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Evaluation of Benchmark Cases for Window and Shading Performance Calculation

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1 Introduction

In the following document the so-called benchmark cases for glazing and shading device configurations are evaluated. Spectral input data for these cases have been provided and cases described in a previous document. In his project the benchmark calculations of different participants serverd two purposes:

First, the participants used different tools which implemented the relevant EN-standards EN 673 and EN 410 for glazings. By comparing the results also with the EN-mode of WIS 2.0, we could get a feedback on the correctnees of implementation. In the second case of solar shading, the benchmark cases can be used to compare different algorithms, e.g. EN standards with other extended algorithms. The cases as such, however, allow no decision which methodology gives the better approximation to physics and to the real use in buildings.

2 Benchmark calculations

2.1 Participants of benchmark calculations

The following institutions and persons participated at the benchmark calculation for glazings:

#	Institution	Participant	Software
#1	BBRI	Gilles Flamant	WIS 2.0 b
#2	CSTB	Bruno Chevalier	unknown
#3	EMPA	Thomas Nussbaumer	GLAD
#4	Glaverbel	Jean Roucour	inhouse
#5	Interpane	Helen Rose Wilson	WIS 2.0 b
#6	Pilkington	Davies	Inhouse / SPECTRUM
#7	SSV	Geotti Bianchini	inhouse
#8	TNO	Henk Oversloot	WIS 2.0b
#9	UCA	Ismail Rodriguez	unknown

#10	ISE	Werner Platzer	Fenster-v2.xls

The following institutions and persons participated in the benchmark calculation for shadings:

#	Institution	Participant	Software
#3	EMPA	Thomas Nussbaumer	GLAD
#8	TNO	Henk Oversloot	WIS 2.0b
#10	ISE	Werner Platzer	calculation-shading.xls

2.2 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)

- GLAZU 9: DGU Compound

4.0 mm	Clear4 (#9)
0.8 mm	PVB (#14)
4.0 mm	Clear4 (#9)
15mm	Argon
6.0mm	LowE Soft (#11)

NB: Pay attention to the fact that the reflection changes at the interface Clear glass to PVB

DGU	double glazed unit
TGU	triple glazed unit

2.3 Shading devices

4 shading devices haven been defined, and cases with different glazings have been used for the benchmark exercise.

- SHADE 1: Exterior blind system
  The lamellae is a dark (brown) lamellae (Warema, C80A6, Colour W7329) of 80mm width. The slat distance is 72mm.

- SHADE 2: Interior blind system
  The system consists of light grey lamellae (Warema Jal-1.25.01, Colour 3050)of width 25mm. The slat distance is 22mm.

- SHADE 3: Integrated blind system

3.90mm	Clear B2 (outside)
22 mm	gap with aluminum type lamellae gas filling air
4.00mm	Hard (inside)

The width of an lamella is 14mm. The slat distance is 12mm.

- SHADE 4: Internal roller blind system
  Verosol textile roller blind grey.

2.4 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
sepctrum 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.

3 Results

3.1 Glazing results

As different boundary conditions have been used in the benchmark execise, we investigated the influence of that with one tool, the ISE Spreadsheet program "Fenster-v2.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.

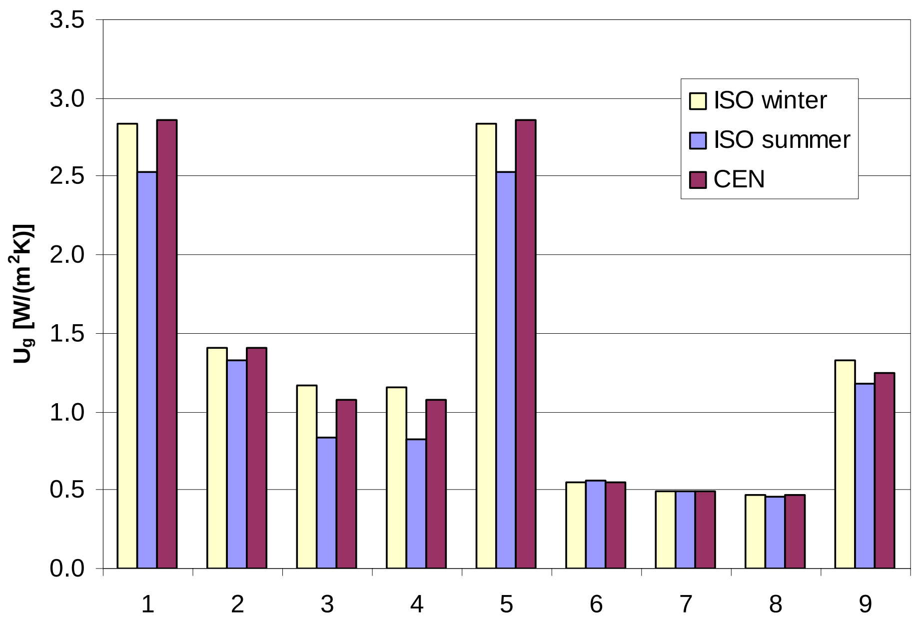

Figure 3-1: Glazing U-value calculated with identical spectral data and ISE-tool "Fenster-v2.xls" for different boundary conditions

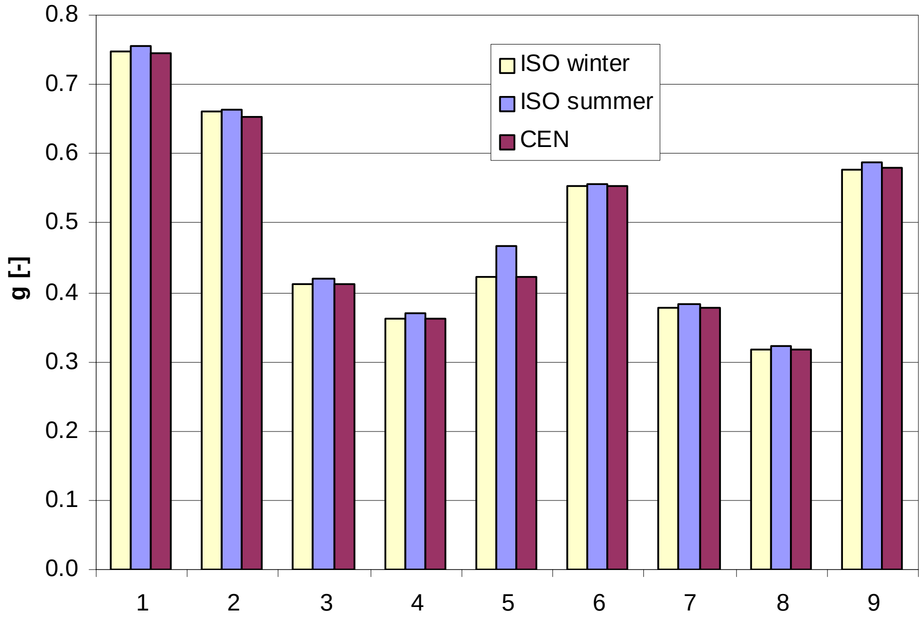

Figure 3-2: Glazing g-value calculated with identical spectral data and ISE-tool "Fenster-v2.xls" for different boundary conditions

The following graphs show the respective results for the participants 1-10. Some columns have not been used when there are only partial results available.

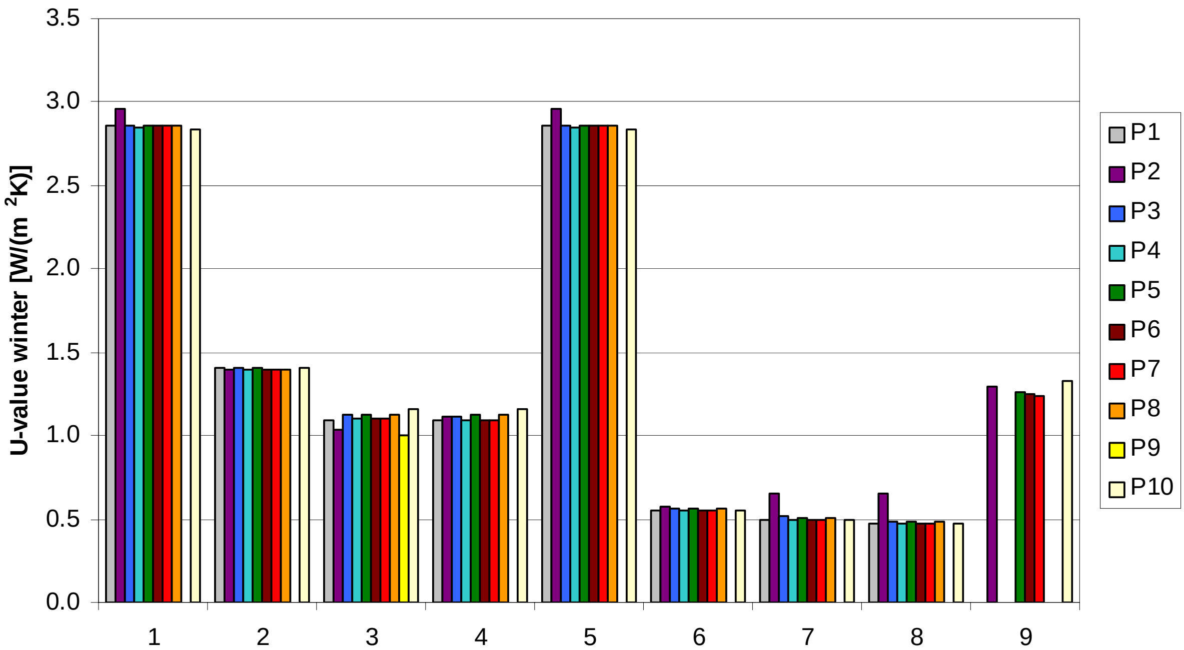

Figure 3-3: Glazing U-value calculated by the participants with different tools (winter conditions)

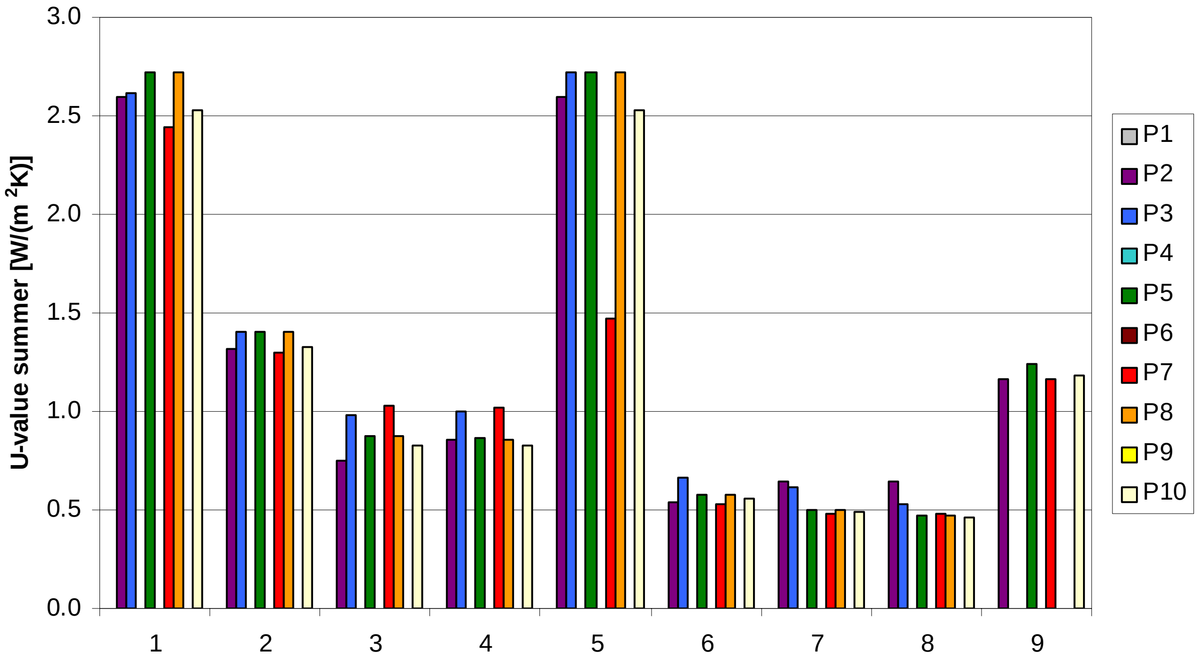

Figure 3-4: Glazing U-value calculated by the participants with different tools (summer conditions)

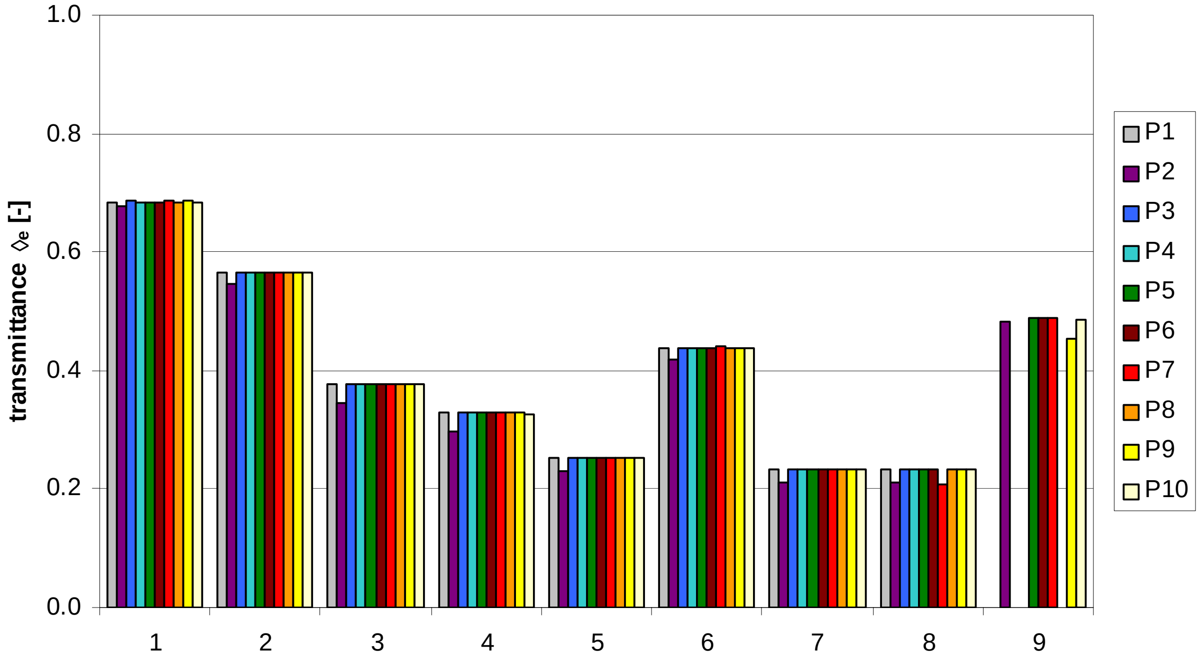

Figure 3-5: Solar transmittance calculated by the participants with different tools

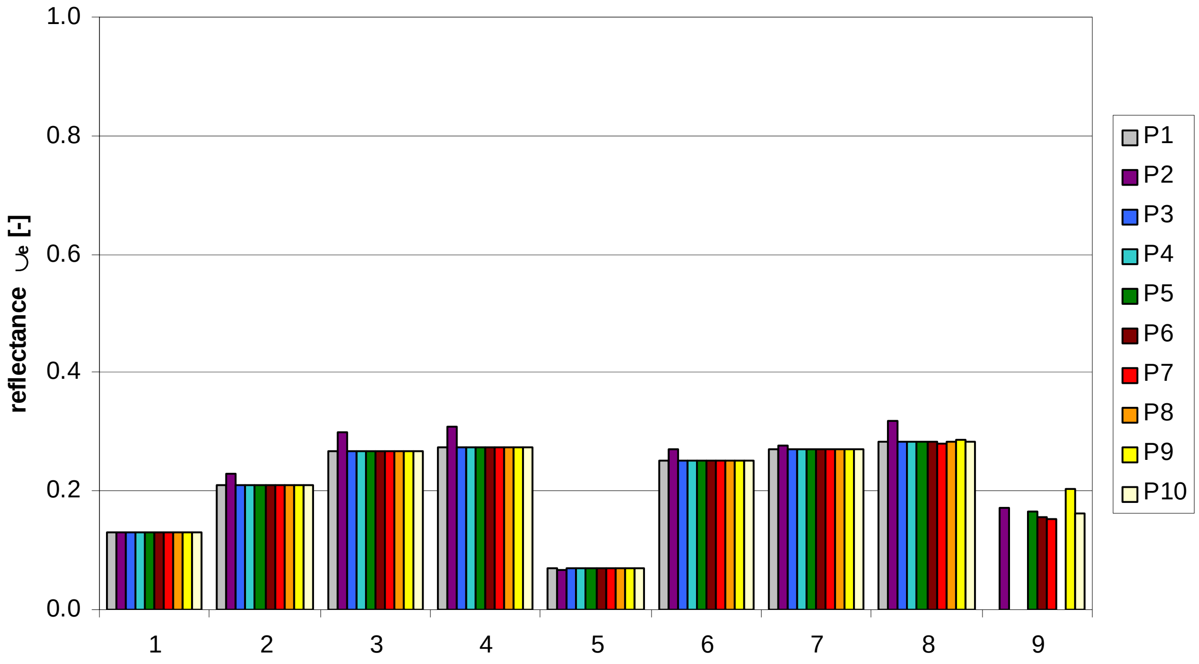

Figure 3-6: Solar reflectance calculated by the participants with different tools

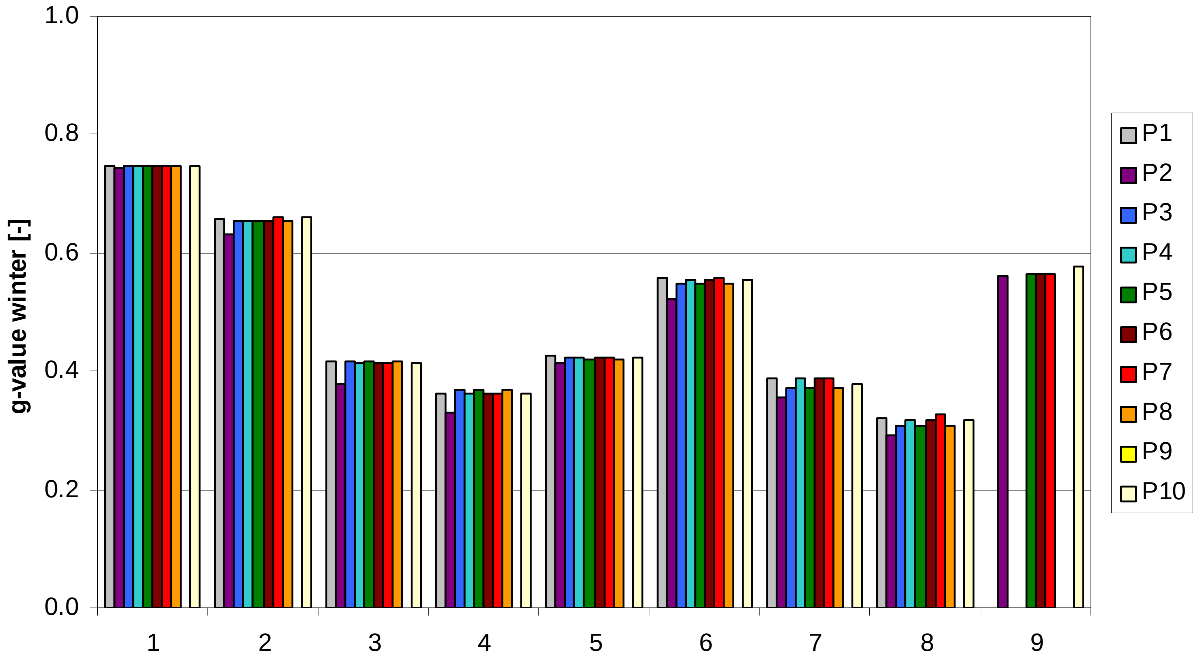

Figure 3-7: Glazing g-value calculated by the participants with different tools (winter conditions)

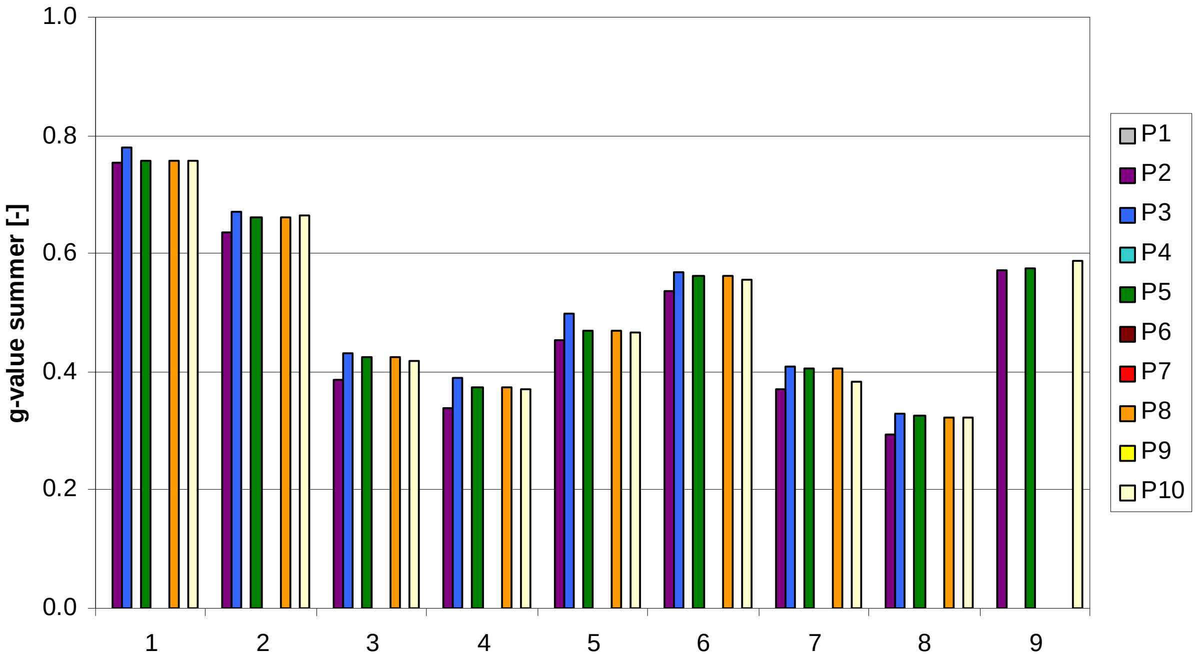

Figure 3-8: Glazing g-value calculated by the participants with different tools (summer conditions

As can be seen in Figure 3-3 there are some differences within the results for the winter U-value. One can be attributed to the small difference between CEN calculations and specified "winter conditions", especially to be seen for glazings 3 and 4 (compare Figure 3-1). However there seems to be a systematic overprediction by participant P2. From the results for glazings 1-8 it seems that participants P1, P4, P6. P7 have used the CEN conditions. P10 would be in line with those if CEN mode had been chosen except for glazing 3 and 4 where it underestimates the U-value by 2% (CEN-mode).

For the summer U-value the result is less convincing (Figure 3-4). Only the two participants (P5, P8) calculating with WIS 2.0b do not differ for all glazings, but there is no consistent overprediction or underprediction by certain participants. P7 is considerably below WIS for glazings 1, 2, 5 and 6, quite close for 7 and 8 and above WIS results for 3 and 4. Participant 3 sometimes agrees with WIS sometimes with participant 7. Certainly the results for P7 and glazing 5 can be excluded. An open question is why participants agreeing very well for winter conditions (P3 and P5) and some glazings in summer, differ so much for other glazings in summer.

The g-value consists of the transmitted part and the secondary heat gains. We checked the optical results (solar transmittance and reflectance of the glazing) separately. In Figure 3-5 and Figure 3-6 there is practically no difference in the results except for participant P2 underpredicting transmittance nd overpredicting reflectance. For glazing 8 also P7 seems to be wrong.

The winter g-value reflects this as again P2 is underpredicting compared with the vast majority, other participants again differ in groups probably because of different boundary conditions (groups P1, P4, P6, P7 -> CEN versus group P2, P3, P5, P8, P10 -> winter). As expected from the previous analysis, P2 underestimates also summer g-values. P3 is consistently above and P10 somewhat below the "WIS" results of P5 and P8.

The maximum difference betwenn minimum and maximum value- neglecting the results of P2 - between U-values even for winter conditions is 8% for glazings 3 and 4, and only for 3 types below 2%; for summer conditions it is mainly around 10% and for glazings 3 and 4 more than 20%! This seems not acceptable and reasons should be investigated.

For the optical integrated values the differences are usually small, but still in the solar range differences of 0.8% occur several times. This is reflected in max. differences in g - for summer and winter similarly between 0.5% and 1.7% - apart from the 2 triple glazings 7 and 8 where differences around 5-6% occur. The problem with these glazings might be connected to the fact that they have a low-e coating exposed to the interior or exterior environment, i.e. a coating on position 1 or 6 respectively. The different programs might treat that surface coefficient in a different way.

The glazing 9 with PVB is a case which cannot be treated according to the standards because the conductivity of the laminate plastic film is not known. Thus it has been not taken into account for the evaluation.

3.2 Shading results

As only some laboratories contributed to the shading exercise a different comparison route is taken. The methodologies of calculation are different not completely defined. TNO used the WIS 2.0b package to calculate the shading-glazing combinations, EMPA used the program GLAD and ISE used an own Excel-tool based on view-factor cacluatltions for curved slats and on the simplified method for the heat transfer calculations according to EN 13363-1.

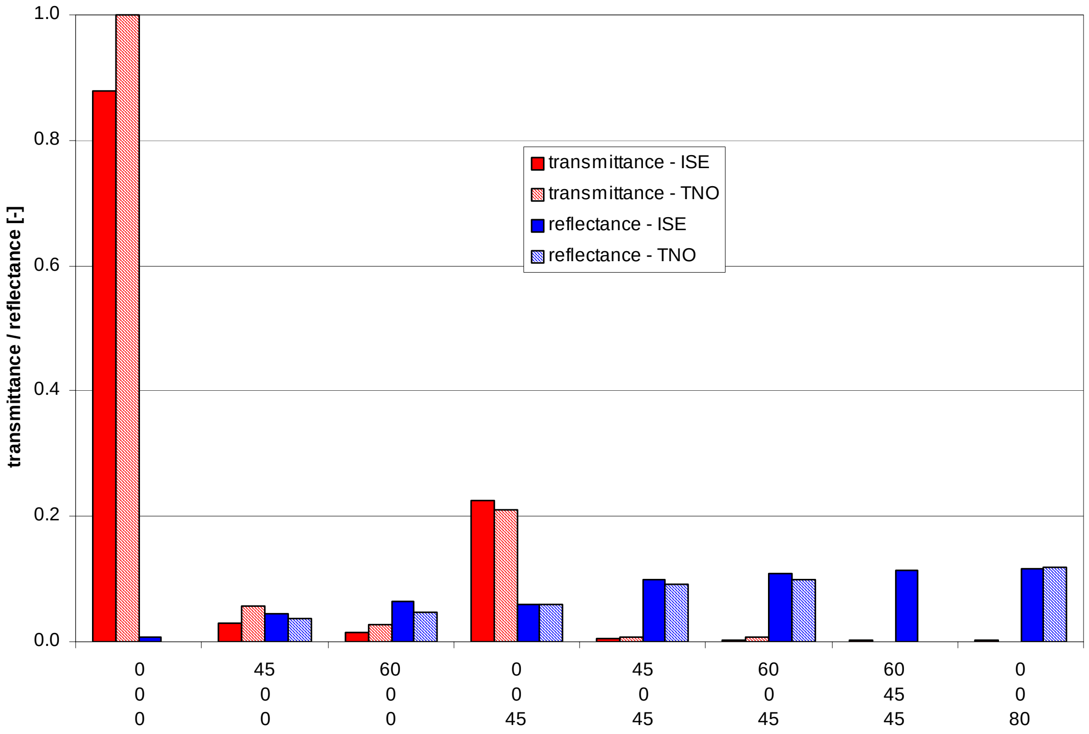

Figure 3-9: Optical properties of exterior brown lamellae shading system SHADE 1(without glazing)
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

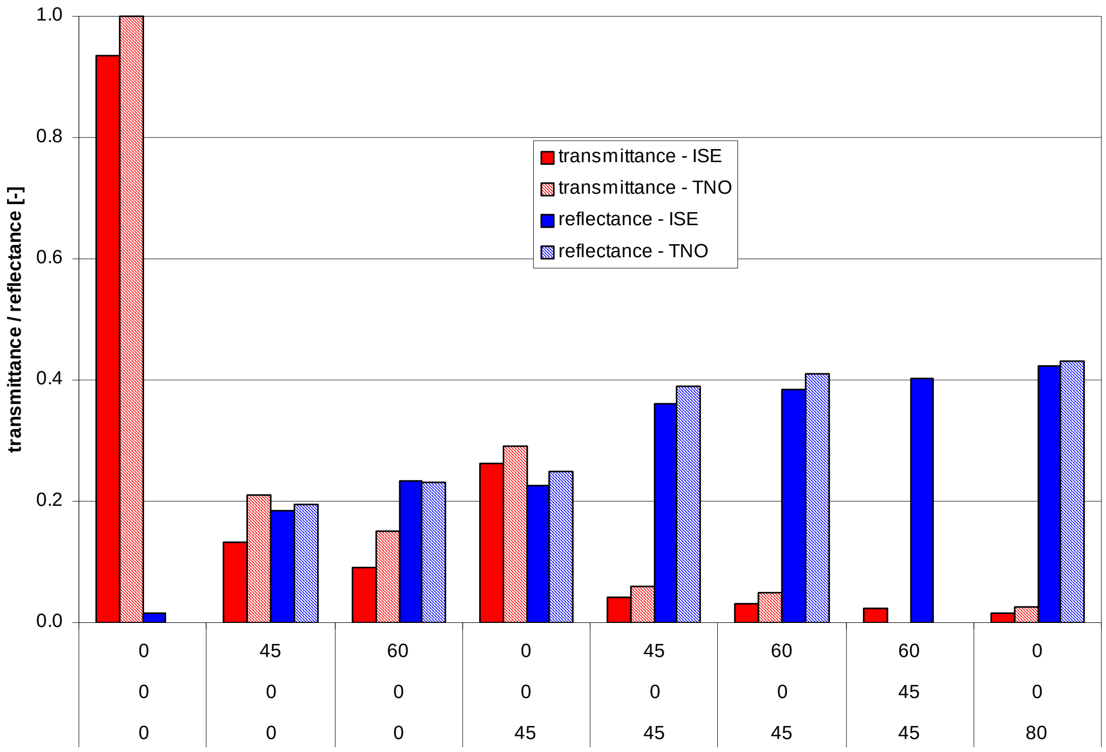

Figure 3-10: Optical properties of interior light grey lamellae shading system SHADE 2 (without glazing)
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

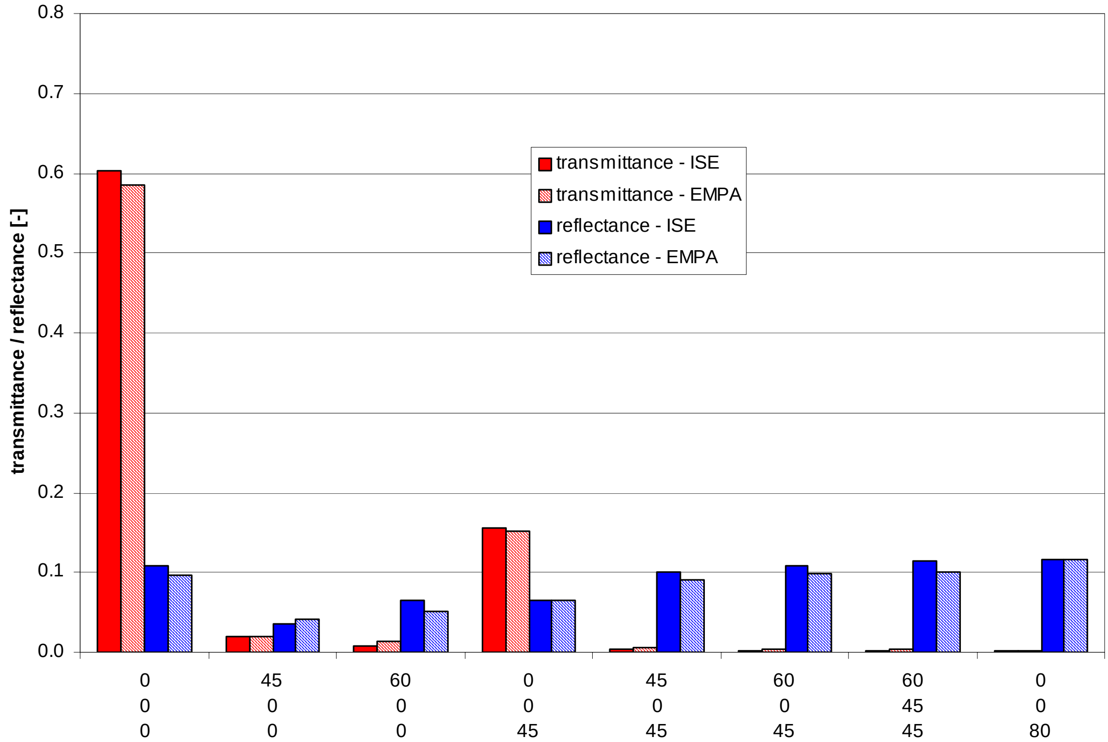

Figure 3-11: Optical properties exterior brown lamellae shading system SHADE 1 + GLAZU1
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

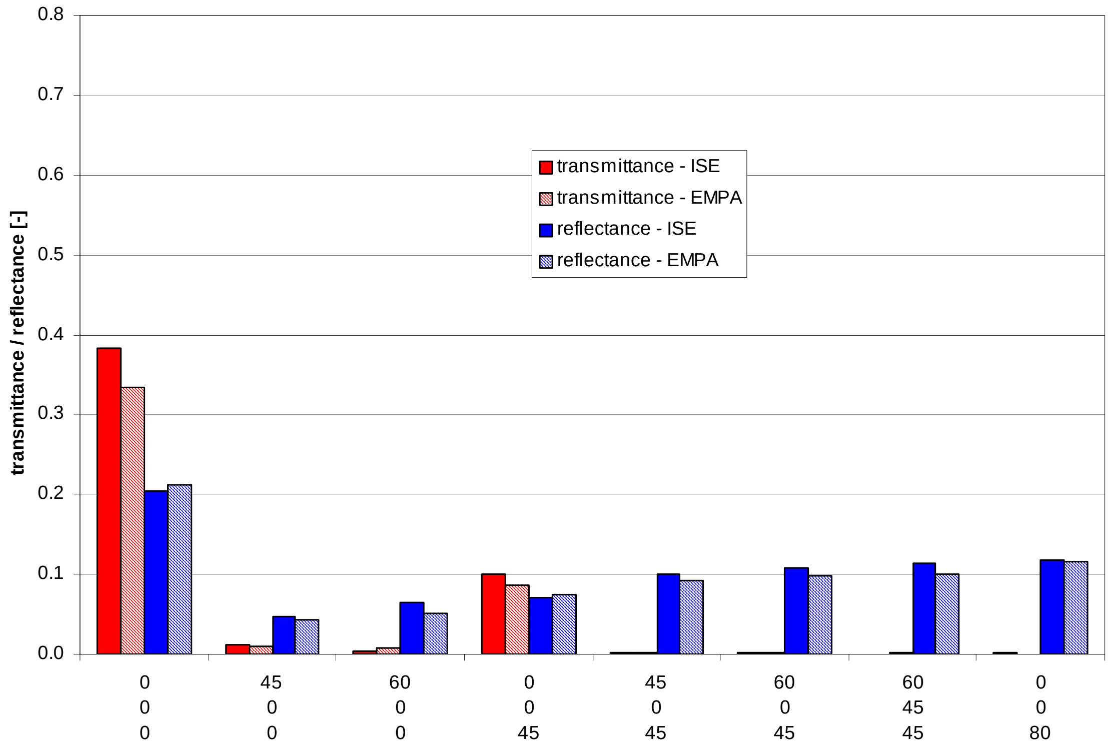

Figure 3-12: Optical properties exterior brown lamellae shading system SHADE 1 + GLAZU6
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

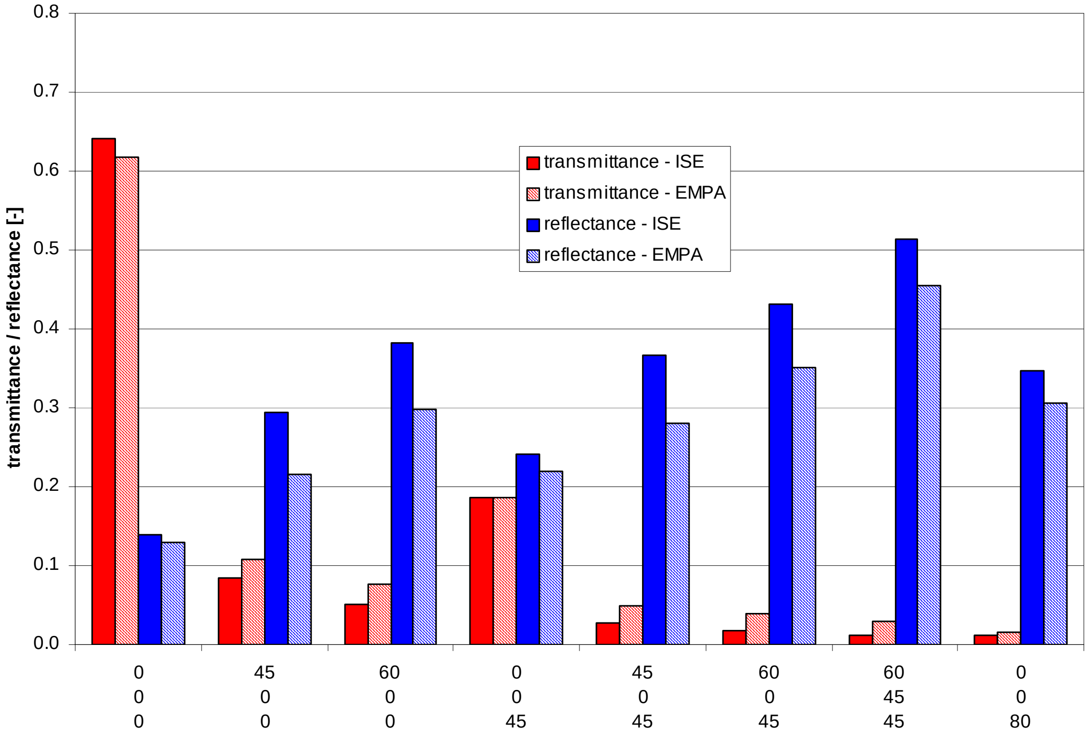

Figure 3-13: Optical properties of interior light grey lamellae shading system GLAZU1 + SHADE2
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

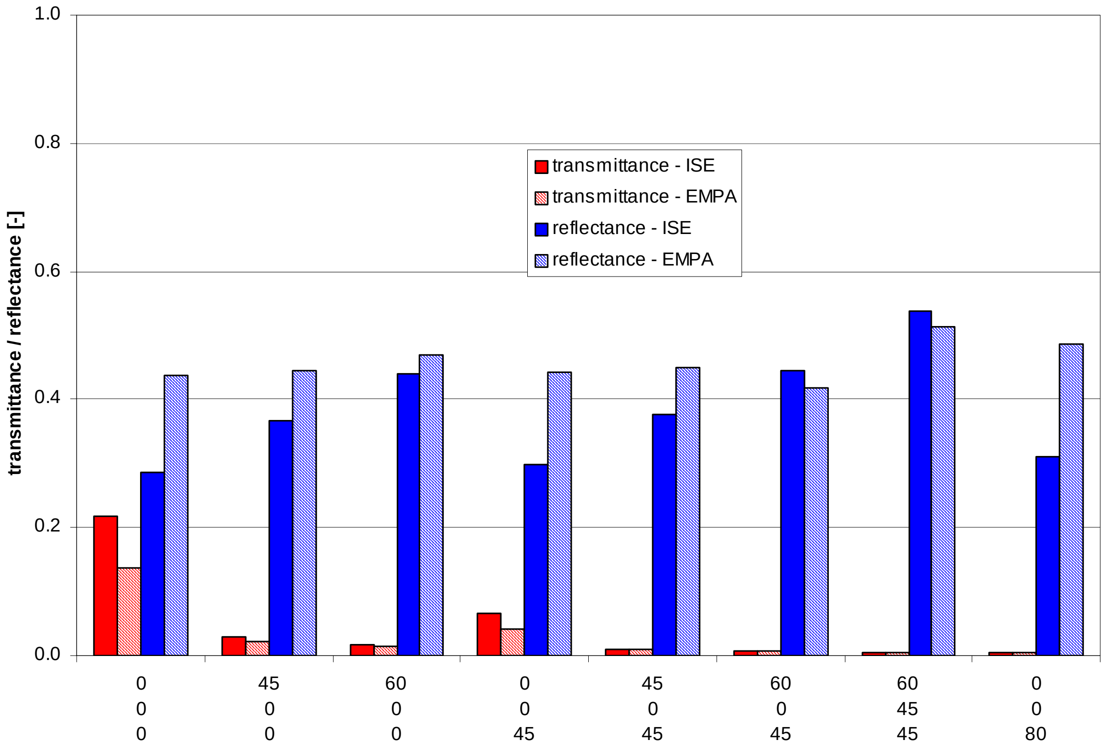

Figure 3-14: Optical properties of interior light grey lamellae shading system GLAZU8 + SHADE2
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

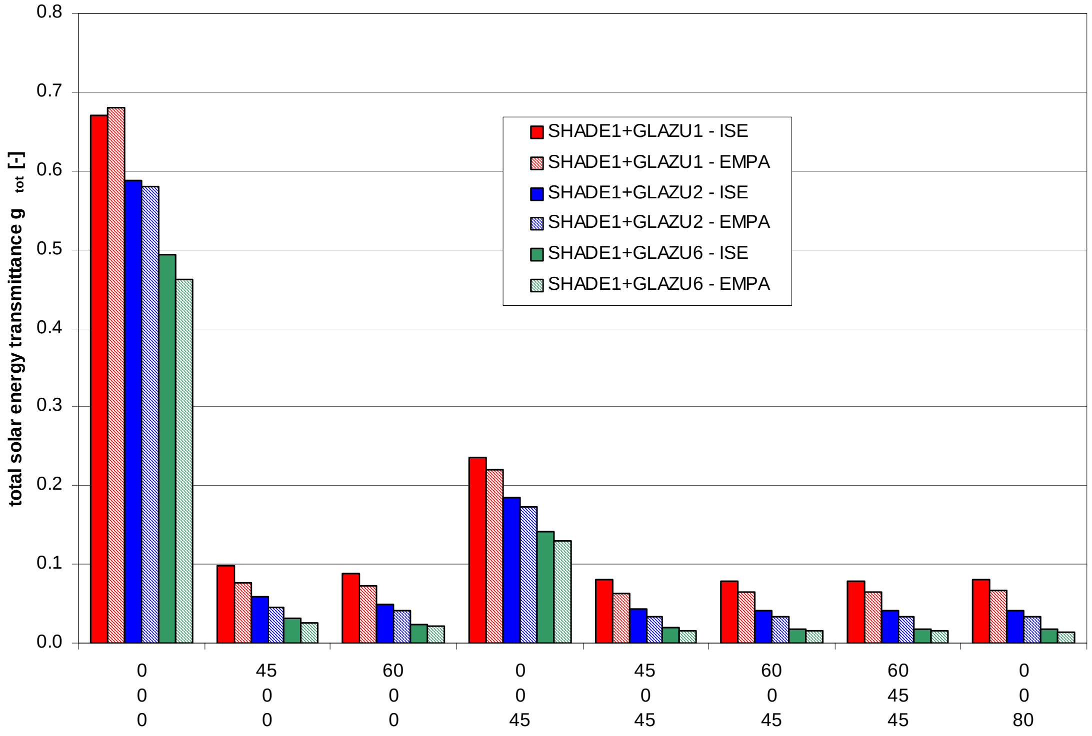

Figure 3-15: Total g-value of exterior brown lamellae shading system SHADE 1 with different glazings
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

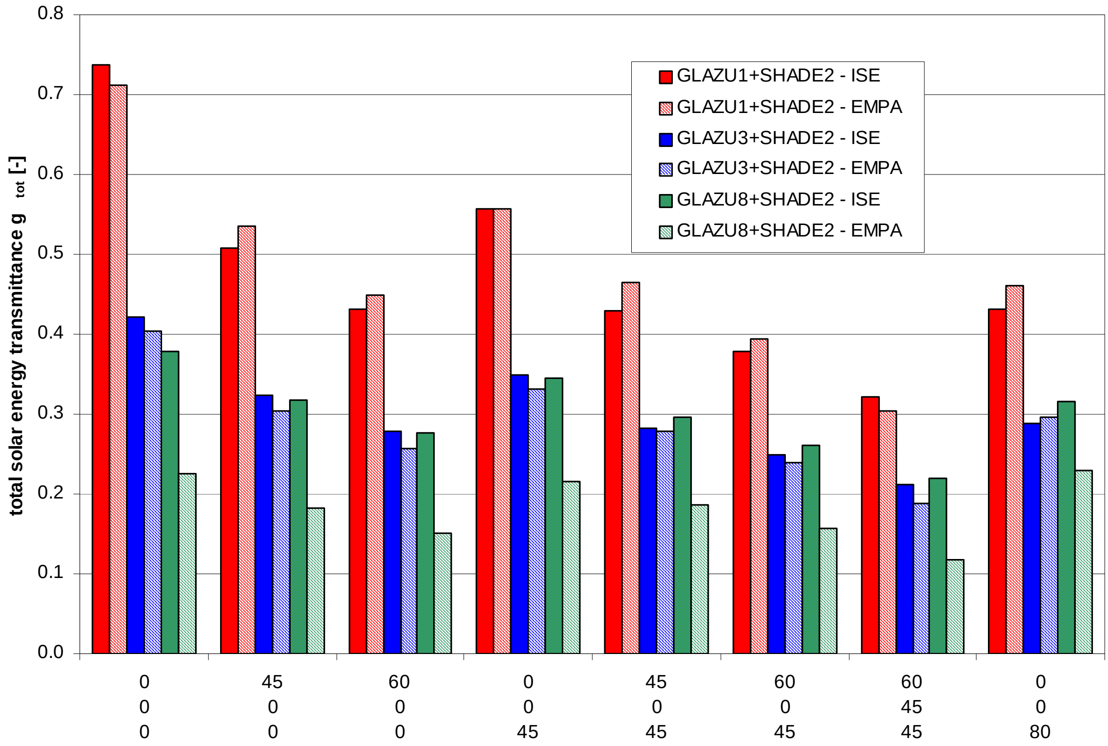

Figure 3-16: Total g-value of interior light grey lamellae shading system SHADE2 with different glazings
NB: x-axis: 1st row: incidence angle; 2nd row: azimuth angle; 3rd row: tilt angle

It was a problem that one participant (TNO) did model the shading devices interchanging the descriptions of SHADE 1 and SHADE2, so the exterior system was used as interior and vice versa. Therefore no comparison of shading devices plus glazings could be made. The other participant (EMPA) did not calculate optical properties of the shading systems without glazings.

4 Conclusion

The comparison of glazing calculation results shows that minor differences occur mainly using summer boundary conditions, both for U-value as for g-value. However, optical calculations were identical within a very small limit, except for one participant which should probably check the calculation tool. For summer conditions the thermal calculations have to be analysed in more detail; each participant should probably check the results with interim values. Is absorptance in the different layers correct? Are thermal resistances calculated correctly? Is the combination used for the g-value according to the standard? A further step should be added soon.

For shading devices the situation is different. There were not enough participants to really compare different tools. It is obvious e.g. from Figure 3-9 and Figure 3-10 that the plane lamella model of WIS underestimates the transmittance for open slats, but mainly gives good correspondence to a similar curved slat model. The models of EMPA and ISE obviously differ to some extent, but mainly give reasonable good correspondence of results within +- 0.02. Only in some cases there are larger discrepancies, e.g. in Figure 3-15 and Figure 3-16 for the combination of Glazing GLAZU8 with the SHADE1 and 2. This should be discussed also in detail.