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 thickenss to be 13 mm)

Consider the house that we analysed in the alst 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 aluminium ?

$$\boldsymbol{U_{window}} = \frac{\boldsymbol{U_{center}A_{center} + U_{edge}A_{edge} + U_{frame}A_{frame}}}{\boldsymbol{A_{window}}}$$

If we are dealing with a double pane window we can disregard the thermal resistance of glass layers

$$\frac{1}{U_{doublepane}} = \frac{1}{h_i} + \frac{1}{h_{space}} + \frac{1}{h_0}$$

$$h_{space} = h_{rad} + h_{conv}$$

Hspace changes by changing the gas that fills the gap. If we take the gap thickness to be 13mm from the graph we know that by changing the gas that fills the gap from air to argon the Uvalue of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 2.65 $\frac{W}{m^2K}$, which means the U-value decreases about 5.36%

By changing the gas that fills the gap from air to krypton, the Uvalue of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 2.6 $\frac{W}{m^2K}$ which means U-value decreases about 7.14%

Uvalue also increase by adding an extra pane. If we use the diagram from the slides we know that when the gap thickness is 13mm and the gas that fills the gap is air then by adding an extra pane the U-value of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 1.8 $\frac{W}{m^2K}$ which is almost a 35.71% decrease.

Another method would be to coat the glass surfaces with a material that has a low emissivity.

Using the diagrams from the slides and taking the gap thickness as 13mm and the gas filling the gap is air, we can tell that by coating the glass surface with a film that has the emissivity of 0.1, the Uvalue of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 1.8 $\frac{W}{m^2K}$ which means there is a 35.71% decrease in the Uvalue.

We know that:

1. Net area of a building located in Piacenza is 105.8 m^2, and the calculated U value is 0.438 $\frac{W}{m^2K}$ for the winter while in the summer it is 0.435 $\frac{W}{m^2K}$
2. A fixed heat absorbing double later glass with a wooden frame window at the east side of a building located in Piacenza has a surface of 14.4m^2
3. $\Delta T_{cooling} = 24°C$
4. $\Delta T_{heating} = 20°C$

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

$$\Delta T_{heating} = 20°C - (-4.8°C) = 24.8°C = 24.8K$$

From the table corresponding to Piacenza. DR=11.9°C = 11.9K

To calculate the cooling load of the fixed window on the West:

$$q_{west\ window} = A \times CF_{westwindow}$$

A=14.4m2

$$CF_{westwindow} = U_{westwindow}(\Delta T_{cooling} - 0.46DR)$$

$$U_{westwindow} = 2.84\ \frac{W}{m^2K}$$

$$CF_{westwindow} = 2.84\ \frac{W}{m^2K} \times (7.9K - 0.46 \times 11.9\mathrm{K}) = 6.89\frac{W}{m^2K}$$

$$PXI_{westwindow} = E_D + E_d = 599 + 188 = 747$$

SHGC=0.54

No internal shading so IAC=1

$$FF_s = 0.56$$

$$CF_{westwindow} = PXI\ \times SHGC\ \times IAC\ \times\ FF_S$$

$$q_{westwindow} = A \times CF_{westwindow} = A \times \left(CF_{heat\ transfer} + CF_{irradation}\right)$$

$$\approx 14.4m^2 \times (6.89 + 747 \times 0.54 \times 1 \times 0.56)\frac{W}{m^2} \approx 3352W$$

To calculate the heating load of the fixed window on the west

$$q_{westwindow} = A \times HF_{westwindow} = A \times U_{westwindow}\Delta T_{heating}$$

$$= 14.4m^2 \times 2.84\frac{W}{m^2K} \times 24.8K \ \approx 1014.22W$$

If the frames were made of aluminum: $U_{westwindow} = 3.61\frac{W}{m^2K}$ and SHGC=0.56

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

$$= 3.61\frac{W}{m^2K} \times (7.9K - 0.46 \times 11.9K) \approx 8.76\ \frac{W}{m^2}$$

Cooling load $q'_{westwindow} = A \times CF'_{westwindow}$

$$= A \times (CF'_{westwindow\ for\ heat\ transfer} + CF'_{westwindow\ irradation}$$

$$\approx 14.4m^2 \times (8.76 + 747 \times 0.54 \times 1 \times 0.56)\ \frac{W}{m^2} \approx 3499.48W$$

Heating load $q'_{westwindow} = A \times HF'_{westwindow} = A \times U'_{westwindow}\Delta T_{heating}$

$$= 14.4m^2 \times 3.61\frac{W}{m^2K} \times 24.8K \approx 1289.2\ W$$

Calculating the cooling load of the fixed window on the south:

$$q_{west\ window} = A \times CF_{southwindow}$$

A=3.6m2

$$CF_{southwindow} = U_{southwindow}(\Delta T_{cooling} - 0.46DR)$$

$$U_{southwindow} = 2.84\ \frac{W}{m^2K}$$

$$CF_{southwindow} = 2.84\ \frac{W}{m^2K} \times (7.9K - 0.46 \times 11.9\text{K}) \approx 6.89\frac{W}{m^2K}$$

$$PXI_{southwindow} = E_D + E_d = 348 + 209 = 577$$

SHGC=0.54

No internal shading so IAC=1

$$FF_s = 0.47$$

$$CF_{southwindow} = PXI \times SHGC \times IAC \times FF_S$$

$$q_{southwindow} = A \times CF_{southwindow} = A \times \left(CF_{heat\ transfer} + CF_{irradation}\right)$$

$$\approx 3.6m^2 \times (6.89 + 557 \times 0.54 \times 1 \times 0.47)\frac{W}{m^2} \approx 553.72W$$

To calculate the heating load of the fixed window on the south

$$q_{southwindow} = A \times HF_{southwindow} = A \times U_{southwindow}\Delta T_{heating}$$

$$= 3.6m^2 \times 2.84\frac{W}{m^2K} \times 24.8K \approx 253.56W$$

If the frames were made of aluminum: $U_{southwindow} = 3.61\frac{W}{m^2K}$ and SHGC=0.56

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

$$= 3.61\frac{W}{m^2K} \times (7.9K - 0.46 \times 11.9K) \approx 8.76\ \frac{W}{m^2}$$

Cooling load $q'_{southwindow} = A \times CF'_{southwindow}$

$$= A \times (CF'_{southwindow\ for\ heat\ transfer} + CF'_{southwindow\ irradation}$$

$$\approx 3.6m^2 \times (8.76 + 557 \times 0.56 \times 1 \times 0.47)\ \frac{W}{m^2} \approx 559.3W$$

Heating load $q'_{southwindow} = A \times HF'_{southwindow} = A \times U'_{southwindow}\Delta T_{heating}$

$$= 3.6m^2 \times 3.61\frac{W}{m^2K} \times 24.8K \approx 322.3\ W$$

To calculate the cooling load of the operable window on the South:

$$q_{south\ window} = A \times CF_{southwindow}$$

A=3.6m2

$$CF_{southwindow} = U_{southwindow}(\Delta T_{cooling} - 0.46DR)$$

$$U_{westwindow} = 2.87\ \frac{W}{m^2K}$$

$$CF_{westwindow} = 2.87\ \frac{W}{m^2K} \times (7.9K - 0.46 \times 11.9\text{K}) = 6.96\frac{W}{m^2K}$$

$$PXI_{westwindow} = E_D + E_d = 348 + 209 = 557$$

SHGC=0.46

No internal shading so IAC=1

$$FF_s = 0.47$$

$$CF_{southwindow} = PXI\ \times SHGC\ \times IAC\ \times\ FF_S$$

$$q_{southwindow} = A \times CF_{southwindow} = A \times \left(CF_{heat\ transfer} + CF_{irradation}\right)$$

$$\approx 3.6m^2 \times (6.89 + 557 \times 0.46 \times 1 \times 0.47)\frac{W}{m^2} \approx 458.58W$$

To calculate the heating load of the operable window on the south

$$q_{southwindow} = A \times HF_{southwindow} = A \times U_{southwindow}\Delta T_{heating}$$

$$= 3.6m^2 \times 2.87\frac{W}{m^2K} \times 24.8K\ \approx 256.23W$$

If the frames were made of aluminum: $U_{westwindow} = 4062\frac{W}{m^2K}$ and SHGC=0.55

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

$$= 4.62\frac{W}{m^2K}\ \times (7.9K - 0.46 \times 11.9K) \approx 11.21\ \frac{W}{m^2}$$

Cooling load $q'_{southwindow} = A \times CF'_{southwindow}$

$$= A \times (CF'_{southwindow\ for\ heat\ transfer} + CF'_{southwindow\ irradation}$$

$$\approx 3.6m^2 \times (11.21 + 557 \times 0.55 \times 1 \times 0.47)\ \frac{W}{m^2} \approx 558.7W$$

Heating load $q'_{westwindow} = A \times HF'_{southwindow} = A \times U'_{southwindow}\Delta T_{heating}$

$$= 3.6m^2 \times 4.62\frac{W}{m^2K} \times 24.8K \approx 412.47\ W$$