Calculating Heat Loss and Solar Gain

Basic Heat Loss Equation

$$Q = A/R * \Delta T_{average} * t$$

Q = heat flow in Btu (**not** a rate, it's an energy amount)

A = wall or window area in square feet (sf)

R = thermal resistance in sf °F hr/Btu (also called the **R-value**)

$\Delta T_{average}$ = temperature difference in °F (difference between interior & exterior)

t = time in hours

Example 1. Heat Loss through Wall

Consider the wall of a house.

- The R–value of the wall equals R-11.
- The area of the wall equals 645 sf
- The internal temperature equals 65 F and the exterior temperature equals 25 F

Calculate the heat flow through the wall during an hour

Q = (645 sf / 11 sf °F hr / Btu)* 40 °F * 1 hr = 2345 Btu

Example 2. Base Case

We define a **base case** house with the following dimensions:

645 sf east wall, 645 sf west wall, 345 sf north wall, 345 sf south wall, and 989 sf roof.

The walls and ceiling have the following physical properties:

R-7 insulation in the walls and R-11 insulation in the ceiling.

The weather at the site is characterized by an average temperature difference between the interior and the exterior equal to 40 F.

Calculate the heat flow through the building envelope during a month.
Neglect heat lost through the floor.

Q = 2*645/7*40*24*30 + 2*345/7*40*24*30 + 989/11*40*24*30
= 5.3 MBtu + 2.8 MBtu + 2.6 MBtu = 10.7 MBtu

Example 3. Add Windows

We will extend the definition of the **base case** to include the following windows dimensions:

58 sf east walls, 129 sf west walls, 0 sf south wall, 26 sf north wall

The windows have the following physical properties: R-value = 2.0.

Calculate the heat flow for a month through the building envelope, including windows, but neglecting floor. The weather at the site is characterized by an average temperature difference between the interior and the exterior equal to 40 F.

Q = (645-58)/7*40*24*30 + 58/2*40*24*30 + (645-129)/7*40*24*30 + 129/2*40*24*30
+345/7*40*24*30 + (345-26)/7*40*24*30 + 26/2*40*24*30 + 989/11*40*24*30
= 12.9 MBtu

For the base case:
- Heat loss through the windows equals 3.1 MBtu
- Heat loss through the walls equals 7.2 MBtu
- Heat loss through the ceiling equals 2.6 MBtu

Air Infiltration

Equation for heat loss due to air infiltration:

$$Q = 0.018 * V * K * \Delta T_{average} * t$$

V = house volume in cf (cubic feet)

K = Number of air changes per hour (ach)

Example 4. Add Air Infiltration Loss

We will extend the definition of the **base case** house to include its volume and air change rate:

V = 14,340 cf K = 1 ach

Calculate the total heat loss for a month, including air infiltration. The weather at the site is characterized by an average temperature difference between the interior and the exterior equal to 40 F.

Q = 12.9 MBtu + 0.018*1*14340*40*24*30 = 7.4 MBtu = 20.3 MBtu

For the base case:
- Heat loss through the windows equals 3.1 MBtu
- Heat loss through the walls equals 7.2 MBtu
- Heat loss through the ceiling equals 2.6 MBtu
- Heat loss through air infiltration equals 7.4 MBtu

Total Heat Loss

The equation for ***monthly*** total building envelope heat loss can be written:

$$\mathbf{Q = (A_{walls}/R_{walls} + A_{windows}/R_{windows} + A_{ceiling}/R_{ceiling} + 0.018*V_{interior}*K)*24\ h/day * \Delta T_{average}*30\ day}$$

The quantity $\Delta T_{average}$ * 30 day can be replaced by the heating degree day

Degree Days

The heating degree day value (base 65F) for a month, HDD, is the sum of the following quantities for each day of the month:

65F - $T_{average}$	($T_{average}$ < 65 F)
0	($T_{average}$ > 65 F)

The building heat loss calculation can be based on this HDD

$$\mathbf{Q = (A_{walls}/R_{walls} + A_{windows}/R_{windows} + A_{ceiling}/R_{ceiling} + 0.018*V_{interior}*K) * 24 * HDD}$$

Heating Degree Days (Base 65) for HARTFORD, CT

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Ann
3	12	120	413	697	1054	1218	1024	844	486	195	38	6104

Cooling Degree Days (Base 65) for HARTFORD, CT

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
0	0	1	5	38	144	277	220	68	5	1	0	759

Base Case Summary

Properties of the Base Case:

Surface	Area	R-value	Window	R-Value	Transmission
East Wall	645 sf	7.0	58 sf	2.0	0.68
West Wall	645 sf	7.0	129 sf	2.0	0.68
North Wall	345 sf	7.0	26 sf	2.0	0.68
South Wall	345 sf	7.0	0	-	-
Roof	989 sf	11.0	0	-	-

Volume = 14,340 cf   K = 1.0 ACH

Example 5. January Heat Loss in Hartford

For the base case house in Hartford, calculate the January heat loss.

Q = [(645-58)/7 + 58/2 + (645-129)/7 + 129/2 +345/7 + (345-26)/7 + 26/2 + 989/11 + 0.018*1*14340] *24*1218

= 20.6 MBtu

Solar Gain

Windows also emit solar energy which heats the building interior.
The solar gain may be calculated as:

Solar Gain = A * Transmission * Insolation

Solar Gain = heat gain (Btu)
A = area of windows (sf)
Transmission = fraction of incident solar radiation transmitted to interior
Insolation = solar radiation incident on window surface (Btu/sf/day)

Hartford AVERAGE INCIDENT SOLAR RADIATION (Btu/sq.ft./day)on vertical surfaces

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
NORTH	190	260	350	440	540	610	580	480	380	280	190	160	370
EAST	400	550	710	860	960	1030	1020	940	780	590	380	330	710
SOUTH	980	1090	1060	960	850	810	850	940	1050	1080	850	820	940
WEST	400	550	710	850	950	1020	1020	930	780	600	380	320	710

Example 6. January Net Heat Loss in Hartford

For the base case, the window transmission equals 0.68.

For the base case house in Hartford, calculate the January net heat loss.
We calculate heat gain as a negative because it reduces the heat loss.

Q = 20.6 MBtu – (58*0.68*400*31 + 129*0.68*400*31 + 26*0.68*190*31)

= 20.6 MBtu – 1.7 MBtu = 18.9 MBtu