

Lumen Pro - Validation of daylight calculations against CIE 171:2006

Daylight Factor (%) - comparison with analytical reference values

Validation Setup

This document presents the validation of the Lumen Pro daylight calculation engine against the analytical reference values of CIE 171:2006 (Test cases to assess the accuracy of lighting computer programs). Eight test cases are covered, split into four series: 5.9 (daylight factor under a 1x1 m and 4x4 m roof opening), 5.10 (the same openings fitted with glazing, transmission 0.88), 5.11 (daylight factor through a 2x1 m and a fully-open 4x3 m vertical facade opening) and 5.12 (the same vertical facade openings fitted with 6 mm glazing, transmission 0.88). All calculations use CIE general sky type 1 (overcast sky, luminance ratio 0.3) and a 100% white diffuse BSDF (0 roughness) on the internal surfaces; the luminance is multiplied by pi to obtain the illuminance at the calculation points. The exterior ground is assumed to have a reflectance of 0.30. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N plus the extended grid G' to N' and compared with the analytical reference values of CIE 171:2006.

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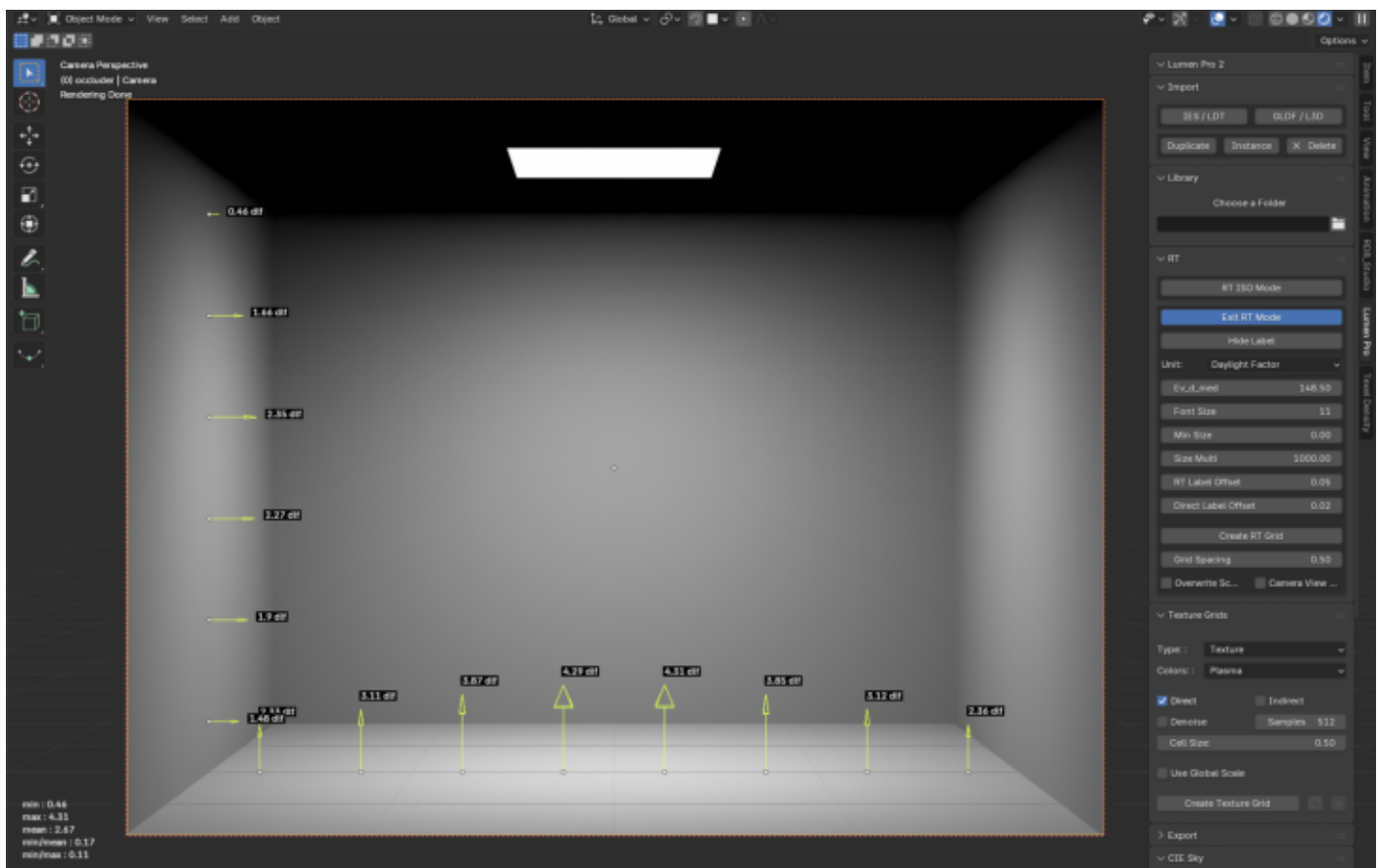
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Test 5.9.3.1 - Daylight Factor (%) - CIE Sky Type 1 - 1x1 m roof opening

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.9.3.1 defines the geometry used for all the tests. It describes a square room 4 x 4 m and 3 m high with an opening in the ceiling of 1 x 1 m (CIE general sky type 1, overcast). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N and compared with the analytical reference values of CIE 171:2006.

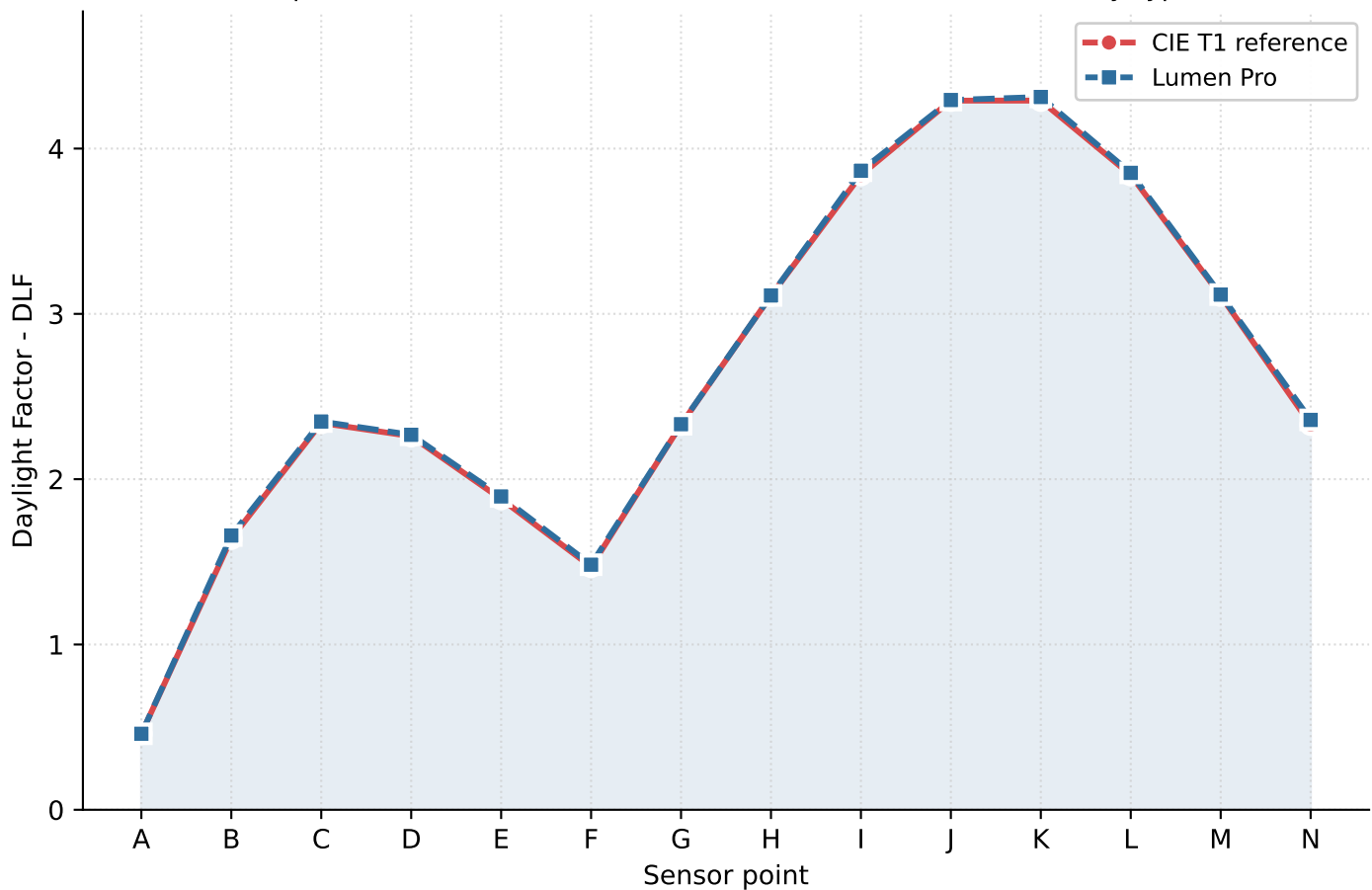


Test model 5.9.3.1 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.9.3.1 - Daylight Factor (%) - CIE Sky Type 1 - 1x1 m roof opening

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE T1 reference	0.46	1.64	2.34	2.26	1.88	1.47	2.33	3.11	3.84	4.29	4.29	3.84	3.11	2.33
Lumen	0.46	1.66	2.35	2.27	1.90	1.48	2.33	3.11	3.87	4.29	4.31	3.85	3.12	2.36
Deviation	-0.00	+0.02	+0.01	+0.01	+0.02	+0.01	+0.00	+0.00	+0.03	+0.00	+0.02	+0.01	+0.01	+0.03

Comparison between calculated and reference DLF values - CIE Sky Type 1

**Accuracy indicators**

Calculation points : 14 MAE : 0.012 RMSE : 0.015 Mean rel. dev. : 0.49 Max rel. dev. : 1.22

Result

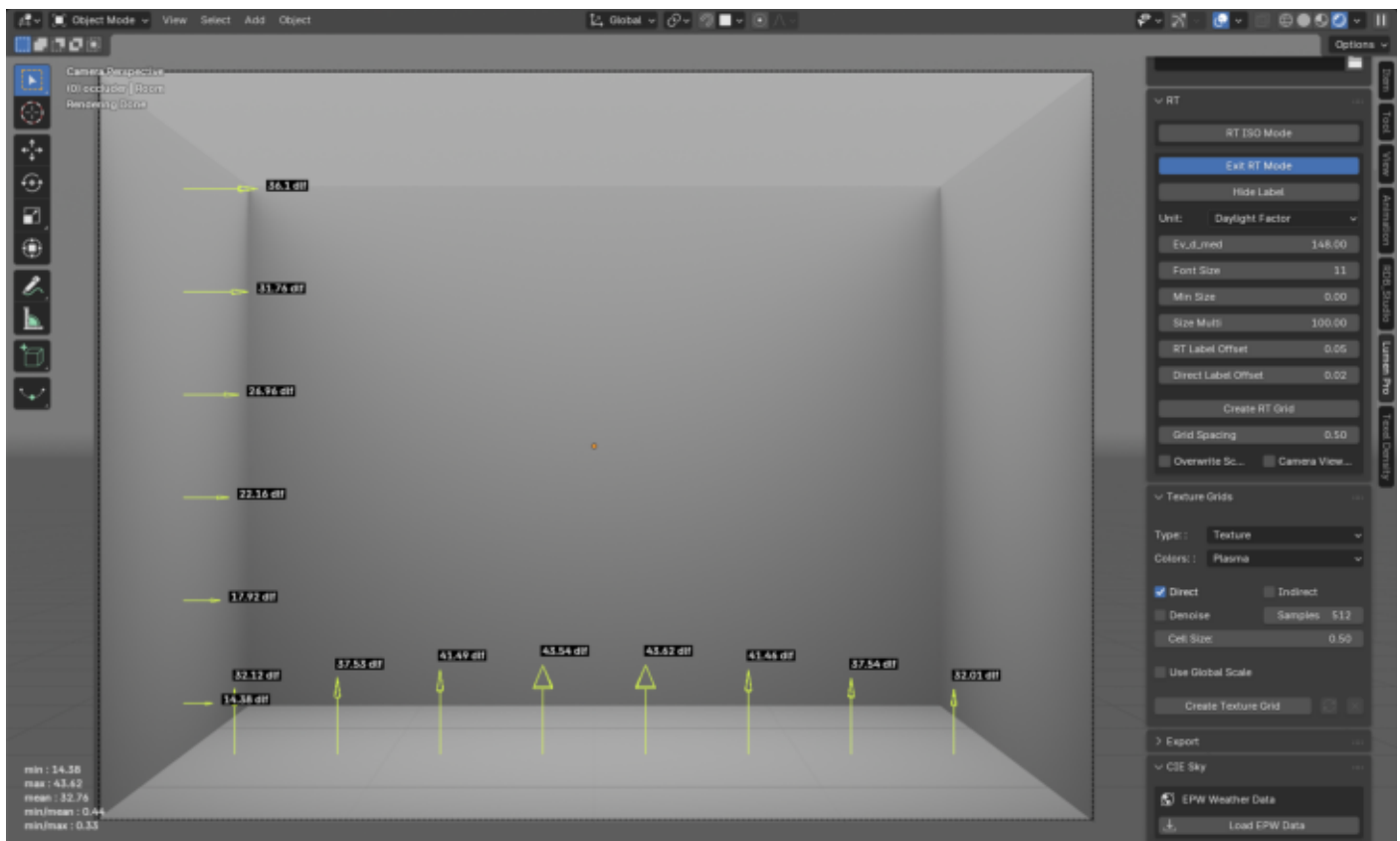
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.9.3.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x4 m roof opening

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.9.3.2 defines the geometry used for all the tests. It describes a square room 4 x 4 m and 3 m high with an opening in the ceiling of 4 x 4 m (CIE general sky type 1, overcast). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N and compared with the analytical reference values of CIE 171:2006.

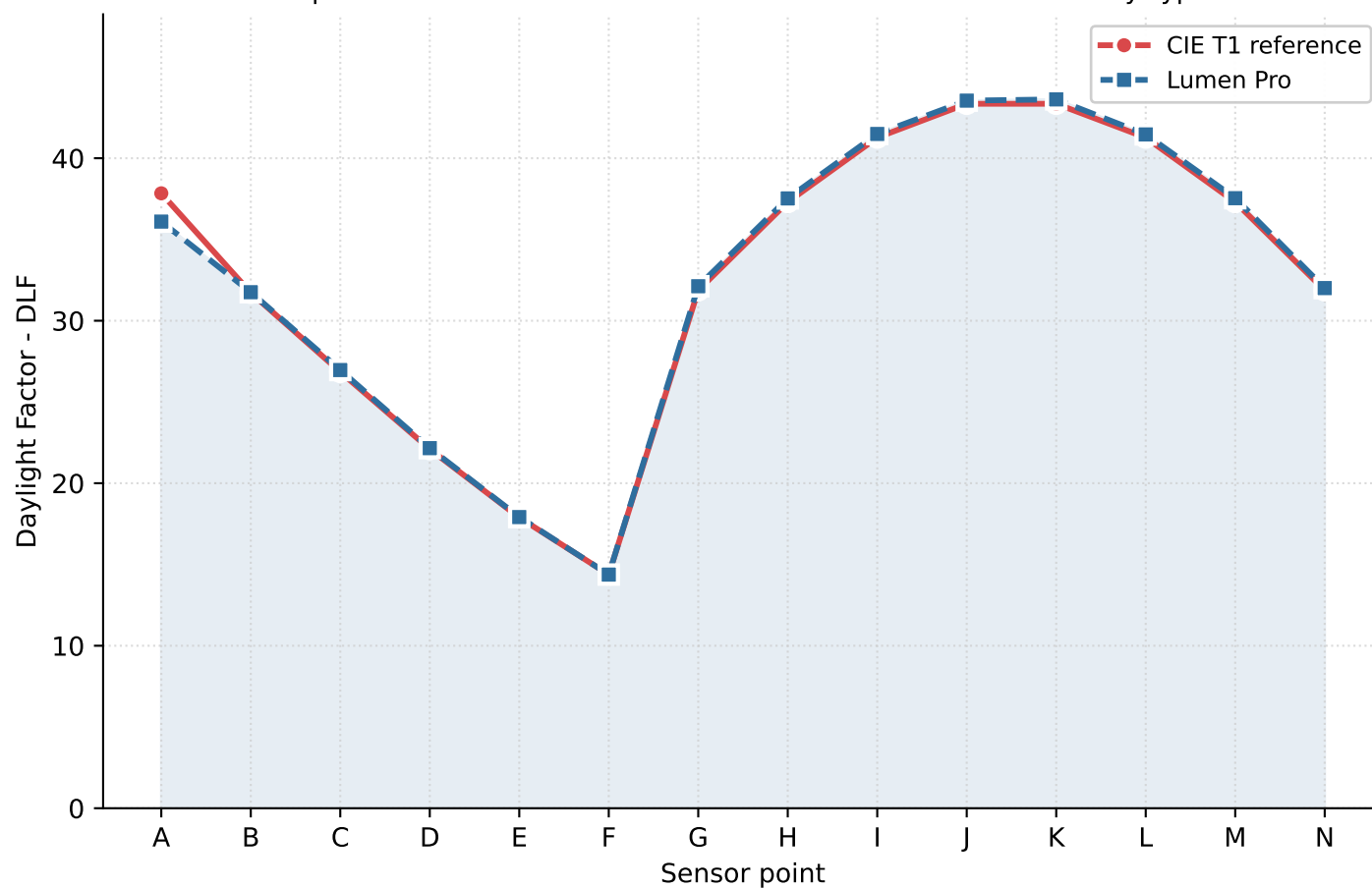


Test model 5.9.3.2 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.9.3.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x4 m roof opening

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE T1 reference	37.84	31.72	26.85	22.10	17.89	14.38	31.87	37.30	41.27	43.35	43.35	41.27	37.30	31.87
Lumen	36.10	31.76	26.96	22.16	17.92	14.38	32.12	37.53	41.49	43.54	43.62	41.46	37.54	32.01
Deviation	-1.74	+0.04	+0.11	+0.06	+0.03	-0.00	+0.25	+0.23	+0.22	+0.19	+0.27	+0.19	+0.24	+0.14

Comparison between calculated and reference DLF values - CIE Sky Type 1

**Accuracy indicators**

Calculation points : 14 MAE : 0.265 RMSE : 0.495 Mean rel. dev. : 0.72 Max rel. dev. : 4.60

Result

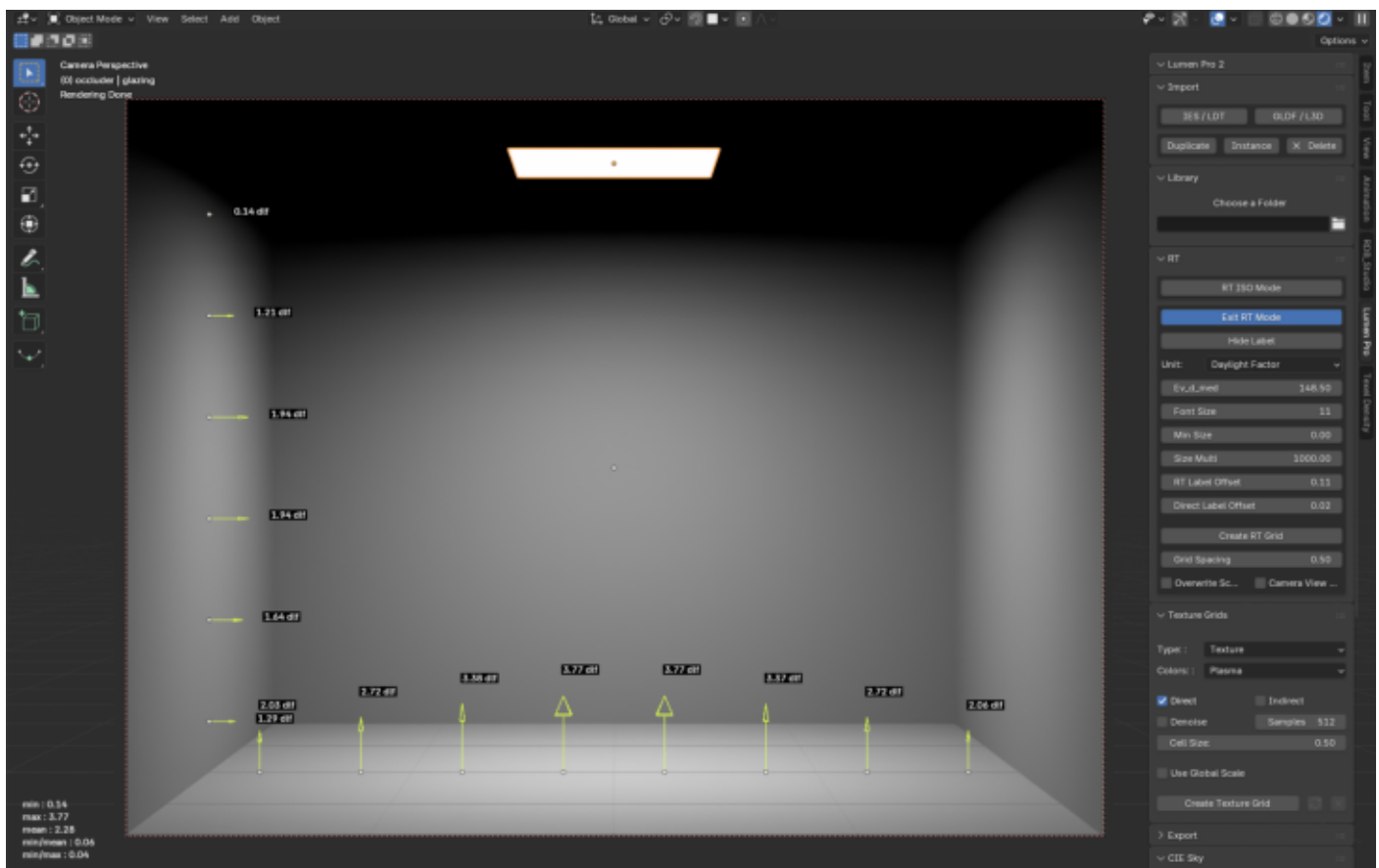
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.10.1.1 - Daylight Factor (%) - CIE Sky Type 1 - 1x1 m roof opening with

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.10.1.1 defines the geometry used for all the tests. It describes a square room 4 x 4 m and 3 m high with an opening in the ceiling of 1 x 1 m (CIE general sky type 1, overcast). The opening is fitted with a plane with a transparent material (0.88 transmission). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N and compared with the analytical reference values of CIE 171:2006.

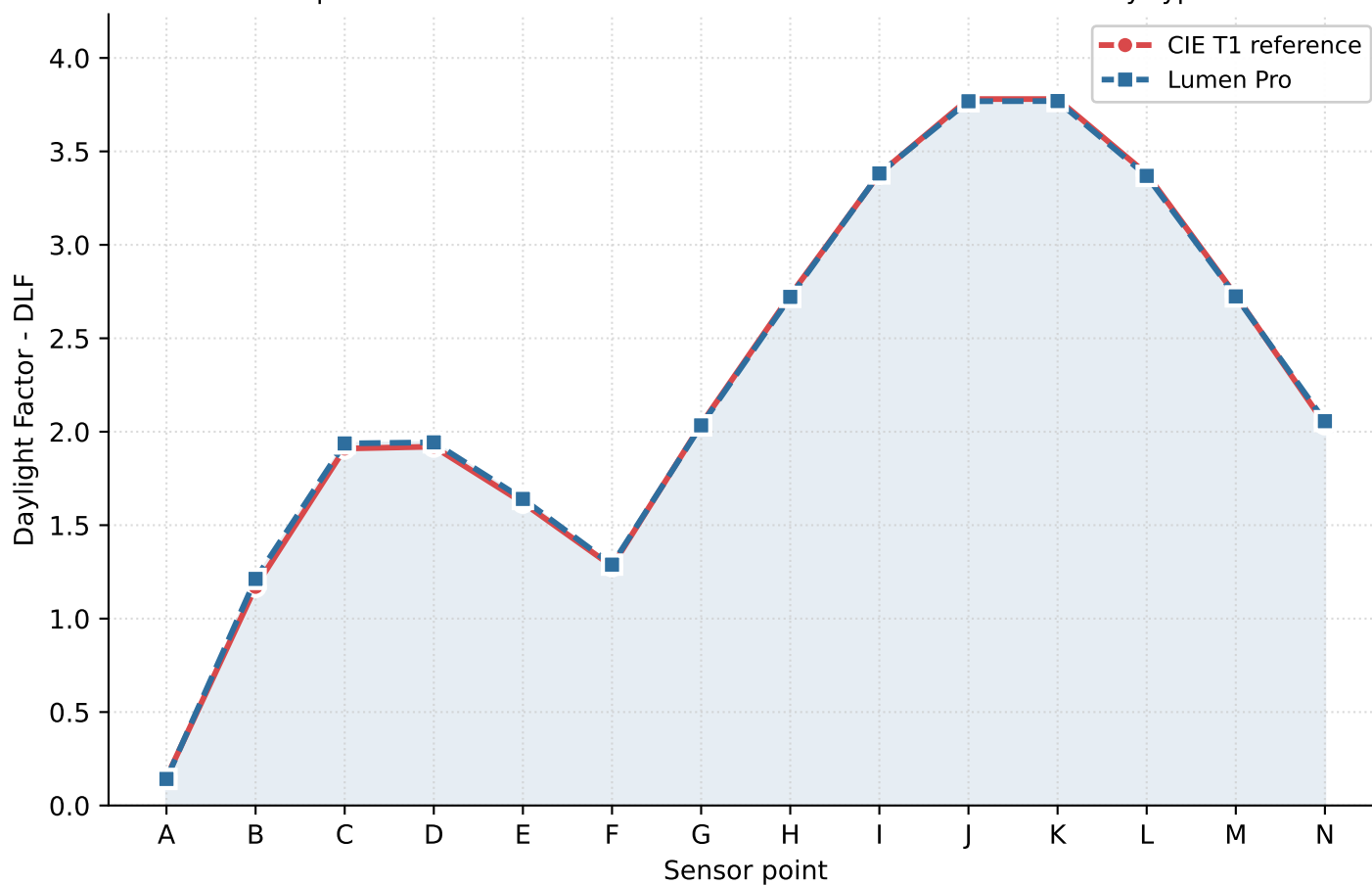


Test model 5.10.1.1 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.10.1.1 - Daylight Factor (%) - CIE Sky Type 1 - 1x1 m roof opening with glazing

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE T1 reference	0.15	1.17	1.91	1.92	1.62	1.28	2.04	2.73	3.38	3.78	3.78	3.38	2.73	2.04
Lumen	0.14	1.21	1.94	1.94	1.64	1.29	2.03	2.72	3.38	3.77	3.77	3.37	2.72	2.06
Deviation	-0.01	+0.04	+0.03	+0.02	+0.02	+0.01	-0.01	-0.01	+0.00	-0.01	-0.01	-0.01	-0.01	+0.02

Comparison between calculated and reference DLF values - CIE Sky Type 1

**Accuracy indicators**

Calculation points : 14 MAE : 0.014 RMSE : 0.018 Mean rel. dev. : 1.15 Max rel. dev. : 5.32

Result

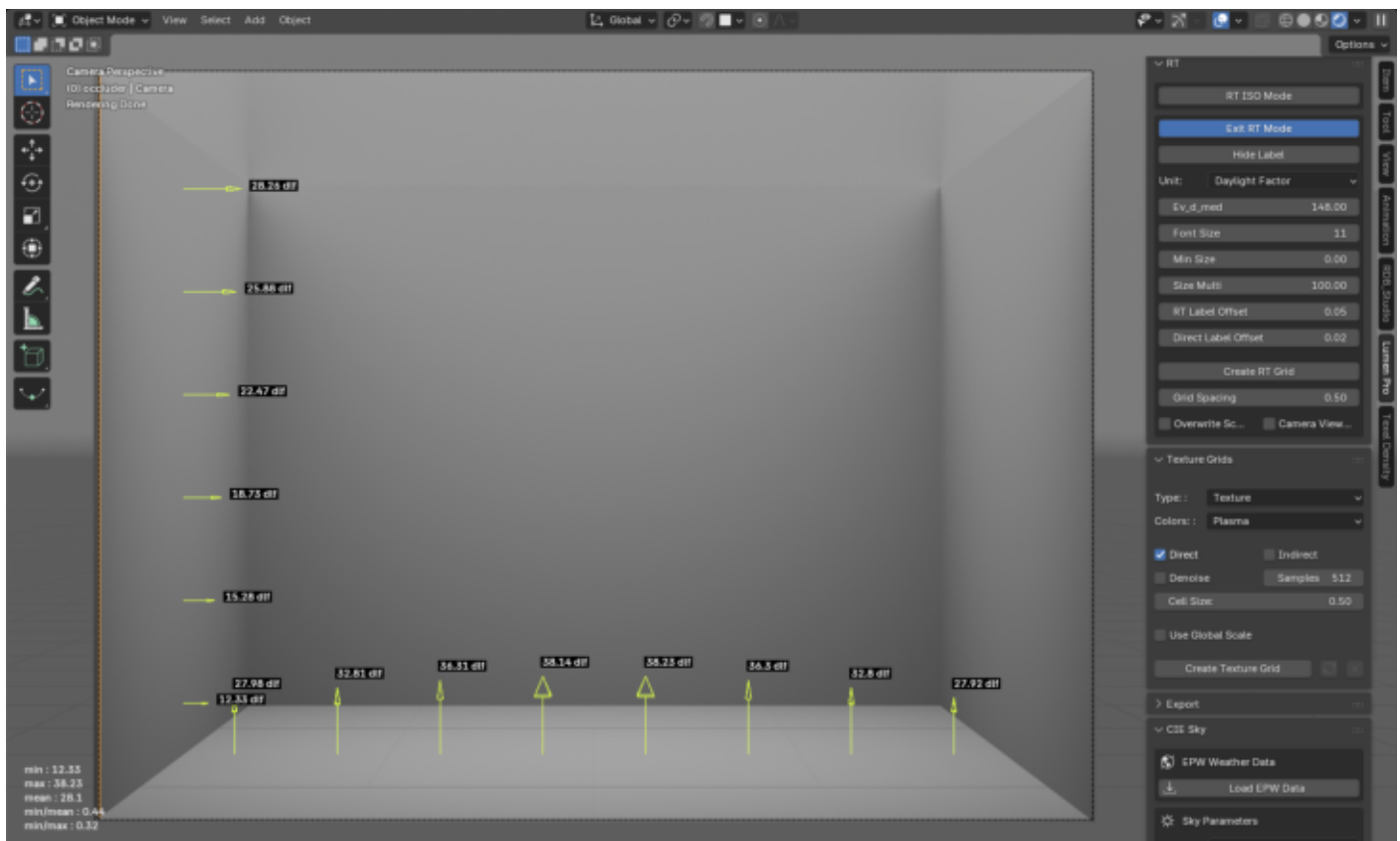
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.10.1.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x4 m roof opening with

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.10.1.2 defines the geometry used for all the tests. It describes a square room 4 x 4 m and 3 m high with an opening in the ceiling of 4 x 4 m (CIE general sky type 1, overcast). The opening is fitted with a plane with a transparent material (0.88 transmission). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N and compared with the analytical reference values of CIE 171:2006.

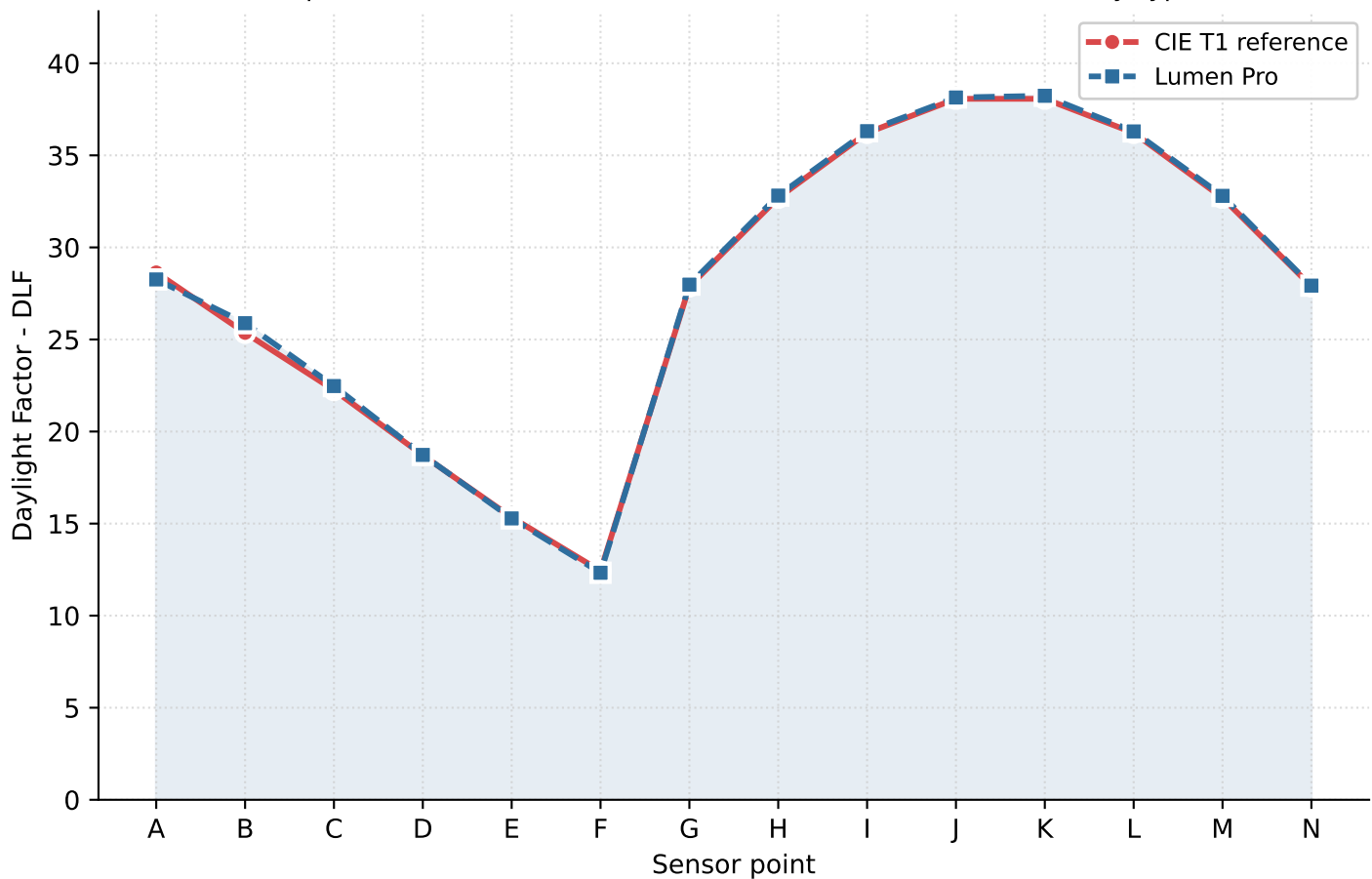


Test model 5.10.1.2 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.10.1.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x4 m roof opening with glazing

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N
CIE T1 reference	28.64	25.36	22.25	18.71	15.34	12.43	27.88	32.69	36.22	38.07	38.07	36.22	32.69	27.88
Lumen	28.26	25.88	22.47	18.73	15.28	12.33	27.98	32.81	36.31	38.14	38.23	36.30	32.80	27.92
Deviation	-0.38	+0.52	+0.22	+0.02	-0.06	-0.10	+0.10	+0.12	+0.09	+0.07	+0.16	+0.08	+0.11	+0.04

Comparison between calculated and reference DLF values - CIE Sky Type 1

**Accuracy indicators**

Calculation points : 14 MAE : 0.149 RMSE : 0.201 Mean rel. dev. : 0.57 Max rel. dev. : 2.07

Result

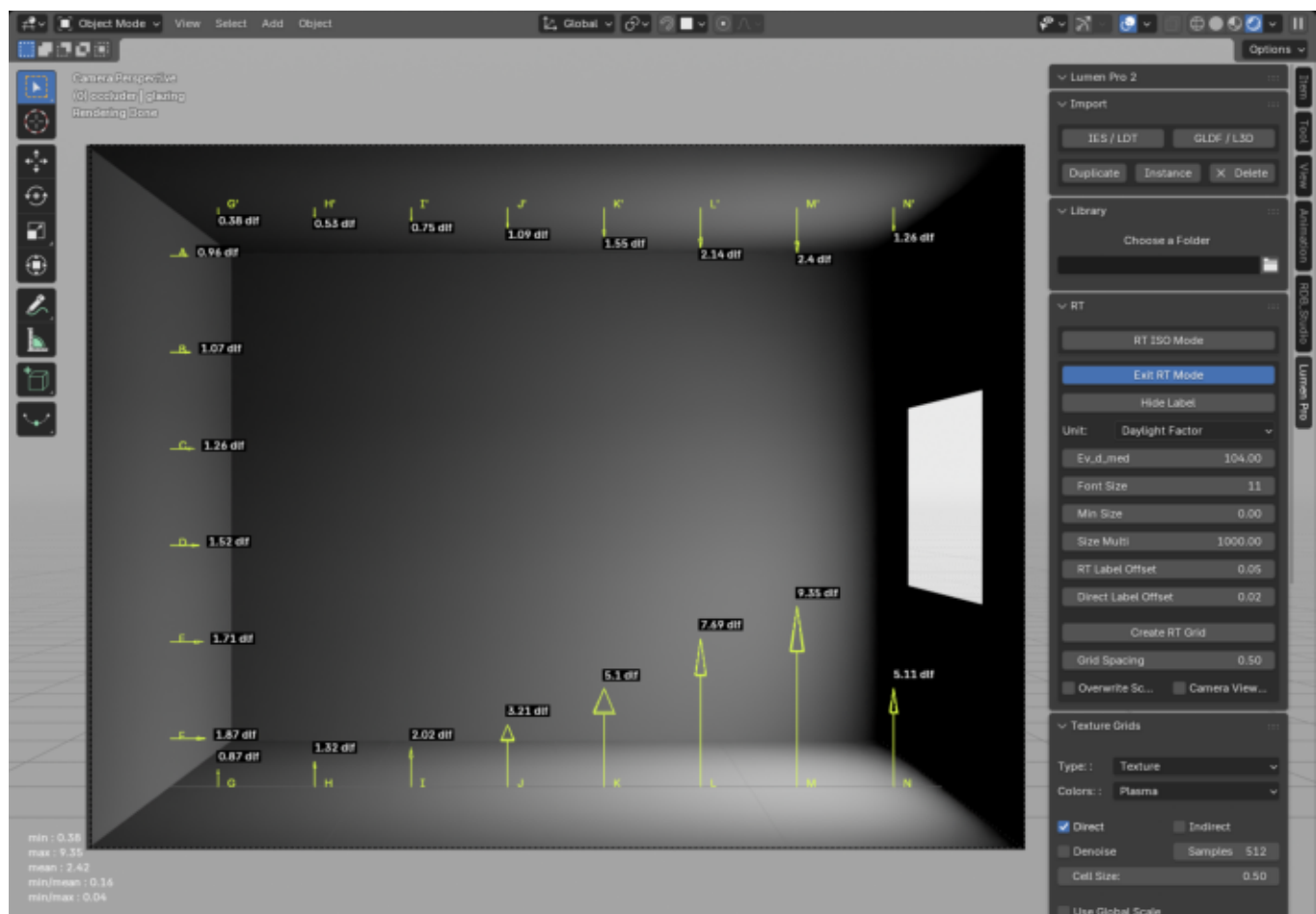
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.11.3.1 - Daylight Factor (%) - CIE Sky Type 1 - 2x1 m vertical facade opening

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.11.3.1 describes a square room 4 x 4 m and 3 m high with an opening of 2 x 1 m in a vertical facade (CIE general sky type 1). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. The exterior ground is assumed to have a reflectance of 0.30. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N plus the extended grid G' to N', and compared with the analytical reference values of CIE 171:2006.

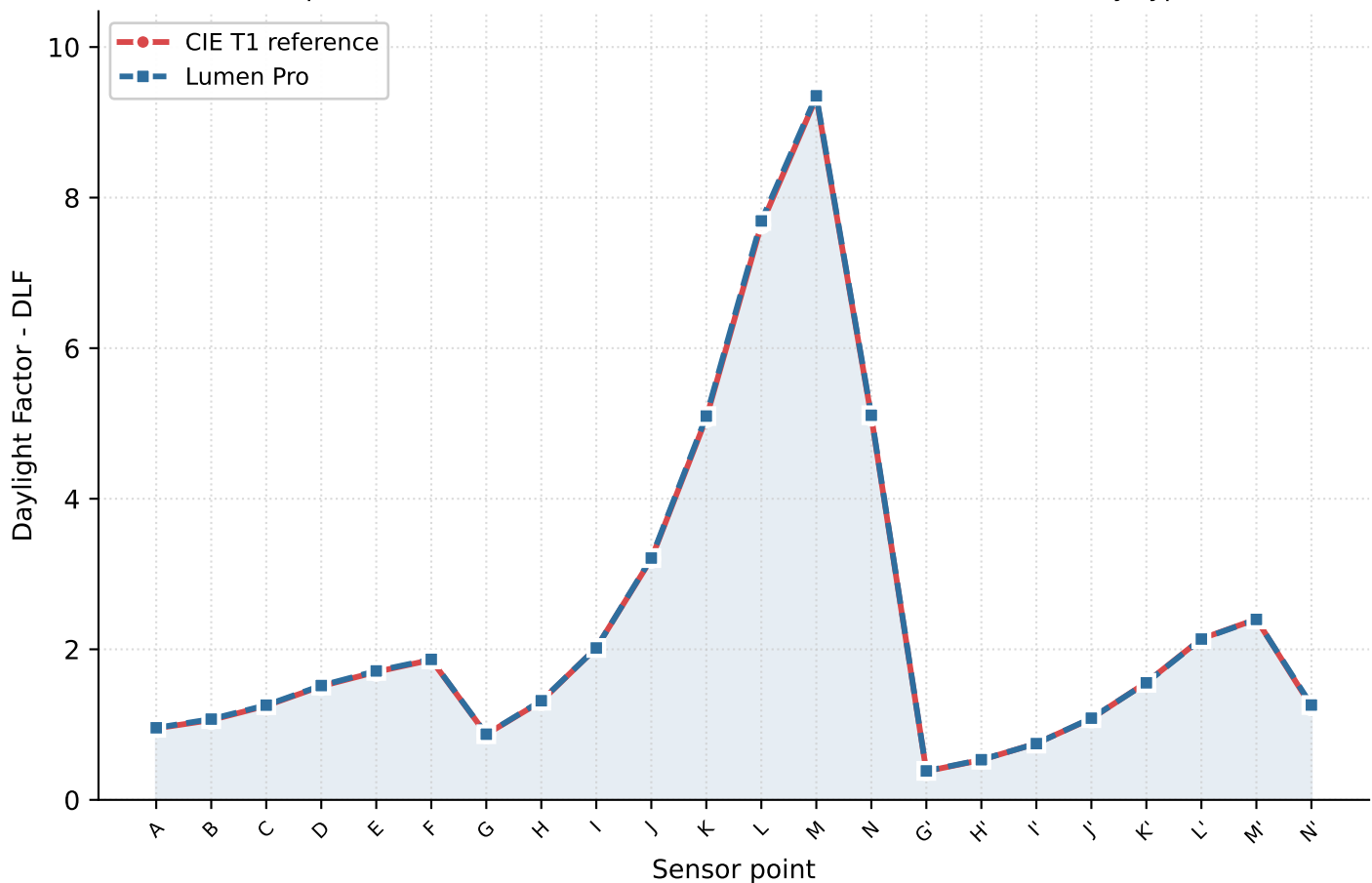


Test model 5.11.3.1 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.11.3.1 - Daylight Factor (%) - CIE Sky Type 1 - 2x1 m vertical facade opening

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N	G'	H'	I'	J'	K'	L'	M'	N'
CIE T1 reference	0.95	1.06	1.25	1.51	1.70	1.86	0.87	1.31	2.02	3.20	5.07	7.64	9.33	5.09	0.38	0.53	0.75	1.08	1.56	2.14	2.40	1.24
Lumen	0.96	1.07	1.26	1.52	1.71	1.87	0.87	1.32	2.02	3.21	5.10	7.69	9.35	5.11	0.38	0.53	0.75	1.09	1.55	2.14	2.40	1.26
Deviation	+0.01	+0.01	+0.01	+0.01	+0.01	+0.01	+0.00	+0.01	-0.00	+0.01	+0.03	+0.05	+0.02	+0.02	+0.00	+0.00	-0.00	+0.01	-0.01	-0.00	-0.00	+0.02

Comparison between calculated and reference DLF values - CIE Sky Type 1



Accuracy indicators

Calculation points : 22 MAE : 0.011 RMSE : 0.016 Mean rel. dev. : 0.56 Max rel. dev. : 1.59

Result

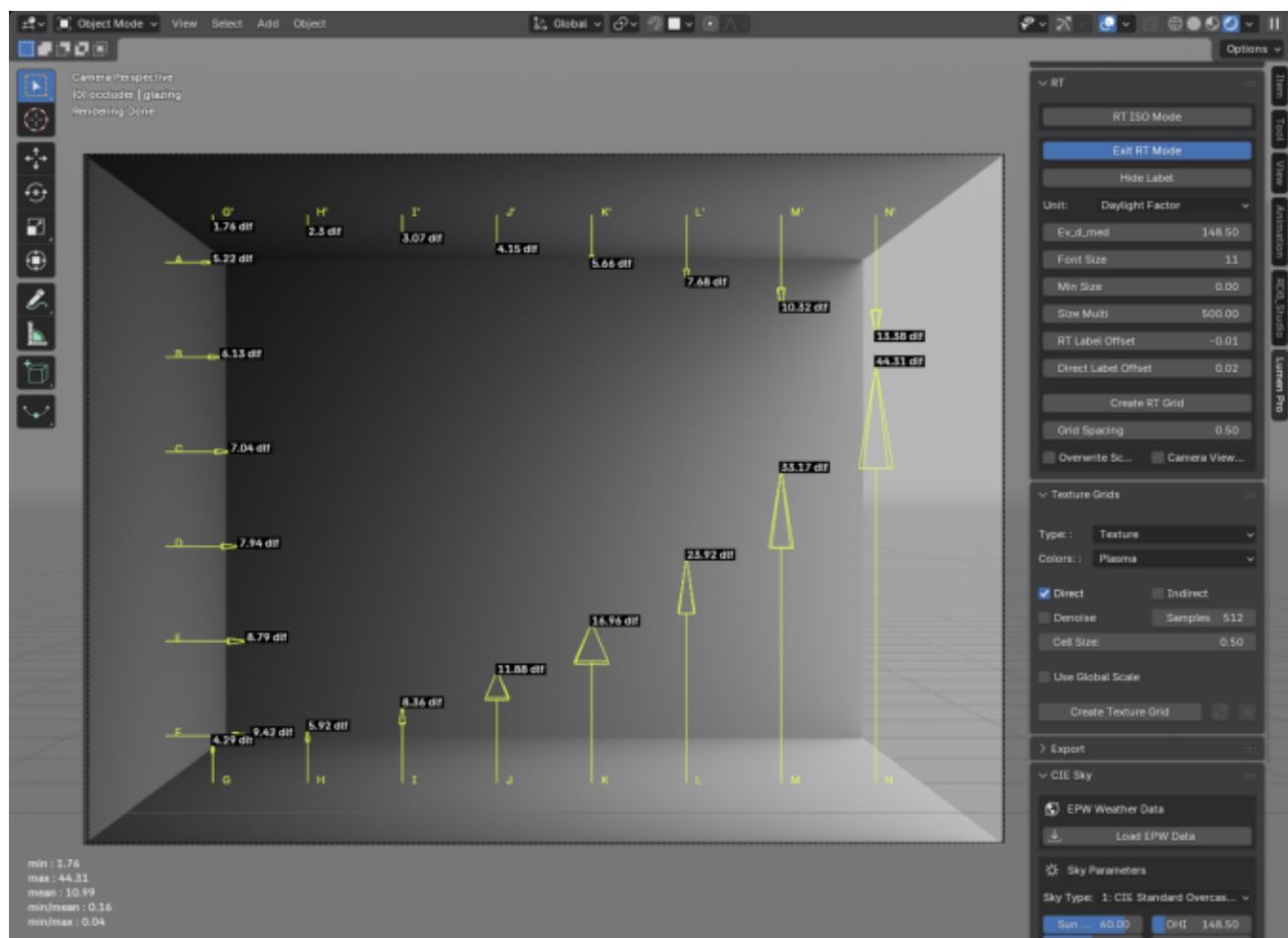
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.11.3.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x3 m vertical facade opening

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.11.3.2 describes a square room 4 x 4 m and 3 m high with the whole vertical facade open (opening of 4 x 3 m, CIE general sky type 1). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. The exterior ground is assumed to have a reflectance of 0.30. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N plus the extended grid G' to N', and compared with the analytical reference values of CIE 171:2006.

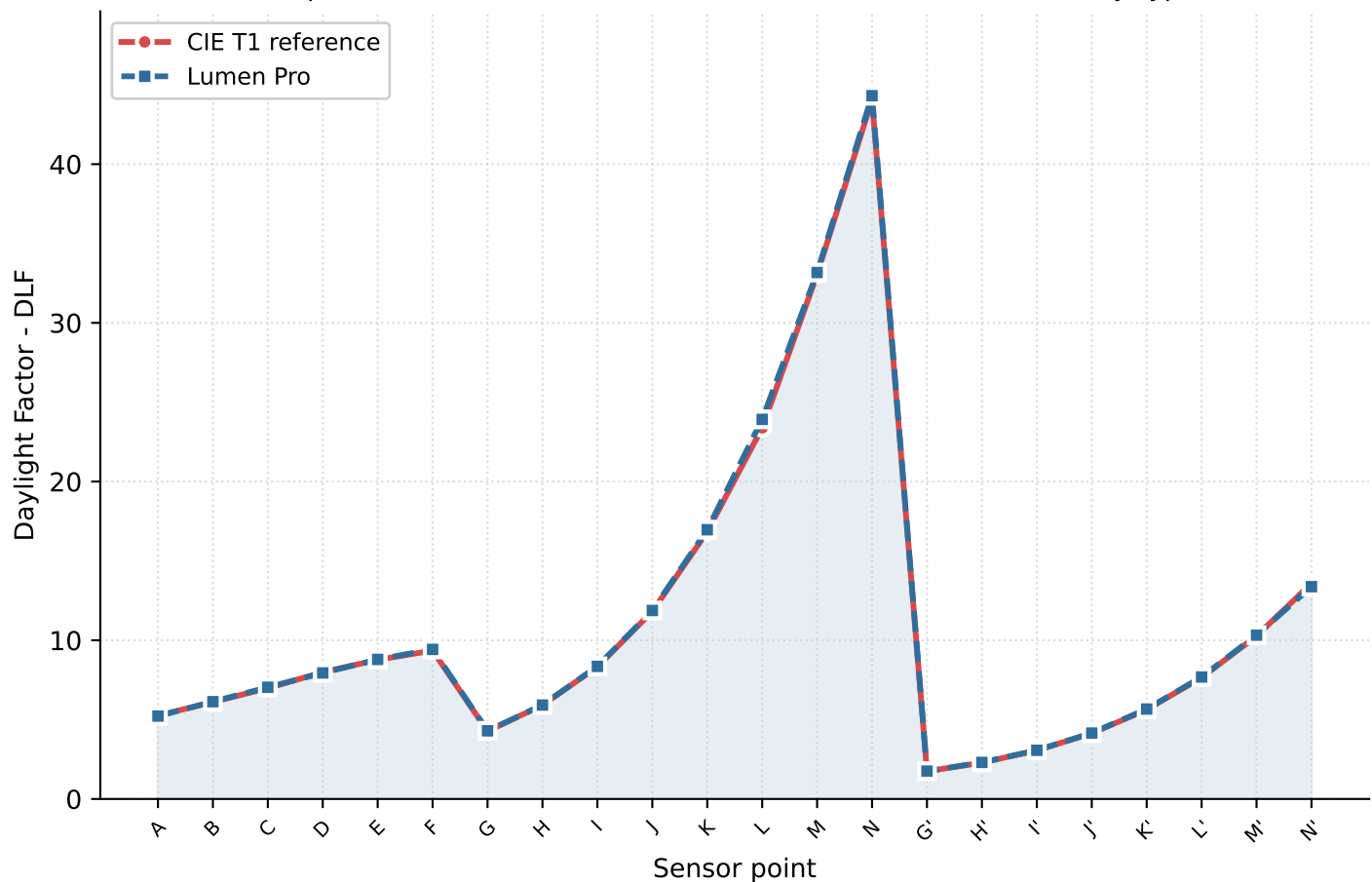


Test model 5.11.3.2 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.11.3.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x3 m vertical facade opening

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N	G'	H'	I'	J'	K'	L'	M'	N'
CIE T1 reference	5.25	6.11	6.98	7.99	8.77	9.35	4.27	5.92	8.33	11.82	16.84	23.38	33.05	44.06	1.74	2.29	3.06	4.14	5.63	7.65	10.27	13.59
Lumen	5.22	6.13	7.04	7.94	8.79	9.42	4.29	5.92	8.36	11.88	16.96	23.92	33.17	44.31	1.76	2.30	3.07	4.15	5.66	7.68	10.32	13.38
Deviation	-0.03	+0.02	+0.06	-0.05	+0.02	+0.07	+0.02	-0.00	+0.03	+0.06	+0.12	+0.54	+0.12	+0.25	+0.02	+0.01	+0.01	+0.01	+0.03	+0.03	+0.05	-0.21

Comparison between calculated and reference DLF values - CIE Sky Type 1



Accuracy indicators

Calculation points : 22 MAE : 0.081 RMSE : 0.143 Mean rel. dev. : 0.63 Max rel. dev. : 2.30

Result

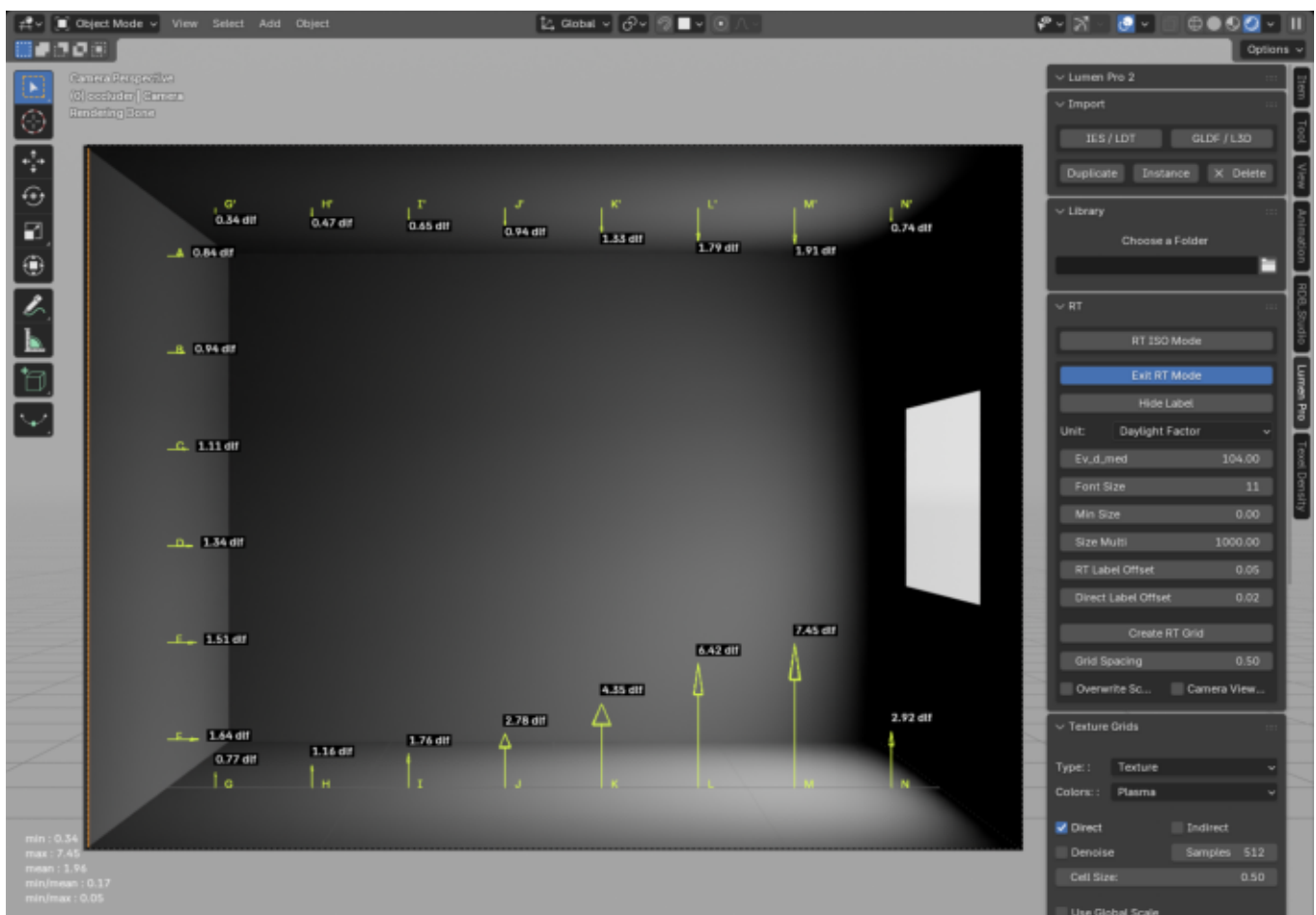
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.12.3.1 - Daylight Factor (%) - CIE Sky Type 1 - 2x1 m glazing (vertical facade opening, 6 mm - T 0.88)

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.12.3.1 describes a square room 4 x 4 m and 3 m high with an opening of 2 x 1 m in a vertical facade, fitted with a 6 mm glazing with a transmission factor of 0.88 (CIE general sky type 1). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. The exterior ground is assumed to have a reflectance of 0.30. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N plus the extended grid G' to N', and compared with the analytical reference values of CIE 171:2006.

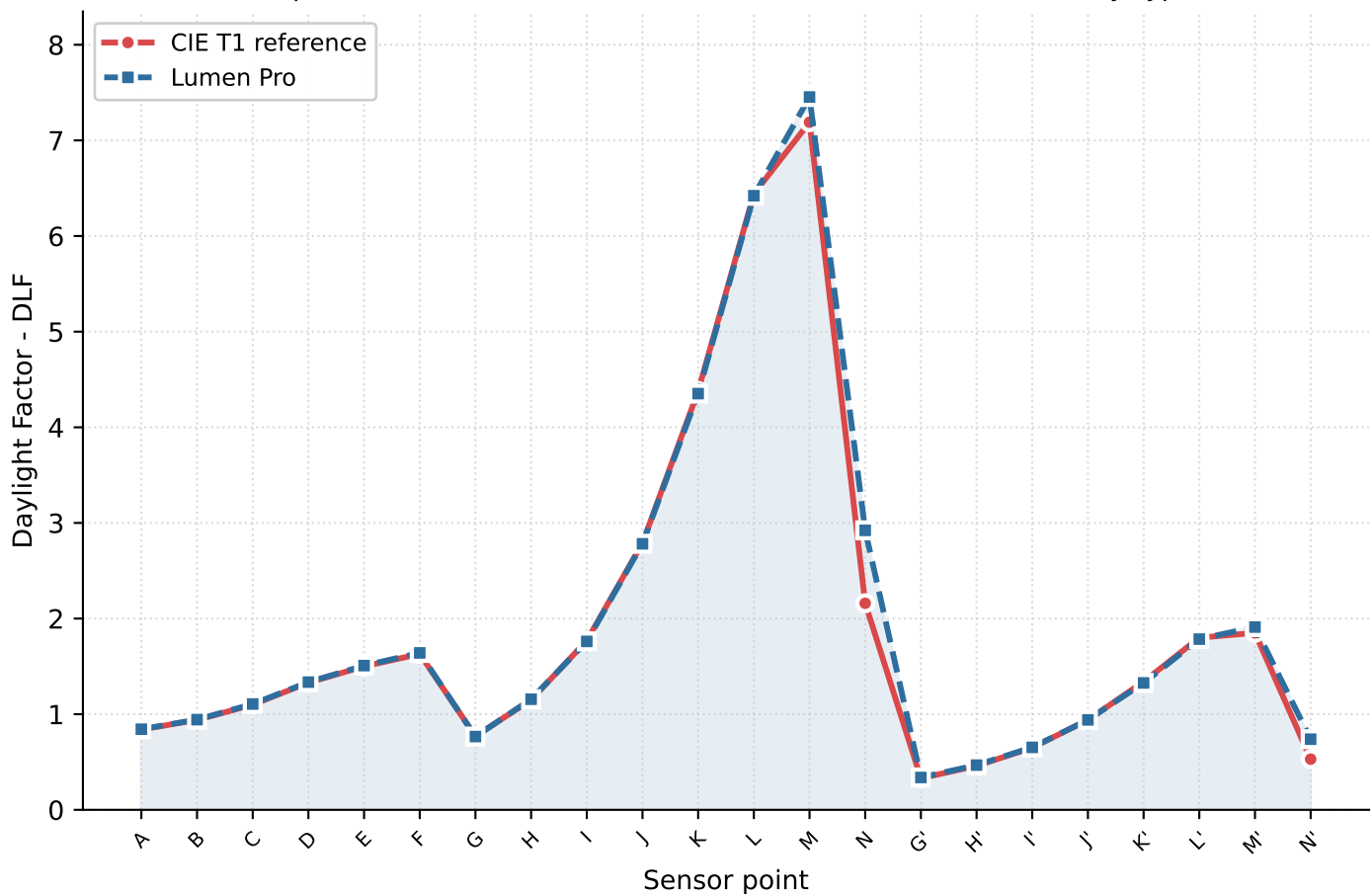


Test model 5.12.3.1 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.12.3.1 - Daylight Factor (%) - CIE Sky Type 1 - 2x1 m glazing (vertical facade opening, 6 mm - T 0.88)

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N	G'	H'	I'	J'	K'	L'	M'	N'
CIE T1 reference	0.84	0.94	1.10	1.33	1.50	1.63	0.77	1.15	1.77	2.79	4.38	6.44	7.19	2.16	0.33	0.46	0.65	0.94	1.34	1.80	1.85	0.53
Lumen	0.84	0.94	1.11	1.34	1.51	1.64	0.77	1.16	1.76	2.78	4.35	6.42	7.45	2.92	0.34	0.47	0.65	0.94	1.33	1.79	1.91	0.74
Deviation	+0.00	+0.00	+0.01	+0.01	+0.01	+0.01	-0.00	+0.01	-0.01	-0.01	-0.03	-0.02	+0.26	+0.76	+0.01	+0.01	+0.00	+0.00	-0.01	-0.01	+0.06	+0.21

Comparison between calculated and reference DLF values - CIE Sky Type 1



Accuracy indicators

Calculation points : 22 MAE : 0.066 RMSE : 0.178 Mean rel. dev. : 4.27 Max rel. dev. : 39.37

Result

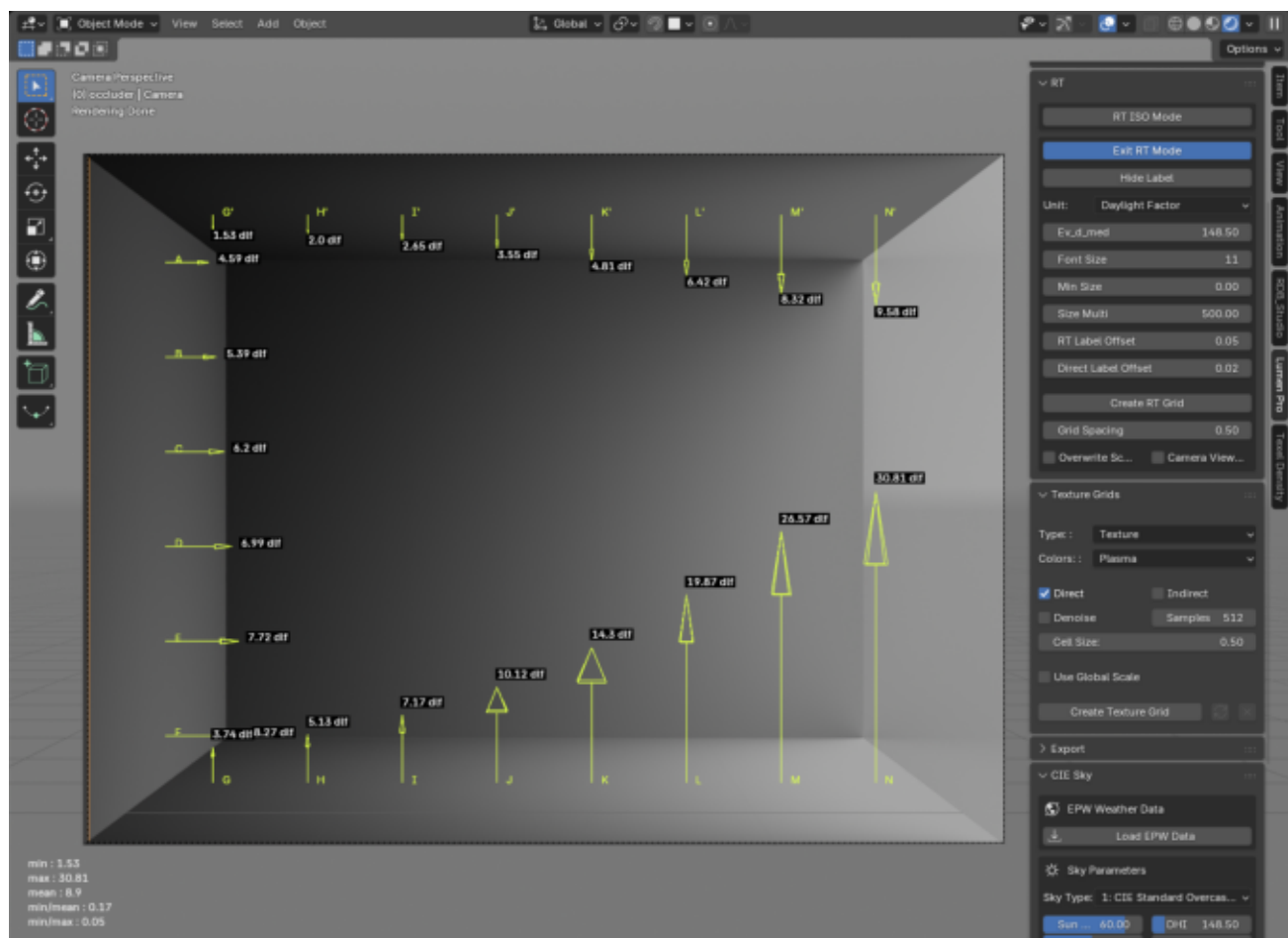
Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.

Test 5.12.3.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x3 m glazing (vertical facade opening, 6 mm - T 0.88)

CIE Sky Type 1 - reference daylight factors (analytical)

Validation Setup

Test 5.12.3.2 describes a square room 4 x 4 m and 3 m high with the whole vertical facade open (opening of 4 x 3 m), fitted with a 6 mm glazing with a transmission factor of 0.88 (CIE general sky type 1). The internal surfaces carry a 100% white diffuse BSDF shader with 0 roughness, acting as a Lambertian reflector, and the luminance is multiplied by pi to obtain the illuminance at the calculation points. The exterior ground is assumed to have a reflectance of 0.30. Only direct light is used (0 bounces), rendered with 512 samples and denoising. The daylight factor is calculated at calculation points A to N plus the extended grid G' to N', and compared with the analytical reference values of CIE 171:2006.

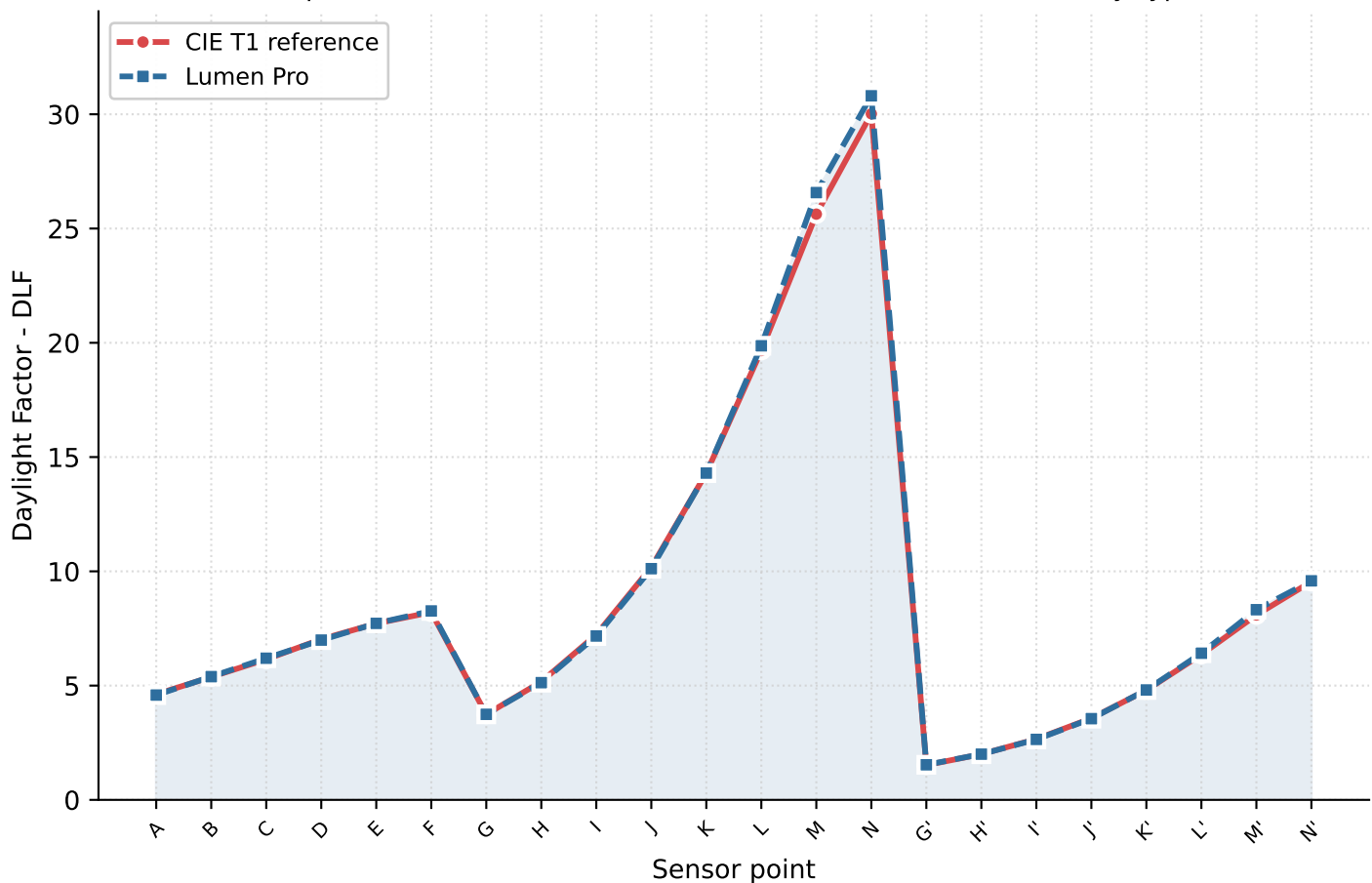


Test model 5.12.3.2 - Document CIE 171:2006 (Lumen Pro 3D view)

Test 5.12.3.2 - Daylight Factor (%) - CIE Sky Type 1 - 4x3 m glazing (vertical facade opening, 6 mm - T 0.88)

Calculation point	A	B	C	D	E	F	G	H	I	J	K	L	M	N	G'	H'	I'	J'	K'	L'	M'	N'
CIE T1 reference	4.62	5.38	6.15	7.03	7.72	8.21	3.74	5.17	7.23	10.18	14.30	19.66	25.63	30.02	1.52	2.00	2.66	3.57	4.80	6.36	8.09	9.55
Lumen	4.59	5.39	6.20	6.99	7.72	8.27	3.74	5.13	7.17	10.12	14.30	19.87	26.57	30.81	1.53	2.00	2.65	3.55	4.81	6.42	8.32	9.58
Deviation	-0.03	+0.01	+0.05	-0.04	+0.00	+0.06	+0.00	-0.04	-0.06	-0.06	-0.00	+0.21	+0.94	+0.79	+0.01	-0.00	-0.01	-0.02	+0.01	+0.06	+0.23	+0.03

Comparison between calculated and reference DLF values - CIE Sky Type 1



Accuracy indicators

Calculation points : 22 MAE : 0.122 RMSE : 0.272 Mean rel. dev. : 0.86 Max rel. dev. : 3.68

Result

Results are very close to the analytical reference; the measured daylight factors match the CIE 171:2006 values within a few percent.