

**Basic Heat Loss Equation**

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

Q = heat flow in Btu

A = area in sf

R = thermal resistance in sf °F hr/Btu

$\Delta T_{\text{average}}$  = temperature difference in °F

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

$$Q = (645 \text{ sf} / 11 \text{ sf } ^\circ\text{F hr} / \text{Btu}) * 40 \text{ } ^\circ\text{F} * 1 \text{ hr} = 2345 \text{ Btu}$$

**Example 2. Base House**

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.

$$\begin{aligned} Q &= 2 * 645 / 7 * 40 * 24 * 30 + 2 * 345 / 7 * 40 * 24 * 30 + 989 / 11 * 40 * 24 * 30 \\ &= 5.3 \text{ MBtu} + 2.8 \text{ MBtu} + 2.6 \text{ MBtu} = 10.7 \text{ MBtu} \end{aligned}$$

### Example 3. Add Windows

We will extend the definition of the **base case** house 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.

$$\begin{aligned} Q &= (645-58)/7*40*24*30 + 58/2*40*24*30 + (645-129)/7*40*24*30 + 129/2*40*24*30 \\ &\quad + 345/7*40*24*30 + (345-26)/7*40*24*30 + 26/2*40*24*30 + 989/11*40*24*30 \\ &= 12.9 \text{ MBtu} \end{aligned}$$

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:

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

V = house volume in ft<sup>3</sup>

K = Number of air changes per hour

### 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.

$$Q = 12.9 \text{ MBtu} + 0.018*1*14340*40*24*30 = 7.4 \text{ MBtu} = 20.3 \text{ MBtu}$$

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 and infiltration heat loss can be written:

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

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

## Degree Day

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

$$\begin{array}{ll} 65F - T_{\text{average}} & (T_{\text{average}} < 65 \text{ F}) \\ 0 & (T_{\text{average}} > 65 \text{ F}) \end{array}$$

The building heat loss calculation can be based on this HDD

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

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 = 14340 cf

K = 1.0 ACH

### Example 5. January Heat Loss in Hartford

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

$$Q = [(645-58)/7 + 58/2 + (645-129)/7 + 129/2 + 345/7 + (345-26)/7 + 26/2 + 989/11 + 0.018*1*14340] *24*1218$$
$$= 20.6 \text{ MBtu}$$

### Solar Gain.

Windows also emit solar energy which heats the building interior.

The solar gain may be calculated as:

$$\text{Solar Gain} = A * \text{transmission} * \text{Insolation}$$

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.

$$Q = 20.6 \text{ MBtu} - (58*0.68*400*31 + 129*0.68*400*31 + 26*0.68*190*31)$$
$$= 20.6 \text{ MBtu} - 1.7 \text{ MBtu} = 18.9 \text{ MBtu}$$