ENERGY BALANCE OF WINDOWS, SOLAR GAINS AND LOSSES IN PASSIVE HOUSE


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Summary

Design window is becoming very important part of the house project, especially of houses with low usage of energy. Designing these windows must be done with respect to not only their thermal-insulating properties, but also to their solar transmission coefficient. On this parameter depends, how much the sun can heat the house. With counting and optimizing of coefficient of thermal transmission and coefficient of transmission solar radiation we could get very good energy balance of the windows and whole house.

Keywords: Energy balance, glazing, passive house

1 Introduction

Mostly in houses with low usage of energy, it is very important to design windows well, because solar gains could balance large part of overall energetic losses. In present there are lots of kinds of insulating glazing that are characterized by different solar and insulation properties. As a most important property we could state its thermal insulation – coefficient of thermal transmission. The other important property is transmission of thermal solar radiation. Combination of these properties effects overall energy balance of windows during the wintertime. Its regular designing including well shading, we could maximize solar gains in wintertime, on the other side protect inner rooms against not accepted solar energy in summer.

2 Theoretic part

2.1 Types of glazing

In present, there is large availability of many types of glazing. In following part of article, there are described some of the most using types of glazing units in standard houses and in low-energy houses.

2.1.1 Older insulating glazing

These insulating glazing are made from two glazing panes (double glazing unit), its distance is settled by differently wide spacer profiles. Hollow between the glazing is filled only by air. That establish coefficient of thermal transmission somewhere between $U_g = 2.5$ to 3.0 $Wm^{-2}.K^{-1}$. These values of coefficient of thermal transmission became insufficient, that went to continuous improve of thermal-insulating properties.

2.1.2 Present insulating glazing

In present, there are making insulating glazing, that are characterized by coefficient of thermal transmission $U_g < 1.15$ $Wm^{-2}.K^{-1}$. This relatively low value of that coefficient is caused by filling hollow with special gas and by using glazing with low emissivity.

Transmission of heat could arise by four ways.

- convection from interspace
- radiation between opposite surfaces of glazing
- conveyance through gas-filling of interspace
- conveyance through spacer profiles

With expressive decreased emissivity ε **(-)**, we could rapidly reduce losses, caused by radiation between opposite surfaces of glazing. Low emissivity of glazing is reached, because very thin layer from silver and metal oxides, coated on the surface of glazing. That caused that surface of the glazing reflects back long-wave thermal radiation, so heat stays in the room. Because of their low emissivity (0.03) are these products called as “Low-E”. Thickness of the metallic coating is from 0.01 to 0.10 micrometer, which caused that nearly full reflection will be restricted to long-wave infrared radiation. For visible light is metalic coating mostly transparency. So the glazing are reaching very high value of visible light transmission τ **(-)**.

Another important factor, that decreased coefficient of thermal transmission of glazing, is type of the gas filled in interspace. In present are mostly used noble gasses – Argon, Krypton, Xenon, FS6.

Tab. 1 Some physical properties of glazing with various filling.

gas	λ_j **(Wm^{-2}K^{-1})**	U_g**(W/m^2.K) with thickness of interspace *d* (m)**		
		0,006	**0,012**	**0,018**
air	0,0258	3,3	2,93	2,8
xenon	0,0054	2,75	2,59	2,56
argon	0,0173	3,04	2,75	2,66
krypto n	0,0093	2,6	2,53	2,54

Next possibility how to decrease energetic losses of glazing is to integrate very thin foil into interspace of glazing.

2.1.3 Double glazing with foils

Glazing with this foil hold weight of regular double glazing unit, but this type of glazing reaches thermal-insulating properties of triple glazing unit. We can say that it is regular double glazing unit, where are in the middle integrated foils with low emisivity. Foil is transparent and both side coating has emisivity about 0.12 and glass sheets may not be coated. Effect of this foils could arise a unit with great insulating properties with coefficient of thermal transmission $U_g = 0.30$ to $0.70\ Wm^{-2}.K^{-1}$.

2.2 Determine energy balance of glazing:

Calculating method is shown in standard ČSN EN 14 438, is used for evaluation balance energetic losses and usable solar gains, that goes to the building through glazing during a period.

Value of energetic balance E for stated period determined by formula (1):

$$E = U_{\mathrm{g}} - \frac{\eta \cdot g \cdot f \cdot H_{\mathrm{p}}}{D_{\mathrm{p}}} \tag{1}$$

U_g coefficient of thermal transmission of glazing ($W.m^{-2}.K^{-1}$)
η coefficient of efficiency usage thermal gain
g overall transmission of thermal solar radiation (-)
f factor that effects upkeep and shadow-casting
H_p value of unscreened solar radiation that is impact on surface of vertical glazing (kWh/m^2)
D_p number of day-degree (K.24 hours)

For needs of calculation of energy balance of glazing, will be used own formulas based on exact state energetic losses and solar gains on differently oriented glazing, during stated months, days and hours.

For calculation of energy balance were used following formulas:

- Overall energetic lost through glazing, during stated period (heating period, month, day) Q_l in MJ

$$Q_l = \frac{U_w \cdot S_w \cdot \Delta t \cdot D}{1 \cdot 10^6} \tag{2}$$

U_w coefficient of thermal transmission ($W.m^{-2}.K^{-1}$)
S_w area of window including frame (m^2)
Δt difference between average temperatures of interior and exterior (K)
D length stated period (s)

- Thermal solar gains in Q_g in MJ:

$$Q_g = S_w \cdot k_r \cdot g \cdot Q_s \tag{3}$$

S_w area of the window (m^2)
k_r correcting coefficient of frame (-)
g solar factor – it characterize overall permeability of sun energy (-)
Q_s overall intensity of impacting sun radiation for stated period (MJ/a)

- Energy balance of windows in MJ, we can calculate by difference between energetic losses and usable solar gains.

$$Q_{bil} = Q_l - k \cdot Q_g \tag{4}$$

Q_{bill} energetic balance for stated period(MJ)
Q_g solar gains for stated period (MJ)
Q_l energetic loss for stated period (MJ)
k level of efficiency of solar gains(-)

- From energetic balance in (MJ) we can calculate back equivalent coefficient of thermal transmission of window.

$$U_{ekv} = \frac{Q_{bil} \cdot 1 \cdot 10^6}{S_w \cdot \Delta t \cdot D} \tag{5}$$

U_{ekv} equivalent coefficient of thermal transmission($W.m^{-2}.K^{-1}$)
Q_{bil} energy balance of window in stated period (MJ)
S_w area of the window (m^2)
Δt difference between average temperatures of interior and exterior (K)
D length stated period (s)

3 Calculating part

3.1 Calculation of coefficient of thermal transmission for various kinds of glazing

Opening terms:

- average interior calculating temperature t_i = 20 ˚C
- average exterior calculating temperature t_e = 3,1 ˚C
  (average temperature from TRY of period November-april)
- correcting coefficient of frame k_r = 0,8
- level of efficiency of solar gains k = 0,7

Tab. 2 Properties of measured windows:

Number of window	Type of the window	correcting coefficient of frame	Solar factor	Coefficient of thermal transmission of glazing	Coefficient of thermal transmission of window
		k_r	g	Ug	Uw
		-	-	$W.m^{-2}.K^{-1}$	$W.m^{-2}.K^{-1}$
1	Double glazing unit Float 4 mm-16Air-Float 4 mm	0,8	0,76	2,8	3,1
2	Double glazing unit with thin metal layer and hollow filled by argon	0,8	0,6	1,1	1,3
3	Triple glazing unit with thin metal layer and hollows filled by argon	0,8	0,48	0,82	0,85
4	Double glazing unit with thin metal layer and hollow filled by krypton	0,8	0,45	0,62	0,72
5	Double glazing unit with 2 thin metal layers and hollows filled by krypton	0,8	0,35	0,40	0,5

Tab. 3 Energetic balance of windows:

Number of window	Type of the window	Energetic losses (MJ/a)	Usable solar gains (MJ/a)	Unusable solar gains (MJ/a)	Energy balance	Equivalent coefficient of thermal transmission
		Q_l	Q_g	Q_g*(1-k)	Q_l-Q_g*k	U_{ekv}
		KWh.a^{-1}	KWh.a^{-1}	KWh.a^{-1}	KWh.a^{-1}	W.m^{-2}.K^{-1}
1	Double glazing unit Float 4 mm-16Air-Float 4 mm	2107,82	624,23	267,53	1483,59	2,06
2	Double glazing unit with thin metal layer and hollow filled by argon	828,07	492,81	211,21	335,26	0,46
3	Triple glazing unit with thin metal layer and hollows filled by argon	617,29	394,25	168,96	223,04	0,31
4	Double glazing unit with thin metal layer and hollow filled by krypton	466,73	369,61	158,41	97,12	0,13
5	Double glazing unit with 2 thin metal layers and hollows filled by krypton	301,12	295,69	126,73	5,43	0,01

Positive value of energy balance means window's overall loss, per contra gain for whole heating season.

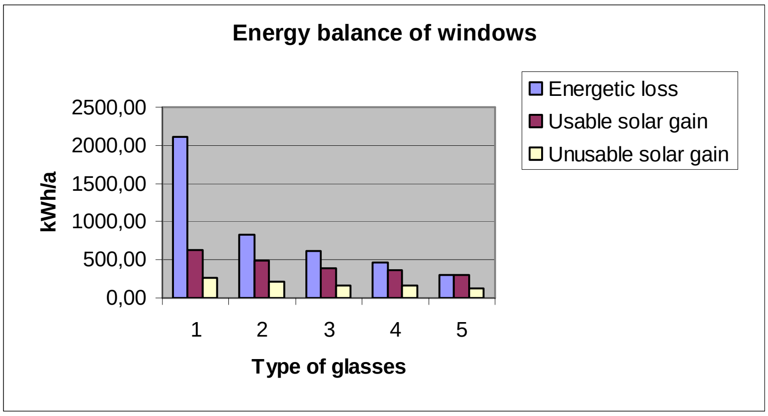

Fig. 1

On the **Fig. 1** we can see proportion between lost energy and energy from solar radiation. Energy from solar radiation is also divided to usable and unusable part, according to level of efficiency of solar gains.

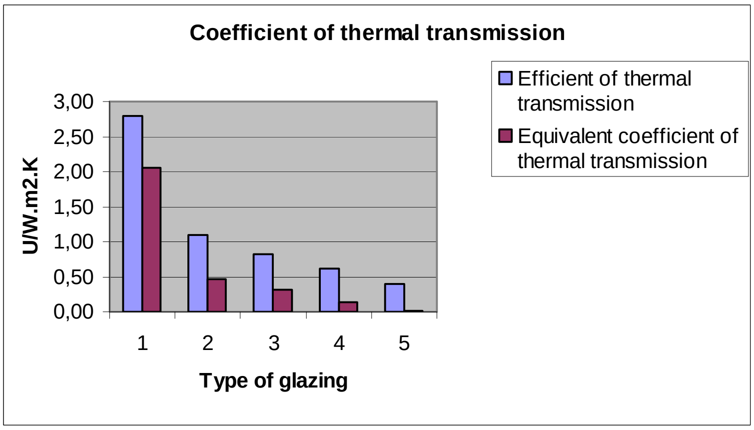

Fig. 2

Fig. 2 shows how can change coefficient of thermal transmission, if calculated also with average solar gains during winter season - for average from all orientation to world side. As we can see, the glazing number 5 (double-glazing unit with two HEAT MIRROR foils) has its equivalent coefficient of thermal transmission equal to 0 $Wm^{-2}.K^{-1}$.

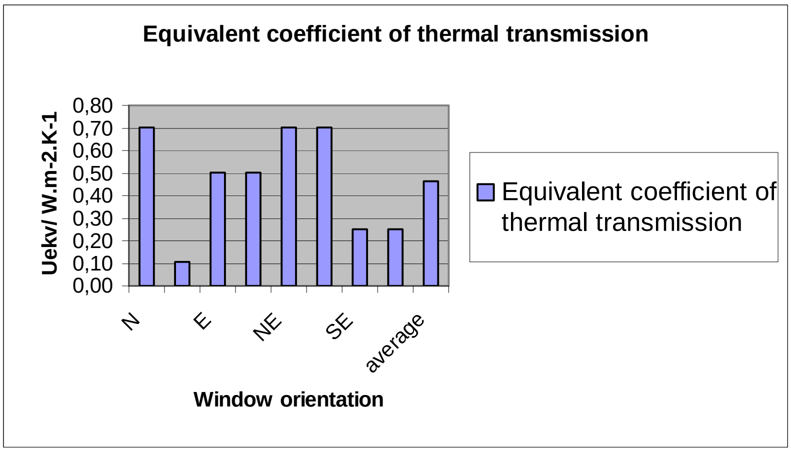

Fig. 3

Fig. 3 shows dependence of equivalent coefficient of thermal transmission glazing number 2 on the window orientation.

3.2 Windows in passive house

Correct design of windows, mean their sizes, types of glazing and orientation to the world sides, it is very important especially on passive houses, because overall energetic losses of whole house should be very small and comparable with overall solar gains during the winter season. Thanks to well done design of the windows, passive houses could be heating, just because of solar radiation also in spring, autumn and warmer parts of the winter.

Tab. 4 Comparison of passive and regular house

	Regular	**Passive**	
External wall	37.5	14.2	$W.K^{-1}$
Ceiling	19.7	12.0	$W.K^{-1}$
Windows	59.7	21.0	$W.K^{-1}$
Floor	32.8	20.6	$W.K^{-1}$
Thermal bridges	47.8	2.3	$W.K^{-1}$
Ventilation	57.0	10.5	$W.K^{-1}$
Overall energy loss	254.8	81.0	$W.K^{-1}$
Overall energy loss	23980.6	7623.3	kWh
Solar gains	4485.3	4247.7	kWh
Inner gains	4123.6	4123.6	kWh
Overall gains	8609.0	8371.4	kWh
level of efficiency of gains	0.9	0.7	-
Need of energy for heating	16232.5	1696.3	kWh
Specific need of heat e_v	40.5	5.0	$kWh.m^{-3}.a^{-1}$
Specific need of heat e_v	**111.4**	**13.8**	$kWh.m^{-2}.a^{-1}$

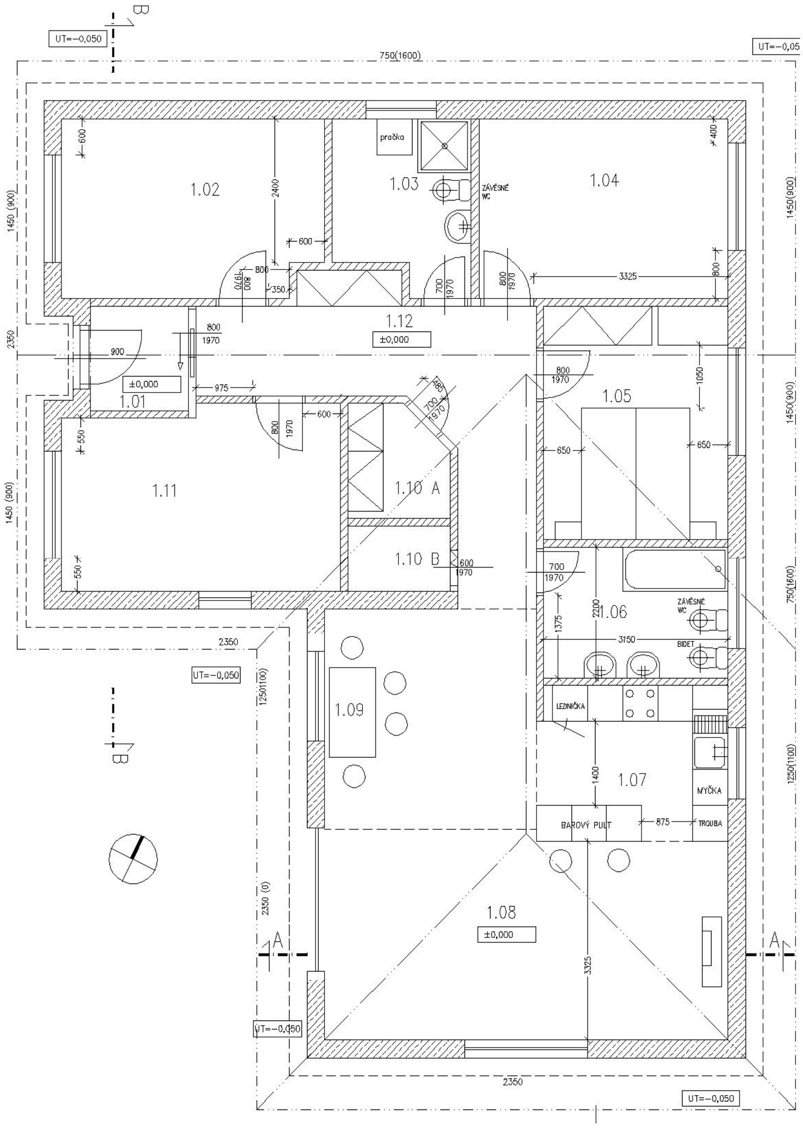

Fig. 4

Fig. 5 shows comparison of energy losses and gains of two houses with same sizes and typologies. Structures of external parts of house are different, according to needs for regular and passive houses.

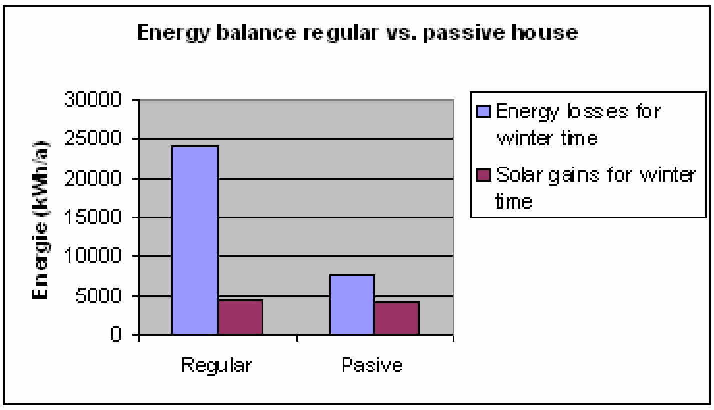

Fig. 5

Overall solar gains in the passive house stated more than 50 % of whole energy loss, that's why we have to design these windows very properly.

3.2.1 Energetic balance of passive house:

- Double-glazed unit with thin metal layer and hollow filled with argon

Tab. 5

	Specific energetic loss	Average exterior temperature	Overall energetic loss	Solar gain	Inner gain	Overall energetic balance
	(W/K)	(˚C)	kWh	kWh	kWh	kWh
January	99,49	-2,5	1665,52	374,16	439,20	-1096,17
February	99,49	-0,3	1357,25	598,40	439,20	-630,93
March	99,49	3,8	1199,18	726,77	439,20	-383,00
April	99,49	9	787,99	726,77	439,20	28,19
May	99,49	13,9	451,54	743,33	439,20	376,23
June	99,49	17	214,91	726,64	439,20	601,18
July	99,49	18,5	111,03	668,60	439,20	664,42
August	99,49	18,1	140,64	722,76	439,20	672,73
September	99,49	14,3	408,32	520,77	439,20	263,66
October	99,49	9,1	806,85	514,60	439,20	-139,19
November	99,49	3,5	1181,98	278,73	439,20	-679,44
December	99,49	-0,6	1524,88	182,13	439,20	-1089,95
			9850,11	6783,64		1412,28

Negative values of energy balance state energy loss of the house. On the following graph we can see behavior of energy balance during whole year. If we count up inner and solar gains and product take from energy loss, we will get energy balance of the house.

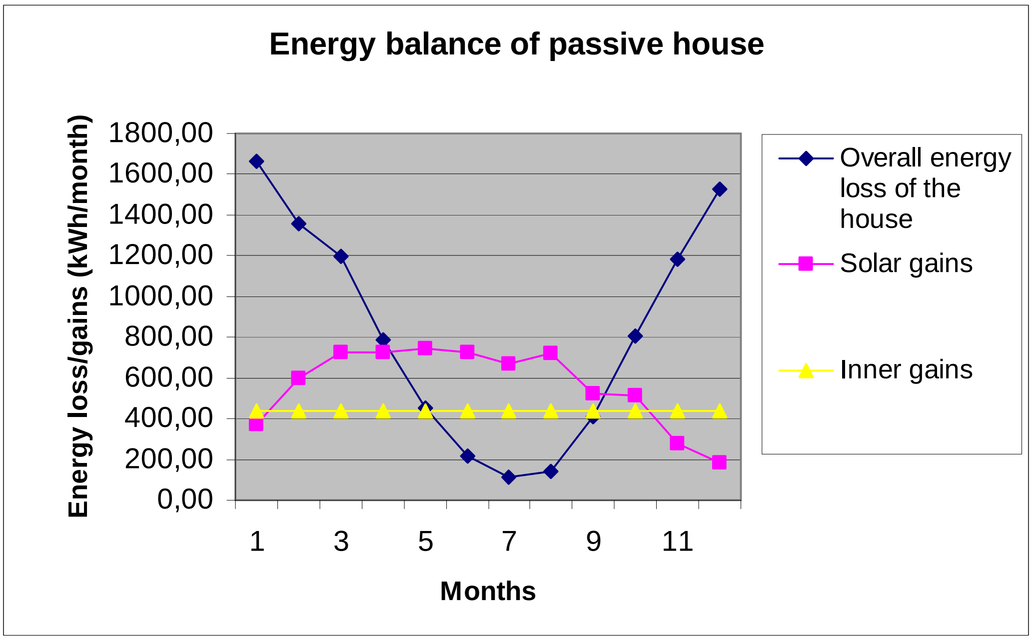

Fig. 6

4 Conclusions

Present modern insulating glazing are specified by great properties, because of them these windows are becoming savers of energy, in contrast with past, when the windows were something like energetic holes in the house. We have got still in our minds that it is still true, that windows have worse thermal insulating properties, but we should not forget on their solar properties and gains that the windows are transmitting to our homes. These gains could, according to type of glazing and orientation, exceed even their energy losses. So that the windows can turn into the best external member of the house, because of their winter solar gains. No other non-transparent construction can make same duty also. For example double-glazing unit with 2 foils with regular coefficient of thermal transmission equals 0.40 $Wm^{-2}.K^{-1}$, there was stated equivalent coefficient of thermal transmission approximately equals 0.01 $Wm^{-2}.K^{-1}$. Also for example well-oriented average double-glazing unit with $U_g = 1.10\ Wm^{-2}.K^{-1}$, is the equivalent value $U_{ekv} = 0.12\ Wm^{-2}.K^{-1}$.

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