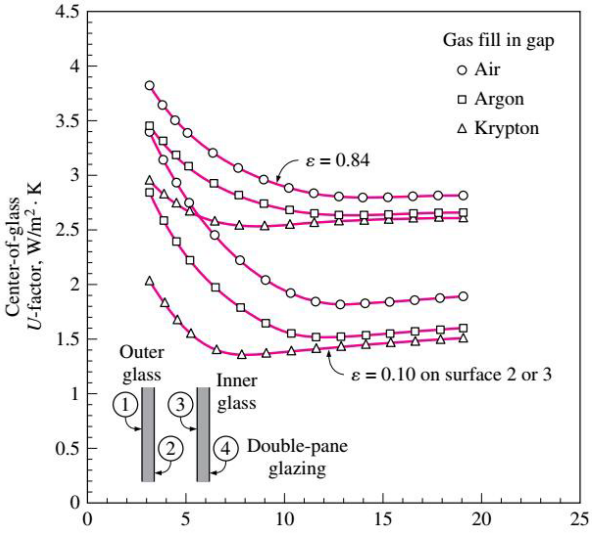
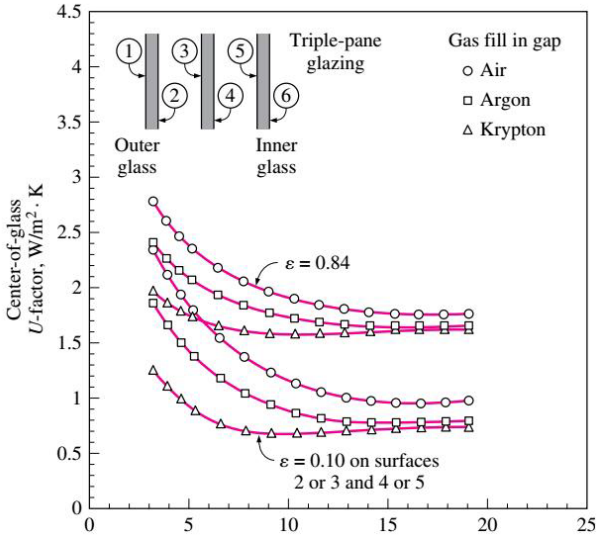
1) Considering these diagrams, it is possible to know how much impact have each design choices over the U-factor (heat passage for unit area).





If we consider a double pane window with a 13mm air layer in between, the U factor (centre of the glass) is around 2.8 W/m^2 K. By f.i. filling the mid-layer with argon instead of air, U reaches a value of around 2,6 W/m^2 K, which means decreasing U of 7%. A definitely larger impact occurs if one of the glasses is coated in order to reduce the emissivity, so the new U is around 1,82 W/m2 K. (reduced of 55%). By adding a third pane of glass, with another air layer of 13mm, U will be reduced to ≈ 1,75 W/m^2 K. So the decrease is 60%. Although being very beneficial, having a 3 glazing window instead of 2 glazing might imply much higher costs.

	Glass section (glazing) only			*Aluminum frame (without thermal break)*			*Wood or vinyl frame*					
Type	Center-of-glass		Edge-of-glass	Fixed	Double door	Sloped skylight	Fixed		Double door		Sloped skylight	
Frame width →	(Not applicable)			32 mm (1¼ in)	53 mm (2 in)	19 mm (¾ in)	41 mm (1⅝ in)		88 mm (3 7/16 in)		23 mm (⅞ in)	
Spacer type →	—	Metal	Insul.	All	All	All	Metal	Insul.	Metal	Insul.	Metal	Insul.
Glazing Type												
Single Glazing												
3 mm (⅛ in) glass	6.30	6.30	—	6.63	7.16	9.88	5.93	—	5.57	—	7.57	—
6.4 mm (¼ in) acrylic	5.28	5.28	—	5.69	6.27	8.86	5.02	—	4.77	—	6.57	—
3 mm (⅛ in) acrylic	5.79	5.79	—	6.16	6.71	9.94	5.48	—	5.17	—	7.63	—
Double Glazing (no coating)												
6.4 mm air space	3.24	3.71	3.34	3.90	4.55	6.70	3.26	3.16	3.20	3.09	4.37	4.22
12.7 mm air space	2.78	3.40	2.91	3.51	4.18	6.65	2.88	2.76	2.86	2.74	4.32	4.17
6.4 mm argon space	2.95	3.52	3.07	3.66	4.32	6.47	3.03	2.91	2.98	2.87	4.14	3.97
12.7 mm argon space	2.61	3.28	2.76	3.36	4.04	6.47	2.74	2.61	2.73	2.60	4.14	3.97
Double Glazing [ε = 0.1, coating on one of the surfaces of air space (surface 2 or 3, counting from the outside toward inside)]												
6.4 mm air space	2.44	3.16	2.60	3.21	3.89	6.04	2.59	2.46	2.60	2.47	3.73	3.53
12.7 mm air space	1.82	2.71	2.06	2.67	3.37	6.04	2.06	1.92	2.13	1.99	3.73	3.53
6.4 mm argon space	1.99	2.83	2.21	2.82	3.52	5.62	2.21	2.07	2.26	2.12	3.32	3.09
12.7 mm argon space	1.53	2.49	1.83	2.42	3.14	5.71	1.82	1.67	1.91	1.78	3.41	3.19
Triple Glazing (no coating)												
6.4 mm air space	2.16	2.96	2.35	2.97	3.66	5.81	2.34	2.18	2.36	2.21	3.48	3.24
12.7 mm air space	1.76	2.67	2.02	2.62	3.33	5.67	2.01	1.84	2.07	1.91	3.34	3.09
6.4 mm argon space	1.93	2.79	2.16	2.77	3.47	5.57	2.15	1.99	2.19	2.04	3.25	3.00
12.7 mm argon space	1.65	2.58	1.92	2.52	3.23	5.53	1.91	1.74	1.98	1.82	3.20	2.95
Triple Glazing [ε = 0.1, coating on one of the surfaces of air spaces (surfaces 3 and 5, counting from the outside toward inside)]												
6.4 mm air space	1.53	2.49	1.83	2.42	3.14	5.24	1.81	1.64	1.89	1.73	2.92	2.66
12.7 mm air space	0.97	2.05	1.38	1.92	2.66	5.10	1.33	1.15	1.46	1.30	2.78	2.52
6.4 mm argon space	1.19	2.23	1.56	2.12	2.85	4.90	1.52	1.35	1.64	1.47	2.59	2.33
12.7 mm argon space	0.80	1.92	1.25	1.77	2.51	4.86	1.18	1.01	1.33	1.17	2.55	2.28

Also the choice of the frame material affects the final result. Let's consider a double pane window as before with a fixed aluminum frame, The total U factor is going to be around 3,5 W/m^2 K. If we change the material in wood or vinyl, then we have U ≈ 2,9 W/m^2 K, that means a decrease of 21%.

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, 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% DP	99.6% HR	99.6% MCDB	99% DP	99% HR	99% MCDB	0.4% WS	0.4% MCDB	1% WS	1% 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 0.4% DB	0.4% MCWB	1% DB	1% MCWB	2% DB	2% MCWB	Evaporation WB/MCDB 0.4% WB	0.4% MCDB	1% WB	1% MCDB	2% WB	2% MCDB	MCWS/PCWD to 0.4% DB 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)

ΔTcooling = 31.9 – 24 = 7.9 °C

ΔTheating = 20 − (−4.8) = 24.8 °C

DR = 11.9 °C

Table 13 Fenestration Solar Load Factors FF_s

Exposure	Single Family Detached	Multifamily
North	0.44	0.27
Northeast	0.21	0.43
East	0.31	0.56
Southeast	0.37	0.54
South	0.47	0.53
Southwest	0.58	0.61
West	0.56	0.65
Northwest	0.46	0.57
Horizontal	0.58	0.73

Table 10 Peak Irradiance, W/m²

Exposure		Latitude 20°	25°	30°	35°	40°	45°	50°	55°	60°
North	E_D	125	106	92	84	81	85	96	112	136
	E_d	128	115	103	93	84	76	69	62	55
	E_t	253	221	195	177	166	162	164	174	191
Northeast/Northwest	E_D	460	449	437	425	412	399	386	374	361
	E_d	177	169	162	156	151	147	143	140	137
	E_t	637	618	599	581	563	546	529	513	498
East/West	E_D	530	543	552	558	560	559	555	547	537
	E_d	200	196	193	190	189	188	187	187	187
	E_t	730	739	745	748	749	747	742	734	724
Southeast/Southwest	E_D	282	328	369	405	436	463	485	503	517
	E_d	204	203	203	204	205	207	210	212	215
	E_t	485	531	572	609	641	670	695	715	732
South	E_D	0	60	139	214	283	348	408	464	515
	E_d	166	193	196	200	204	209	214	219	225
	E_t	166	253	335	414	487	557	622	683	740
Horizontal	E_D	845	840	827	806	776	738	691	637	574
	E_d	170	170	170	170	170	170	170	170	170
	E_t	1015	1010	997	976	946	908	861	807	744

EAST WINDOW (frame fixed)

$U_{window\ east}$ = 2.84 W/m2K heat-absorbing double-layer glass (fixed with a wooden frame)

$HF_{window\ east} = U_{window\ east} * \Delta T_{heating} = 2.84 * 24.8 = 70.44$ W/m2

$Q_{window\ east} = HF_{window\ east} * A_{window\ east} = 70.4 * 14.4 =$ **1014.2 W**

$$CF_{fen} = U(\Delta t - 0.46\,DR) + PXI \times SHGC \times IAC \times FF_s$$

CF window east = 2.84 * (7.9 – 0.46 * 11.9) + (559 + 188) * 0.54 * 1 * 0.31 = 132 W/m2
Q window east = CF window east * A window east = 132 * 14.4 = **1900.8 W**

WEST WINDOW (frame fixed)
$U_{window\ west}$ = 2.84 W/m2K heat-absorbing double-layer glass (fixed with a wooden frame)
$HF_{window\ west} = U_{window\ west} * \Delta T_{heating}$ = 2.84 * 24.8 = 70.44 W/m2
$Q_{window\ west} = HF_{window\ west} * A_{window\ west}$ = 70.4 * 14.4 = 1014.2 W

IAC = 1
$CF_{window\ west}$ = 2.84 * (7.9 – 0.46 * 11.9) + (559 + 188) * 0.54 * 1 * 0.56 = 232.78 W/m2
$Q_{window\ west} = CF_{window\ west} * A_{window\ west}$ = 232.78 * 14.4 = **3352.032 W**

SOUTH WINDOW (frame fixed)
$U_{window\ south}$ = 2.84 W/m2K heat-absorbing double-layer glass (fixed with a wooden frame)
$HF_{window\ south} = U_{window\ south} * \Delta T_{heating}$ = 2.84 * 24.8 = 70.44 W/m2
$Q_{window\ south} = HF_{window\ south} * A_{window\ south}$ = 70.4 * 3.6 = 253.44 W

IAC = 1
$CF_{window\ south}$ = 2.84 * (7.9 – 0.46 * 11.9) + (348 + 209) * 0.54 * 1 * 0.47 = 148.26 W/m2
$Q_{window\ south} = CF_{window\ south} * A_{window\ south}$ = 148.26 * 3.6 = **533.74 W**

SOUTH WINDOW (frame operable)
$U_{window\ south}$ = 2.87 W/m2K heat-absorbing double-layer glass (operable with a wooden frame)
$HF_{window\ south} = U_{window\ south} * \Delta T_{heating}$ = 2.87 * 24.8 = 71.18 W/m2
$Q_{window\ south} = HF_{window\ south} * A_{window\ south}$ = 71.18 * 3.6 = 256.23 W

IAC = 1
$CF_{window\ south}$ = 2.87 * (7.9 – 0.46 * 11.9) + (348 + 209) * 0.46 * 1 * 0.47 = 127.39 W/m2
$Q_{window\ south} = CF_{window\ south} * A_{window\ south}$ = 127.39 * 3.6 = **458.60 W**

ALUMINUM FRAME:

EAST WINDOW (frame fixed)
$U_{window\ east}$ = 3.61 W/m2K heat-absorbing double-layer glass (fixed with aluminum frame) (before 2.84)
$HF_{window\ east} = U_{window\ east} * \Delta T_{heating}$ = 3.61 * 24.8 = 89.53 W/m2 (before 70.4)
$Q_{window\ east} = HF_{window\ east} * A_{window\ east}$ = 89.53 * 14.4 = 1289.20 W (before 1014.2)

$CF_{window\ east}$ = 3.61 * (7.9 – 0.46 * 11.9) + (559 + 188) * 0.56 * 1 * 0.31 = 138.43 W/m2 (before 132)
$Q_{window\ east} = CF_{window\ east} * A_{window\ east}$ = 138.43 * 14.4 = 1993.39 W (before 1900.8)

WEST WINDOW (frame fixed)
$U_{window\ west}$ = 3.61 W/m2K heat-absorbing double-layer glass (fixed with aluminum frame) (before 2.84)
$HF_{window\ west} = U_{window\ west} * \Delta T_{heating}$ = 3.61 * 24.8 = 89.53 W/m2 (before 70.44)
$Q_{window\ west} = HF_{window\ west} * A_{window\ west}$ = 89.53 * 14.4 = 1289.20 W (before 1014.2)

$CF_{window\ west}$ = 3.61 * (7.9 – 0.46 * 11.9) + (559 + 188) * 0.56 * 1 * 0.56 = 243.02 W/m2 (before 232.78)

$Q_{window\ west} = CF_{window\ west} * A_{window\ west} = 243.02 * 14.4 = 3499.49$ W (before 3352.032)

SOUTH WINDOW (frame fixed 3.6 m_2)
$U_{window\ south} = 3.61$ W/m_2K heat-absorbing double-layer glass (fixed with aluminum frame) (before 2.84)
$HF_{window\ south} = U_{window\ south} * \Delta T_{heating} = 3.61 * 24.8 = 89.53$ W/m_2 (before 70.44)
$Q_{window\ south} = HF_{window\ south} * A_{window\ south} = 89.53 * 3.6 = 322.31$ W (before 253.44)

$CF_{window\ south} = 3.61 * (7.9 – 0.46 * 11.9) + (348 + 209) * 0.56 * 1 * 0.47 = 155.36$ W/m_2 (before 148.26)
$Q_{window\ south} = CF_{window\ south} * A_{window\ south} = 155.36 * 3.6 = 559.30$ W (before 533.74)

SOUTH WINDOW (frame operable 3.6 m_2)
$U_{window\ south} = 4.62$ W/m_2K heat-absorbing double-layer glass (operable with aluminum frame) (before 2.87)
$HF_{window\ south} = U_{window\ south} * \Delta T_{heating} = 4.62 * 24.8 = 114.58$ W/m_2 (before 71.18)
$Q_{window\ south} = HF_{window\ south} * A_{window\ south} = 114.58 * 3.6 = 412.47$ W (before 256.23)

$CF_{window\ south} = 4.62 * (7.9 – 0.46 * 11.9) + (348 + 209) * 0.55 * 1 * 0.47 = 155.19$ W/m_2 (before 127.39)
$Q_{window\ south} = CF_{window\ south} * A_{window\ south} = 155.19 * 3.6 = 558.68$ W (before 458.60)