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Energy performance of windows in various building types

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Energy performance factors

1. Thermal performance
   - Heat loss (U - value),
   - Heat gains (g – value),
   - Air leakage (L – value)
2. Sunlight transmittance (LT – value)

Certification of windows in Europe

source: www.odyseja.com.pl

Czech Republic

- windows classification
- 7 classes – from A to G
- $E_{ref} = 282,4 \times g_w - 98,7 \times (U_w + L_w)$

source: www.victoriatravel.com.pl

Denmark

- glazing classification
- 3 classes – from A to C
- $E_{ref} = 196,4 \times g_g - 90,36 \times U_g$

source: www.primatravels.com

Finland

- windows classification
- 7 classes – from A to G
- $E_{ref} = 140,4 \times U_w - 160 \times g_w + 50 \times L$

source: www.slovakia.travel

Slovakia

- windows classification
- 7 classes – from A to G
- $E_{ref} = 266,6 \times g_w - 96,6 \times (U_w + L_w)$

source: www.w-spodnicy.pl

Sweden

- windows classification
- 7 classes – from A to G
- zależy tylko od U

source: www.blogi.szkolazklasa.pl

Great Britain

- windows classification
- 7 classes – from A to G
- $E_{ref} = 218,6 \times g_w - 68,5 \times (U_w + L_{50})$

ISO 18292 – thermal performance

ISO 18292 - Energy performance of fenestration systems for residential buildings - Calculation procedure

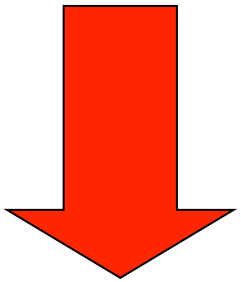
$$E_{ref,heating} = I_{heating} \cdot g - D_{heating} \cdot U$$

$$E_{ref,cooling} = I_{cooling} \cdot g - D_{cooling} \cdot U$$

question - *D, I* reference values

Building energy characteristic impact

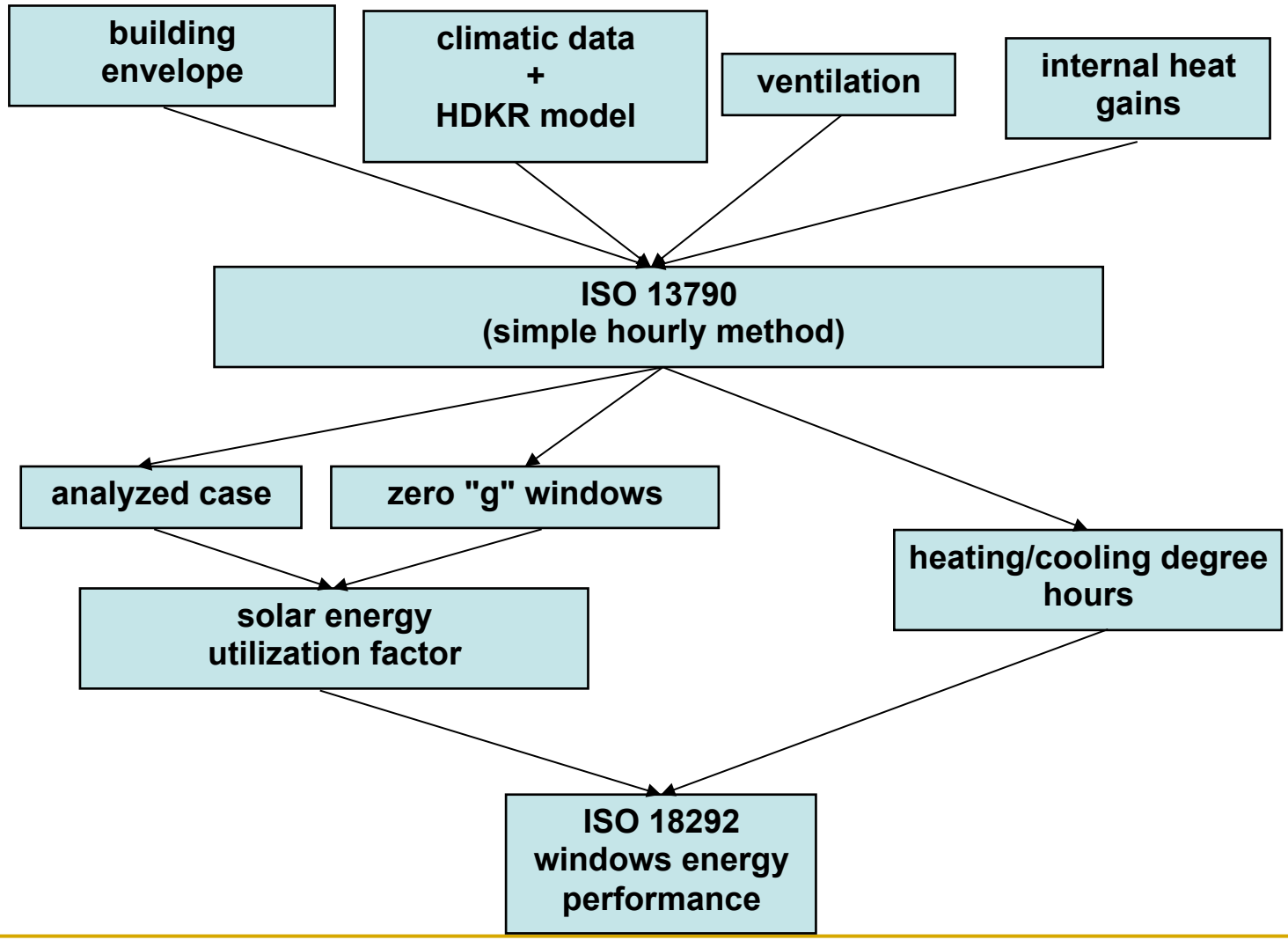
Heat gains/heat loss ratio



Heating/cooling season lenght (D)

Effective irradiation (I)

Calculation algorithm



Integrated thermal performance

$$PE_{ref,total} = -E_{ref,heating} \cdot PRF_{heating} + E_{ref,heating} \cdot PRF_{cooling}$$

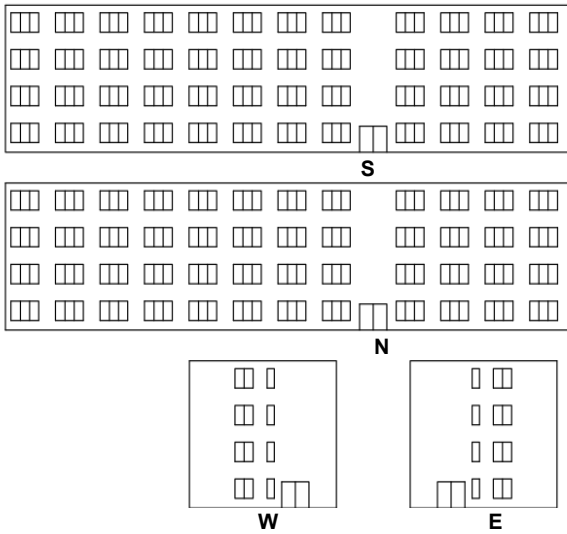
$$PRF_{heating} = \frac{w_{natural\ gas}}{\eta_{heating}} = \frac{1.1}{0.78} = 1.4$$

$$PRF_{cooling} = \frac{w_{electricity}}{\eta_{cooling}} = \frac{3.0}{2.7} = 1.1$$

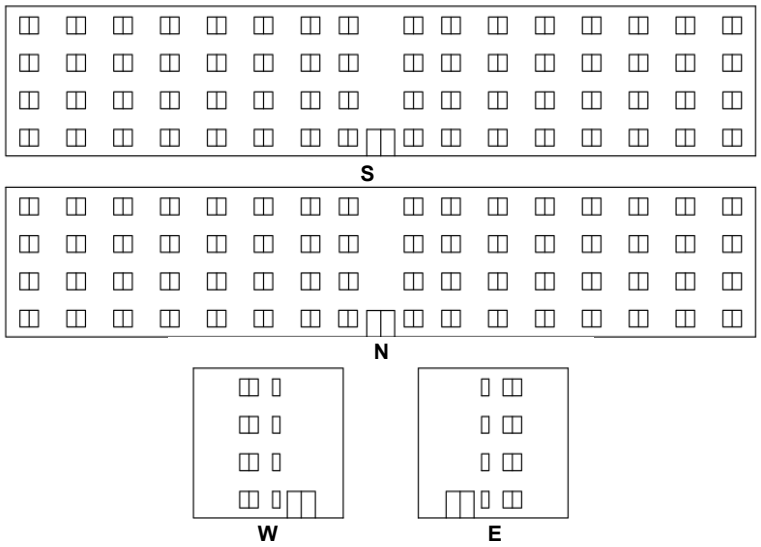
Primary Energy Factors for heating and cooling installations

Reference buildings

Office building



Hospital



	Window fraction on a facade [%]	
Orientation	**Office building**	**Hospital**
N	31,3%	17.8%
E	9,2%	7.8%
S	31,3%	17.8%
W	9,2%	7.8%

Internal heat gains and ventilation

1. Ventilation:
   - Office building – 4 288 m^3/h,
   - Hospital – 50 021 m^3/h.
2. Internal heat gains:

	Average heat gains $[W/m^2]$	
Hours	**Office bulding**	**Hospital**
workday		
17-23	**15,2**	**9.2**
7-17	**1,6**	**9.4**
17-23	**1,6**	**2.2**
weekend		
17-23	**1,6**	**6.4**
7-17	**1,6**	**9.4**
17-23	**1,6**	**2.2**
average (week)	**5.6**	**6.6**

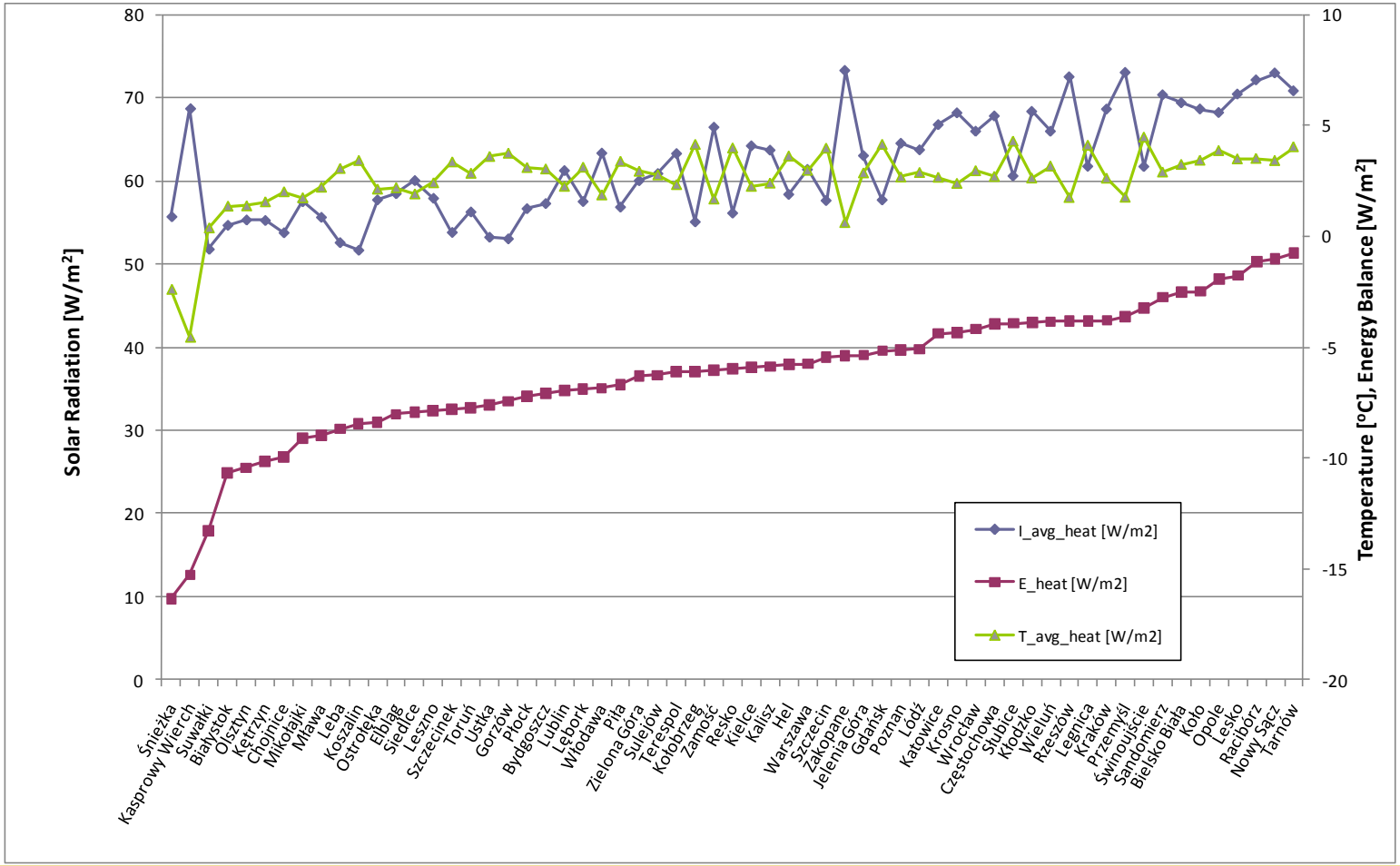
Reference buildings' construction

- heated/cooled space - 4466.17 m2,
- building volume - 14960 m3,
- ground floor/roof area - 1298.30 m2,
- roof pitch - 0°.

Thermal properties

Construction type	*C [J/(K·m²)]*	*Walls U [W/m²K]*	*Roof U [W/m²K]*	*Ground floor U [W/m²K]*
WT2008 (light)	110 000	0.3	0.25	0.45
WT2008 (heavy)	260 000	0.3	0.25	0.45
70s standard	260 000	1.16	0.5	0.7

Climatic data



Scope of the analysis

1. Reference values calculation
   - location (Suwałki, Warszawa, Tarnów),
   - construction type (WT2008 - light/heavy, 70s standard – heavy)
   - building orientation
2. Thermal performance calculation for 12 different window types

Results – Degreehours and Irradiation

Results for Warsaw

Building type	Orientation	Construction Type	Degreehours		Irradiation	
			D_h	D_c	I_h	I_c
			kDh	kDh	kWh/m^2	kWh/m^2
Office building	N	70s standard	95,6	4,5	263,5	110,6
		WT2008 (heavy)	84,5	18,3	193,9	244,9
		WT2008 (light)	84,7	17,2	189,2	243,7
	E	70s standard	95,9	4,4	266,7	110,6
		WT2008 (heavy)	84,8	18,2	195,1	243,6
		WT2008 (light)	85,1	17,0	191,1	241,7
Hospital	N	70s standard	104,0	-0,1	380,6	0,0
		WT2008 (heavy)	103,7	-0,1	390,2	0,0
		WT2008 (light)	104,0	-0,1	367,2	0,0
	E	70s standard	104,0	-0,1	323,3	23,4
		WT2008 (heavy)	103,7	-0,1	333,6	19,9
		WT2008 (light)	104,0	-0,1	310,8	29,4

Results – windows classification

- Office building

Window type	1	2	3	4	5	6	7	8	9	10	11	12
U_w	0.80	0.80	1.0	1.0	1.2	1.2	1.2	1.3	1.4	1.4	1.6	1.6
g_w	0.21	0.28	0.28	0.35	0.32	0.35	0.42	0.44	0.35	0.42	0.35	0.42
Heating season balance [kWh/m^2]												
Tarnów	5	1	6	2	9	7	3	4	10	8	12	11
Warszawa	5	1	6	2	9	7	3	4	10	8	12	11
Suwałki	3	1	5	2	8	7	4	6	10	9	12	11
Cooling season balance [kWh/m^2]												
Tarnów	1	3	2	8	5	7	11	12	6	10	4	9
Warszawa	1	3	2	8	4	7	11	12	6	10	5	9
Suwałki	1	3	2	8	5	7	11	12	6	10	4	9
Primary energy balance [kWh/m^2]												
Tarnów	1	2	3	4	5	6	7	8	9	10	11	12
Warszawa	2	1	4	3	7	6	5	8	10	9	12	11
Suwałki	2	1	4	3	7	6	5	8	10	9	12	11

- Hospital

Window type	1	2	3	4	5	6	7	8	9	10	11	12
U_w	0.80	0.80	1.0	1.0	1.2	1.2	1.2	1.3	1.4	1.4	1.6	1.6
g_w	0.21	0.28	0.28	0.35	0.32	0.35	0.42	0.44	0.35	0.42	0.35	0.42
Heating season balance [kWh/m^2]												
Tarnów	10	4	7	3	8	6	1	2	11	5	12	9
Warszawa	8	4	7	3	9	6	1	2	11	5	12	10
Suwałki	5	1	6	2	9	7	3	4	10	8	12	11
Cooling season balance [kWh/m^2]												
Tarnów	1	2	3	5	4	6	9	12	7	10	8	11
Warszawa	1	2	3	5	4	6	9	12	7	10	8	11
Suwałki	1	2	3	5	4	6	9	12	7	10	8	11
Primary energy balance [kWh/m^2]												
Tarnów	8	4	7	3	9	6	1	2	11	5	12	10
Warszawa	8	4	7	2	9	6	1	3	11	5	12	10
Suwałki	5	1	6	2	9	7	3	4	10	8	12	11

Results – reference values

Building type	Degreehoours		Irradiation	
	D_h	D_c	I_h	I_c
	kDh	kDh	Wh/m^2	Wh/m^2
Office building	86.3	18.2	177.1	236.3
Hospital	107.1	-0.1	350.4	18.1

Results – energy performance of various windows

Type	Office Building					Hospital				
	U_w	g_w	E_h	E_c	E_p	U_w	g_w	E_h	E_c	E_p
	W/(m^{2}K)	-	kWh/m^2	kWh/m^2	kWh/m^2	W/(m^{2}K)	-	kWh/m^2	kWh/m^2	kWh/m^2
1	0,8	0,21	-31,8	35,1	84,1	0,8	0,21	-12,1	3,9	21,5
2	0,8	0,28	-19,5	51,6	84,9	0,8	0,28	12,4	5,1	-11,9
3	1	0,28	-36,7	48,0	105,4	1	0,28	-9,0	5,2	18,5
4	1	0,35	-24,3	64,5	106,1	1	0,35	15,5	6,4	-14,9
5	1,2	0,32	-46,9	53,8	126,3	1,2	0,32	-16,4	5,9	29,8
6	1,2	0,35	-41,6	60,9	126,6	1,2	0,35	-5,9	6,5	15,5
7	1,2	0,42	-29,2	77,4	127,4	1,2	0,42	18,6	7,7	-17,9
8	1,3	0,44	-34,3	80,3	137,8	1,3	0,44	14,9	8,1	-12,2
9	1,4	0,35	-58,8	57,2	147,1	1,4	0,35	-27,3	6,5	46,0
10	1,4	0,42	-46,4	73,8	147,8	1,4	0,42	-2,8	7,7	12,5
11	1,6	0,35	-76,1	53,6	167,5	1,6	0,35	-48,7	6,5	76,4
12	1,6	0,42	-63,7	70,1	168,3	1,6	0,42	-24,2	7,8	43,0

Conclusions

- U-value is not the only factor affecting energy performance of windows therefore it is a need for a rating system that would be based on an overall energy performance during both heating and cooling seasons.
- in Poland the performance of windows does not differ significantly for various locations, building envelope standard and orientation. However, there is a need of a proper set of data depending on the building function,
- thermal performance of windows is not the only aspect that should be taken into account, windows are an important source of natural daylight that allows for reduction of electricity consumption for lighting, therefore a method of daylight potential implementation into the windows rating system should be developed.