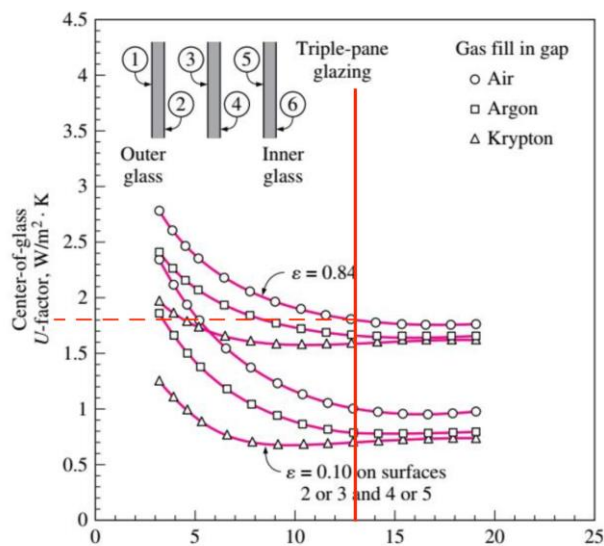
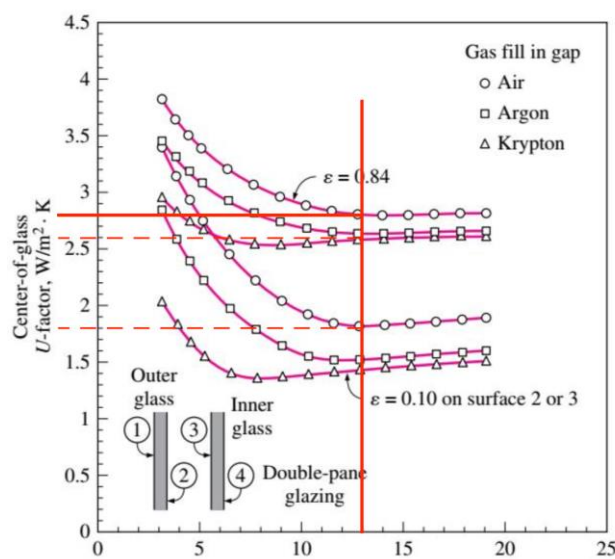


# Task1.

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 thickness to be 13 mm)



	BENCHMARK	1	2	3
GAP	13mm	13mm	13mm	13mm
$\epsilon$	0,84	0,84	0,10	0,84
N° PANE	2	2	2	3
GAS	AIR	KRYPTON	AIR	AIR
U <sub>FACTOR</sub>	2,8 W/m <sup>2</sup> K	2,6 W/m <sup>2</sup> K	1,8 W/m <sup>2</sup> K	1,8 W/m <sup>2</sup> 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 UFACTOR value decreases by 7%, thus improving the thermal transmittance of the window.

2. in the second comparison, using a low emissivity coating, the UFACTOR value

decreases by 36%, greatly improving the thermal transmittance compared to the benchmark.

3. in the last comparison, adding an extra pane, the UFACTOR value, still decreases

by 36%, proving a great improvement in the thermal efficiency of the window.

## Task 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 m<sup>2</sup> on the west, fixed 3.6 m<sup>2</sup> on the south and an operable 3.6 m<sup>2</sup> 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<sub>SUMMER</sub>: 24°

T<sub>WINTER</sub>: 20°

HEATING DB 99%: - 4,8

COOLING DB/MCWB 1%: 31,9

$$\Delta T_{\text{cooling}} = 31,9 - 24 = 7,9 \text{ }^{\circ}\text{C}$$

$$\Delta T_{\text{heating}} = 20 - (-4,8) = 24,8 \text{ }^{\circ}\text{C}$$

EAST SIDE OF THE BUILDING

45° LATITUDE

No internal shading – AIC = 1

$$\text{DR} = 11,9$$

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## Wood Frame Section

### WINDOW 1

$$A_{W1\text{east}} = 14,4 \text{ m}^2$$

EAST

FIXED

WOOD FRAME

Heating:

$$U_{W1\text{east}} = 2,84 \text{ W/m}^2 \text{ K}$$

$$\text{HF}_{W1\text{east}} = U_{W1\text{east}} * \Delta T_{\text{cooling}} = 2,84 * 24,8 = 70,44$$

$$Q_{W1\text{east}} = \text{HF}_{W1\text{east}} * A_{W1\text{east}} = 70,44 * 14,4 = 1014,2 \text{ W}$$

## Cooling

### Part for Heat transfer

$$\text{CF}_{W1\text{east}} = U_{W1\text{east}} * (\Delta T_{\text{cooling}} - 0,46 * \text{DR}) = 2,84 (7,9 - 0,46 * 11,9) = 6,9 \text{ W/m}^2$$

### Part for Irradiation part

$$E_D = 559$$

$$E_d = 188$$

East window of a detached house - FFS = 0.31

$$\text{SHGC} = 0,54$$

$$\text{PXi}_{W1\text{east}} = E_D + E_d = 559 + 188 = 747$$

$$CF_{W1east} = PXI * SHGC * IAC * FF_s = 747 * 0.54 * 1 * 0.31 = 125.1$$

$$CF_{fenestration1east} = U_{W1east} * (\Delta T_{cooling} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 6.9 + 125.1 = 132 \text{ W/m}^2$$

$$\dot{Q}_{W1east} = CF_{fenestration1east} * A_{W1east} = 132 * 14.4 = 1900.8 \text{ W}$$

## WINDOW 2

$$A_{W2west} = 14,4 \text{ m}^2$$

WEST

FIXED

WOOD FRAME

Heating:

$$U_{W2west} = 2,84 \text{ W/m}^2 \text{ K}$$

$$HF_{W2west} = U_{W2west} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44$$

$$Q_{W2west} = HF_{W2west} * A_{W2west} = 70.44 * 14.4 = 1014.2 \text{ W}$$

Cooling

Part for Heat transfer

$$CF_{W2west} = U_{W2west} * (\Delta T_{cooling} - 0.46 * DR) = 2,84 (7,9 - 0,46 \cdot 11,9) = 6,9 \text{ W/m}^2$$

$$E_D = 559$$

$$E_d = 188$$

West window of a detached house - FFS = 0.31

$$SHGC = 0.54$$

$$PXI_{W2west} = E_D + E_d = 559 + 188 = 747$$

$$CF_{W2west} = PXI * SHGC * IAC * FF_s = 747 * 0.54 * 1 * 0.56 = 225.9$$

$$CF_{\text{fenestration2west}} = U_{\text{w2west}} * (\Delta T_{\text{cooling}} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 6.9 + 225.9 = 232.8 \text{ W/m}^2$$

$$Q_{\text{w2west}} = CF_{\text{fenestration2west}} * A_{\text{W2west}} = 232.8 * 14.4 = 3352.32 \text{ W}$$

### WINDOW 3

$$A_{\text{W3south}} = 3.6 \text{ m}^2$$

SOUTH

FIXED

WOOD FRAME

Heating:

$$U_{\text{W3south}} = 2.84 \text{ W/m}^2 \text{ K}$$

$$HF_{\text{W3south}} = U_{\text{W3south}} * \Delta T_{\text{cooling}} = 2.84 * 24.8 = 70.44 \text{ W/m}^2$$

$$Q_{\text{W3south}} = HF_{\text{W3south}} * A_{\text{W3south}} = 70.44 * 3.6 = 253.6 \text{ W}$$

Cooling

Heat transfer part

$$CF_{\text{W3south}} = U_{\text{W3south}} * (\Delta T_{\text{cooling}} - 0.46 * DR) = 2.84 (7.9 - 0.46 * 11.9) = 6.9 \text{ W/m}^2$$

Part for Irradiation part

$$E_D = 348$$

$$E_d = 209$$

South window of a detached house - FFS = 0.31

$$SHGC = 0.54$$

$$PXI_{\text{W3south}} = E_D + E_d = 348 + 209 = 557$$

$$CF_{\text{W3south}} = PXI * SHGC * IAC * FF_s = 557 * 0.54 * 1 * 0.47 = 141.4$$

$$CF_{\text{fenestration3south}} = U_{W3\text{south}} * (\Delta T_{\text{cooling}} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 6.9 + 141.4 = 148.3 \text{ W/m}^2$$

$$\dot{Q}_{W3\text{south}} = CF_{\text{fenestration3south}} * A_{W3\text{south}} = 148.3 * 3.6 = 533.88 \text{ W}$$

## WINDOW 4

$$A_{W4\text{south}} = 3.6 \text{ m}^2$$

SOUTH  
OPERABLE  
WOOD FRAME

Heating:

$$U_{W4\text{south}} = 2.87 \text{ W/m}^2 \text{ K}$$

$$HF_{W4\text{south}} = U_{W4\text{south}} * \Delta T_{\text{cooling}} = 2.87 * 24.8 = 71.17 \text{ W/m}^2$$

$$Q_{W4\text{south}} = HF_{W4\text{south}} * A_{W4\text{south}} = 71.17 * 3.6 = 256.2 \text{ W}$$

## Cooling

Heat transfer part

$$CF_{W4\text{south}} = U_{W4\text{south}} * (\Delta T_{\text{cooling}} - 0.46 * DR) = 2.87 (7.9 - 0.46 * 11.9) = 6.96 \text{ W/m}^2$$

Part for Irradiation part

$$E_D = 348$$

$$E_d = 209$$

South window of a detached house - FFS = 0.47

$$SHGC = 0.46$$

$$PXI_{W4\text{south}} = E_D + E_d = 348 + 209 = 557$$

$$CF_{W4\text{south}} = PXI * SHGC * IAC * FF_s = 557 * 0.46 * 1 * 0.47 = 120.4$$

$$CF_{\text{fenestration4south}} = U_{w3\text{south}} * (\Delta T_{\text{cooling}} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 6.9 + 120.4 = 127.3 \text{ W/m}^2$$

$$\dot{Q}_{w4\text{south}} = CF_{\text{fenestration4south}} * A_{w4\text{south}} = 127.3 * 3.6 = 458.28 \text{ W}$$

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$$\dot{Q}_{\text{Total windows Cooling wood frame}} = 1900.8 + 3352.32 + 533.88 + 458.28 = 6245.3 \text{ W}$$

$$\dot{Q}_{\text{Total windows Heating wood frame}} = 1014.2 + 1014.2 + 253.6 + 256.2 = 2538.2 \text{ W}$$


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## Aluminium Frame Section

### Window 1

$$A_{w1\text{east}} = 14.4 \text{ m}^2$$

EAST

FIXED

Aluminium FRAME

Heating:

$$U_{w1\text{east}} = 3.61 \text{ W/m}^2 \text{ K}$$

$$HF_{w1\text{east}} = U_{w1\text{east}} * \Delta T_{\text{cooling}} = 3.61 * 24.8 = 89.52 \text{ W/m}^2$$

$$Q_{w1\text{east}} = HF_{w1\text{east}} * A_{w1\text{east}} = 89.52 * 14.4 = 1289.1 \text{ W}$$

### Cooling

Part for Heat transfer

$$CF_{w1\text{east}} = U_{w1\text{east}} * (\Delta T_{\text{cooling}} - 0.46 * DR) = 3.61 * (7.9 - 0.46 * 11.9) = 8.7 \text{ W/m}^2$$

Part for Irradiation part

$$E_D = 559$$

$$E_d = 188$$

East window of a detached house - FFS = 0.31

SHGC= 0.56

$$PXi_{W1east} = E_D + E_d = 559 + 188 = 747$$

$$CF_{W1east} = Pxi * SHGC * IAC * FF_s = 747 * 0.56 * 1 * 0.31 = 129.6$$

$$CF_{fenestration1east} = U_{w1east} * (\Delta T_{cooling} - 0.46 * DR) + Pxi * SHGC * IAC * FF_s = 8.7 + 129.6 = 138.3 \text{ W/m}^2$$

$$\dot{Q}_{w1east} = CF_{fenestration1east} * A_{W1east} = 138.3 * 14.4 = 1991.5 \text{ W}$$

## WINDOW 2

$$A_{W2west} = 14,4 \text{ m}^2$$

WEST

FIXED

Aluminium FRAME

Heating:

$$U_{W2west} = 3.61 \text{ W/m}^2 \text{ K}$$

$$HF_{W2west} = U_{W2west} * \Delta T_{cooling} = 3.61 * 24.8 = 70.44$$

$$Q_{W2west} = HF_{W2west} * A_{W2west} = 70.44 * 14.4 = 1014.3 \text{ W}$$

Cooling

Part for Heat transfer

$$CF_{W2west} = U_{W2west} * (\Delta T_{cooling} - 0.46 * DR) = 3.61 (7,9 - 0,46 * 11,9) = 8.7 \text{ W/m}^2$$

$$E_D = 559$$

$$E_d = 188$$

West window of a detached house - FFS = 0.56



$$\text{SHGC} = 0.56$$

$$\text{PXi}_{\text{W2west}} = E_D + E_d = 559 + 188 = 747$$

$$\text{CF}_{\text{W2west}} = \text{PXi} * \text{SHGC} * \text{IAC} * \text{FF}_s = 747 * 0.56 * 1 * 0.56 = 234.26$$

$$\text{CF}_{\text{fenestration2west}} = U_{\text{W2west}} * (\Delta T_{\text{cooling}} - 0.46 * \text{DR}) + \text{PXi} * \text{SHGC} * \text{IAC} * \text{FF}_s = 8.7 + 234.26 = 242.96 \text{ W/m}^2$$

$$\dot{Q}_{\text{W2west}} = \text{CF}_{\text{fenestration2west}} * A_{\text{W2west}} = 242.96 * 14.4 = 3498.6 \text{ W}$$

### WINDOW 3

$$A_{\text{W3south}} = 3.6 \text{ m}^2$$

SOUTH

FIXED

ALUMINIUM FRAME

Heating:

$$U_{\text{W3south}} = 3.61 \text{ W/m}^2 \text{ K}$$

$$\text{HF}_{\text{W3south}} = U_{\text{W3south}} * \Delta T_{\text{cooling}} = 3.61 * 24.8 = 89.52 \text{ W/m}^2$$

$$\dot{Q}_{\text{W3south}} = \text{HF}_{\text{W3south}} * A_{\text{W3south}} = 89.52 * 3.6 = 322.2 \text{ W}$$

Cooling

Heat transfer part

$$\text{CF}_{\text{W3south}} = U_{\text{W3south}} * (\Delta T_{\text{cooling}} - 0.46 * \text{DR}) = 3.61 (7.9 - 0.46 * 11.9) = 8.7 \text{ W/m}^2$$

Part for Irradiation part

$$E_D = 348$$

$$E_d = 209$$

South window of a detached house -  $\text{FFS} = 0.47$

$$\text{SHGC} = 0.56$$

$$\text{PXi}_{\text{W3south}} = E_D + E_d = 348 + 209 = 557$$

$$CF_{W3\text{south}} = PXI * SHGC * IAC * FF_s = 557 * 0.56 * 1 * 0.47 = 146.6$$

$$CF_{\text{fenestration3south}} = U_{W3\text{south}} * (\Delta T_{\text{cooling}} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 8.7 + 146.6 = 155.3 \text{ W/m}^2$$

$$Q'_{W3\text{south}} = CF_{\text{fenestration3south}} * A_{W3\text{south}} = 155.3 * 3.6 = 559.08 \text{ W}$$

## WINDOW 4

$$A_{W4\text{south}} = 3.6 \text{ m}^2$$

SOUTH  
OPERABLE  
ALUMINIUM FRAME

Heating:

$$U_{W4\text{south}} = 4.62 \text{ W/m}^2 \text{ K}$$

$$HF_{W4\text{south}} = U_{W4\text{south}} * \Delta T_{\text{cooling}} = 4.62 * 24.8 = 114.57 \text{ W/ m}^2$$

$$Q_{W4\text{south}} = HF_{W4\text{south}} * A_{W4\text{south}} = 114.57 * 3.6 = 412.4 \text{ W}$$

## Cooling

Heat transfer part

$$CF_{W4\text{south}} = U_{W4\text{south}} * (\Delta T_{\text{cooling}} - 0.46 * DR) = 4.62 (7.9 - 0.46 * 11.9) = 11.2 \text{ W/m}^2$$

Part for Irradiation part

$$E_D = 348$$

$$E_d = 209$$

South window of a detached house - FFS = 0.47

$$SHGC = 0.55$$

$$PXI_{W4\text{south}} = E_D + E_d = 348 + 209 = 557$$

$$CF_{W4south} = PXI * SHGC * IAC * FF_s = 557 * 0.55 * 1 * 0.47 = 143.95$$

$$CF_{fenestration4south} = U_{w3south} * (\Delta T_{cooling} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 11.2 + 143.98 = 155.18 \text{ W/m}^2$$

$$Q'_{w4south} = CF_{fenestration4south} * A_{W4south} = 155.18 * 3.6 = 558.65 \text{ W}$$

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$$Q'_{\text{Total windows Cooling Aluminium frame}} = 1991.5 + 3498.6 + 559.08 + 558.65 = 6607.8 \text{ W}$$

$$Q'_{\text{Total windows Heating Aluminium frame}} = 1289.1 + 1289.1 + 322.2 + 412.4 = 3312.8 \text{ W}$$


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## Conclusion

$$Q'_{\text{Total windows Cooling Aluminium frame}} (6607 \text{ W}) > Q'_{\text{Total windows Cooling wood frame}} (6245.3 \text{ W})$$

$$Q'_{\text{Total windows Heating Aluminium frame}} (3312.8 \text{ W}) > Q'_{\text{Total windows Heating wood frame}} (2538.2 \text{ W})$$

Based on the results **wood** is a better material to use for the frames than **aluminium** since it has better resistance in cooling and heating aspects