

# Building a Solar House



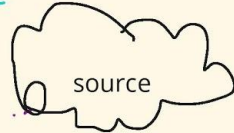
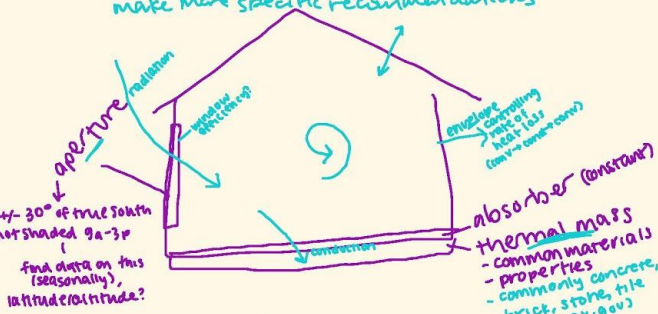
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# How do we maximize the efficiency of a solar house with the least financial resources?

- Considering price, what aspects of a solar home are worth investing in?

# Model

- first figure out how to do aperture / envelope / thermal mass sensitivity analysis → set size of house + components location ahead of time
  - if successful, parameter sweep w/ seasons, location, etc. to make more specific recommendations
- assume 100% of energy goes thru window!



$$\theta = 25.72$$

$$A = 3.19 * 12.2 = 38.918$$

insulative properties of envelope

-making assumption that envelope is all non-aperture, non-thermal-mass house

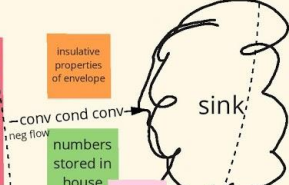
Radiation to conduction  
Solar radiation through aperture

heat in thermal mass

conduction thru thermal mass

Heat of air in house

Convection  
 $Q = hA(T_o - T_i)$



insulative properties of envelope

numbers stored in house

both envelope and window/ start with envelope

- Equivalent heat transfer coefficient of  $Q_{window} = U_{eq} A_{window} (T_{inner surface} - T_{outer surface})$
- Conductivity of fiberglass insulation (p.o.)
- Density and heat capacity of tile for energy storage
- Typical heat transfer coefficients for indoor air

$$e = 0.11$$

$$q = 361 \cos(\pi t - (12 * 3600)) + 224 \cos(\pi t - (6 * 3600)) + 210$$

(q in W/m²; t is in seconds)

$$dU/dt = (0.6) (1000)(A)$$

$$A = 0.34$$

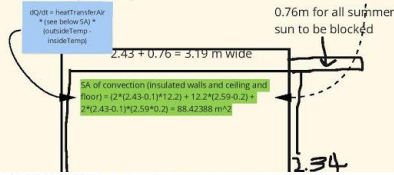
$$0.707 \sin(\theta) = 0.23$$

First cut - assume 1000W/m² (correct order of magnitude) to calibrate, then figure out the sun movement

altered to A = (0.34 \* 0.707) \* 1.2

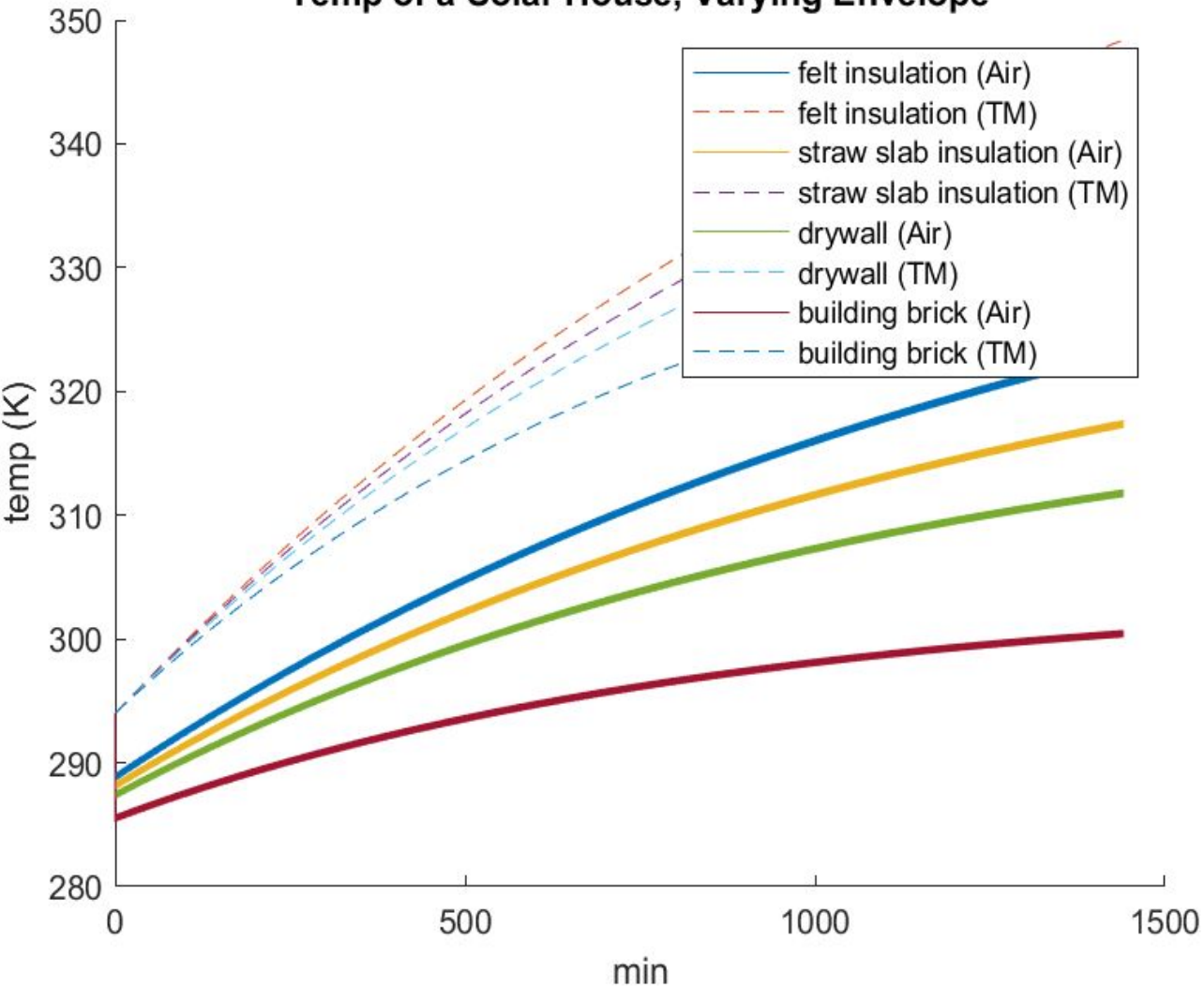
parameters:  
- R value  
- angle of sun

house outer dimensions:  
2.43m wide \* 2.59m high \*



```
rate_func = @(T,x) [((-1 * (heat_to_temp(x(1), massOfAir, specificHeatOfAir) - outsideTemperature)) ...
/ (1 / ((1 / (thermal_Resistance_Convection(internalAreaOfTransfer, heatTransferAir)) ...
+ thermal_Resistance_Conduction(internalAreaOfTransfer, thicknessOfWalls, thermalConductivityOfWalls) ...
+ thermal_Resistance_Convection(externalAreaOfTransfer, heatTransferAir)))) ...
(1 / (thermal_Resistance_Convection(glassAreaOfTransfer, heatTransferAir) ...
+ thermal_Resistance_Conduction(glassAreaOfTransfer, thicknessOfGlass, thermalConductivityOfGlass) ...
+ thermal_Resistance_Convection(glassAreaOfTransfer, heatTransferAir)))))) ...
(-1 * ((-1 * (heat_to_temp(x(2), massOfConcrete, specificHeatOfConcrete) - heat_to_temp(x(1), massOfAir, specificHeatOfAir)) ...
/ thermal_Resistance_Convection(thermalMassAreaOfTransfer, heatTransferAir))); ...
(concreteEval * solarInsolation * ((ledgeDepth * tand(angleOfSun)) * lengthInternal)) ...
- (-1 * ((-1 * (heat_to_temp(x(2), massOfConcrete, specificHeatOfConcrete) - heat_to_temp(x(1), massOfAir, specificHeatOfAir)) ...
/ thermal_Resistance_Convection(thermalMassAreaOfTransfer, heatTransferAir))))];
```

## Temp of a Solar House, Varying Envelope



## Envelope Costs (\$/m<sup>2</sup>)

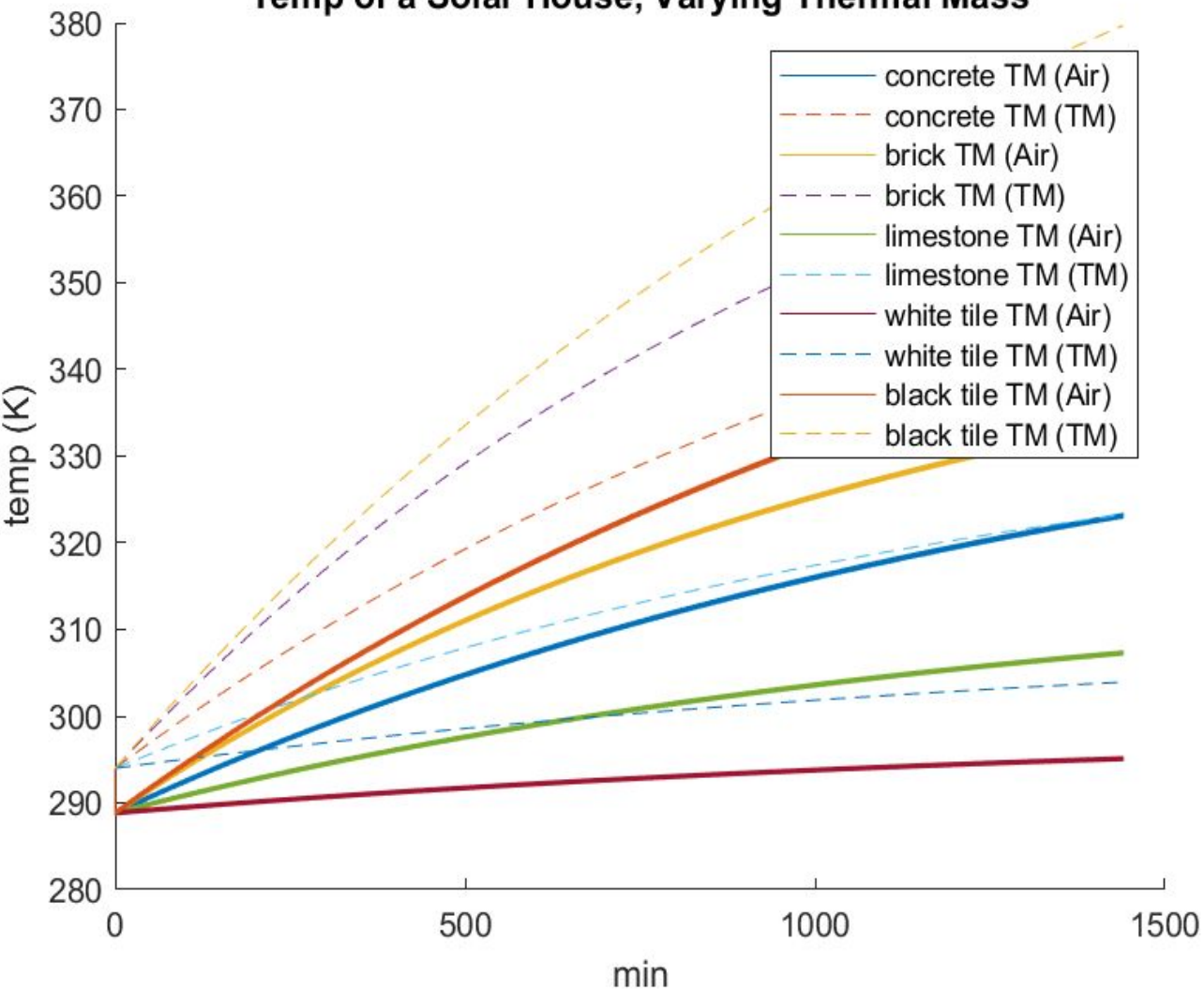
felt = 7.16

straw slab = 1506.95

**drywall = 3.99**

brick = 387.50

Temp of a Solar House, Varying Thermal Mass



## Thermal Mass Costs

Concrete: \$21-323 per m<sup>2</sup>

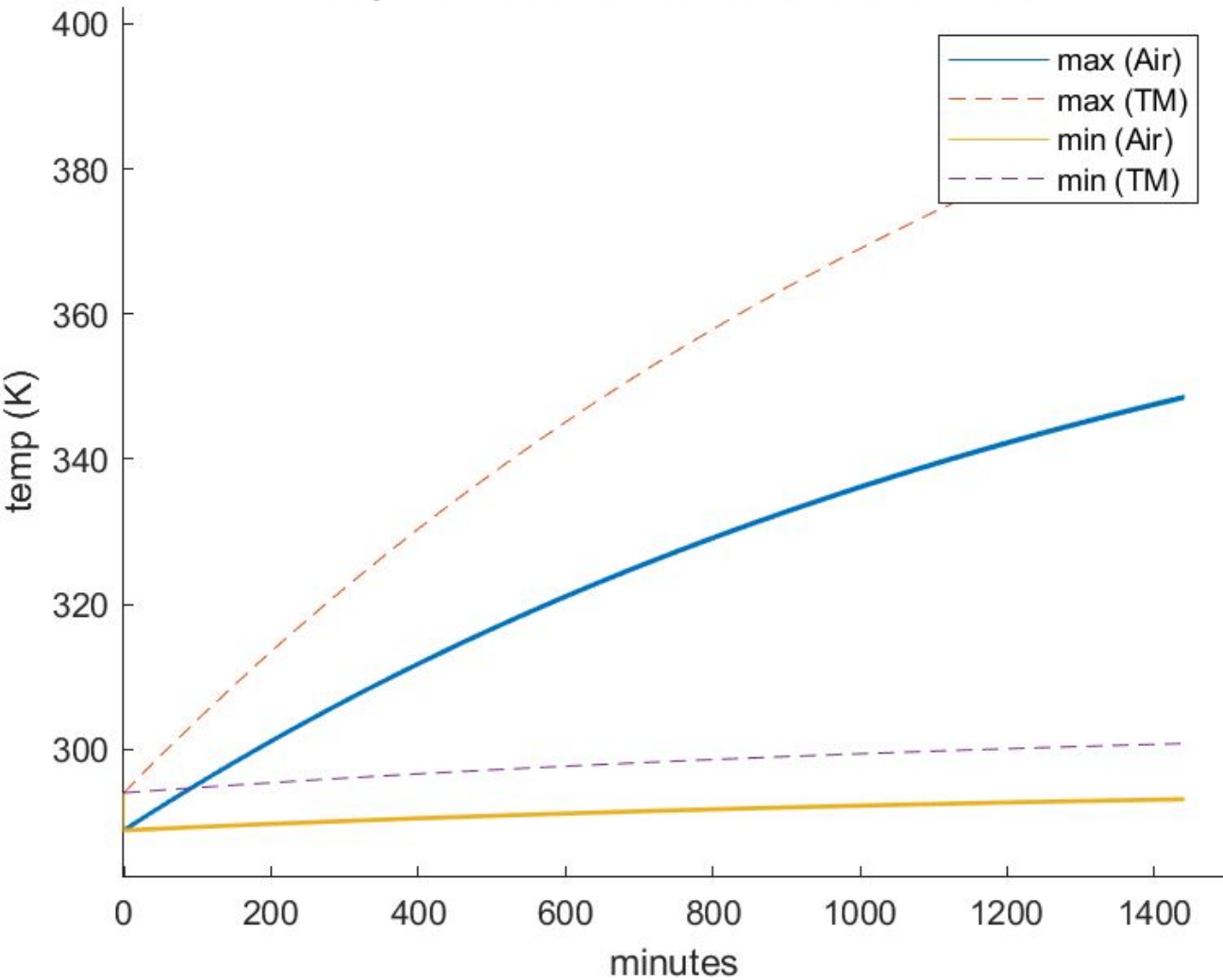
Brick: \$54-215 per m<sup>2</sup>

Limestone: \$32-108 per m<sup>2</sup>

requires regular maintenance

**Tile:** \$11-215 per m<sup>2</sup>

Temp of a Solar House, Seasonal Variation



max = 72 deg from  
horizontal, summer

min = 25 deg from  
horizontal, winter

# Resources

- <https://www.smarterhomes.org.nz/smart-guides/design/thermal-mass-for-heating-and-cooling/#:~:text=Concrete%20slab%20floors%20should%20be,won't%20store%20enough%20heat>
- <https://www.yourhome.gov.au/passive-design/thermal-mass>
- [https://www.engineeringtoolbox.com/thermal-conductivity-d\\_429.html](https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)
- [https://www.engineeringtoolbox.com/solar-radiation-absorbed-materials-d\\_1568.html](https://www.engineeringtoolbox.com/solar-radiation-absorbed-materials-d_1568.html)
- <https://www.pveducation.org/pvcdrom/properties-of-sunlight/calculation-of-solar-insolation>
- <https://nsrdb.nrel.gov/data-sets/archives.html>
- <https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/solar-radiation>
- <https://www.nrel.gov/gis/solar.html>
- <https://www.energy.gov/energysaver/energy-efficient-home-design/passive-solar-home-design>
- <https://home.costhelper.com/limestone-tile.html>
- <https://www.hgtv.com/design/remodel/interior-remodel/average-cost-install-tile-floor>
- <https://www.concretenetwork.com/concrete/interiorfloors/cost.html#:~:text=Concrete%20flooring%20cost%20ranges%20between,a%20high%2Dend%2C%20customized%20floor>
- <https://www.improvenet.com/r/costs-and-prices/brick-paver-flooring>
- <https://www.homedepot.com/p/USG-Sheetrock-Brand-1-2-in-x-4-ft-x-8-ft-Ultralight-Gypsum-Board-14113411708/202530243>
- <https://www.homeadvisor.com/cost/walls-and-ceilings/install-a-brick-stone-or-block-wall/>
- <https://www.grainger.com/product/ROXUL-4-in-x-48-in-x-24-in-Mineral-19NE80>
- <https://www.buildingwithawareness.com/cost/>