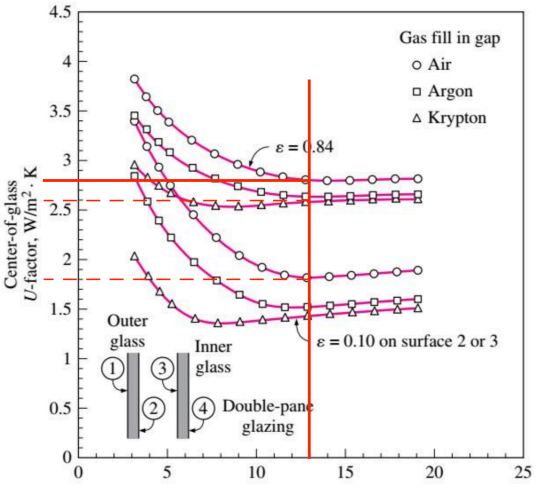
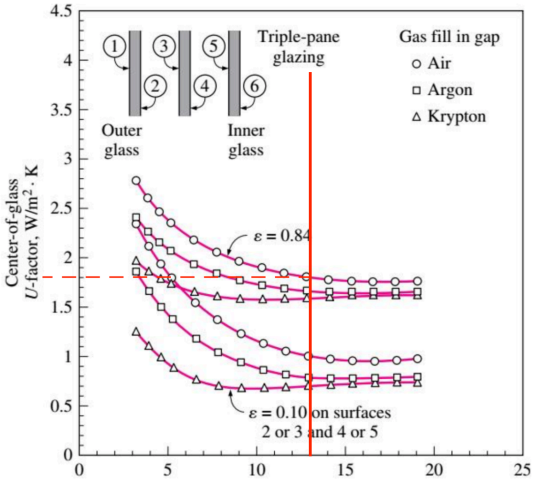
WEEK 8 SUBMISSION **PAOLA GOBBI - 926210**

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
ε	0,84	**0,84**	**0,10**	0,84
N° PANE	2	2	2	**3**
GAS	AIR	**KRYPTON**	AIR	AIR
U_{FACTOR}	2,8 $W/m^2 K$	2,6 $W/m^2 K$	1,8 $W/m^2 K$	1,8 $W/m^2 K$
%	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.

2. Consider the house that we analysed 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 aluminium ?

PIACENZA

LAT: 44,92 N

LONG: 9,73 E

ELEV :138

T_{SUMMER}*: 24°*

T_{WINTER}*: 20°*

HEATING DB 99%: - 4,8

COOLING DB/MCWB 1%: 31,9

$\Delta T_{COOLING} = 31{,}9 - 24 = 7{,}9\ ℃$

$\Delta T_{HEATING} = 20 - (-4{,}8) = 24{,}8\ ℃$

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:

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

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

$$Q_{window3\_south} = HF_{window3\_south} \cdot \mathrm{A}_{window3\ \ south} = 70{,}44 \cdot 3{,}6 = 253{,}6\,W$$

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:

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

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

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

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.