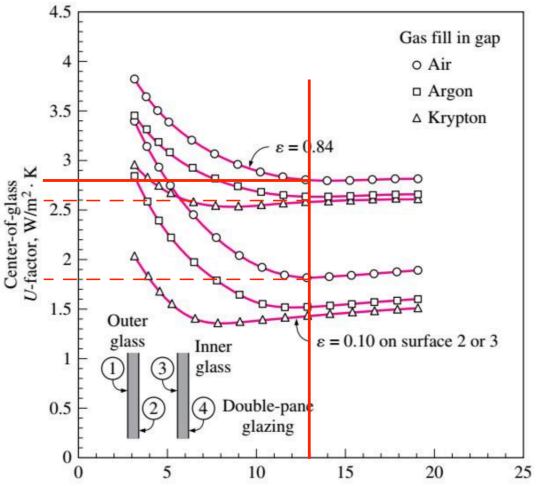
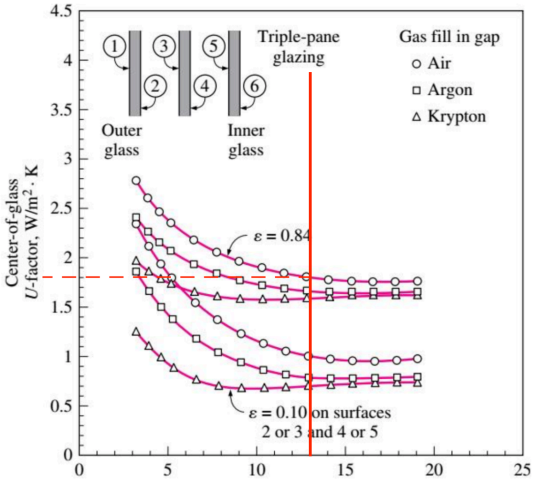
WEEK 8 SUBMISSION

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 thickenss to be 13 mm)**





	BENCHMARK	1	2	3
GAP	13mm	13mm	13mm	13mm
e	0,84	**0,84**	**0,10**	0,84
N° PANE	2	2	2	**3**
GAS	AIR	**KRYPTON**	AIR	AIR
U_{FACTOR}	2,8 W/m^2K	2,6 W/m^2K	1,8 W/m^2K	1,8 W/m^2K
%	100%	93%	64%	64%

1. from the graph it is possible to see that by comparing the benchmark with the first case where the gas (krypton) has been changed, the U_{FACTOR} value decreases by 7%, thus improving the thermal transmittance of the window.

2. in the second comparison, using a low emissivity coating, the U_{FACTOR} value decreases by 36%, greatly improving the thermal transmittance compared to the benchmark.

3. in the last comparison, adding an extra pane, the U_{FACTOR} value, still decreases by 36%, proving a great improvement in the thermal efficiency of the window.

EAST SIDE OF THE BUILDING

45° LATITUDE

No internal shading – AIC = 1

DR = 11,9

WINDOW_1

$A_{window1\_east} = 14{,}4\ m^2$

→ EAST

→ FIXED

→ WOOD FRAME

HEATING:

$U_{window1\_east} = 2{,}84\ {}^{W}/_{m^2}\,K$

$HF_{window1_{east}} = U_{window1\_east} \cdot \Delta T_{cooling} = 2{,}84 \cdot 24{,}8 = 70{,}44\ {}^{W}/_{m^2}$

$Q_{window1_{east}} = HF_{window1\_east} \cdot \mathrm{A}_{window1\_east} = 70{,}44 \cdot 14{,}4 = 1014{,}2\ W$

COOLING:

Heat transfer part

$CF_{window1\_east} = U_{window1\_east}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$

$= 2{,}84\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 6{,}9\ {}^{W}/_{m^2}$

Irradiation part

$E_D = 559$

$E_d = 188$

East window of a detached house - $FF_S = 0{,}31$

$SHGC = 0{,}54$

$PXI_{window1\_east} = E_D + E_d = 559 + 188 = 747$

$CF_{window1\_east} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 747 \cdot 0{,}54 \cdot 1 \cdot 0{,}31 = 125{,}1$

$$CF_{fenestration1\_east}$$

$$= U_{window1\_east}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right) + PXI \cdot SHGC \cdot IAC \cdot FF_S$$

$$= 6{,}9 + 125{,}1 = 132\ {}^{W}/_{m^2}$$

$$\dot{Q}_{\ window1\_east} = CF_{fenestration1\_east} \cdot A_{window1\_east} = 132 \cdot 14{,}4 = 1900{,}8\ W$$

WINDOW_2

$$A_{window2\_west} = 14{,}4\ m^2$$

→ WEST

→ FIXED

→ WOOD FRAME

HEATING:

$$U_{window2\_west} = 2{,}84\ {}^{W}/_{m^2}\,K$$

$$HF_{window2\_west} = U_{window2\_west} \cdot \Delta T_{cooling} = 2{,}84 \cdot 24{,}8 = 70{,}44\ {}^{W}/_{m^2}$$

$$Q_{window2\_west} = HF_{window2\_west} \cdot \mathrm{A}_{window2\_west} = 70{,}44 \cdot 14{,}4 = 1014{,}2\ W$$

COOLING:

Heat transfer part

$$CF_{window2\_west} = U_{window2\_west}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$$

$$= 2{,}84\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 6{,}9\ {}^{W}/_{m^2}$$

Irradiation part

$$E_D = 559$$

$$E_d = 188$$

West window of a detached house - $FF_S = 0{,}56$

$$SHGC = 0{,}54$$

$$PXI_{window2\_west} = E_D + E_d = 559 + 188 = 747$$

$$CF_{window2\_west} = PXI \cdot SHGC \cdot IAC \cdot FF_S$$
$$= 747 \cdot 0{,}54 \cdot 1 \cdot 0{,}56 = 225{,}9$$

$$CF_{fenestration2\_west}$$
$$= U_{window2\_west}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right) + PXI \cdot SHGC \cdot IAC \cdot FF_S$$
$$= 6{,}9 + 225{,}9 = 232{,}8\ {}^{W}/_{m^2}$$

$$\dot{Q}_{window2\_west} = CF_{fenestration2\_west} \cdot A_{window2\_west} = 232{,}8 \cdot 14{,}4$$
$$= 3352{,}32W$$

WINDOW_3

$$A_{window3\_south} = 3{,}6\ m^2$$

→ SOUTH

→ FIXED

→ WOOD FRAME

HEATING:

$$U_{window3\_south} = 2{,}84\ {}^{W}/_{m^2}\,K$$

$$HF_{window3\_south} = U_{window3\_south} \cdot \Delta T_{cooling} = 2{,}84 \cdot 24{,}8 = 70{,}44\ {}^{W}/_{m^2}$$

$$Q_{window3\_south} = HF_{window3\_south} \cdot A_{window3\_south} = 70{,}44 \cdot 3{,}6 = 253{,}6\ W$$

COOLING:

Heat transfer part

$$CF_{window3\_south} = U_{window3\_south}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$$
$$= 2{,}84\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 6{,}9\ {}^{W}/_{m^2}$$

Irradiation part

$$E_D = 348$$

$$E_d = 209$$

South window of a detached house - $FF_S = 0{,}47$

$SHGC = 0{,}54$

$PXI_{window3\_south} = \ E_D + \ E_d = 559 + 188 = 557$

$CF_{window3\_south} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 557 \cdot 0{,}54 \cdot 1 \cdot 0{,}47 = 141{,}4$

$CF_{fenestration3\_south}$

$= U_{window3\_south}(\Delta T_{cooling} - 0{,}46 \cdot DR\ ) + PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 6{,}9 + 141{,}4\ = 148{,}3\ {}^{W}/_{m^2}$

$\dot{Q}\ _{window3\_south} = CF_{fenestration3\_south} \cdot A_{window3\ south} = 148{,}3 \cdot 3{,}6$

$= 533{,}88\ W$

WINDOW_4

$A_{window4\_south} = 3{,}6\ m^2$

→ SOUTH

→ OPERABLE

→ WOOD FRAME

HEATING:

$U_{window4\_south} = 2{,}87\ {}^{W}/_{m^2}\,K$

$HF_{window4\_south} = U_{window4\_south} \cdot \Delta T_{cooling} = 2{,}87 \cdot 24{,}8 = 71{,}17\ {}^{W}/_{m^2}$

$Q_{window4\_south} = HF_{window4\_south} \cdot \mathrm{A}_{window4\_south} = 71{,}17 \cdot 3{,}6 = 256{,}2\ W$

COOLING:

Heat transfer part

$CF_{window4\_south} = U_{window4\_south}\ (\Delta T_{cooling} - 0{,}46 \cdot DR\ )$

$= 2{,}87\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 6{,}96\ {}^{W}/_{m^2}$

Irradiation part

$E_D = 348$

$E_d = 209$

$SHGC = 0{,}46$

South window of a detached house - $FF_S = 0{,}47$

$PXI_{window4\_south} = E_D + E_d = 559 + 188 = 557$

$CF_{window4\_south} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 557 \cdot 0{,}46 \cdot 1 \cdot 0{,}47 = 120{,}4$

$CF_{fenestration4\_south}$

$= U_{window4\_south}(\Delta T_{cooling} - 0{,}46 \cdot DR) + PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 6{,}9 + 120{,}4 = 127{,}3\ {}^{W}/_{m^2}$

$\dot{Q}_{window4\_south} = CF_{fenestration4\_south} \cdot A_{window4\ south} = 127{,}3 \cdot 3{,}6$

$= 458{,}28\ W$

$\dot{Q}_{TOTAL\_windows\_cooling\_wood\ frame}$

$= \dot{Q}_{window1\_east} + \dot{Q}_{window2\_west} + \dot{Q}_{window3\_south} + \dot{Q}_{window4\_south}$

$= 1900{,}8 + 3352{,}32 + 533{,}88 + 458{,}28 = 6245{,}3\ W$

$\dot{Q}_{TOTAL\_windows\_heating\_wood\ frame}$

$= \dot{Q}_{window1\_east} + \dot{Q}_{window2\_west} + \dot{Q}_{window3\_south} + \dot{Q}_{window4\_south}$

$= 1014{,}2 + 1014{,}2 + 253{,}6 + 256{,}2 = 2538{,}2\ W$

CHANGE OF MATERIAL OF WINDOW FRAMES (aluminium)

WINDOW_1

$A_{window1\_east} = 14{,}4\ m^2$

→ EAST

→ FIXED

→ ALUMINIUM FRAME

HEATING:

$U_{window1\_east} = 3{,}61\ {}^{W}/_{m^2}\,K$

$HF_{window1_{east}} = U_{window1\_east} \cdot \Delta T_{cooling} = 3{,}61 \cdot 24{,}8 = 89{,}52\ {}^{W}/_{m^2}$

$Q_{window1_{east}} = HF_{window1\_east} \cdot \mathrm{A}_{window1\ \ east} = 89{,}52 \cdot 14{,}4 = 1289{,}1\ W$

COOLING:

Heat transfer part

$CF_{window1\_east} = U_{window1\_east}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$

$= 3{,}61\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 8{,}7\ {}^{W}/_{m^2}$

Irradiation part

$E_D = 559$

$E_d = 188$

$SHGC = 0{,}56$

East window of a detached house - $FF_S = 0{,}31$

$PXI_{window1\_east} = E_D + E_d = 559 + 188 = 747$

$CF_{window1\_east} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 747 \cdot 0{,}56 \cdot 1 \cdot 0{,}31 = 129{,}6$

$CF_{fenestration1\_east}$

$= U_{window1\_east}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right) + PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 8{,}7 + 129{,}6 = 138{,}3\ {}^{W}/_{m^2}$

$\dot{Q}_{\ window1\_east} = CF_{fenestration1\_east} \cdot A_{window1\_east} = 138{,}3 \cdot 14{,}4 = 1991{,}5\ W$

WINDOW_2

$A_{window2\_west} = 14{,}4\ m^2$

→ WEST

→ FIXED

→ ALUMINIUM FRAME

HEATING:

$U_{window2\_west} = 3{,}61\ {}^{W}/_{m^2}\,K$

$HF_{window2\_west} = U_{window2\_west} \cdot \Delta T_{cooling} = 3{,}61 \cdot 24{,}8 = 89{,}52\ {}^{W}/_{m^2}$

$Q_{window2\_west} = HF_{window2\_west} \cdot \mathrm{A}_{window2\ \_west} = 89{,}52 \cdot 14{,}4 = 1289{,}1\ W$

COOLING:

Heat transfer part

$CF_{window2\_west} = U_{window2\_west}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$

$= 3{,}61\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 8{,}7\ {}^{W}/_{m^2}$

Irradiation part

$E_D = 559$

$E_d = 188$

$SHGC = 0{,}56$

West window of a detached house - $FF_S = 0{,}56$

$PXI_{window2\_west} = E_D + E_d = 559 + 188 = 747$

$CF_{window2\_west} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 747 \cdot 0{,}56 \cdot 1 \cdot 0{,}56 = 234{,}26$

$CF_{fenestration2\_west}$

$= U_{window2\_west}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right) + PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 8{,}7 + 234{,}26 = 242{,}96\ {}^{W}/_{m^2}$

$\dot{Q}_{\ window2\_west} = CF_{fenestration2\_west} \cdot A_{window2\ \_west} = 242{,}96 \cdot 14{,}4$

$= 3498{,}6\ W$

WINDOW_3

$A_{window3\_south} = 3{,}6\ m^2$

→ SOUTH

→ FIXED

→ ALUMINIUM FRAME

HEATING:

$U_{window3\_south} = 3{,}61\ {}^{W}/_{m^2}\,K$

$HF_{window3\_south} = U_{window3\_south} \cdot \Delta T_{cooling} = 3{,}61 \cdot 24{,}8 = 89{,}52\ {}^{W}/_{m^2}$

$Q_{window3\_south} = HF_{window3\_south} \cdot \mathrm{A}_{window3\ \ south} = 89{,}52 \cdot 3{,}6 = 322{,}2\ W$

COOLING:

Heat transfer part

$CF_{window3\_south} = U_{window3\_south}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$

$= 3{,}61\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 8{,}7\ {}^{W}/_{m^2}$

Irradiation part

$E_D = 348$

$E_d = 209$

$SHGC = 0{,}56$

South window of a detached house - $FF_S = 0{,}47$

$PXI_{window3\_south} = E_D + E_d = 559 + 188 = 557$

$CF_{window3\_south} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 557 \cdot 0{,}56 \cdot 1 \cdot 0{,}47 = 146{,}6$

$CF_{fenestration3\_south}$

$= U_{window3\_south}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right) + PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 8{,}7 + 146{,}6 = 155{,}3\ {}^{W}/_{m^2}$

$\dot{Q}_{window3\_south} = CF_{fenestration3\_south} \cdot A_{window3\ \ south} = 155{,}3 \cdot 3{,}6$

$= 559{,}08\ W$

WINDOW_4

$A_{window4\_south} = 3{,}6\ m^2$

→ SOUTH

→ OPERABLE

→ ALUMINIUM FRAME

HEATING:

$U_{window4\_south} = 4{,}62\ {}^{W}/_{m^2}\,K$

$HF_{window4\_south} = U_{window4\_south} \cdot \Delta T_{cooling} = 4{,}62 \cdot 24{,}8 = 114{,}57\ {}^{W}/_{m^2}$

$Q_{window4\_south} = HF_{window4\_south} \cdot \mathrm{A}_{window4\_south} = 114{,}57 \cdot 3{,}6 = 412{,}4\ W$

COOLING:

Heat transfer part

$CF_{window4\_south} = U_{window4\_south}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right)$

$= 4{,}62\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 11{,}2\ {}^{W}/_{m^2}$

Irradiation part

$E_D = 348$

$E_d = 209$

$SHGC = 0{,}55$

South window of a detached house - $FF_S = 0{,}47$

$PXI_{window4\_south} = E_D + E_d = 559 + 188 = 557$

$CF_{window4\_south} = PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 557 \cdot 0{,}55 \cdot 1 \cdot 0{,}47 = 143{,}98$

$CF_{fenestration4\_south}$

$= U_{window4\_south}\left(\Delta T_{cooling} - 0{,}46 \cdot DR\right) + PXI \cdot SHGC \cdot IAC \cdot FF_S$

$= 11{,}2 + 143{,}98 = 155{,}18\ {}^{W}/_{m^2}$

$\dot{Q}_{window4\_south} = CF_{fenestration4\_south} \cdot A_{window4\_south} = 155{,}18 \cdot 3{,}6$

$= 558{,}65\ W$

$$\dot{Q}_{TOTAL\_windows\_cooling_{\_aluminium\ frame}}$$
$$= \dot{Q}_{window1_{\_east}} + \dot{Q}_{window2_{\_west}} + \dot{Q}_{window3_{\_south}} + \dot{Q}_{window4_{\_south}}$$
$$= 1991{,}5 + 3498{,}6 + 559{,}08 + 558{,}65 = 6607{,}8\ W$$

$$\dot{Q}_{TOTAL\_windows\_heating_{\_aluminium\ frame}}$$
$$= \dot{Q}_{window1_{\_east}} + \dot{Q}_{window2_{\_west}} + \dot{Q}_{window3_{\_south}} + \dot{Q}_{window4_{\_south}}$$
$$= 1289{,}1 + 1289{,}1 + 322{,}2 + 412{,}4 = 3312{,}8\ W$$

Conclusion:

$\dot{Q}_{TOTAL\_windows\_cooling_{\_wood\ frame}} = 6245{,}3\ W$

$\dot{Q}_{TOTAL\_windows\_cooling_{\_alluminium\ frame}} = 6607{,}8\ W$

$\Delta\ \dot{Q}_{cooling} = 6607{,}8 - 6245{,}3 = \ 362{,}5\ W$

$\dot{Q}_{TOTAL\_windows\_heating_{\_wood\ frame}} = 2538{,}2\ \ W$

$\dot{Q}_{TOTAL\_windows\_heating_{\_aluminium\_\ frame}} = 3312{,}8\ W$

$\Delta\ \dot{Q}_{heating} = 3312{,}8 - 2538{,}2 = \ 774{,}6\ W$

The results show that a window with a wooden frame has a greater resistance in cooling and heating than a window with an aluminium frame.