1.020 Ecology II: Engineering for Sustainability
Spring 2008

Lectures 08_10 Outline: Radiative Energy Transfer, Building Energy

Motivation/Objective

Extend house energy model to account for radiation to and from roof. Review effect of building materials on energy loss.

Approach

1. Revise system definition to include two parts: 1) interior house space, walls, floor and 2) roof. Identify unknowns (interior temperature T_i and roof temperature T_r).
2. Write coupled energy balance equations (rate form) for interior and roof
3. Relate terms in the energy balance eqs to unknown interior and roof temperatures and other inputs.
4. Specify heat capacities, thermal resistances, meteorological inputs, etc, solve energy balance eqs. for unknown interior and roof temperatures (MATLAB)
5. Compute heat loss, examine impact of building material properties

Concepts and Definitions Needed:

Interior energy balance:

Change in interior internal energy = Conduction/convection between interior & outside

Roof energy balance:

Change in roof internal energy = Conduction/convection between interior & roof + Conduction/convection between roof & outside + net incident radiation ($\dot{Q}_{rad}$)

Net SW and LW radiation into roof:

$$\dot{Q}_{rad} = \alpha_r A_r S_g + (LW_{in} - LW_{out}) = \alpha_r A_r S_g + \sigma \varepsilon_{sky} T_{sky}^4 - \sigma \varepsilon_r T_r^4$$

α_r = roof SW absorptivity, $\varepsilon_{sky}, \varepsilon_r$ = sky & roof LW emissivities

This approach (with radiation) gives same results as Lectures 8&9 (no radiation) only when $T_i = T_{air}$ and the radiation terms cancel so $\dot{Q}_{rad} = 0$.

Complete balance eqs:

$$C_{vh} \frac{dT_i}{dt} = A_w \frac{[T_{air} - T_i]}{R_{ia}} + A_f \frac{[T_{soil} - T_i]}{R_{is}} + A_r \frac{[T_r - T_i]}{R_{ri}} \qquad \text{Interior}$$

$$C_{vr} \frac{dT_r}{dt} = A_r \frac{[T_i - T_r]}{R_{ri}} + A_r \frac{[T_{air} - T_r]}{R_{ra}} + \alpha_r A_r S_g + \sigma \varepsilon_{sky} T_{sky}^4 - \sigma \varepsilon_r T_r^4 \qquad \text{Roof}$$

Obtain T_{air}, T_{sky}, S_g from meteorological records.

Modeling Example -- Building Energy

Note differences in interior temperature and energy consumption when radiation is included. Also, note effects of diurnal and seasonal variation in incident radiation.