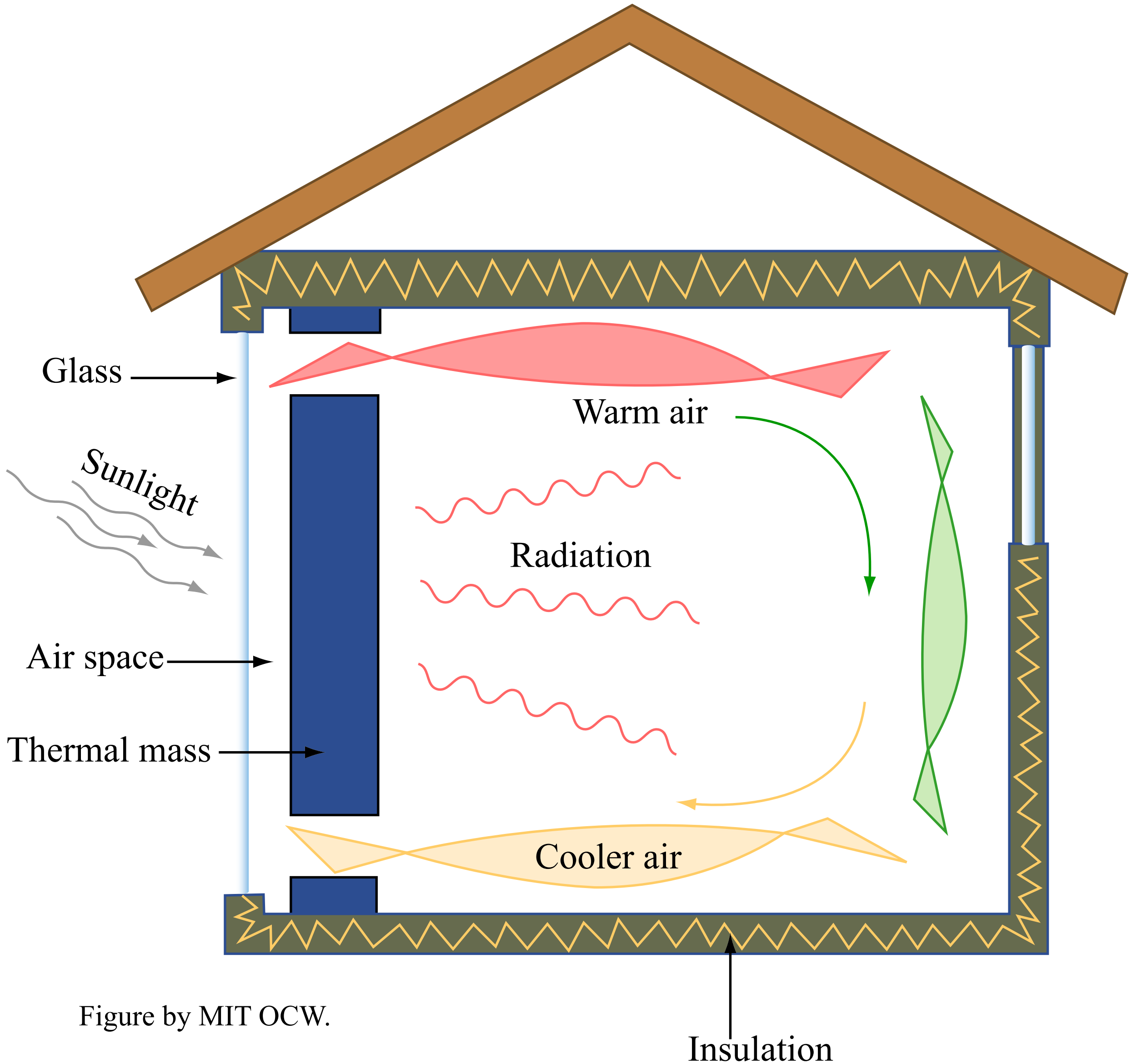
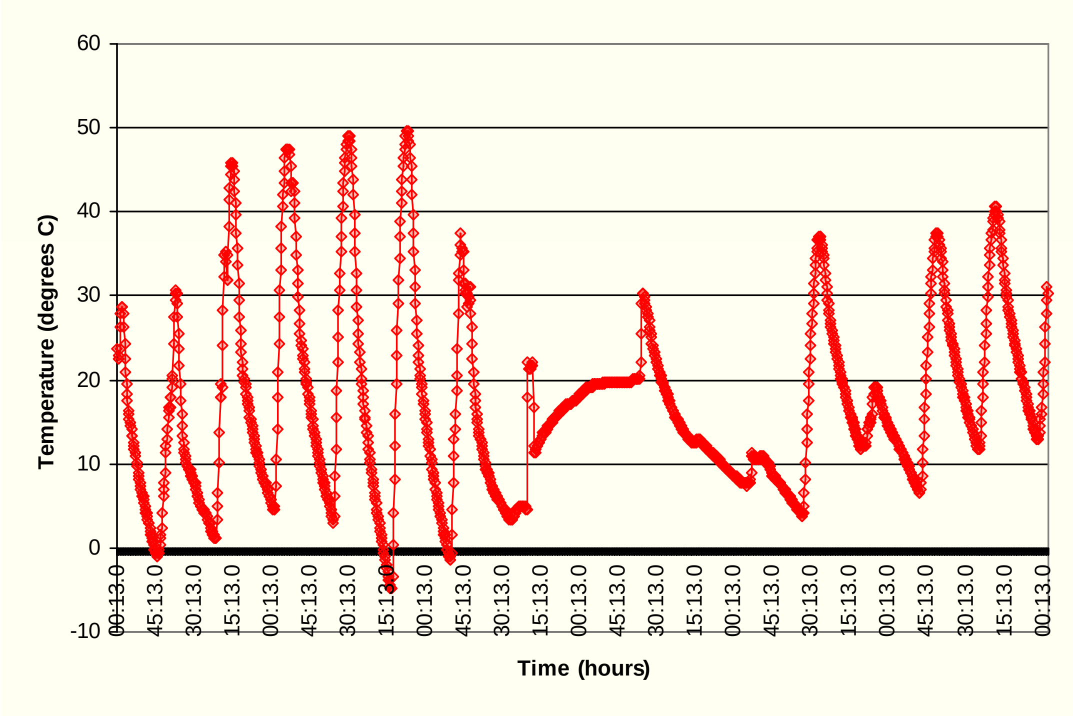


Figure by MIT OCW.

Passive Solar Heating

Taking advantage of free heating for “elfhouse”

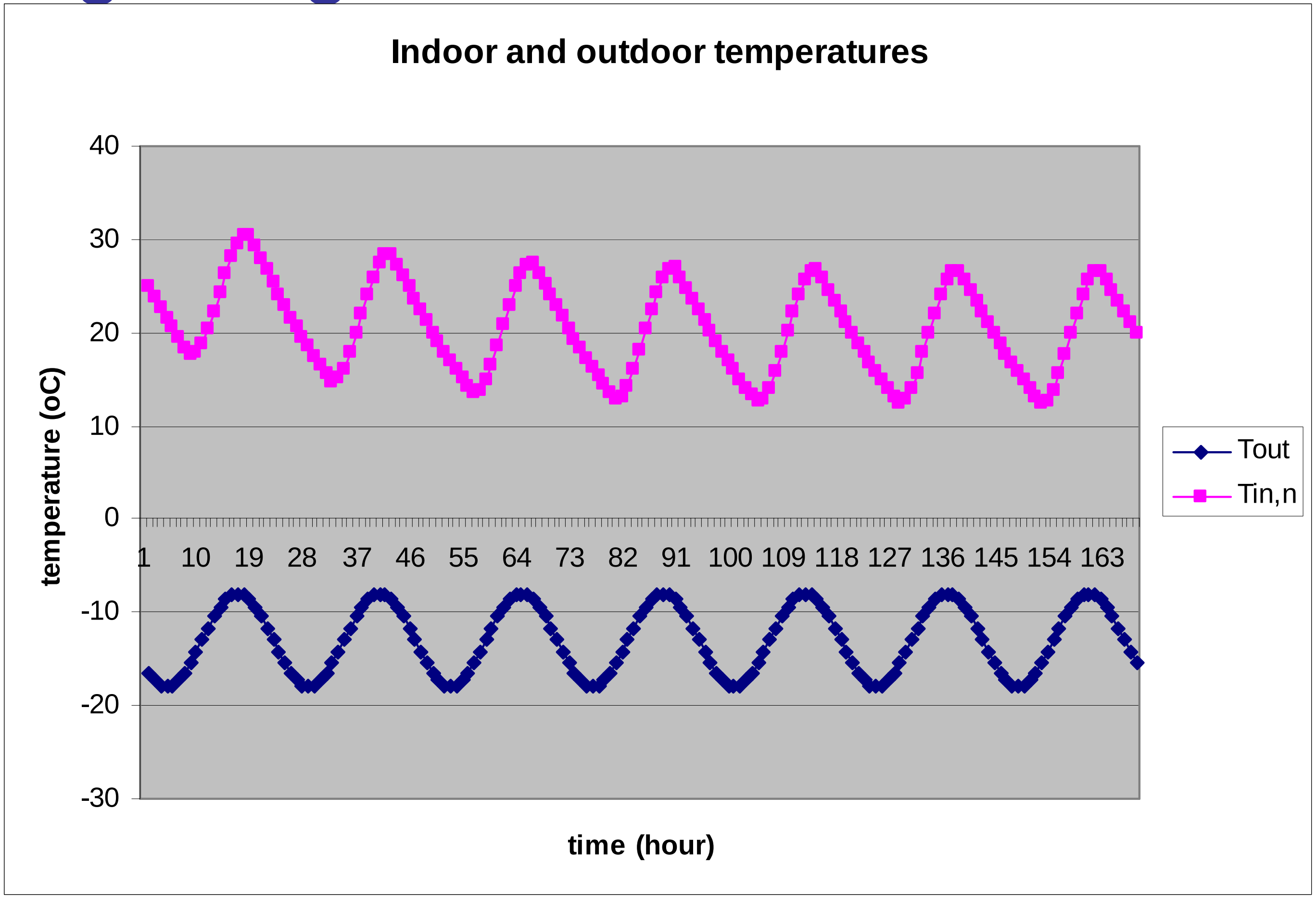


Average Temperature First Week = 16.9 deg C
Average Temperature Second Week = 17.3 deg C

Insulation, glass and mass for a full-size house

- Walden, made of 15 cm extruded polystyrene (no openings, no airflow):~1,000 W of heat needed at 0 ^{o}F.
- Henry David needs fresh air, which requires another 500 W to heat.

Walden with south-facing, double-pane glazing and water for thermal storage

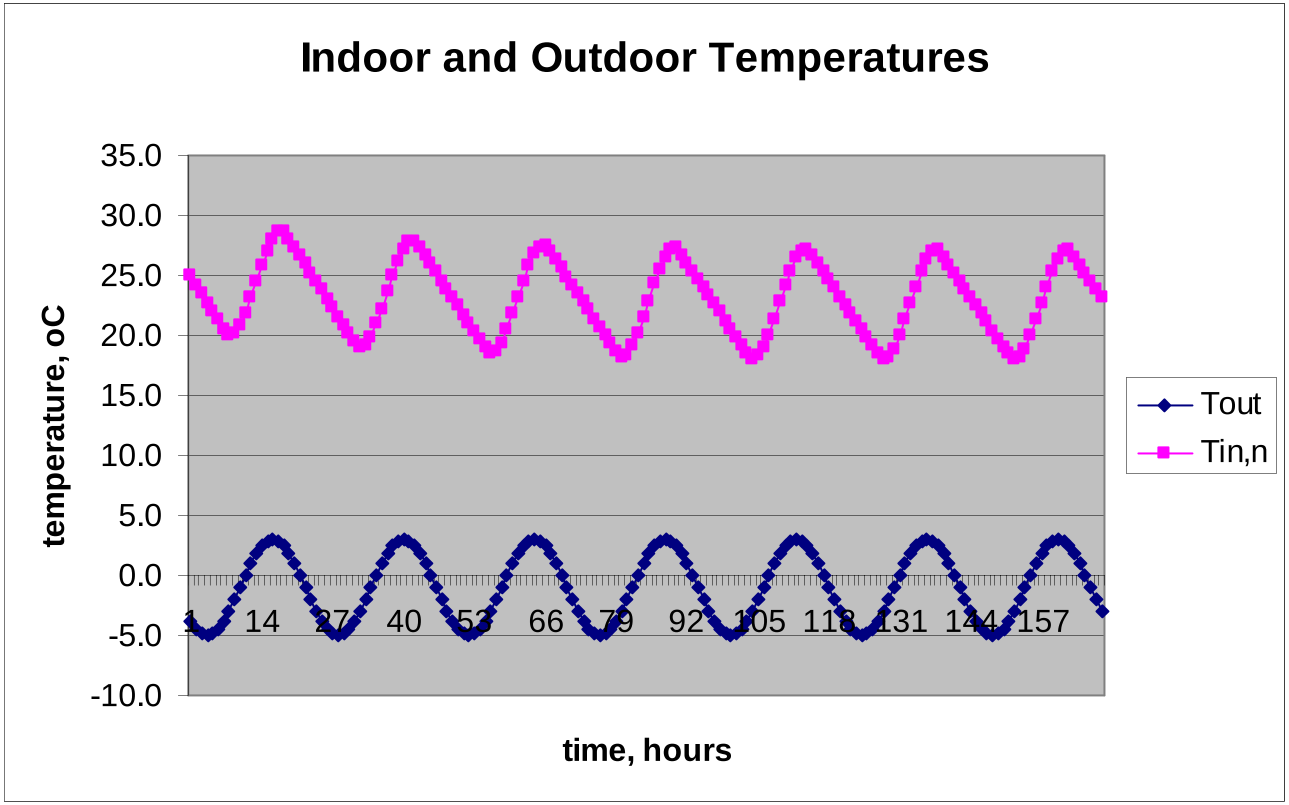


5 m^2 glazing, 1000 kg water

Passive solar design guidelines

- South glass – within 30^o of due south
- Glass area ~12% of floor area
- Mass area ~ 6x glass area
- Rules from http://www.wbdg.org/design/psheating.php

Try these guidelines – they look pretty good!



2. Keeping cool in the summer

- Shade the windows
- Control internal heat sources
- Use natural ventilation to keep indoor temperatures close to outdoor values
  - Wind-driven
  - Buoyancy-driven
- Use thermal mass and restrict airflow during the day when daytime temperatures are hot

Wind-driven flows for Gay Head

- Better choice than buoyancy-driven flows
  - Open site
  - Low building
- Need cross ventilation path
  - A few m^2 on both the windward and leeward sides should be enough
- Need exposed thermal mass for night cooling (but it’s necessary for passive heating in winter)

3. Waste disposal

Clivus Multrum composting toilets

Note: need electricity (AC or DC) and small amounts of water (1-3 gal/day for composter, 3 oz. per flush for foam-flush toilet)

4. Water conservation
a. Graywater systems

- Reduces use of potable water for irrigation
- Good for plants
- Reduces energy and chemicals associated with potable water systems
- Recharges groundwater
- Reduces strain on existing sewage and septic systems (if available)
- Reclaims otherwise wasted nitrogen and phosphorus
- Information source: http://greenbuilding.typepad.com/naturecenter/

Wellfleet system

- Toilet water is added to greywater stream
- System includes filters
- Plants in bog garden take up nitrogen
- Run-off is desirable for surrounding area
- State and local codes must be followed
- Greywater central for information: http://www.oasisdesign.net/greywater/index.htm

5.a. Energy conservation

- Lights – no incandescents
- Fans
- Computers – flat-panel displays, shut down when not in use
- Refrigeration
- Hot water – low-flow, low standby losses

5.b. Renewable electricity
On-site photovoltaic system

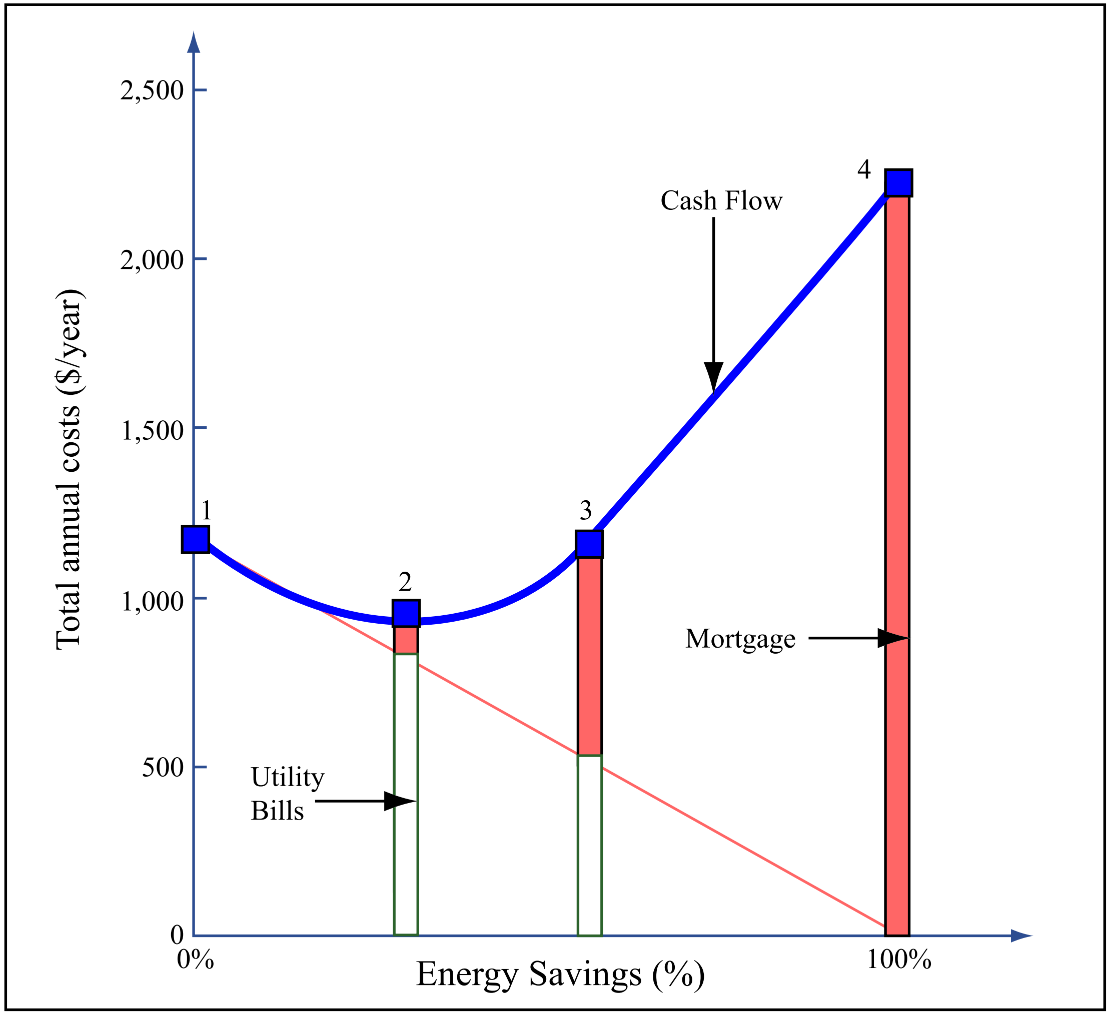


Figure by MIT OCW.

NOT economical for houses – consider fuel switch for fridge and hot-water

PV Basics

- About 1000 W/m^2 from the sun, maximum
- PV cells are 12-20% efficient in converting solar irradiance to electricity
- A 1 m^2 panel will produce about 150 Watts of DC electricity, under peak sun conditions
- For New England, sizing rules are based on 4.5 hours/day of peak-equivalent sun
- A 1 m^2 panel will therefore produce about 675 Whr of electricity
- Add up all electrical loads and include 20-40% sizing margin for system losses (inverter, storage)
- Example: 10 kWh/day (my house) would require ~ 15 m^2 of PV panels before storage loss adder, 20 m2 with losses
- An array of 20 m^2 produces 3 kW peak (remember for comparison with wind)
- Install on roof or on ground

Wind turbine basics

- Freshman physics: power = force x velocity
- Force is pressure x area
- Wind pressure = $\frac{1}{2} \rho v^2$
- Wind power = $\frac{1}{2} \rho v^2 \pi r^2 v = \frac{1}{2} \rho \pi r^2 v^3$
- For $r = 1$ m and $v = 1$m/s, $P \cong 2$ W
- $r = 1.5$ m and $v = 6$ m/s, $P \cong 0.91$ kW

Wind turbine basics

- Efficiency http://en.wikipedia.org/wiki/Wind_power
  - 59% theoretical maximum
  - 30% theoretical maximum for propeller-type turbines
  - 35% achievable for vertical axis “egg beaters”
  - 10-20% achievable for propellers

Wind turbine examples

- US DOE example (http://www.eere.energy.gov/consumer/your_home/electricity/index.cfm/mytopic=11010)
  - 1.5 kW turbine will provide 300 kWh/month (10 kWh/day) in an area with an average wind speed of 14 mph (6.3 m/s)
- Bergey (wikipedia example)
  - 1.5 kW turbine: 1.5 m radius blades, 21 m tower

6. Material selection

- Recycled tire flooring at Wellfleet
  - Anti-slip
  - Durable
  - Easy to maintain