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CEN-Benchmark Calculations for Glazings using WIS 2.0b

Werner J. Platzer
platzer@ise.fhg.de
Fraunhofer Institute for Solar Energy Systems
(Fraunhofer ISE)
Heidenhofstr. 2, D-79110 Freiburg, Germany
Tel. ++49-761-4588-5131, Fax ++49-761-4588-9000

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Contact:

On benchmark cases:
The author of this report

On Thematic Network WinDat:
WinDat coordinator: Dick van Dijk, TNO Building and Construction Research, Delft, The Netherlands
Email: H.vanDijk@bouw.tno.nl

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Introduction

In the following document the so-called benchmark cases for glazing configurations are evaluated. Spectral input data for these cases have been provided and cases described in a previous document. Using the data and the comparison from several other participants using different tools we could establish the results for the benchmark cases using EN 673 and EN 410.

1 Benchmark calculations

1.1 Participants of benchmark calculations

The following institutions and persons participated in the benchmark CEN-calculation for glazings:

#	Institution	Participant	Software
#1	BBRI	Gilles Flamant	WIS 2.0 b
#4	Glaverbel	Jean Roucour	inhouse
#6	Pilkington	Davies	Inhouse / SPECTRUM
#7	SSV	Geotti Bianchini	inhouse
#10	ISE	Werner Platzer	Fenster-v3.xls WIS 2.0b

1.2 Glazings

The following glazing configurations were used for the benchmark calculations. The glass configurations are listed starting with outside and last inside.

- GLAZU 1: DGU float
  4.00 mm Clear4 (#9)
  12 mm Air
  4.00 mm Clear4 (#9)
- GLAZU 2: DGU heat mirror (coating pos. 3)
  4.00 mm Clear4 (#9)
  12mm Argon
  6.00 mm LowE Soft (#11)

- GLAZU 3: DGU solar control 1(coating pos. 2)
  5.93 mm Solar (#3)
  15mm 40%Argon+60%Krypton
  4.00 mm Clear4 (#9)
- GLAZU 4: DGU solar control 2(coating pos. 2)
  4.00 mm Solar Soft (#13)
  15mm 40%Argon+60%Krypton
  4.00 mm Clear4 (#9)
- GLAZU 5: DGU absorbing
  3.87mm Abs (#4)
  12mm Air
  3.87mm Abs (#4)
- GLAZU 6: TGU low U (coating pos. 3 and 5)
  4.00 mm Clear4 (#9)
  12mm Krypton
  4.00 mm LowE Soft (#11)
  12mm Krypton
  4.00 mm LowE Soft (#11)
- GLAZU 7: TGU exterior low-e (coatings pos 1, 3 and 5)
  4.00mm Hard4 (#7)
  12mm 90% Krypton, 10% Air
  5.93 mm Solar (#3)
  12mm 90% Krypton, 10% Air
  5.93 mm Solar (#3)
- GLAZU 8: TGU interior low-e (coatings pos 2,4,6)
  5.93 mm Solar (#3)
  12mm 90% Krypton, 10% Air
  5.93 mm Solar (#3)
  12mm 90% Krypton, 10% Air
  4.00mm Hard4 (#7)

DGU double glazed unit
TGU triple glazed unit

1.3 Boundary conditions

Three different boundary conditions have been used:

a) CEN conditions

Temperature of interior and exterior glass with DT=15K and average 10°C
Heat transfer coefficients h_i=8 W/m^{2}K and h_e=23 W/m^{2}K

Irradiation level not relevant for CEN mode
spectrum solar (global AM1) according to EN 410 table 2

b) winter and summer conditions close to ISO 15099

Temperatures (air and radiative)
- Winter: inside Ti=20°C, outside Te=0°C
- Summer: inside Ti=25°C, outside Te=30°C

Heat transfer coefficients:
- Winter inside $h_{c,i}$=3.6 W/m^{2}K, $h_{r,i}$=4.4*ε_i/0.837 (=> h_i=8 W/m^{2}K)
  outside $h_{c,e}$=19 W/m^{2}K, $h_{r,e}$=4.0*ε_i/0.837 (=> h_e=23 W/m^{2}K)
- Summer inside $h_{c,i}$=2.5 W/m^{2}K, $h_{r,i}$=4.4*ε_i/0.837 (=> h_i=6.9 W/m^{2}K)
  outside $h_{c,e}$=8 W/m^{2}K, $h_{r,e}$=4.0*ε_i/0.837(=> h_e=12 W/m^{2}K)

Irradiation:
- level Summer 500 W/m2, Winter 300 W/m2
- spectrum solar (global AM1) according to EN 410 table 2
  visual (D65) according to EN 410 table 1
– incidence angles 0° (normal), plus 45° and 60° altitude (where relevant)

Wind:
outside wind speed at the window surface V_s (free stream) can be calculated from the convective heat transfer coefficients according. to FDIS ISO 15099:

$$h_{c,e}=4.7 + 7.6\ V_s$$

so for example the average winter wind speed would be around 1.9 m/s.

The conditions given do not exactly match the conditions by FDIS ISO 15099, however, they are chosen in such a way that the winter case goes completely parallel with the standard heat transfer coefficients given by the EN standards (EN 410 for g-value, EN 673 for U-value) for vertical windows with h_i=8 W/m^{2}K and h_e=23 W/m^{2}K for ordinary glass with effective emissivity (observe: not normal emissivity!). Thus the calculations for the winter case are comparable with calculations according to the standards as they are given now.

2 Results

2.1 CEN mode results

The U-value from most participants has been given (according to EN 673) only with two digits. Therefore here results from our tool Fenster-v3.xls are quoated. These results as well as the results from WIS are consistent in the second decimal with all CEN benchmark results, however they disagree in the third decimal. The third decimal for the U-value is not given according to the standard, and many programs just output two decimals. Therefore one can say that WIS and the CEN benchmark results agree in U-value. The optical results agree mainly in the third decimal except very few values which may be a rounding error from the fourth decimal. Only for the g-value some deviations in the third decimal can be seen. This might be due to a different discretization of the spectral data in the programs. The CEN benchmark results are confirmed by several participants using different programs, but deviations as seen here have been also occured within this group. Therefore on cannot say that there is a significant deviation of the WIS results from the CEN benchmark results.

Table 1: Investigated glazings

	Glazing 1		Gap_12		Glazing 2		Gap_23		Glazing 3		thickness
Glazing	d1 [mm]	type	d_12 [mm]	gas	d2 [mm]	type	d_23 [mm]	gas	d3 [mm]	type	D [mm]
GLAZU1	4.00	Clear4	12.0	Air	4.00	Clear4					20.00
GLAZU2	4.00	Clear4	12.0	Argon	4.00	LowE Soft					20.00
GLAZU3	5.93	Solar	15.0	40%Ar/60 %Kr	4.00	Clear4					24.93
GLAZU4	4.00	Solar Soft	15.0	40%Ar/60 %Kr	4.00	Clear4					23.00
GLAZU5	3.87	Abs	12.0	Air	3.87	Abs					19.74
GLAZU6	4.00	Clear4	12.0	Krypton	4.00	LowE Soft	12.0	Krypton	4.00	LowE Soft	36.00
GLAZU7	4.00	Hard4	12.0	90%Kr/10 %Air	5.93	Solar	12.0	90%Kr/10% Air	5.93	Solar	39.86
GLAZU8	5.93	Solar	12.0	90%Kr/10 %Air	5.93	Solar	12.0	90%Kr/10% Air	4.00	Hard4	39.86

Table 2: Results for WIS2.0b and CEN benchmark results (red)

		thermal	visible range			solar range			energy
Glazing		U	tau	rho_out	rho_in	tau	rho_out	rho_in	g
GLAZU1	WIS 2.0b	2.862	0.803	0.148	0.148	0.685	0.132	0.132	0.747
	Benchmark	2.862	0.803	0.148	0.148	0.685	0.131	0.132	0.747
GLAZU2	WIS 2.0b	1.406	0.776	0.129	0.125	0.565	0.211	0.219	0.656
	Benchmark	1.407	0.776	0.129	0.125	0.565	0.211	0.219	0.655
GLAZU3	WIS 2.0b	1.093	0.700	0.118	0.135	0.377	0.268	0.309	0.414
	Benchmark	1.095	0.700	0.118	0.135	0.376	0.267	0.309	0.413
GLAZU4	WIS 2.0b	1.085	0.655	0.106	0.124	0.328	0.275	0.337	0.363
	Benchmark	1.087	0.655	0.106	0.124	0.328	0.274	0.337	0.362
GLAZU5	WIS 2.0b	2.864	0.529	0.103	0.103	0.252	0.070	0.070	0.425
	Benchmark	2.865	0.529	0.103	0.103	0.252	0.070	0.070	0.423
GLAZU6	WIS 2.0b	0.548	0.677	0.165	0.158	0.439	0.252	0.260	0.558
	Benchmark	0.549	0.676	0.165	0.158	0.439	0.252	0.260	0.556
GLAZU7	WIS 2.0b	0.487	0.505	0.184	0.150	0.232	0.272	0.285	0.390
	Benchmark	0.494	0.505	0.183	0.150	0.232	0.272	0.285	0.387
GLAZU8	WIS 2.0b	0.471	0.505	0.150	0.184	0.232	0.285	0.272	0.319
	Benchmark	0.472	0.505	0.150	0.184	0.232	0.285	0.272	0.317

2.2 Other boundary conditions

As different boundary conditions have been used in the benchmark exercise, we investigated the influence of that with one tool, the ISE Spreadsheet program "Fenster-v3.xls". It turned out that the differences in result for the stated "winter conditions" close to ISO 15099 and the "CEN conditions" according to EN673/EN410 was marginal.

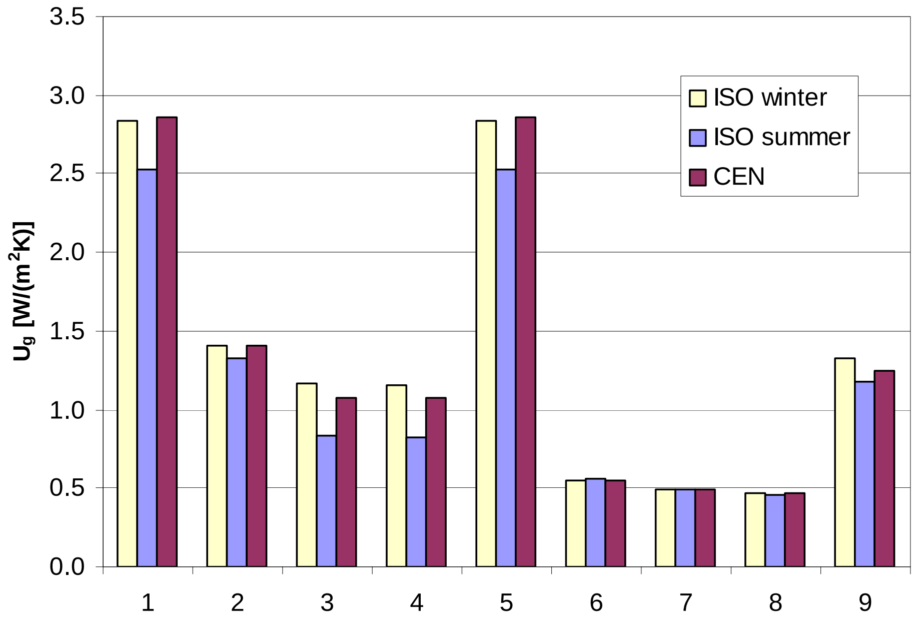

Figure 2-1: Glazing U-value calculated with identical spectral data and ISE-tool "Fenster-v2.xls" for different boundary conditions

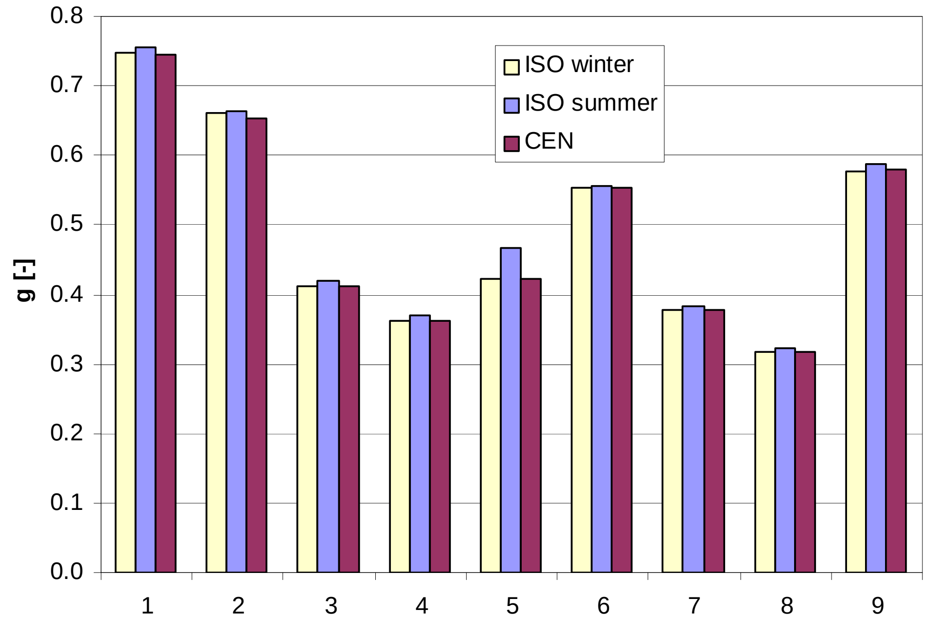

Figure 2-2: Glazing g-value calculated with identical spectral data and ISE-tool "Fenster-v2.xls" for different boundary conditions

The following table gives a comparison for ISO 15099 winter conditions between WIS and the Fraunhofer ISE tool “Fenster-v3.xls”. Here no definitive benchmark results could be generated because the group of participants produced no unified results. The results from Fraunhofer ISE are taken as comparison for two reasons. Firstly for this tool the agreement between CEN mode calculation and benchmark results was similarly excelent as for WIS 2.0b, and secondly, the results for summer U-values and g-values lie mainly in the centre between the extremes of other participants results. Of course the the last argument does not imply automatically that the results are correct.

Table 3: Results for WIS2.0b and ISE tool "Fenster-v3" results for boundary conditions "Winter"

WINTER		thermal	visible range			solar range			energy
Glazing	Tool	U	tau	rho_out	rho_in	tau	rho_out	rho_in	g
GLAZU1	WIS 2.0b	2.861	0.803	0.148	0.148	0.685	0.132	0.132	0.746
	ISE	2.861	0.803	0.148		0.685	0.131		0.746
GLAZU2	WIS 2.0b	1.408	0.776	0.129	0.125	0.565	0.211	0.219	0.654
	ISE	1.408	0.776	0.129		0.565	0.211		0.654
GLAZU3	WIS 2.0b	1.123	0.700	0.118	0.135	0.377	0.268	0.309	0.417
	ISE	1.123	0.700	0.118		0.376	0.267		0.417
GLAZU4	WIS 2.0b	1.123	0.655	0.106	0.124	0.328	0.275	0.337	0.367
	ISE	1.123	0.655	0.106		0.328	0.274		0.367
GLAZU5	WIS 2.0b	2.863	0.529	0.103	0.103	0.252	0.070	0.070	0.421
	ISE	2.863	0.529	0.103		0.252	0.070		0.421
GLAZU6	WIS 2.0b	0.564	0.677	0.165	0.158	0.439	0.252	0.260	0.548
	ISE	0.564	0.676	0.165		0.439	0.252		0.548
GLAZU7	WIS 2.0b	0.511	0.505	0.184	0.150	0.232	0.272	0.285	0.373
	ISE	0.511	0.505	0.183		0.232	0.272		0.373
GLAZU8	WIS 2.0b	0.482	0.505	0.150	0.184	0.232	0.285	0.272	0.308
	ISE	0.482	0.505	0.150		0.232	0.285		0.308

Table 4: Results for WIS2.0b and ISE tool "Fenster-v3" results for boundary conditions "Summer"

WINTER		thermal	visible range			solar range			energy
Glazing	Tool	U	tau	rho_out	rho_in	tau	rho_out	rho_in	g
GLAZU1	WIS 2.0b	2.723	0.803	0.148	0.148	0.685	0.132	0.132	0.757
	ISE	2.534	0.803	0.148		0.685	0.131		0.755
GLAZU2	WIS 2.0b	1.400	0.776	0.129	0.125	0.565	0.211	0.219	0.660
	ISE	1.329	0.776	0.129		0.565	0.211		0.659
GLAZU3	WIS 2.0b	0.873	0.700	0.118	0.135	0.377	0.268	0.309	0.424
	ISE	0.835	0.700	0.118		0.376	0.267		0.420
GLAZU4	WIS 2.0b	0.860	0.655	0.106	0.124	0.328	0.275	0.337	0.375
	ISE	0.822	0.655	0.106		0.328	0.274		0.369
GLAZU5	WIS 2.0b	2.725	0.529	0.103	0.103	0.252	0.070	0.070	0.470
	ISE	2.535	0.529	0.103		0.252	0.070		0.466
GLAZU6	WIS 2.0b	0.581	0.677	0.165	0.158	0.439	0.252	0.260	0.562
	ISE	0.556	0.676	0.165		0.439	0.252		0.559
GLAZU7	WIS 2.0b	0.502	0.505	0.184	0.150	0.232	0.272	0.285	0.407
	ISE	0.491	0.505	0.183		0.232	0.272		0.392
GLAZU8	WIS 2.0b	0.474	0.505	0.150	0.184	0.232	0.285	0.272	0.324
	ISE	0.458	0.505	0.150		0.232	0.285		0.321

As can be seen in Table 3 there are no significant differences between the results for the winter. This is to be expected as both tools agree very well for the CEN mode which is close to the winter conditions.

For the summer case the result is less coherent (Table 4). Especially the U-values differ – interestingly enough for the simple case of an uncoated double glazing! The next figure shows the spread of results from other participants in the calculations group (anonymized). Also here there is a significant spread of results which means that there is a problem waiting to be solved in future, probably for all participants and tools. P5 and P7 used WIS2.0b.[1]

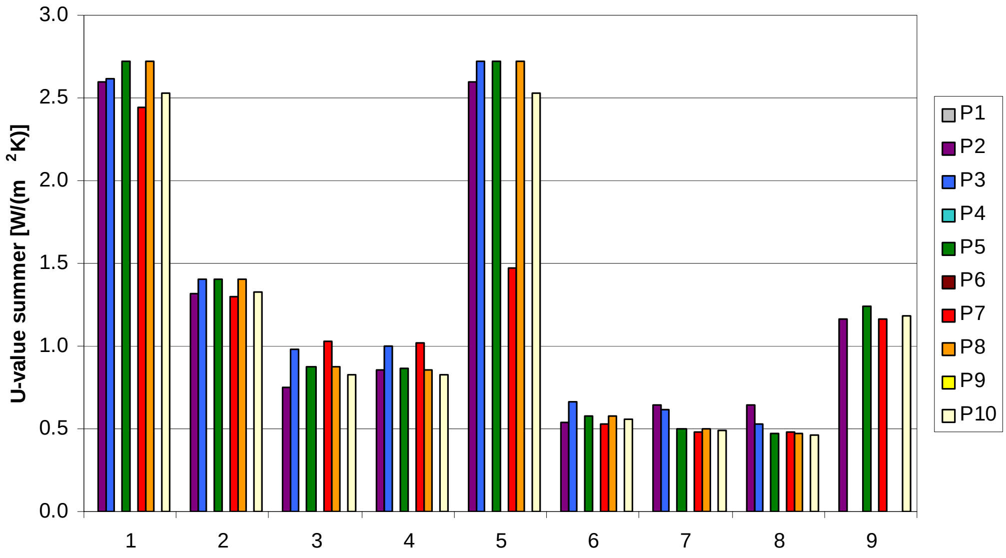

Figure 2-3: Comparison of results for summer U-value from other participants

3 Conclusion

The comparison of glazing calculation results shows that differences occur using summer boundary conditions, both for U-value as for g-value. However, optical calculations were identical within a very small limit. Similarly for CEN mode WIS agrees very well with the CEN benchmark results. Differences may be attributed to different spectral discretization (reading the input data distributed in a common format).

[1] See document windat-ise-wjp-040227 benchmark evaluation-v2.doc