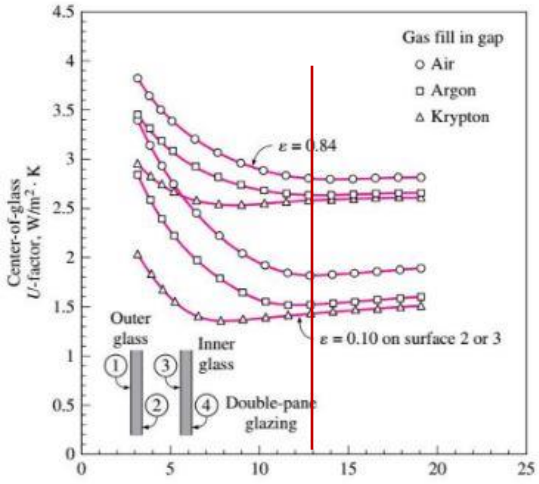
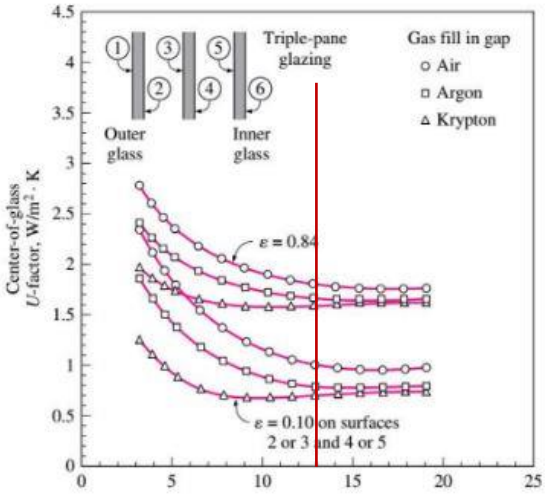
1) Using the diagrams given in the presentation calculate how much (%) is the effect of applying
different modifications (changing the gas, adding an extra pane, using a low emissivity coating) on the U value with respect to a benchmark case of double layer with air and no coating? (keep the gap thickens to be 13 mm)?




Soln: Benchmark:

With Double pane glazing ( $\varepsilon$=0.84 ) & gap thickness 13mm

U- Value of a double pane glazing window if the gap is filled with air is $2.8\frac{w}{m^2k}$

| $\varepsilon$ value | 0.84 | | 0.10 | | | 0.84 | | | 0.1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of panes | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| Gas | Argon | Krypton | Air | Argon | Krypton | Air | Argon | Krypton | Air | Argon | krypton |
| U value | 2.65 | 2.6 | 1.8 | 1.5 | 1.4 | 1.8 | 1.7 | 1.6 | 1 | 0.8 | 0.7 |
| % of change | 5.4 | 7.2 | 35.7 | 46.4 | 50 | 35.7 | 39.2 | 42.8 | 64.3 | 71.4 | 75 |

2) Consider the house that we analyzed in the last two examples, calculate the heating and cooling load of the other windows which are fixed 14.4 m2 on the west, fixed 3.6 m2 on the south and an operable 3.6 m2 on the south (the same window and frame type). How much does the total value change if I change the frame of the window from wooden one to aluminum?

Sol:

**PIACENZA, Italy** WMO#: **160840**

Lat: **44.92N** Long: **9.73E** Elev: **138** StdP: **99.68** Time Zone: **1.00 (EUW)** Period: **89-10** WBAN: **99999**

**Annual Heating and Humidification Design Conditions**

| Coldest Month | Heating DB | | Humidification DP/MCDB and HR | | | | | | Coldest month WS/MCDB | | | | MCWS/PCWD to 99.6% DB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 99.6% | 99% | 99.6% DP | 99.6% HR | 99.6% MCDB | 99% DP | 99% HR | 99% MCDB | 0.4% WS | 0.4% MCDB | 1% WS | 1% MCDB | MCWS | PCWD |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) | (l) | (m) | (n) | (o) |
| 1 | -6.2 | -4.8 | -11.6 | 1.4 | 3.1 | -8.8 | 1.8 | 1.8 | 8.8 | 5.6 | 7.7 | 6.2 | 2.1 | 250 |

(1)

**Annual Cooling, Dehumidification, and Enthalpy Design Conditions**

| Hottest Month | Hottest Month DB Range | Cooling DB/MCWB | | | | | | Evaporation WB/MCDB | | | | | | MCWS/PCWD to 0.4% DB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.4% DB | 0.4% MCWB | 1% DB | 1% MCWB | 2% DB | 2% MCWB | 0.4% WB | 0.4% MCDB | 1% WB | 1% MCDB | 2% WB | 2% MCDB | MCWS | PCWD |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) | (l) | (m) | (n) | (o) | (p) |
| 8 | 11.9 | 33.1 | 22.7 | 31.9 | 22.4 | 30.3 | 21.8 | 24.6 | 30.2 | 23.7 | 29.2 | 22.9 | 28.3 | 2.4 | 90 |

(2)

Latitude ≈ 45

$T_{cooling}$ = 24°c

$T_{heating}$ = 20°c

$\Delta T_{cooling}$ = 31.9°c - 24°c = 7.9 °c

$\Delta T_{heating}$ = 20°c – (-4.8)°c = 24.8 °c

From the table DR = 11.9 °c

**FIXED WINDOW ON WEST SIDE**

Area = 14.4 $m^2$

**COOLING LOAD**

$q_{west\ window} = A\ x\ CF_{west\ window}$

$CF_{west\ window(heat\ transfer)} = U_{west\ window}\ (\Delta T_{cooling}$ - 0.46 DR)

$U_{west\ window} = 2.84 \frac{w}{m^2 k}$

$CF_{west\ window(heat\ transfer)} = 2.84 \frac{w}{m^2 k} (7.9\ \text{k} - 0.46\ (11.9\ \text{k}))$

$\approx 6.89\ \frac{w}{m^2}$

Irradiation

$E_D$ = 559

$E_d$ = 188

$PXI_{\text{west window}} = E_D + E_d$

= 559 +188 = 747

Since no internal shading, so IAC = 1

SHGC = 0.54

$FF_s$ = 0.56

| Glazing Type | Glazing Layers | ID[b] | Property[c,d] | Center of Glazing | Frame: Operable: Aluminum | Operable: Aluminum with Thermal Break | Operable: Reinforced Vinyl/Aluminum Clad Wood | Operable: Wood/Vinyl | Operable: Insulated Fiberglass/Vinyl | Fixed: Aluminum | Fixed: Aluminum with Thermal Break | Fixed: Reinforced Vinyl/Aluminum Clad Wood | Fixed: Wood/Vinyl | Fixed: Insulated Fiberglass/Vinyl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clear | 1 | 1a | *U* | 5.91 | 7.24 | 6.12 | 5.14 | 5.05 | 4.61 | 6.42 | 6.07 | 5.55 | 5.55 | 5.35 |
| | | | SHGC | 0.86 | 0.75 | 0.75 | 0.64 | 0.64 | 0.64 | 0.78 | 0.78 | 0.75 | 0.75 | 0.75 |
| | 2 | 5a | *U* | 2.73 | 4.62 | 3.42 | 3.00 | 2.87 | 5.83 | 3.61 | 3.22 | 2.86 | 2.84 | 2.72 |
| | | | SHGC | 0.76 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.69 | 0.69 | 0.67 | 0.67 | 0.67 |
| | 3 | 29a | *U* | 1.76 | 3.80 | 2.60 | 2.25 | 2.19 | 1.91 | 2.76 | 2.39 | 2.05 | 2.01 | 1.93 |
| | | | SHGC | 0.68 | 0.60 | 0.60 | 0.51 | 0.51 | 0.51 | 0.62 | 0.62 | 0.60 | 0.60 | 0.60 |
| Low-e, low-solar | 2 | 25a | *U* | 1.70 | 3.83 | 2.68 | 2.33 | 2.21 | 1.89 | 2.75 | 2.36 | 2.03 | 2.01 | 1.90 |
| | | | SHGC | 0.41 | 0.37 | 0.37 | 0.31 | 0.31 | 0.31 | 0.38 | 0.38 | 0.36 | 0.36 | 0.36 |
| | 3 | 40c | *U* | 1.02 | 3.22 | 2.07 | 1.76 | 1.71 | 1.45 | 2.13 | 1.76 | 1.44 | 1.40 | 1.33 |
| | | | SHGC | 0.27 | 0.25 | 0.25 | 0.21 | 0.21 | 0.21 | 0.25 | 0.25 | 0.24 | 0.24 | 0.24 |
| Low-e, high-solar | 2 | 17c | U | 1.99 | 4.05 | 2.89 | 2.52 | 2.39 | 2.07 | 2.99 | 2.60 | 2.26 | 2.24 | 2.13 |
| | | | SHGC | 0.70 | 0.62 | 0.62 | 0.52 | 0.52 | 0.52 | 0.64 | 0.64 | 0.61 | 0.61 | 0.61 |
| | 3 | 32c | *U* | 1.42 | 3.54 | 2.36 | 2.02 | 1.97 | 1.70 | 2.47 | 2.10 | 1.77 | 1.73 | 1.66 |
| | | | SHGC | 0.62 | 0.55 | 0.55 | 0.46 | 0.46 | 0.46 | 0.56 | 0.56 | 0.54 | 0.54 | 0.54 |
| Heat-absorbing | 1 | 1c | *U* | 5.91 | 7.24 | 6.12 | 5.14 | 5.05 | 4.61 | 6.42 | 6.07 | 5.55 | 5.55 | 5.35 |
| | | | SHGC | 0.73 | 0.64 | 0.64 | 0.54 | 0.54 | 0.54 | 0.66 | 0.66 | 0.64 | 0.64 | 0.64 |
| | 2 | 5c | *U* | 2.73 | 4.62 | 3.42 | 3.00 | 2.87 | 2.53 | 3.61 | 3.22 | 2.86 | 2.84 | 2.72 |
| | | | SHGC | 0.62 | 0.55 | 0.55 | 0.46 | 0.46 | 0.46 | 0.56 | 0.56 | 0.54 | 0.54 | 0.54 |
| | 3 | 29c | *U* | 1.76 | 3.80 | 2.60 | 2.25 | 2.19 | 1.91 | 2.76 | 2.39 | 2.05 | 2.01 | 1.93 |
| | | | SHGC | 0.34 | 0.31 | 0.31 | 0.26 | 0.26 | 0.26 | 0.31 | 0.31 | 0.30 | 0.30 | 0.30 |
| Reflective | 1 | 11 | *U* | 5.91 | 7.24 | 6.12 | 5.14 | 5.05 | 4.61 | 6.42 | 6.07 | 5.55 | 5.55 | 5.35 |
| | | | SHGC | 0.31 | 0.28 | 0.28 | 0.24 | 0.24 | 0.24 | 0.29 | 0.29 | 0.27 | 0.27 | 0.27 |
| | 2 | 5p | *U* | 2.73 | 4.62 | 3.42 | 3.00 | 2.87 | 2.53 | 3.61 | 3.22 | 2.86 | 2.84 | 2.72 |
| | | | SHGC | 0.29 | 0.27 | 0.27 | 0.22 | 0.22 | 0.22 | 0.27 | 0.27 | 0.26 | 0.26 | 0.26 |
| | 3 | 29c | *U* | 1.76 | 3.80 | 2.60 | 2.25 | 2.19 | 1.91 | 2.76 | 2.39 | 2.05 | 2.01 | 1.93 |
| | | | SHGC | 0.34 | 0.31 | 0.31 | 0.26 | 0.26 | 0.26 | 0.31 | 0.31 | 0.30 | 0.30 | 0.30 |

**Table 10 Peak Irradiance, W/m²**

| Exposure | | Latitude 20° | 25° | 30° | 35° | 40° | 45° | 50° | 55° | 60° |
|---|---|---|---|---|---|---|---|---|---|---|
| North | $E_D$ | 125 | 106 | 92 | 84 | 81 | 85 | 96 | 112 | 136 |
| | $E_d$ | 128 | 115 | 103 | 93 | 84 | 76 | 69 | 62 | 55 |
| | $E_t$ | 253 | 221 | 195 | 177 | 166 | 162 | 164 | 174 | 191 |
| Northeast/Northwest | $E_D$ | 460 | 449 | 437 | 425 | 412 | 399 | 386 | 374 | 361 |
| | $E_d$ | 177 | 169 | 162 | 156 | 151 | 147 | 143 | 140 | 137 |
| | $E_t$ | 637 | 618 | 599 | 581 | 563 | 546 | 529 | 513 | 498 |
| East/West | $E_D$ | 530 | 543 | 552 | 558 | 560 | 559 | 555 | 547 | 537 |
| | $E_d$ | 200 | 196 | 193 | 190 | 189 | 188 | 187 | 187 | 187 |
| | $E_t$ | 730 | 739 | 745 | 748 | 749 | 747 | 742 | 734 | 724 |
| Southeast/Southwest | $E_D$ | 282 | 328 | 369 | 405 | 436 | 463 | 485 | 503 | 517 |
| | $E_d$ | 204 | 203 | 203 | 204 | 205 | 207 | 210 | 212 | 215 |
| | $E_t$ | 485 | 531 | 572 | 609 | 641 | 670 | 695 | 715 | 732 |
| South | $E_D$ | 0 | 60 | 139 | 214 | 283 | 348 | 408 | 464 | 515 |
| | $E_d$ | 166 | 193 | 196 | 200 | 204 | 209 | 214 | 219 | 225 |
| | $E_t$ | 166 | 253 | 335 | 414 | 487 | 557 | 622 | 683 | 740 |
| Horizontal | $E_D$ | 845 | 840 | 827 | 806 | 776 | 738 | 691 | 637 | 574 |
| | $E_d$ | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 |
| | $E_t$ | 1015 | 1010 | 997 | 976 | 946 | 908 | 861 | 807 | 744 |

**Table 13 Fenestration Solar Load Factors $FF_s$**

| Exposure | Single Family Detached | Multifamily |
|---|---|---|
| North | 0.44 | 0.27 |
| Northeast | 0.21 | 0.43 |
| East | 0.31 | 0.56 |
| Southeast | 0.37 | 0.54 |
| South | 0.47 | 0.53 |
| Southwest | 0.58 | 0.61 |
| West | 0.56 | 0.65 |
| Northwest | 0.46 | 0.57 |
| Horizontal | 0.58 | 0.73 |

$CF_{west\ window(irradiation)} = PXI\ x\ SHGC\ x\ IAC\ x\ FF_s$

= 747 x 0.54 x 1 x 0.56 = 225.89

$q_{west\ window} = A\ x\ CF_{west\ window} = A\ x\ (CF_{west\ window(heat\ transfer)} + (CF_{west\ window(irradiation)})$

= 14.4 $m^2$ x (6.89 +225.89) $\frac{w}{m^2}$ = 3352.07 W

HEATING LOAD

$q_{west\ window} = A\ x\ HF_{west\ window} = A\ x\ U_{west\ window}\ x\ \Delta T_{heating}$

= 14.4 $m^2$ x 2.84 $\frac{w}{m^2k}$ x 24.8 k = 1014.22 W

**If the frame is aluminium**

$U'_{west\ window} = 3.61\frac{w}{m^2k}$

SHGC' = 0.56

Cooling load

$CF'_{west\ window(heat\ transfer)} = U'_{west\ window}\ (\Delta T_{cooling}$ - 0.46 DR)

= $3.61\frac{w}{m^2k}(7.9K - 0.46\ x\ 11.9\ k)$ = $8.76\frac{w}{m^2}$

$CF'_{west\ window(irradiation)} = PXI\ x\ SHGC'\ x\ IAC\ x\ FF_s$

= 747 x 0.56 x 1 x 0.56 = 234.26

$q'_{west\ window} = A\ x\ (CF'_{west\ window(heat\ transfer)} + (CF'_{west\ window(irradiation)})$

= 14.4 $m^2$ x (8.76 +234.26) $\frac{w}{m^2}$ = 3499.48W

Heating load

$q'_{west\ window} = A\ x\ HF'_{west\ window} = A\ x\ U'_{west\ window}\ x\ \Delta T_{heating}$

= 14.4 $m^2$ x 3.61 $\frac{w}{m^2k}$ x 24.8 k = 1289.20 W

**FIXED WINDOW ON SOUTH SIDE**

Area = 3.6 $m^2$

**COOLING LOAD**

$q_{south\ window} = A\ x\ CF_{south\ window}$

$CF_{south\ window(heat\ transfer)} = U_{south\ window}\ (\Delta T_{cooling}$ - 0.46 DR)

$U_{south\ window} = 2.84\frac{w}{m^2k}$

$CF_{south\ window(heat\ transfer)} = 2.84\frac{w}{m^2k}(7.9\ k$ - 0.46 (11.9 k)) $\approx 6.89\ \frac{w}{m^2}$

Irradiation

$E_D$ = 348

$E_d$ = 209

PXI $_{\text{west window}}$ = $E_D$ + $E_d$ = 348 + 209 = 557

Since no internal shading, so IAC = 1

SHGC = 0.54

$FF_s$ = 0.47

$CF_{south\ window(irradiation)} = PXI\ x\ SHGC\ x\ IAC\ x\ FF_s = 557 \text{ x } 0.54 \text{ x } 1 \text{ x } 0.47 = 141.36$

$q_{south\ window} = AxCF_{southwindow} = Ax(CF_{south\ window(heat\ transfer)} + (CF_{south\ window(irradiation)})$

= 3.6 $m^2$ x (6.89 +141.36) $\frac{w}{m^2}$ = 533.72 W

HEATING LOAD

$q_{south\ window} = A\ x\ HF_{south\ window} = A\ x\ U_{south\ window}\ x\ \Delta T_{heating}$

= 3.6 $m^2$ x 2.84 $\frac{w}{m^2k}$ x 24.8 k = 253.56 W

**If the frame is aluminum**

$U'_{south\ window} = 3.61\frac{w}{m^2k}$

SHGC' = 0.56

Cooling load

$CF'_{south\ window(heat\ transfer)} = U'_{south\ window}\ (\Delta T_{cooling}$ - 0.46 DR)

= $3.61\frac{w}{m^2k}(7.9K - 0.46\ x\ 11.9\ k)$ = $8.76\frac{w}{m^2}$

$CF'_{south\ window(irradiation)} = PXI\ x\ SHGC'\ x\ IAC\ x\ FF_s$ = 557 x 0.56 x 1 x 0.47 = 146.6

$q'_{south\ window} = A\ x\ (CF'_{south\ window(heat\ transfer)} + (CF'_{south\ window(irradiation)})$

= 3.6 $m^2$ x (8.76 +146.60) $\frac{w}{m^2}$ = 559.30W

Heating load

$q'_{south\ window} = A\ x\ HF'_{south\ window} = A\ x\ U'_{south\ window}\ x\ \Delta T_{heating}$

= 3.6 $m^2$ x 3.61 $\frac{w}{m^2k}$ x 24.8 k = 322.30 W

**OPERABLE WINDOW ON SOUTH SIDE**

Area = 3.6 $m^2$

**COOLING LOAD**

$q_{south\ window} = A\ x\ CF_{south\ window}$

$CF_{south\ window(heat\ transfer)} = U_{south\ window}\ (\Delta T_{cooling}$ - 0.46 DR)

$U_{south\ window} = 2.87 \frac{w}{m^2 k}$

$CF_{south\ window(heat\ transfer)} = 2.87 \frac{w}{m^2 k}$ (7.9 k - 0.46 (11.9 k)) $\approx 6.96\ \frac{w}{m^2}$

Irradiation

$E_D$ = 348

$E_d$ = 209

PXI $_{\text{south window}}$ = $E_D$ + $E_d$ = 348 + 209 = 557

Since no internal shading, so IAC = 1

SHGC = 0.46

$FF_s$ = 0.47

$CF_{south\ window(irradiation)} = PXI\ x\ SHGC\ x\ IAC\ x\ FF_s$ = 557 x 0.46 x 1 x 0.47 = 120.42

$q_{south\ window} = AxCF_{south\ window} = A(CF_{south\ window(heat\ transfer)} + (CF_{south\ window(irradiation)})$

= 3.6 $m^2$ x (6.96 +120.42) $\frac{w}{m^2}$ = 458.58 W

HEATING LOAD

$q_{south\ window} = A\ x\ HF_{south\ window} = A\ x\ U_{south\ window}\ x\ \Delta T_{heating}$

= 3.6 $m^2$ x 2.87 $\frac{w}{m^2 k}$ x 24.8 k = 256.23 W

**If the frame is aluminium**

$U'_{south\ window} = 4.62 \frac{w}{m^2 k}$

SHGC' = 0.55

Cooling load

$CF'_{south\ window(heat\ transfer)} = U'_{south\ window}\ (\Delta T_{cooling}$ - 0.46 DR)

= 4.62 $\frac{w}{m^2 k}$ $(7.9K - 0.46\ x\ 11.9\ k)$ = 11.21 $\frac{w}{m^2}$

$CF'_{west\ window(irradiation)} = PXI\ x\ SHGC'\ x\ IAC\ x\ FF_s$ = 557 x 0.55 x 1 x 0.47 = 143.98

$q'_{west\ window} = A\ x\ (CF'_{west\ window(heat\ transfer)} + (CF'_{west\ window(irradiation)})$

= 3.6 $m^2$ x (11.21 +143.98) $\frac{w}{m^2}$ = 558.70 W

Heating load

$q'_{south\ window} = A\ x\ HF'_{south\ window} = A\ x\ U'_{south\ window}\ x\ \Delta T_{heating}$

= 3.6 $m^2$ x 4.62 $\frac{w}{m^2 k}$ x 24.8 k = 412.47 W