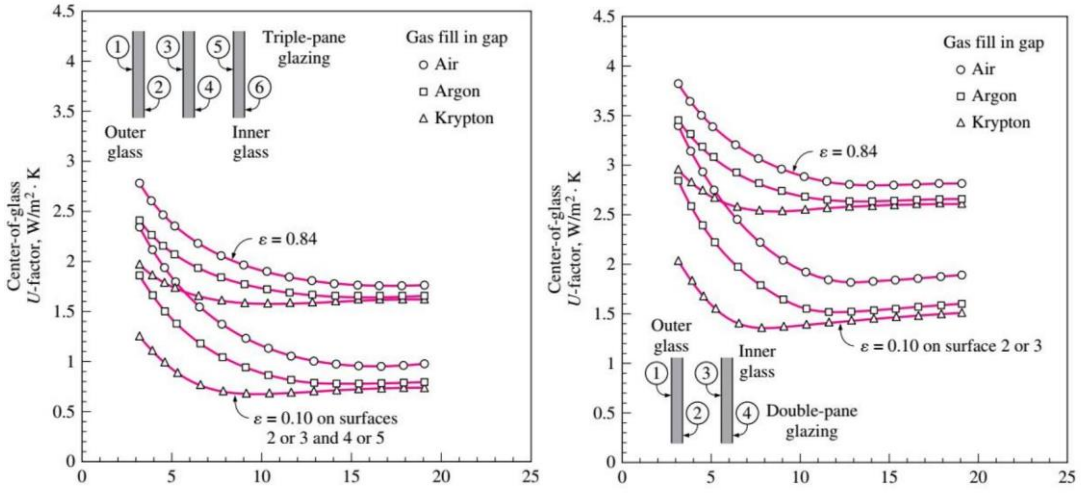
Week8 YU YUE

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 thickness to be 13 mm)

Benchmark:
with Double pane glazing (ε=0.84) and gap thickness is 13mm filled with air
U value=2.8W/㎡ K



Refer to the diagram:

	benchmark	1	2	3
ε	0.84	0.84	0.10	0.84
Pane number	2	2	2	3
Gas	air	krypton	air	air
U-value （W/㎡ K)	2.8	2.6	1.8	1.8
Change （%)	100	93	64	64

2. Consider the house that we analyzed 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 aluminum?

PIACENZA, Italy WMO#: **160840**

Lat: **44.92N** Long: **9.73E** Elev: **138** StdP: **99.68** Time Zone: **1.00 (EUW)** Period: **89-10** WBAN: **99999**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
	99.6%	99%	99.6%			99%			0.4%		1%			
			DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
1	-6.2	-4.8	-11.6	1.4	3.1	-8.8	1.8	1.8	8.8	5.6	7.7	6.2	2.1	250

(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
8	11.9	33.1	22.7	31.9	22.4	30.3	21.8	24.6	30.2	23.7	29.2	22.9	28.3	2.4	90

(2)

T SUMMER : 24℃ T WINTER : 20℃

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

$\Delta T_{cooling} = 20 - (-4.8) = 24.8℃$

WOOD FRAME:

1Fixed window on East side:

A=14.4 m²

Cooling Load:

Heat transfer part

$CF_{window1_{east-heat}} = U_{window1_{east}}(\Delta T_{cooling} - 0.46 * DR)$

$= 2.84 * (7.9 - 0.46 * 11.9) = 6.9$ W/m²

Irradiation part

$E_D = 559$

$E_d = 188$

East window of a detached house -FF_s = 0.31

$SHGC$ = 0,54

$PXI_{window1_{east}} = E_D + E_d = 559 + 188 = 747$

$CF_{window1_{east-irr}} = PXI * SHGC * IAC * FF_s = 747 * 0.54 * 1 * 0{,}31 = 125.1$

$CF_{fenestration1_{east}} = CF_{window1_{east-heat}} + CF_{window1_{east-irr}} = 6.9 + 125.1 = 132$ W/m²

$\dot{Q}_{window1_{east}} = CF_{fenestration1_{east}} * A_{window1_{east}} = 132 * 14.4 = 1900.8W$

Heating Load:

$U_{window1_{east}} = 2.84\text{W/㎡ K}$

$HF_{window1_{east}} = U_{window1_{east}} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\text{W/㎡}$

$Q_{window1_{east}} = HF_{window1_{east}} * A_{window1_{east}} = 132 * 14.4 = 1014.2W$

2Fixed window on West side:

A=14.4 ㎡

Cooling Load:

Heat transfer part

$CF_{window2_{west-heat}} = U_{window2_{west}}(\Delta T_{cooling} - 0.46 * DR)$

$= 2.84 * (7.9 - 0.46 * 11.9) = 6.9\ \text{W/㎡}$

Irradiation part

$E_D = 559$

$E_d = 188$

West window of a detached house -FF_s = 0.56

$SHGC$ = 0,54

$PXI_{window2_{west}} = E_D + E_d = 559 + 188 = 747$

$CF_{window2_{west-irr}} = PXI * SHGC * IAC * FF_s = 747 * 0.54 * 1 * 0.56 = 225.9$

$CF_{fenestration2_{west}} = CF_{window2_{west-heat}} + CF_{window2_{west-irr}} = 6.9 + 225.9 = 232.8\text{W/㎡}$

$\dot{Q}_{window2_{west}} = CF_{fenestration2_{west}} * A_{window2_{west}} = 232.8 * 14.4 = 3352.32W$

Heating Load:

$U_{window2_{west}} = 2.84\text{W/㎡ K}$

$HF_{window2_{west}} = U_{window2_{west}} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\text{W/㎡}$

$Q_{window2_{west}} = HF_{window2_{west}} * A_{window2_{west}} = 89.52 * 14.4 = 1014.2W$

3Fixed window on south side:

A=3.6 ㎡

Cooling Load:

Heat transfer part

$CF_{window3_{south-heat}} = U_{window3_{south}}(\Delta T_{cooling} - 0.46 * DR)$

$= 2.84 * (7.9 - 0.46 * 11.9) = 6.9\ \text{W/㎡}$

Irradiation part

$E_D = 348$
$E_d = 209$
south window of a detached house -FF_s = 0.47
$SHGC$ = 0,54
$PXI_{window3_{south}} = E_D + E_d = 348 + 209 = 557$
$CF_{window3_{south-irr}} = PXI * SHGC * IAC * FF_s = 557 * 0.54 * 1 * 0.47 = 141.4$

$CF_{fenestration3_{south}} = CF_{window3_{south-heat}} + CF_{window3_{south-irr}} = 6.9 + 141.4 = 148.3\ \mathrm{W/㎡}$

$\dot{Q}_{window3_{south}} = CF_{fenestration3_{south}} * A_{window3_{south}} = 148.3 * 3.6 = 533.88W$

Heating Load:

$U_{window3_{south}} = 2.84\mathrm{W/㎡\ K}$

$HF_{window3_{south}} = U_{window3_{south}} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\mathrm{W/㎡}$

$Q_{window3_{south}} = HF_{window3_{south}} * A_{window3_{south}} = 70.44 * 3.6 = 253.6W$

4 Operable window on south side:
A=3.6 ㎡

Cooling Load:
Heat transfer part
$CF_{window4_{south-heat}} = U_{window4_{south}}\left(\Delta T_{cooling} - 0.46 * DR\right)$

$= 2.87 * (7.9 - 0.46 * 11.9) = 6.96\ \mathrm{W/㎡}$

Irradiation part
$E_D = 348$
$E_d = 209$
south window of a detached house -FF_s = 0.47
$SHGC$ = 0.46
$PXI_{window4_{south}} = E_D + E_d = 348 + 209 = 557$
$CF_{window4_{south-irr}} = PXI * SHGC * IAC * FF_s = 557 * 0.46 * 1 * 0.47 = 120.4$

$CF_{fenestration4_{south}} = CF_{window4_{south-heat}} + CF_{window4_{south-irr}} = 6.9 + 120.4 = 127.3\mathrm{W/㎡}$

$\dot{Q}_{window4_{south}} = CF_{fenestration4_{south}} * A_{window4_{south}} = 127.3 * 3.6 = 458.28W$

Heating Load:

$U_{window4_{south}} = 2.87\mathrm{W/㎡\ K}$

$HF_{window4_{south}} = U_{window4_{south}} * \Delta T_{cooling} = 2.87 * 24.8 = 71.17\mathrm{W/㎡}$

$Q_{window4_{south}} = HF_{window4_{south}} * A_{window4_{south}} = 71.17 * 3.6 = 256.2W$

$$\dot{Q}_{total\_windows\_cooling\_woodframe} = \dot{Q}_{window1_{east}} + \dot{Q}_{window2_{west}} + \dot{Q}_{window3_{south}} + \dot{Q}_{window4_{south}} = 1900.8 + 3352.32 + 533.8 + 458.28 = 6245.3W$$

$$Q_{total\_windows\_heating\_woodframe} = Q_{window1_{east}} + Q_{window2_{west}} + Q_{window3_{south}} + Q_{window4_{south}} = 1014.2 + 1014.2 + 253.6 + 256.2 = 2538.2W$$

ALUMINIUM FRAME:

1Fixed window on East side:

A=14.4 ㎡

Cooling Load:

Heat transfer part

$$CF_{window1_{east-heat}} = U_{window1_{east}}(\Delta T_{cooling} - 0.46 * DR)$$

$$= 3.61 * (7.9 - 0.46 * 11.9) = 8.7\text{W/㎡}$$

Irradiation part

$E_D = 559$

$E_d = 188$

East window of a detached house -FF_s = 0.31

$SHGC$ = 0,56

$$PXI_{window1_{east}} = E_D + E_d = 559 + 188 = 747$$

$$CF_{window1_{east-irr}} = PXI * SHGC * IAC * FF_s = 747 * 0.56 * 1 * 0{,}31 = 129.6$$

$$CF_{fenestration1_{east}} = CF_{window1_{east-heat}} + CF_{window1_{east-irr}} = 8.7 + 129.6 = 138.3\text{W/㎡}$$

$$\dot{Q}_{window1_{east}} = CF_{fenestration1_{east}} * A_{window1_{east}} = 138.3 * 14.4 = 1991.5W$$

Heating Load:

$$U_{window1_{east}} = 3.61\text{W/㎡ K}$$

$$HF_{window1_{east}} = U_{window1_{east}} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52\text{W/㎡}$$

$$Q_{window1_{east}} = HF_{window1_{east}} * A_{window1_{east}} = 132 * 14.4 = 1289.1W$$

2Fixed window on West side:

A=14.4 ㎡

Cooling Load:

Heat transfer part

$$CF_{window2_{west-heat}} = U_{window2_{west}}(\Delta T_{cooling} - 0.46 * DR)$$

$$= 3.61 * (7.9 - 0.46 * 11.9) = 8.7\ \text{W/㎡}$$

Irradiation part

$E_D = 559$

$E_d = 188$
West window of a detached house -FF_s = 0.56
$SHGC$ = 0,56
$PXI_{window2_{west}} = E_D + E_d = 559 + 188 = 747$
$CF_{window2_{west-irr}} = PXI * SHGC * IAC * FF_s = 747 * 0.56 * 1 * 0.56 = 234.26$

$CF_{fenestration2_{west}} = CF_{window2_{west-heat}} + CF_{window2_{west-irr}} = 8.7 + 234.26 = 242.96\text{W/㎡}$

$\dot{Q}_{window2_{west}} = CF_{fenestration2_{west}} * A_{window2_{west}} = 242.96 * 14.4 = 3498.6W$

Heating Load:

$U_{window2_{west}} = 3.61\text{W/㎡ K}$

$HF_{window2_{west}} = U_{window2_{west}} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52\text{W/㎡}$

$Q_{window2_{west}} = HF_{window2_{west}} * A_{window2_{west}} = 89.52 * 14.4 = 1289.1W$

3Fixed window on south side:
A=3.6 ㎡

Cooling Load:
Heat transfer part
$CF_{window3_{south-heat}} = U_{window3_{south}}(\Delta T_{cooling} - 0.46 * DR)$

$= 3.61 * (7.9 - 0.46 * 11.9) = 8.7\text{W/㎡}$

Irradiation part
$E_D = 348$
$E_d = 209$
south window of a detached house -FF_s = 0.47
$SHGC$ = 0,56
$PXI_{window3_{south}} = E_D + E_d = 348 + 209 = 557$
$CF_{window3_{south-irr}} = PXI * SHGC * IAC * FF_s = 557 * 0.56 * 1 * 0.47 = 146.6$

$CF_{fenestration3_{south}} = CF_{window3_{south-heat}} + CF_{window3_{south-irr}} = 8.7 + 146.6 = 155.3\text{ W/㎡}$

$\dot{Q}_{window3_{south}} = CF_{fenestration3_{south}} * A_{window3_{south}} = 155.3 * 3.6 = 559.08W$

Heating Load:

$U_{window3_{south}} = 3.61\text{W/㎡ K}$

$HF_{window3_{south}} = U_{window3_{south}} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52\text{W/㎡}$

$Q_{window3_{south}} = HF_{window3_{south}} * A_{window3_{south}} = 89.52 * 3.6 = 322.2W$

4 Operable window on south side:
A=3.6 ㎡

Cooling Load:

Heat transfer part

$CF_{window4_{south-heat}} = U_{window4_{south}}(\Delta T_{cooling} - 0.46 * DR)$

$= 4.62 * (7.9 - 0.46 * 11.9) = 11.2\ \mathrm{W/㎡}$

Irradiation part

$E_D = 348$

$E_d = 209$

south window of a detached house -FF_s = 0.47

$SHGC$ =0.55

$PXI_{window4_{south}} = E_D + E_d = 348 + 209 = 557$

$CF_{window4_{south-irr}} = PXI * SHGC * IAC * FF_s = 557 * 0.55 * 1 * 0.47 = 143.98$

$CF_{fenestration4_{south}} = CF_{window4_{south-heat}} + CF_{window4_{south-irr}} = 11.2 + 143.98$

$= 155.18\mathrm{W/㎡}$

$\dot{Q}_{window4_{south}} = CF_{fenestration4_{south}} * A_{window4_{south}} = 155.18 * 3.6 = 558.65W$

Heating Load:

$U_{window4_{south}} = 4.62\mathrm{W/㎡\ K}$

$HF_{window4_{south}} = U_{window4_{south}} * \Delta T_{cooling} = 4.62 * 24.8 = 114.57\mathrm{W/㎡}$

$Q_{window4_{south}} = HF_{window4_{south}} * A_{window4_{south}} = 114.57 * 3.6 = 412.4W$

$\dot{Q}_{total\_windows\_cooling\_aluminiumframe}$

$= \dot{Q}_{window1_{east}} + \dot{Q}_{window2_{west}} + \dot{Q}_{window3_{south}} + \dot{Q}_{window4_{south}}$

$= 1991.5 + 3498.6 + 559.08 + 558.65 = 6607.8W$

$Q_{total\_windows\_heating\_aluminiumframe}$

$= Q_{window1_{east}} + Q_{window2_{west}} + Q_{window3_{south}} + Q_{window4_{south}}$

$= 1289.1 + 1289.1 + 322.2 + 412.4 = 3312.8W$

Change:

$\Delta\dot{Q}_{total\_windows\_cooling}$

$= \dot{Q}_{total\_windows\_cooling\_aluminiumframe} - \dot{Q}_{total\_windows\_cooling\_woodframe}$

$= 6607.8 - 6245.3 = 362.5W$

$Q_{total\_windows\_heating}$

$= Q_{total\_windows\_heating\_aluminiumframe} - Q_{total\_windows\_heating\_woodframe}$

$= 3312.8 - 2538.2 = 774.6W$