Tiny Houses

The thermal network of repurposed cargo containers

HOUSTON GREEN BUILDING RESOURCE CENTER PROGRAM 6/24/15

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Characteristics of repurposed containers

- Structural integrity
- Inexpensive
- Durable exterior surface
- Small, compact, low surface to volume ratio
- Massive, conductive, high diffusion

CLOSED MODE DYNAMICS OF THERMAL ENVELOPES

Summer Day

High R-value
Low thermal emissivity
Reflect sun/Shade
Vent skin/double envelope
Daylight
BBQ

Summer Night

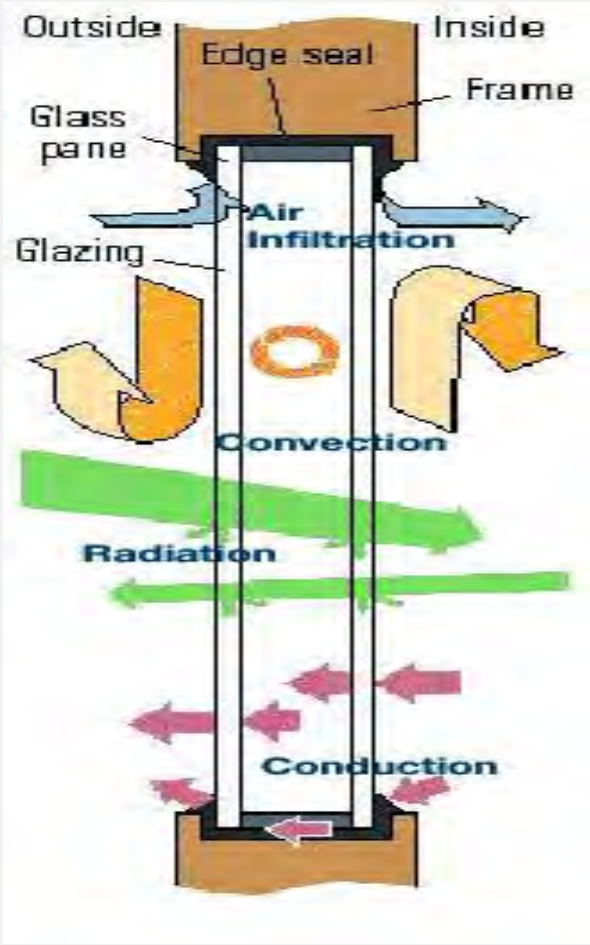
High R-value
Low thermal emissivity
Re-emit thermal radiation
BBQ

Winter Day

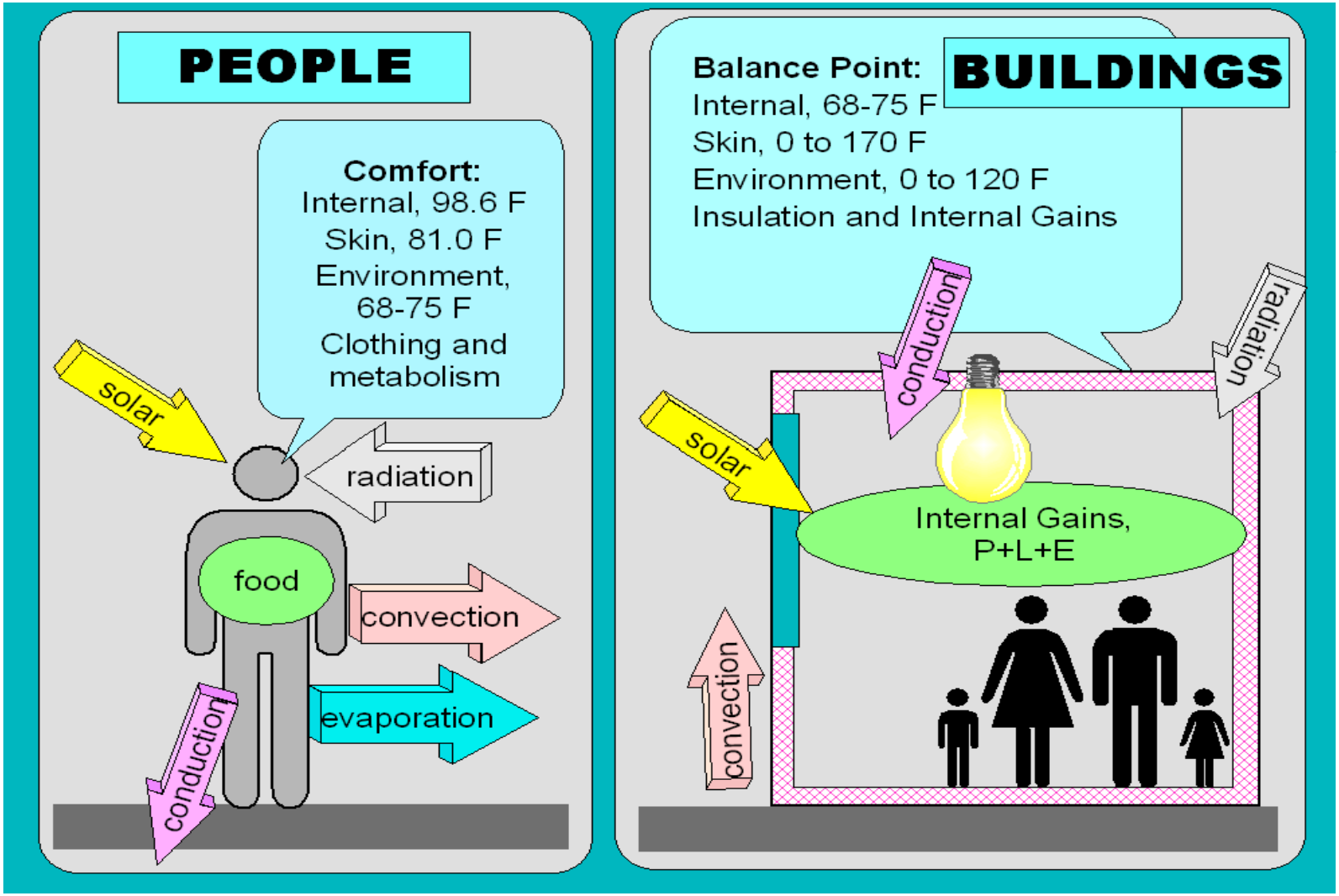
High R-value
Low thermal emissivity
Admit sun
Bake cookies

Winter Night

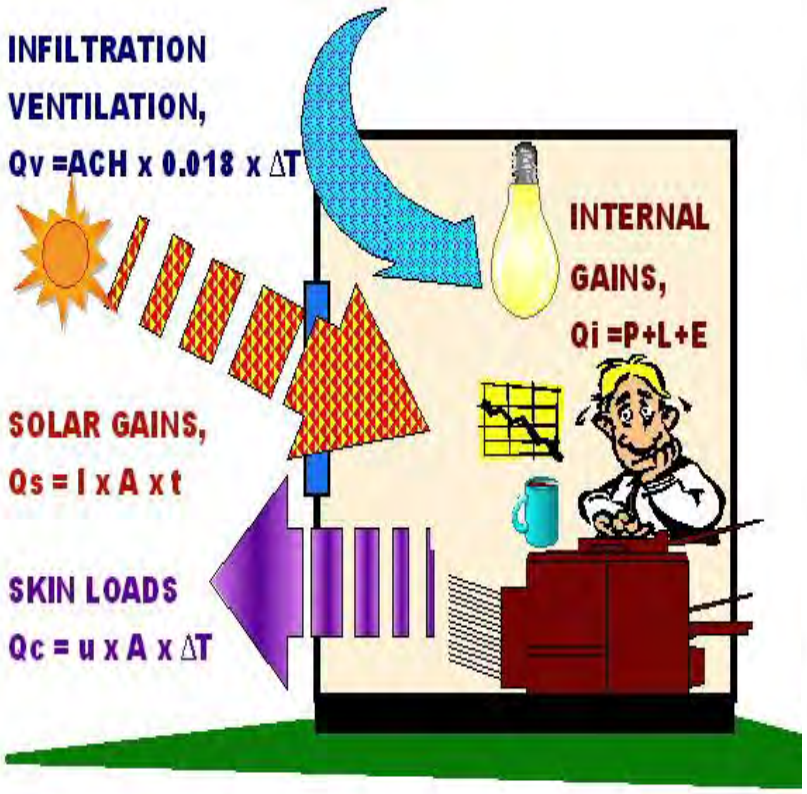
High R-value
Low thermal emissivity
Block thermal radiation
Cover windows
Bake cookies



BALANCE POINT (thermal equilibrium temperature)



Heat transfer coefficients and energy balance

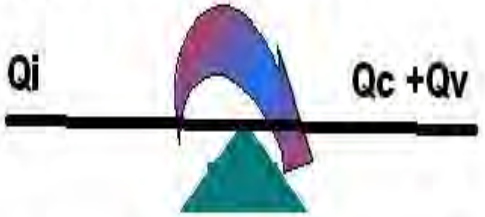


MODIFIED LOSS COEFICIENT, BTU/DEGREE DAY

$\Sigma ua = (u1 \times A1) + (u2 \times A2) + \ldots$

$MLC = 24\ HR/DAY \times (\Sigma uA + (ACH \times 0.018)$

BALANCE POINT



GAINS = LOSSES

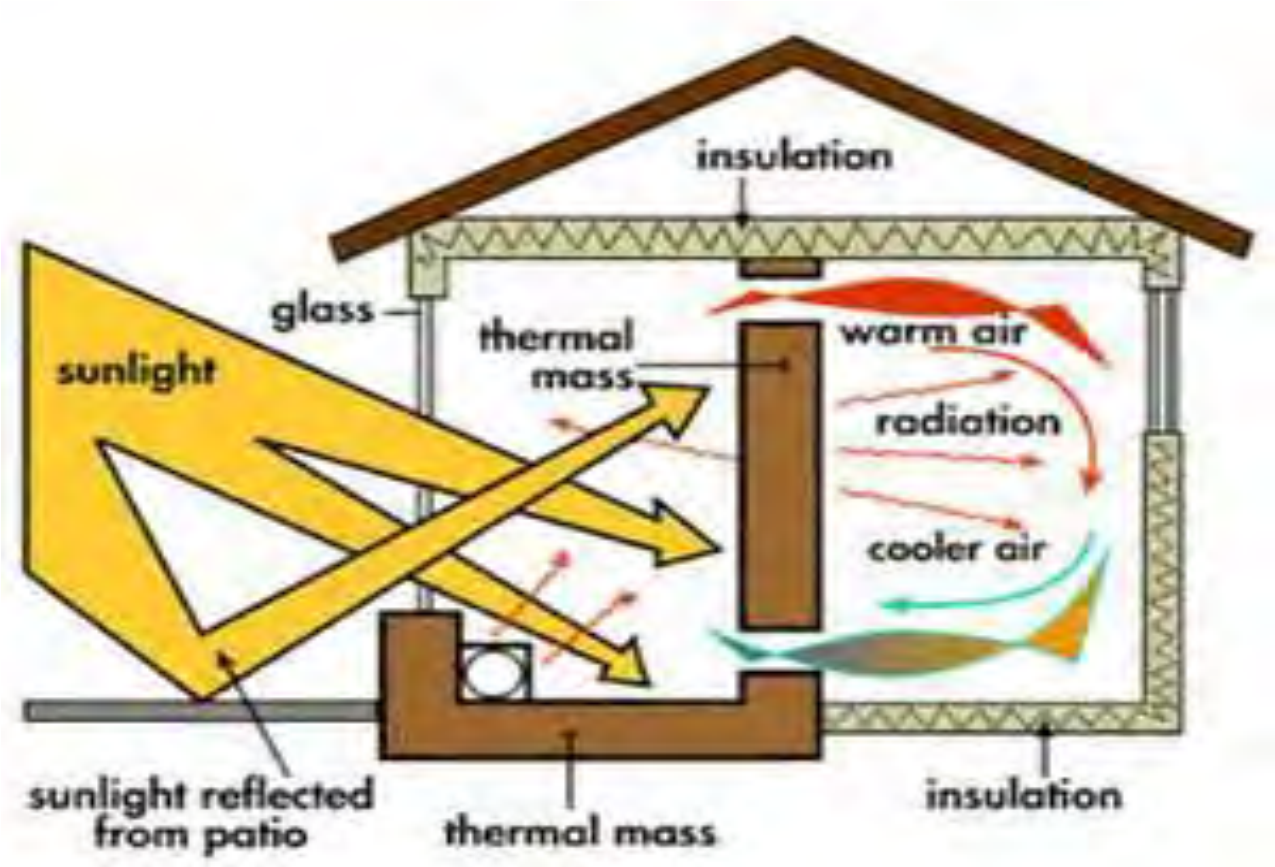
$Qi = Qc + Qi$

$Qi = (\Sigma uA + (ACH \times 0.018)) \times (Tin - Tout)$

$(Tin - Tout) = Qi / (\Sigma uA + (ACH \times 0.018))$

$Tout = Tin - \{Qi / (\Sigma uA + (ACH \times 0.018))\}$

Different barriers work at different times, but all the events happen simultaneously



Forces, components and barriers

Sensible Thermal Forces

- Conduction
- Convection
- Air Change
- Solar Radiation
- Thermal Radiation

Sensible Heat Barrier Traits

- Conductivity, k, C, u
- Resistance, r = 1/k, R=1/C R=1/u
- Thermal Emittance, ε
- Thermal Bridging
- Thermal Diffusity
- Thermal Inertia (mass)
- Decrement Factor

Sensible Thermal Barrier Types

- Thermal insulation
- Thermal inertia
- Radiant barriers
- Solar reflectance SIR
- Infrared emitters

CONDUCTION- transfer of heat through a solid material by molecule to molecule contact

If a 2000 ft^2 enclosure skin area is 50% glass (R-2.0) and 50% wall (R-12), what is the overall average insulation?

The answer is R-3.4

The reason is that dealing with R-values is like dealing with denominators, they cannot be averaged directly (e.g., the average of ½ and ¼ is not 1/3, but rather 3/8). We have to work instead with conductance, so 1/R = u-value of an assembly's thermal conductivity.

For a 2000 ft^2 enclosure of 50% glass (R-2) and 50% solid (R-12), we see that:

1000/2 + 1000/12 = 583.3 Btu/hr F for the whole enclosure

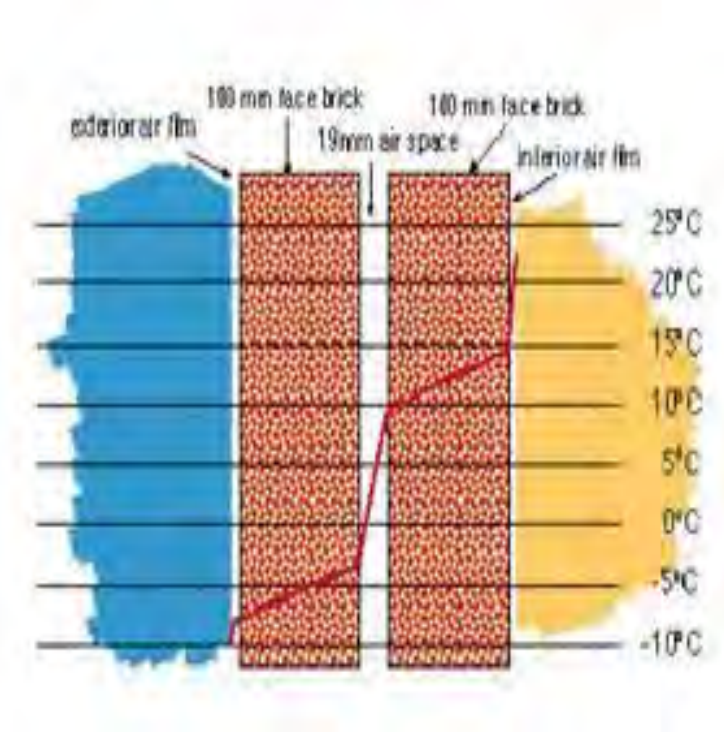
The average square foot conductance is thus:

583.3/2000 = 0.29 Btu/hr ft^2 F and R- value = 1/0.21 = R-4.8

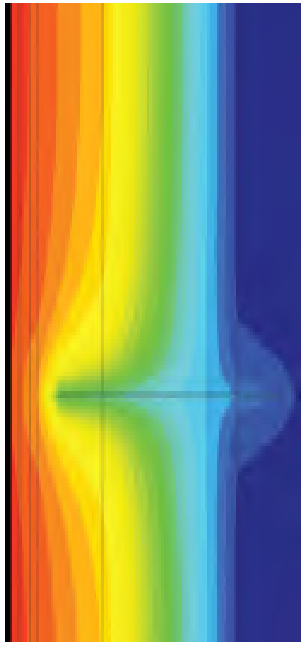
A Neolithic stone hut with animal hide door is R- 6.0

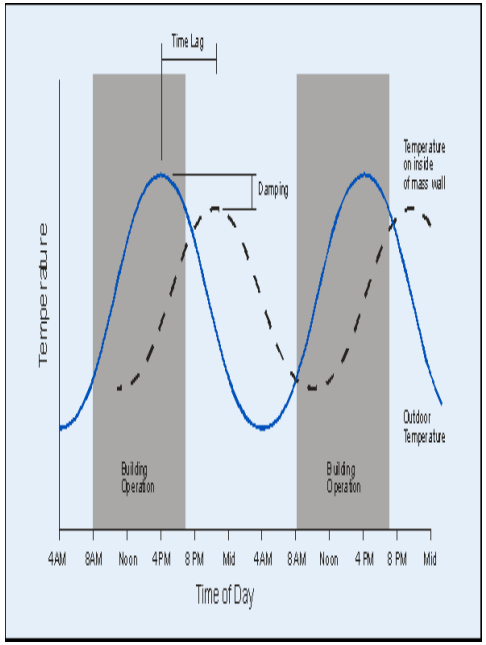
Static versus dynamic heat transfer

MASSLESS, HOMOGENOUS, INSTANTANEOUS

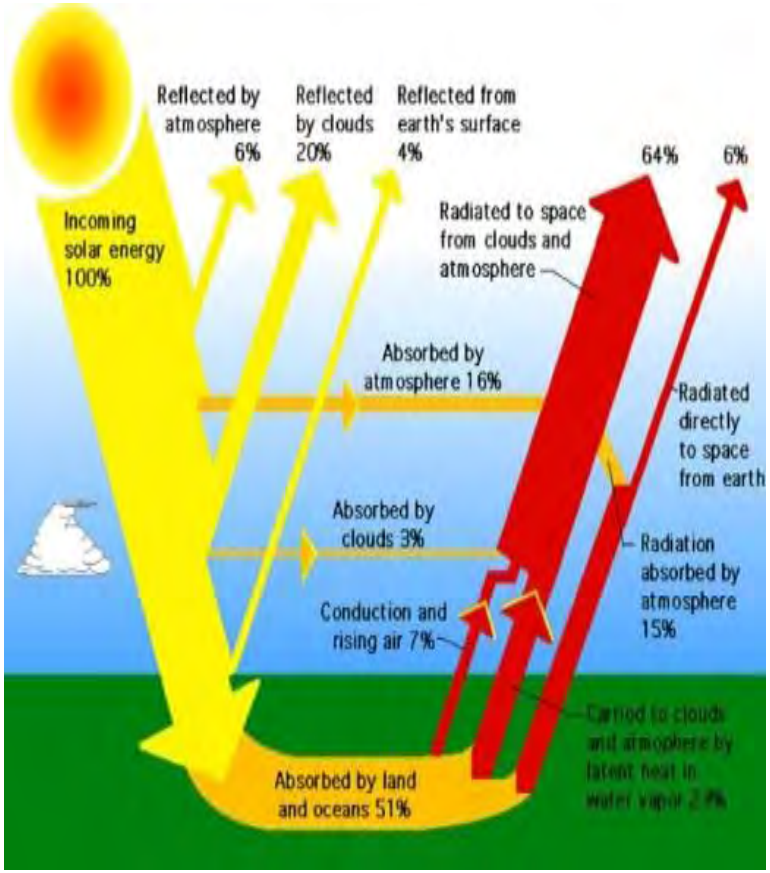


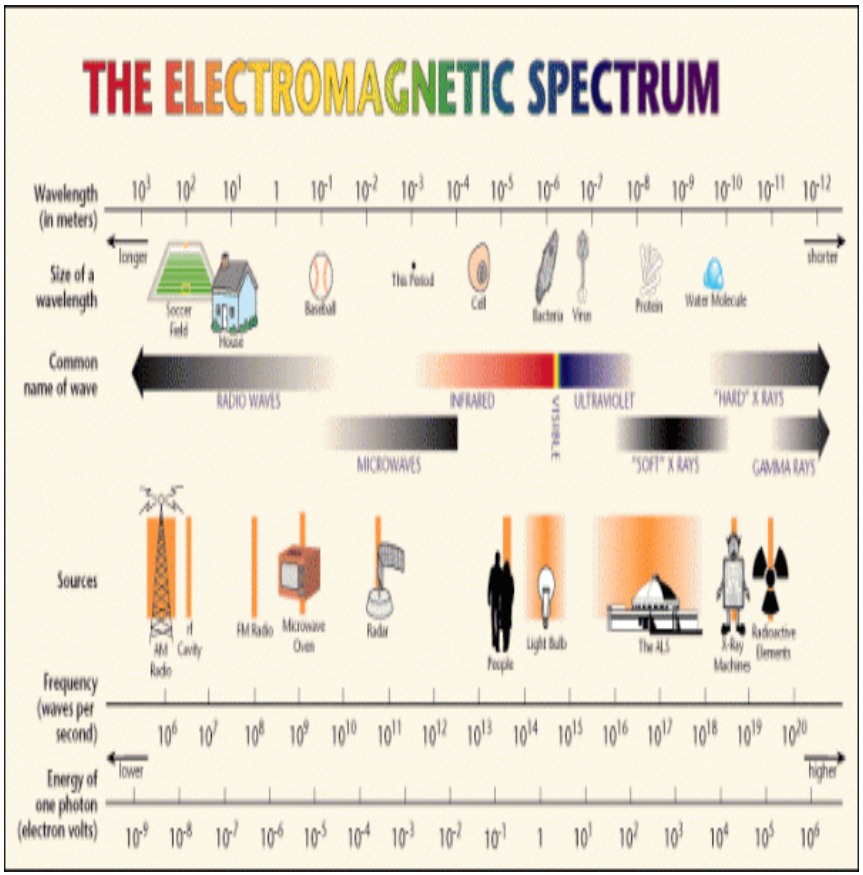
INERTIA, DIFFUSITY, RADIANT, SOL-AIR TEMPS



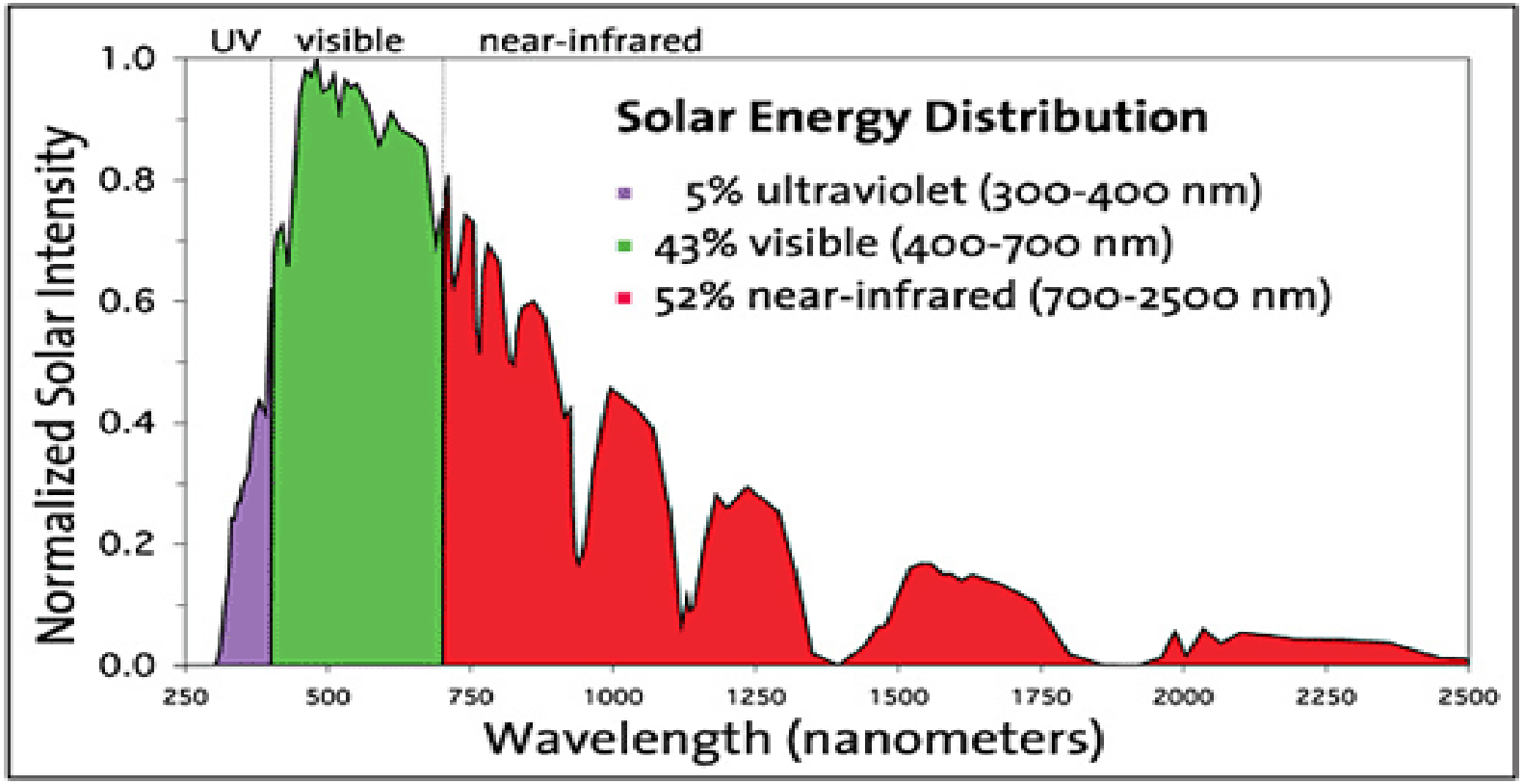


Radiation—the transfer of heat by net electromagnetic interchange

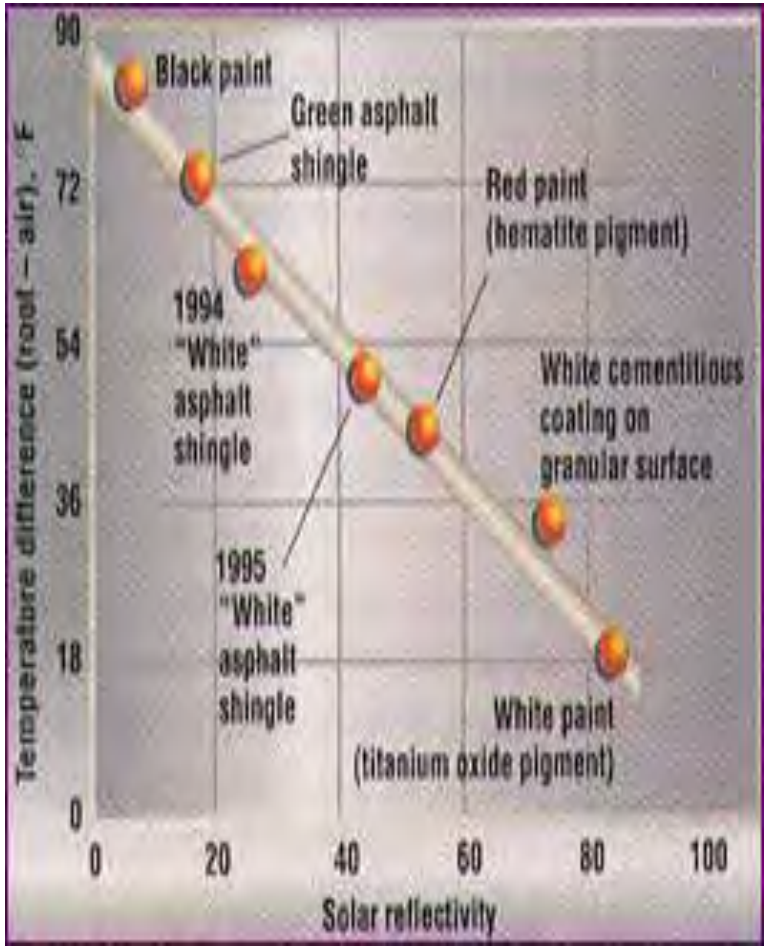


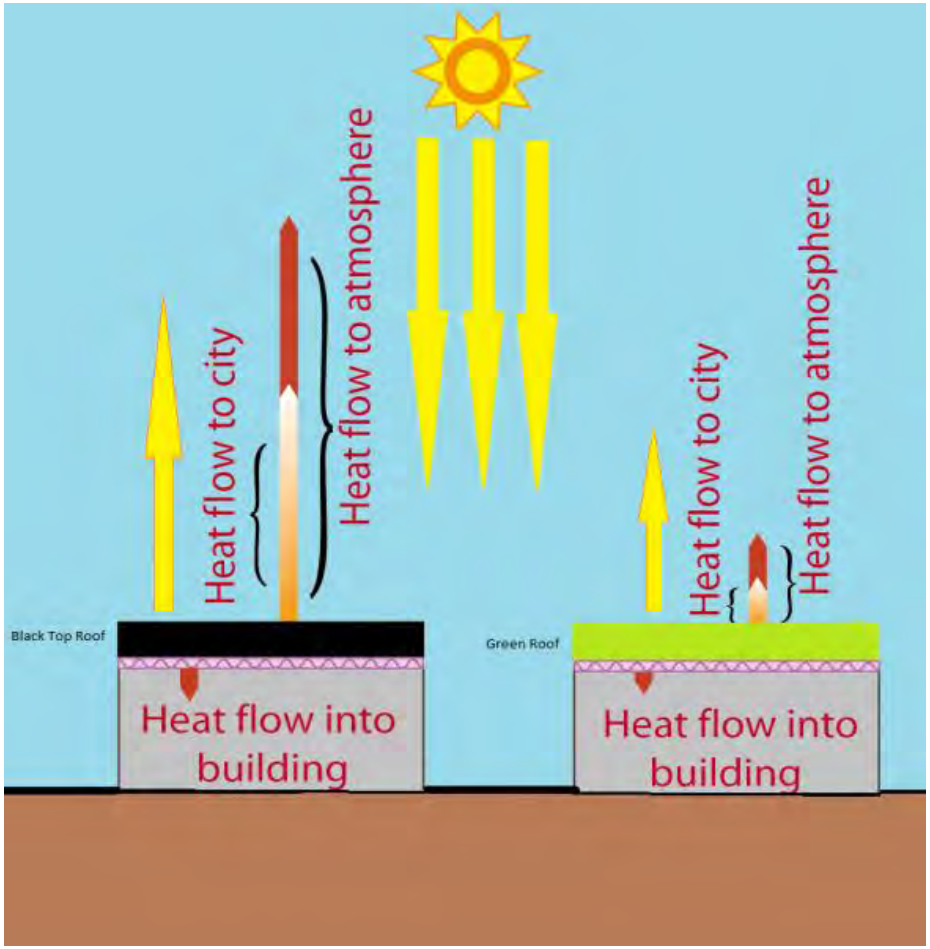


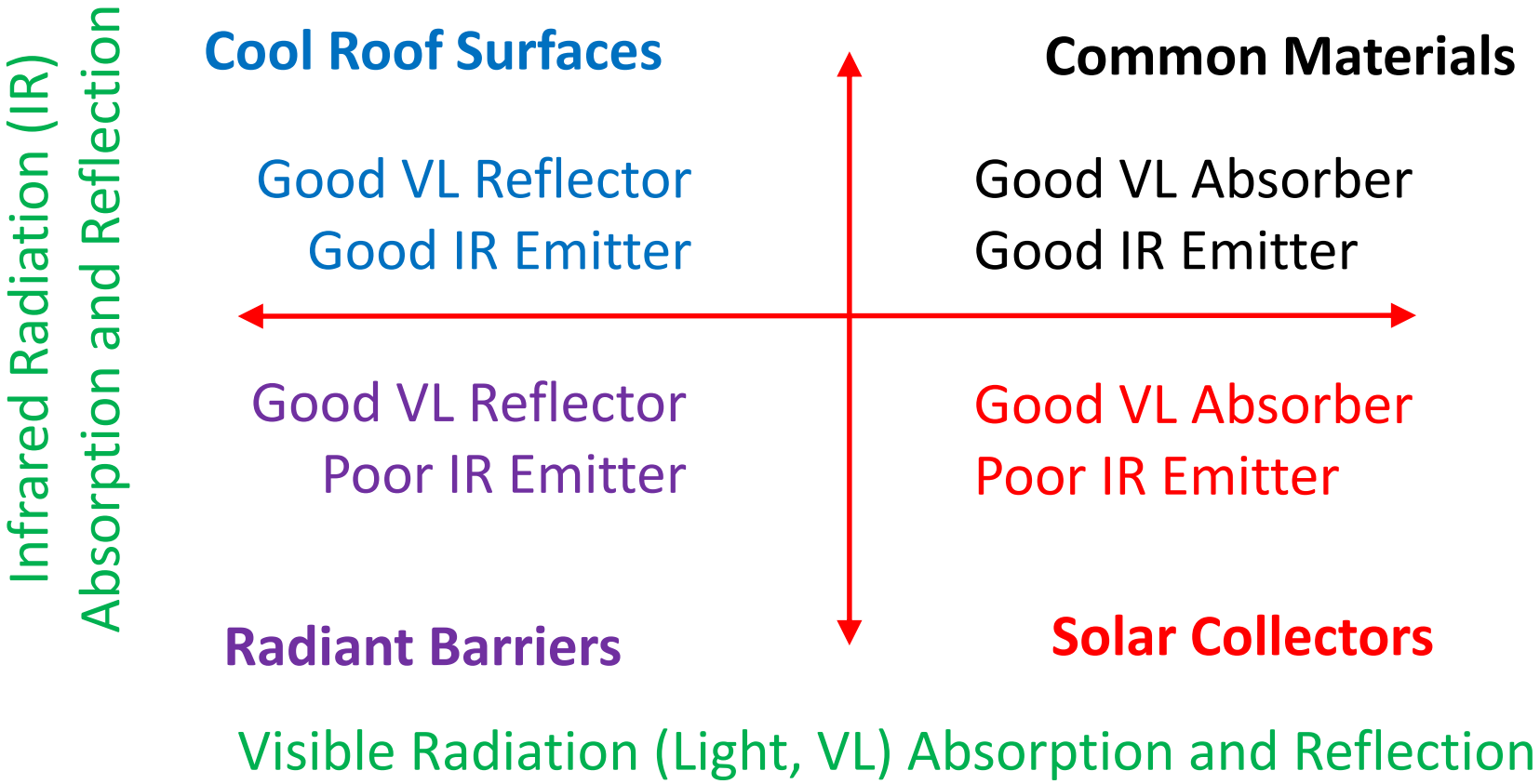
Radiation (electromagnetic heat): ultraviolet, visible, infrared…



Radiation and re-radiation

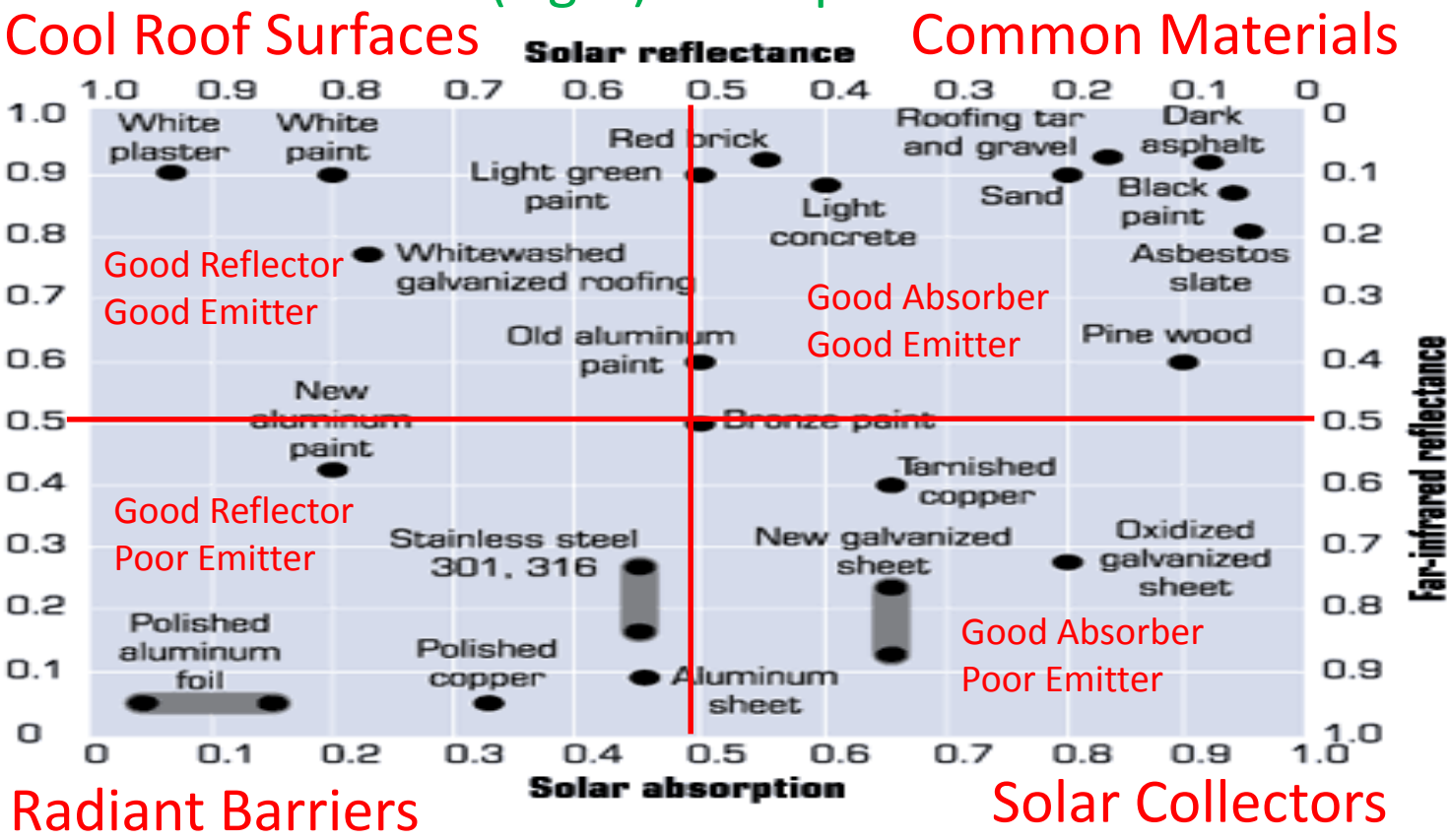




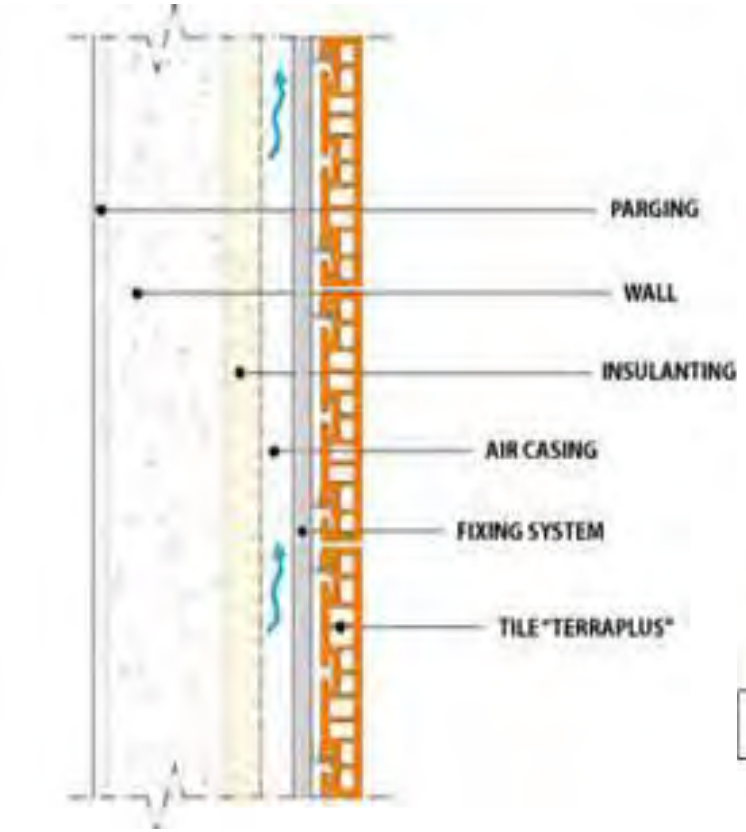

Infrared Radiation (IR) Absorption and Reflection
Cool Roof Surfaces
Good VL Reflector
Good IR Emitter
Common Materials
Good VL Absorber
Good IR Emitter
Good VL Reflector
Poor IR Emitter
Radiant Barriers
Good VL Absorber
Poor IR Emitter
Solar Collectors
Visible Radiation (Light, VL) Absorption and Reflection

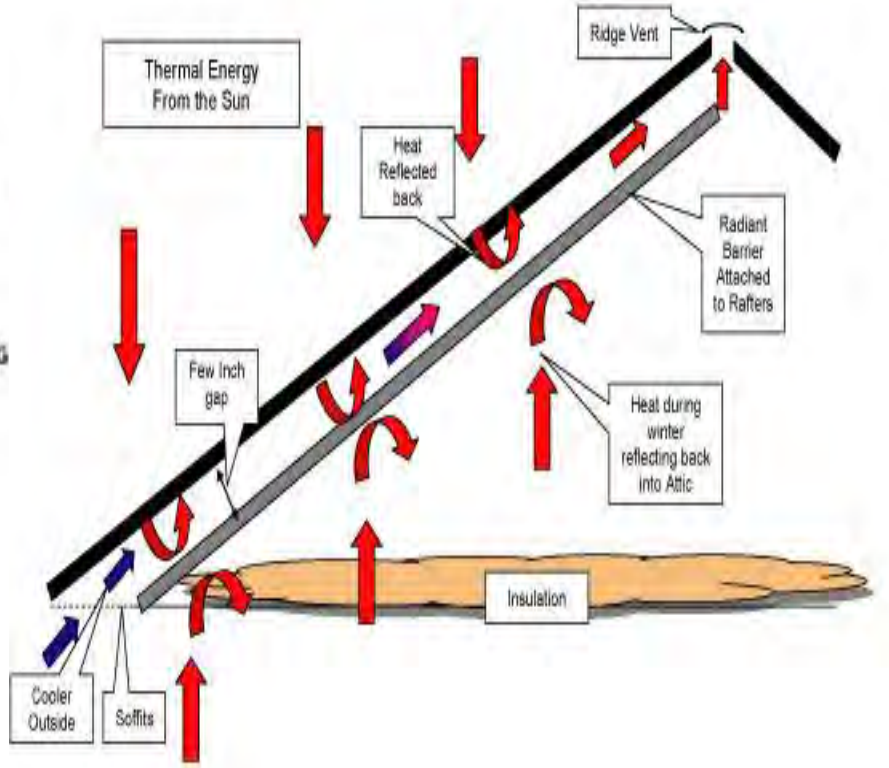
Infrared Radiation Absorption and Reflection

Visible Radiation (Light) Absorption and Reflection



Convection—transfer of heat by motion of a fluid (liquid or gas)





Refrigerated Container Homes

- 0.5 to 2.0 inches of insulation
- Up to about R-12, but still under code
- More expensive than standard dry containers

Almere House, Amsterdam, Bentham Crouwel Architects, 1984

link to Almere House plans and photos

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