Ecole Polytechnique

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PHY 555 – Energy & Environment

PC8 – Low consumption housing – Solution Strategies

1. "Classical" house

1.Estimate, for an internal temperature of 20 °C and an outdoor temperature of 10 °C, the heat loss by thermal conduction through the walls.

Use the thermal conductivity of hollow concrete blocks to get the heat resistance R of all walls. Total heat flux $\phi=\Delta T/R$. Adding boundary layer of air effectively doubles value. 3.7 kW

What would be the annual energy loss of the house by diffusion through the walls per unit area?

Hours per year, divide by area of walls. 250 $kWh/yr/m^2$

Same question if the wall is covered with 4 cm of expanded polystyrene and plasterboard BA13 (13 mm thick).

Thermal resistances (or specific resistances per m2) will add in series. Reduce to 62 $kWh/yr/m^2$, or 0.9 kW)

What is the grey energy involved in the insulation of walls? What is its energy payback time?

Need volume of building material (thickness and area). EPT is 84 days

2.The walls are covered with 20 % of single pane windows of 5 mm thickness. What is the heat loss due to windows?

For 5 mm glass, a naive calculation of the thermal conductivity coefficient gives 152W/(°K m^2). In our house, we would have an additional heat loss of 52kW.

Manufacturers give a surface transmittance of heat …. Compare the resulting transmittance with the previously obtained result; where does the difference come from?

Adding in boundary layer effect, we see that the value given for windows is essentially that of the boundary layer (0.17 °K m^2 /W). With this, heat loss is 1.5kW via windows.

3. What is the total heat loss of the home? What would be the total annual energy consumption? (using simple assumptions about the annual temperature profile)

Using the provided distribution, assigning calculated values to walls (0.8 x 3.7kW) and windows (1.5 kW) can get approximate total of 11.8 kW.

2 –Timber frame house

1.Redo the calculation of heat losses. What embodied energy is involved in the construction of the walls?

Same calculation as before, should give 364 W.

2.Heat loss should not exceed, according to Minergie standards for low-energy houses, 42 kWh/m2/year for the envelope (walls and roof). What cellulose wool thickness would be needed to achieve these standards?

Using distribution, need 19 $kWh/m^2/yr$ for walls. Careful, these standards are given in terms of liveable area ($100m^2$). So we need to achieve R=0.05. This gives 22 cm for thickness of wool.

Then compare the embodied energy used to energy savings. What is the average time of return on investment?

Same calculation as before. About factor of 2 compared to polystyrene (factor of 6 if you include concrete, since this is a new build).

3 –Double Flux Ventilation

1.In a classical house, not tight to air, the air renewal must be made to a rate close to 1 interior volume per hour. Estimate the heat loss by air renewal. (Dry air has a heat capacity cair=1,007kJ/kg/K and density μair=1,2kg/m3*).*

The volume of the house is 250 m^3. Heat loss by air renewal is therefore $E/t = c_{air} \times \mu_{air} \times V \times \Delta T$ /hr, giving 0.83 kW. Relevant once insulation is done.

2.In a low-energy house, it is necessary to recover the heat from the exhaust air to preheat the incoming air. Perform an energy balance of the ventilation system and determine the temperature of the air entering the house and the stale air outlet temperature

Available heat is $Q_{avail}=C_p(T_1-T_2)$. transferred heat is: $Q_{transfered}=\eta Q_{avail}=C_p(T_1-T'_1)=C_p(T'_2-T_2)$. Solving gives T_2'=16.8°C and T_1'=4.2°C.

4 –Provencal Well

1.What is the magnitude of the temperature variation at a depth of 1 m? 2 m?
The final temperature versus time and depth reads:

$$\theta(x,t)=\theta_0-\theta_1\exp\left[-\sqrt{\frac{\omega\mu c}{2\kappa}}x\right]\cos(\omega t-\sqrt{\frac{\omega\mu c}{2\kappa}}x)$$

Temperature fluctuations are mitigated width increasing depth, and are also delayed in time:

$$\Delta t(x)=\sqrt{\frac{\mu c}{2\kappa\omega}}=2\times10^6\times x$$

At a depth of 1 m, the thermal amplitude is attenuated by a factor of 0.67 (to 13 °C). The temporal delay is 22 days.
At 2 m depth, the attenuation is 0.45 for an amplitude of 9 °C and a 45-day lag.

How deep should the Provençal well be installed?
At 3 m, the oscillation amplitude is reduced by a factor of 3, for an amplitude of 6 °C and a lag of 68 days.

What other device could exploit the temperature difference between the ground and the air?
Heat pump.