submission week **8**

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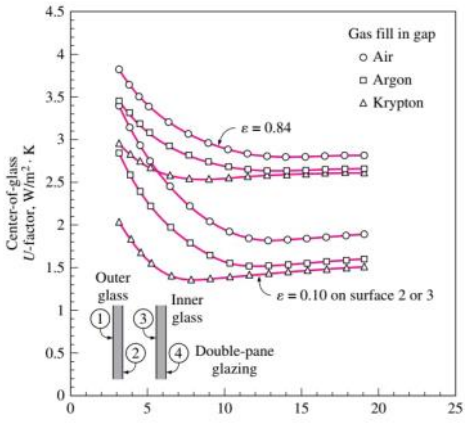
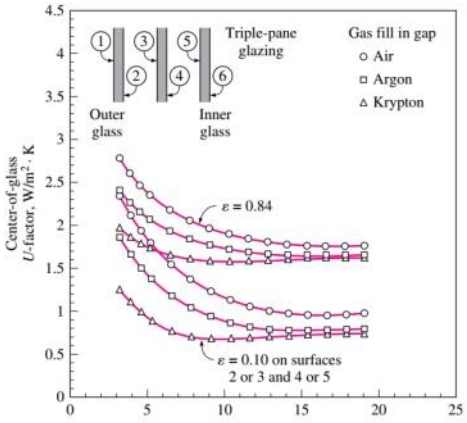
1 Using the diagrams given in the presentation about heat transfer through windows calculate how much (%) is the effect of applying different modifications (changing the gas, adding an extra pane, using a low emissivity coating) on the U value with respect to a benchmark case of double layer with air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





	BENCHMARK CASE	CASE 1	CASE 2	CASE 3
GAP	13 mm	13 mm	13 mm	13 mm
ε	0.84	0.84	0.84	0.10
N PANE	2	2	3	2
GAS	air	kripton	air	air
U-factor	2.8 W/m² K	2.6 W/m² K	1.8 W/m² K	1.8 W/m² K
%	100%	93%	64%	64%

CASE 1: the thermal performance of the window increases by 7%.

CASE 2: the thermal performance of the window increases by 36%.

CASE 3: the thermal performance of the window increases by 36%.

2 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 m^2 on the west, fixed 3.6 m^2 on the south and an operable 3.6 m^2 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?

WINDOW 1	West	Fixed Frame	Heat-absorbing glazing	2 glazing layers	Wood Frame	14.4 surface area

FENESTRATION HEATING

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

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

$$HF_{window_{West}} = U_{window_{West}} \times \Delta T_{heating} = 2.84 * 24.8 = 70.43 \frac{W}{m^2 K}$$

$$\dot{Q}_{window_{West_{Heating}}} = HF_{window_{West}} \times A_{window_{West}} = 70.43 * 14.4 = \mathbf{1014.22\ W}$$

FENESTRATION COOLING

$CF_{fen} = U\ (\Delta T - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$

$CF_{window_{West_{HeatTrasnferPart}}} = U_{window_{West}}\left(\Delta T_{cooling}\ - 0.46\ DR\right) = 2.84\ (7.9 - 0.46 * 11.9) = 6.9\frac{W}{m^2}$

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

$DR = 11.9\ °C$

$PXI_{window_{West}} = E_D + E_d = 559 + 188 = 747$ (no external shading)

$SHGC =\ 0.54$

$IAC =\ 1$ (no internal shading)

$FFs = 0.56$ (Western window of a detached house)

$CF_{window_{West_{IrradiationPart}}} = PXI \times SHGC \times IAC \times FF_S = 747\ * 0.54\ * 1\ * 0.56 = 225.9$

$CF_{window_{West}} = CF_{window_{West_{HeatTrasnferPart}}} + CF_{window_{West_{IrradiationPart}}} =\ 6.9 + 225.9 = 232.8\frac{W}{m^2}$

$\dot{Q}_{window_{West_{Cooling}}} =\ CF_{window_{West}} \times A_{window_{West}} = 232.8\ * 14.4 =$ **$3352.32\ W$**

WINDOW 1	West	Fixed Frame	Heat-absorbing glazing	2 glazing layers	Alluminium Frame	14.4 surface area

FENESTRATION HEATING

$U_{window_{West}} = 3.61\frac{W}{m^2K}$

$\Delta\ T_{heating} = 24.8\ °C$

$HF_{window_{West}} = U_{window_{West}} \times \Delta T_{heating} = 3.61\ * 24.8 = 89.53\ \frac{W}{m^2K}$

$\dot{Q}_{window_{West_{Heating}}} =\ HF_{window_{West}} \times A_{window_{West}} = 89.53 * 14.4 =$ **1289.23 W**

FENESTRATION COOLING

$CF_{window_{West_{HeatTrasnferPart}}} = U_{window_{West}}\left(\Delta T_{cooling}\ - 0.46\ DR\right) = 3.61\ (7.9 - 0.46 * 11.9) = 8.75\frac{W}{m^2}$

$\Delta\ T_{cooling} = 7.9\ °C$

$DR = 11.9\ °C$

$PXI_{window_{West}} = 747$

$SHGC =\ 0.56$

$IAC =\ 1$

$FFs = 0.56$

$CF_{window_{West_{IrradiationPart}}} = PXI \times SHGC \times IAC \times FF_S = 747\ * 0.56\ * 1\ * 0.56 = 234.25$

$CF_{window_{West}} = CF_{window_{West_{HeatTrasnferPart}}} + CF_{window_{West_{IrradiationPart}}} =\ 8.75 + 234.25 = 243\frac{W}{m^2}$

$\dot{Q}_{window_{West_{Cooling}}} =\ CF_{window_{West}} \times A_{window_{West}} = 243\ * 14.4 =$ **$3499.2\ W$**

WINDOW 2	South	Fixed Frame	Heat-absorbing glazing	2 glazing layers	Wood Frame	3.6 surface area

FENESTRATION HEATING

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

$\Delta T_{heating} = 24.8\,°C$

$HF_{window_{South}} = U_{window_{South}} \times \Delta T_{heating} = 2.84 * 24.8 = 70.43\ \frac{W}{m^2 K}$

$\dot{Q}_{window_{South_{Heating}}} = HF_{window_{South}} \times A_{window_{South}} = 70.43 * 3.6 = \mathbf{253.55\ W}$

FENESTRATION COOLING

$CF_{window_{South_{HeatTrasnferPart}}} = U_{window_{South}}\left(\Delta T_{cooling} - 0.46\ DR\right) = 2.84\ (7.9 - 0.46 * 11.9) = 6.9 \frac{W}{m^2}$

$\Delta T_{cooling} = 7.9\,°C$

$DR = 11.9\,°C$

$PXI_{window_{South}} = E_D + E_d = 348 + 209 = 557$

$SHGC = 0.54$

$IAC = 1$

$FFs = 0.47$

$CF_{window_{South_{IrradiationPart}}} = PXI \times SHGC \times IAC \times FF_S = 557 * 0.54 * 1 * 0.47 = 141.37$

$CF_{window_{South}} = CF_{window_{South_{HeatTrasnferPart}}} + CF_{window_{South_{IrradiationPart}}} = 6.9 + 141.37 = 148.27 \frac{W}{m^2}$

$\dot{Q}_{window_{South_{Cooling}}} = CF_{window_{South}} \times A_{window_{South}} = 148.27 * 3.6 = \mathbf{533.77\ W}$

WINDOW 2	South	Fixed Frame	Heat-absorbing glazing	2 glazing layers	Alluminium Frame	3.6 surface area

FENESTRATION HEATING

$U_{window_{South}} = 3.61 \frac{W}{m^2 K}$

$\Delta T_{heating} = 24.8\,°C$

$HF_{window_{South}} = U_{window_{South}} \times \Delta T_{heating} = 3.61 * 24.8 = 89.53\ \frac{W}{m^2 K}$

$\dot{Q}_{window_{South_{Heating}}} = HF_{window_{South}} \times A_{window_{South}} = 89.53 * 3.6 = \mathbf{322.31\ W}$

FENESTRATION COOLING

$CF_{window_{South_{HeatTrasnferPart}}} = U_{window_{South}}\left(\Delta T_{cooling} - 0.46\ DR\right) = 3.61\ (7.9 - 0.46 * 11.9) = 8.75 \frac{W}{m^2}$

$\Delta T_{cooling} = 7.9\,°C$

$DR = 11.9\,°C$

$PXI_{window_{South}} = 557$

$SHGC = 0.56$

$IAC = 1$

$FFs = 0.47$

$CF_{window_{South_{IrradiationPart}}} = PXI \times SHGC \times IAC \times FF_S = 557 * 0.56 * 1 * 0.47 = 146.6$

$CF_{window_{South}} = CF_{window_{South_{HeatTrasnferPart}}} + CF_{window_{South_{IrradiationPart}}} = 8.75 + 146.6 = 155.35 \frac{W}{m^2}$

$\dot{Q}_{window_{South_{Cooling}}} = CF_{window_{South}} \times A_{window_{South}} = 155.35 * 3.6 = \mathbf{559.26\ W}$

WINDOW 3	South	Operable Frame	Heat-absorbing glazing	2 glazing layers	Wood Frame	3.6 surface area

FENESTRATION HEATING

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

$\Delta T_{heating} = 24.8\ °C$

$HF_{window_{South}} = U_{window_{South}} \times \Delta T_{heating} = 2.87 * 24.8 = 71.18\ \frac{W}{m^2 K}$

$\dot{Q}_{window_{South_{Heating}}} = HF_{window_{South}} \times A_{window_{South}} = 71.18 * 3.6 = \mathbf{256.25\ W}$

FENESTRATION COOLING

$CF_{window_{South_{HeatTrasnferPart}}} = U_{window_{South}}\left(\Delta T_{cooling} - 0.46\ DR\right) = 2.87\ (7.9 - 0.46 * 11.9) = 6.96 \frac{W}{m^2}$

$\Delta T_{cooling} = 7.9\ °C$

$DR = 11.9\ °C$

$PXI_{window_{South}} = E_D + E_d = 348 + 209 = 557$

$SHGC = 0.46$

$IAC = 1$

$FFs = 0.47$

$CF_{window_{South_{IrradiationPart}}} = PXI \times SHGC \times IAC \times FF_S = 557 * 0.46 * 1 * 0.47 = 120.42$

$CF_{window_{South}} = CF_{window_{South_{HeatTrasnferPart}}} + CF_{window_{South_{IrradiationPart}}} = 6.96 + 120.42 = 127.38 \frac{W}{m^2}$

$\dot{Q}_{window_{South_{Cooling}}} = CF_{window_{South}} \times A_{window_{South}} = 127.38 * 3.6 = \mathbf{458.57\ W}$

WINDOW 3	South	Operable Frame	Heat-absorbing glazing	2 glazing layers	Alluminium Frame	3.6 surface area

FENESTRATION HEATING

$U_{window_{South}} = 4.62 \frac{W}{m^2 K}$

$\Delta T_{heating} = 24.8\ °C$

$HF_{window_{South}} = U_{window_{South}} \times \Delta T_{heating} = 4.62 * 24.8 = 144.58\ \frac{W}{m^2 K}$

$\dot{Q}_{window_{South_{Heating}}} = \ HF_{window_{South}} \times A_{window_{South}} = 144.58 * 3.6 = \ \mathbf{412.49\ W}$

FENESTRATION COOLING

$CF_{window_{South_{HeatTrasnferPart}}} = U_{window_{South}}\left(\Delta T_{cooling} \ - 0.46\ DR\right) = 4.62\ (7.9 - 0.46 * 11.9)$
$= 11.21 \frac{W}{m^2}$

$\Delta\ T_{cooling} = 7.9\ °C$

$DR = 11.9\ °C$

$PXI_{window_{South}} = 557$

$SHGC = \ 0.55$

$IAC = \ 1$

$FFs = 0.47$

$CF_{window_{South_{IrradiationPart}}} = PXI \times SHGC \times IAC \times FF_S = 557\ * 0.55\ * 1\ * 0.47 = 144$

$CF_{window_{South}} = CF_{window_{South_{HeatTrasnferPart}}} + CF_{window_{South_{IrradiationPart}}} = \ 11.21 + 144 = 155.21 \frac{W}{m^2}$

$\dot{Q}_{window_{South_{Cooling}}} = \ CF_{window_{South}} \times A_{window_{South}} = 155.21\ * 3.6 = \mathbf{558.75\ W}$

WINDOW 4	East	Fixed Frame	Heat-absorbing glazing	2 glazing layers	Wood Frame	14.4 surface area

FENESTRATION HEATING

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

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

$HF_{window_{East}} = U_{window_{East}} \times \Delta T_{heating} = 2.84\ * 24.8 = 70.43\ \frac{W}{m^2 K}$

$\dot{Q}_{window_{East_{Heating}}} = \ HF_{window_{East}} \times A_{window_{East}} = 70.43 * 14.4 = \ \mathbf{1014.22\ W}$

FENESTRATION COOLING

$CF_{window_{East_{HeatTrasnferPart}}} = U_{window_{East}}\left(\Delta T_{cooling} \ - 0.46\ DR\right) = 2.84\ (7.9 - 0.46 * 11.9) = 6.9 \frac{W}{m^2}$

$\Delta\ T_{cooling} = 7.9\ °C$

$DR = 11.9\ °C$

$PXI_{window_{East}} = 747$

$SHGC = \ 0.54$

$IAC = \ 1$

$FFs = 0.31$

$CF_{window_{East_{IrradiationPart}}} = 747\ * 0.54\ * 1\ * 0.31 = 125.1$

$CF_{window_{West}} = CF_{window_{West_{HeatTrasnferPart}}} + CF_{window_{West_{IrradiationPart}}} = \ 6.9 + 125.1 = 132 \frac{W}{m^2}$

$\dot{Q}_{window_{West_{Cooling}}} = \ CF_{window_{West}} \times A_{window_{West}} = 132\ * 14.4 = \mathbf{1900.8\ W}$

WINDOW 4	East	Fixed Frame	Heat-absorbing glazing	2 glazing layers	Alluminium Frame	14.4 surface area

FENESTRATION HEATING

$U_{window_{East}} = 3.61 \frac{W}{m^2 K}$

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

$HF_{window_{East}} = U_{window_{East}} \times \Delta T_{heating} = 3.61 * 24.8 = 89.53\ \frac{W}{m^2 K}$

$\dot{Q}_{window_{East_{Heating}}} = HF_{window_{East}} \times A_{window_{East}} = 89.53 * 14.4 = \mathbf{1289.23\ W}$

FENESTRATION COOLING

$CF_{window_{East_{HeatTrasnferPart}}} = U_{window_{East}}\left(\Delta T_{cooling} - 0.46\ DR\right) = 3.61\ (7.9 - 0.46 * 11.9) = 8.76 \frac{W}{m^2}$

$\Delta T_{cooling} = 7.9\ °C$

$DR = 11.9\ °C$

$PXI_{window_{East}} = 747$

$SHGC = 0.56$

$IAC = 1$

$FFs = 0.31$

$CF_{window_{East_{IrradiationPart}}} = 747 * 0.56 * 1 * 0.31 = 129.68$

$CF_{window_{West}} = CF_{window_{West_{HeatTrasnferPart}}} + CF_{window_{West_{IrradiationPart}}} = 8.76 + 129.68 = 138.44 \frac{W}{m^2}$

$\dot{Q}_{window_{West_{Cooling}}} = CF_{window_{West}} \times A_{window_{West}} = 138.44 * 14.4 = \mathbf{1993.54\ W}$

Conclusions:

$\dot{Q}_{total_{Windows_{Heating_{WodenFrame}}}} = 1014.22 + 253.55 + 256.25 + 1014.22 = \mathbf{2538.24\ W}$

$\dot{Q}_{total_{Windows_{Cooling_{WodenFrame}}}} = 3352.32 + 533.77 + 458.57 + 1900.8 = \mathbf{6245.46\ W}$

$\dot{Q}_{total_{Windows_{Heating_{AlluminiumFrame}}}} = 1289.23 + 322.31 + 412.49 + 1289.23 = \mathbf{3313.26\ W}$

$\dot{Q}_{total_{Windows_{Cooling_{AlluminiumFrame}}}} = 3499.2 + 559.26 + 558.75 + 1993.54 = \mathbf{6610.75\ W}$

$\Delta \dot{Q}_{total_{Windows_{Heating_{WodenFrame-AlluminiumFrame}}}} = 3313.26 - 2538.24 = \mathbf{775.02\ W}$

$\Delta \dot{Q}_{total_{Windows_{Cooling_{WodenFrame-AlluminiumFrame}}}} = 6610.75 - 6245.46 = \mathbf{364.29\ W}$

From the results we can conclude that aluminum frame windows are worse than wooden frame windows because heat transfer is bigger in aluminum frame windows than in wooden frame windows.