Investigation of potential energy savings due to manual switching of lights (at half-power) for the entire floor of an office building

EXECUTIVE SUMMARY REPORT

Prepared for:
Functional Devices Inc.

Prepared by:
Dr. Thanos Tzempelikos, M.A.Sc. Ph.D.
Assistant Professor, School of Civil Engineering
Purdue University

October 2009

Introduction

This report contains the summary and the results of a study about the potential energy savings due to manual switching of lights (at half power) for the entire floor of a medium-size office building in Chicago. Lighting control can result in significant energy savings, especially in commercial buildings with large glass facades. With automated systems, lights should turn off or dim at a lower level when the available natural light on the work plane exceeds a pre-determined target value (usually around 500 lx or 43 fc). However, the occupants' involvement is neglected in most of the computational software and standard energy calculations. Occupants tend to override the automated system and change their lighting environment without necessarily following a specific pattern. Occupant switching behavior is complicated and it depends, except for the individual personality, on the available daylight, time of the day, type of electric lighting, type of switch and location relative to the closest windows. Recent studies have dealt with the problem of identifying occupant light switching preferences. Some of these studies (listed in the reference section) focused on the probability that people will switch on or switch off lights.

The present study took into account the findings of previous work on this topic and took occupant switching patterns into account for a realistic estimation of potential energy savings in a typical office space (entire floor). The building layout is presented in Figure 1. There are perimeter zones and core zones, as well as conference (meeting) rooms on the corners. Occupants seated near the perimeter experience higher exposure to daylight and therefore the switching probability will be higher. People seated in the core of the building have limited access to daylight and therefore switching off lights is less frequent. The office consists of cubicles (individual workstations) in the perimeter and in the core zones, and there is an open area on the south side (main entrance zone). The total office space is 9000 ft^2, from which 3100 ft^2 are perimeter zones, 3900 ft^2 are interior zones and 2000 ft^2 are corridors and general use spaces. The work schedule is from 8am to 6pm.

The sides are covered (70%) by windows (double glazed with a low-emissivity coating) and normal transmittance equal to 30% (this value represents a medium-tinted glass or a shading device to simulate realistic situation –if the windows are more transparent, the energy savings will be higher than those presented in this study). Lighting was modeled as series of T-8 fluorescent lamps (2' x 4'), in all workstations. In order to achieve 450 lux on the work plane, the average lighting power density was 1.4W/ft^2.

The method followed consists of the following steps:

1. Prediction of work plane illuminance (natural light) on each hour of the year
2. Calculation of people (%) switching on/off lights using behavioral models
3. Calculation of occupant-area averaged lighting energy use with manual switching for the perimeter and the core areas
4. Calculation of the potential energy savings due to manual switching of lights

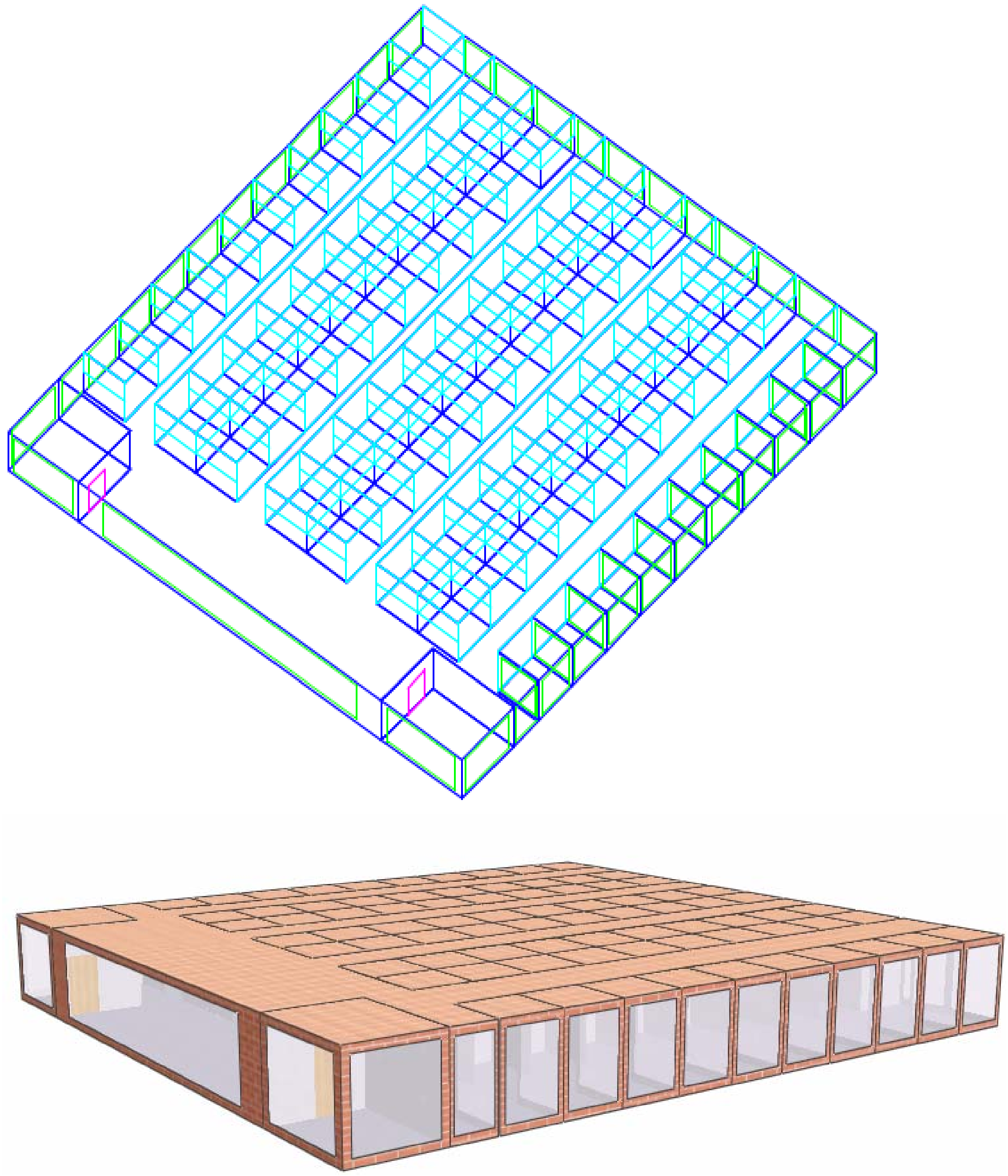


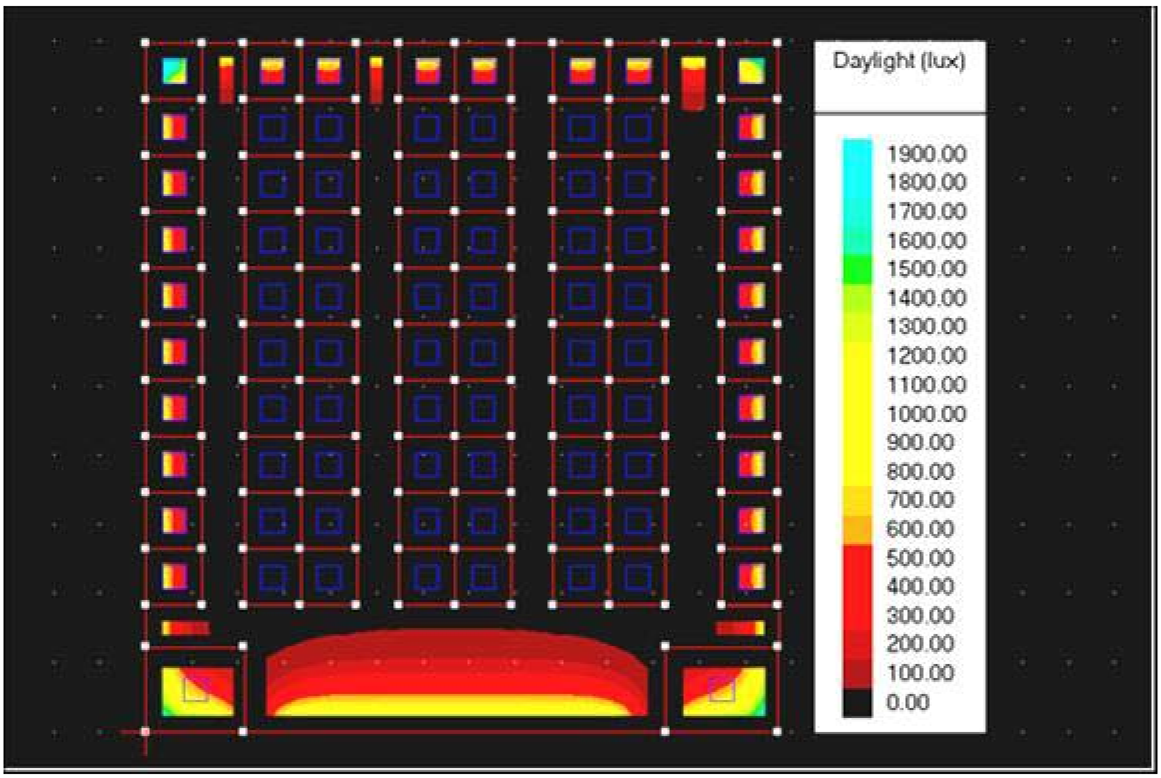
Figure 1. Schematics of the office floor and space layout.

1. Prediction of work plane illuminance (daylight) in all spaces

Daylight availability was calculated based on the state-of-the-art Perez et al model (Perez, 1992), using the hourly weather statistical data for Chicago, IL. The model uses the hourly data to calculate hourly direct and diffuse solar radiation on each tilted (vertical) surface of the building, and then hourly illuminance on the exterior is computed

from the Perez model, which takes into account anisotropic sky distributions throughout the year.
Then the transmitted daylight on each of the spaces was calculated using the optical properties of the windows. The ray-tracing technique of Radiance (LBNL, 2000) was finally used to calculate natural light levels on a pre-selected grid on the work plane (0.85m or 2.6 ft from the floor). This method takes into account reflected light from all surrounding surfaces and transmitted light through openings (above cubicle separators) into other adjacent rooms.

Hourly daylight values are needed to calculate the total lighting levels in each space (including electric lighting) and input this information in the probabilistic models for occupant behavior, as explained below. An example of work plane illuminance distribution in all perimeter zones on March 21st is shown in Figure 2.



Due to the large number of data (8760 hours in the year for each space), a monthly average was calculated for each hour of each month, using the simulation results for the perimeter zones and the core zones separately. Figure 3 shows the averaged natural lighting levels for the perimeter zones: The vertical axis is the hour of the day and the horizontal axis is the month number (Jan-Dec). Higher daylight levels are observed around noon, and around summer and shoulder seasons, as expected. Figure 4 shows the respective results for the interior (core) spaces, which are of course exposed to less natural light (the highest daylight levels in the core reach 120 lux in the summer around noon).

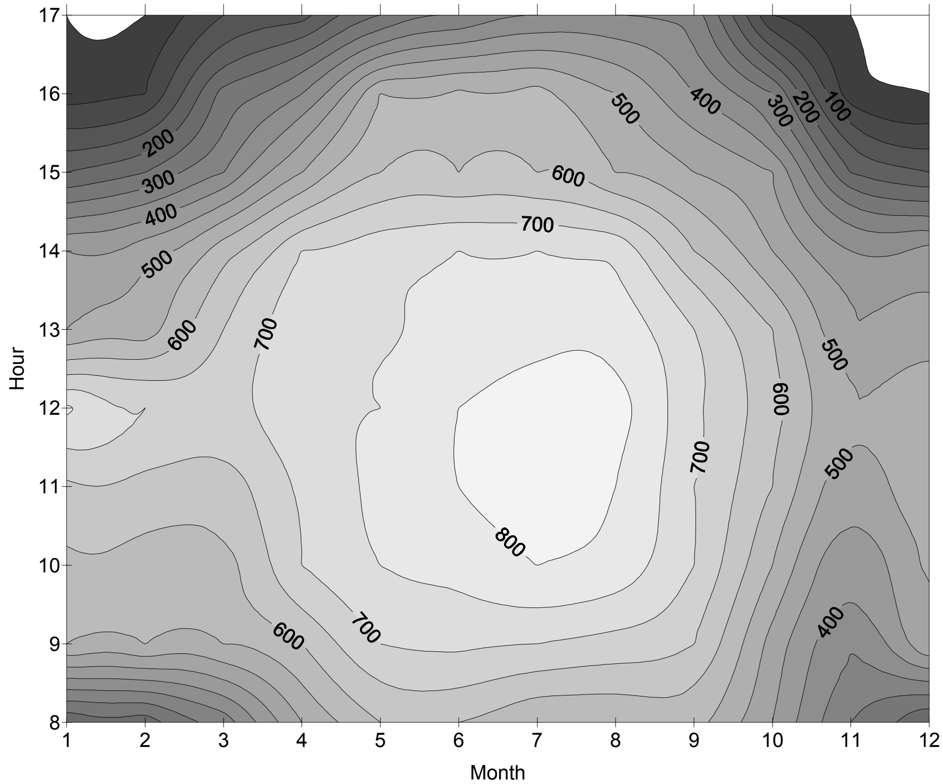


Figure 3. Average daylight levels (lux) in the perimeter zones throughout the year.

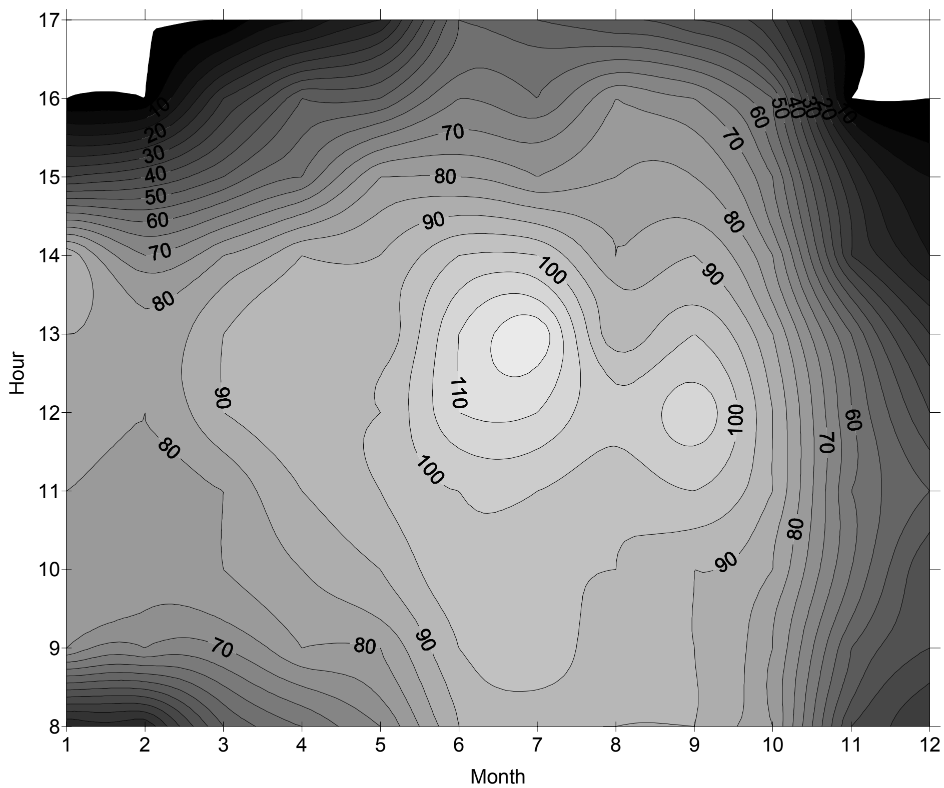


Figure 4. Average daylight levels (lux) in the core zones throughout the year.

2. Behavioral patterns and calculation of people (%) switching off lights using behavioral models

The first study of behavioral patterns of occupants interacting with lighting systems started in 1979 by Hunt. The switch-on probability (probability of people switching on electric lights) was computed as a function of minimum work plane illuminance. Many other studies resulted in similar results during the last decade. Figure 5 shows the results for switch-on probability. This curve will be used to estimate the percentage of people switching lights on at arrival.

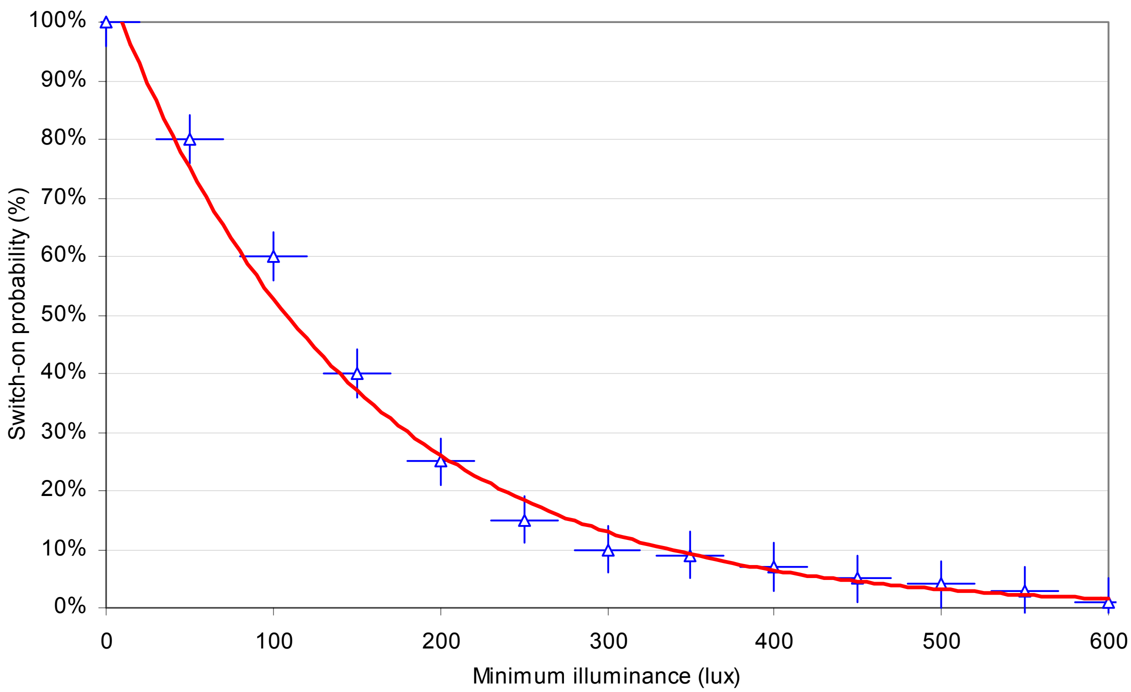


Figure 5. Switch-on probability based on the studies of Hunt and Lamparter.

The following equation describes the curve of Figure 5 with very good accuracy (R^2= 0.98):

$$\%\ \text{switch on} = 1.0695 \cdot e^{-0.0071 \cdot wpi}$$

where "wpi" is the work plane illuminance.

However, for the present study, it is also important to calculate the switch-off probability. Assuming that the lights will be on by the time of arrival, the switch-off probability will show the percentage of people who would switch off electric lights, depending on the available natural light levels. More recently, a few researchers have worked on this topic and produced relationships for the switch-off probability, based on real measurements and field studies. Boyce et al. (2006) conducted a study with more than 33 people in individual workstations. The switch off probability (data points with error bars every 100 lux bins) as a function of work plane available illuminance is shown in Figure 6. This data was used in the present study, approximated by a polynomial regression curve (red line).

The best polynomial regression curve as achieved using a 5^{th}-degree polynomial. After smoothing the curve, the probability that a person will switch off electric lighting(or the percentage of people who would switch off lights) is a function of work plane illuminance (wpi) and has the following form:

$$\text{\% switch off} = -5.885 \cdot 10^{-14} \cdot wpi^5 + 1.511 \cdot 10^{-11} \cdot wpi^4 + 6.493 \cdot 10^{-8} \cdot wpi^3 + 2.273 \cdot 10^{-6} \cdot wpi^2 + 1.615 \cdot 10^{-8} \cdot wpi + 8.339 \cdot 10^{-11}$$

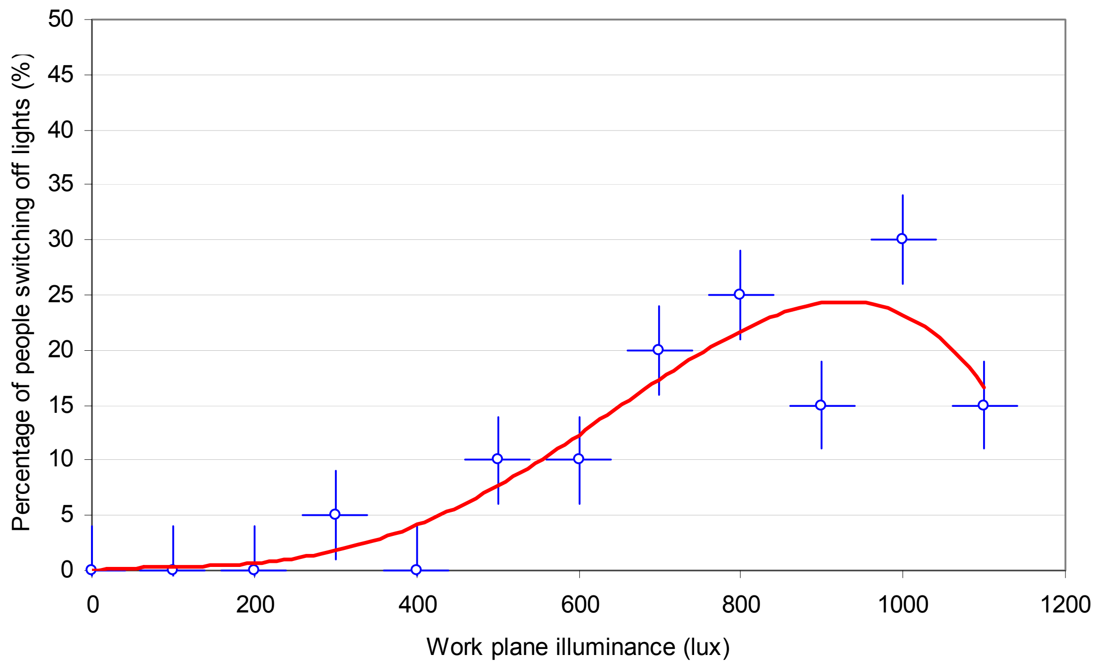


Figure 6. Probability of switching-off lights as a function of work plane illuminance.

3. Calculation of occupant-area averaged lighting energy use with manual switching for the perimeter and the core areas

The switch-on and switch-off probability functions were used in the calculations for prediction of resulting work plane illuminance in the perimeter and core areas (separately) as follows. First, the average natural light levels from step 1 are input in the model. At 8am (arrival time), all the lights are assumed to be 50% on (using a lighting management system), so the additional 450/2=225 lux from electric lighting are added to the natural light levels, to calculate the total (natural and artificial) lighting levels on the work plane.

The total lighting levels are then used in the switch-on and switch-off probability functions, to estimate the percentage of people who would switch lights at 100% power or switch off lights within that hour respectively.

If x% switch lights on (at full power), and y% turn lights off, then (1-x-y)% keep the lights at 50% power. The realistic lighting levels during the next hours are computed by taking into account the actions during the previous times.

The resulting distribution of occupants switching lights on or off is equivalent to the distribution of average illuminance at 9am in each space, considering the change in lighting levels when lights are switched. In other words, the work plane illuminance at 9am is equal to the available daylight at 9am plus the electric lighting levels calculated based on the percentage of people switching lights on (electric lighting levels at 450 lux), the percentage of people switching lights off, as well as the % of people who did not change electric lighting levels (remaining at 225 lux) before 9am.

Based on the work plane illuminance at 9am, the switch-on and switch-off probabilities are calculated based on the natural illuminance distributions at 10am and the process continues for each hour in the day, for the 12 months, for both perimeter and interior zones. The model takes into account the percentage of people who switch lights from 0 to 50%, from 50% to100%, as well as from 100% to 50% and from 50% to zero for each hour. Appendix A presents the analytical results. Figures 7-9 show the average percentage of people switching lights on, off, or not changing the light levels respectively, for each hour in the year for the perimeter zones. Figures 10-12 present the same results for the core (interior zones).

4. Calculation of the potential energy savings due to manual switching of lights

Based on the above results, the lighting energy use is calculated as the weighted average of the percentage of switched-on, switched-off and maintained-levels lights in each area (also shown in Appendix A) for each hour. **The lighting energy savings (compared to no lighting control) are due to the percentage of people who (i) do not turn lights at full power because they are relatively comfortable with natural light levels and lights at 50% and (ii) switch lights off depending on available natural light.** These percentages are multiplied by the respective areas (for perimeter and core) and by the total number of hours for the year. Figs. 13 and 14 present the respective energy savings from manual light switching. Savings reach 57% for perimeter zones and 45% for interior darker zones, resulting in an average of 50% for the entire floor. Automatic stepped dimming control only achieves 24% savings for the perimeter zones or 10% for the entire floor.

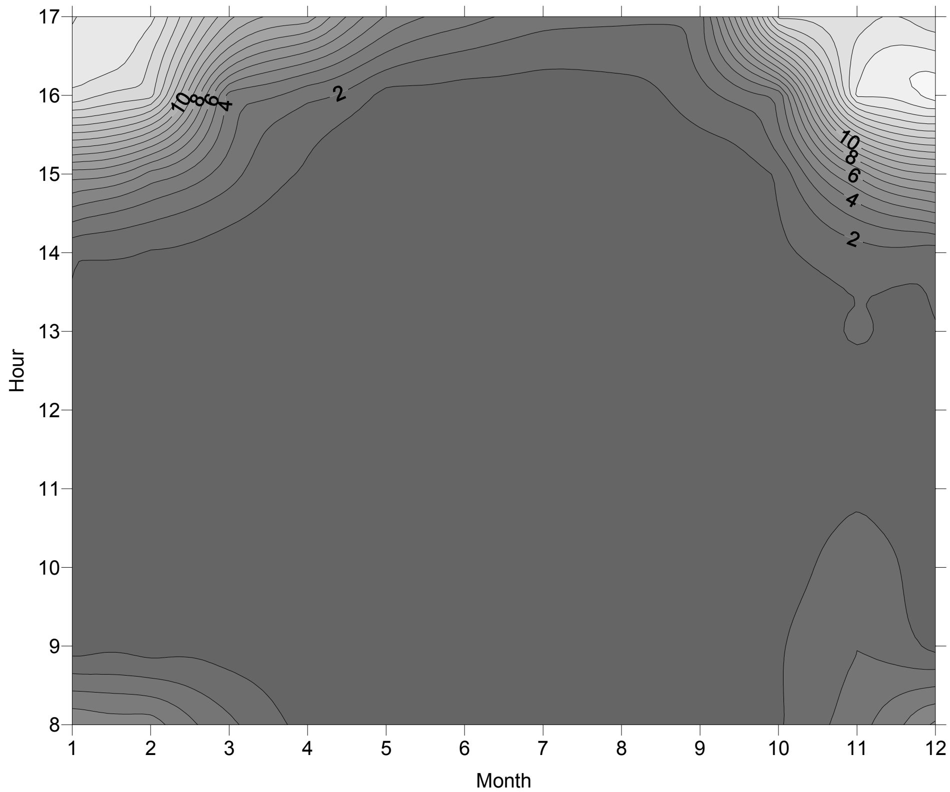


Figure 7. Percentage of people (%) switching lights on for every hour in the year (monthly average) for the perimeter zones.

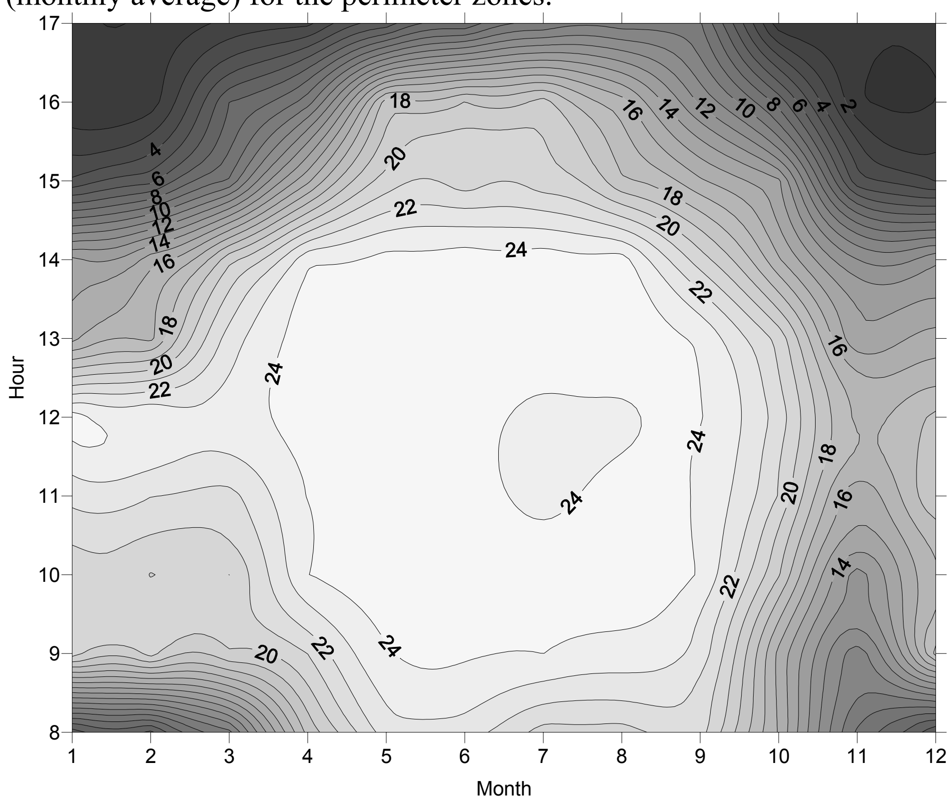


Figure 8. Percentage of people (%) switching lights off for every hour in the year (monthly average) for the perimeter zones.

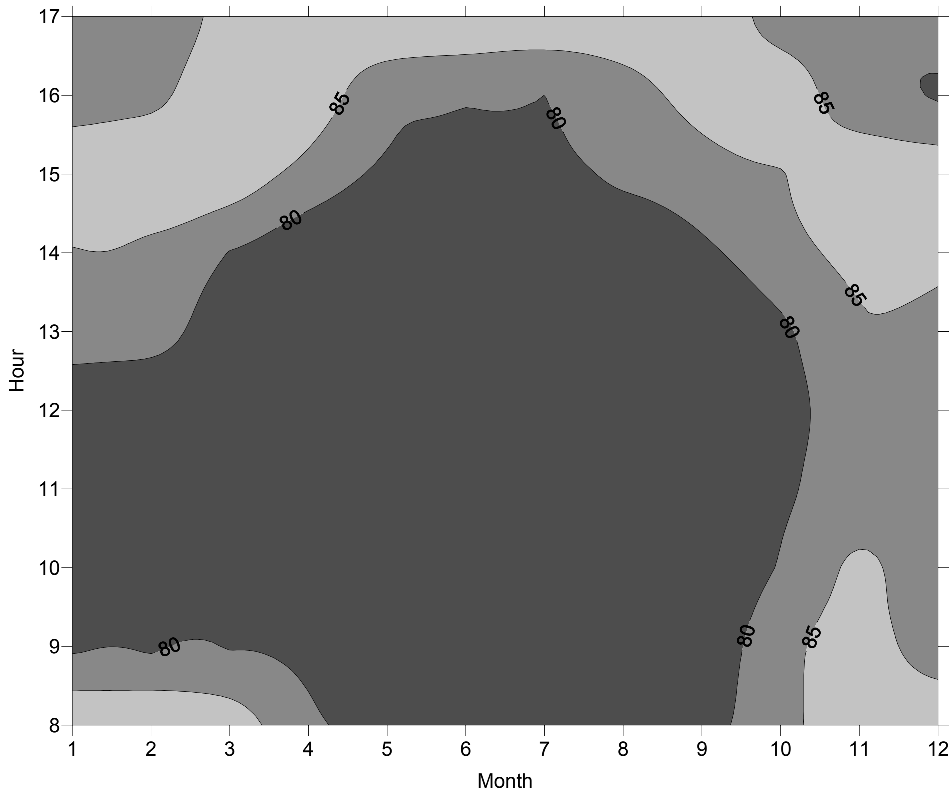


Figure 9. Percentage of people (%) not switching lights (on or off) for every hour in the year (monthly average) for the perimeter zones.

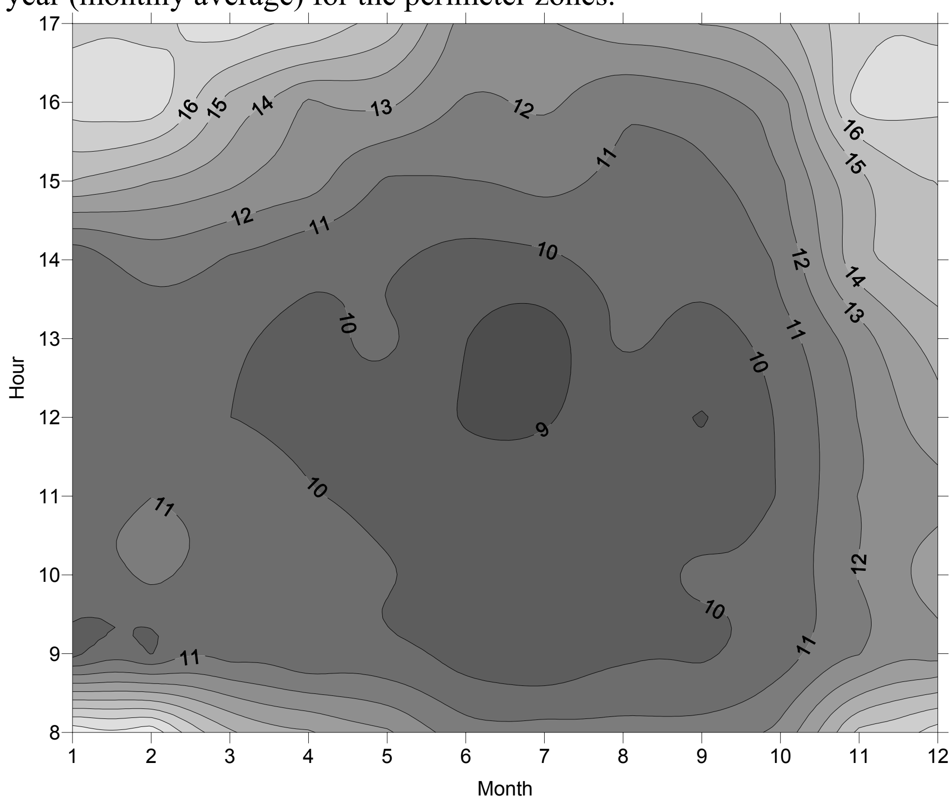


Figure 10. Percentage of people (%) switching lights on for every hour in the year (monthly average) for the interior zones.

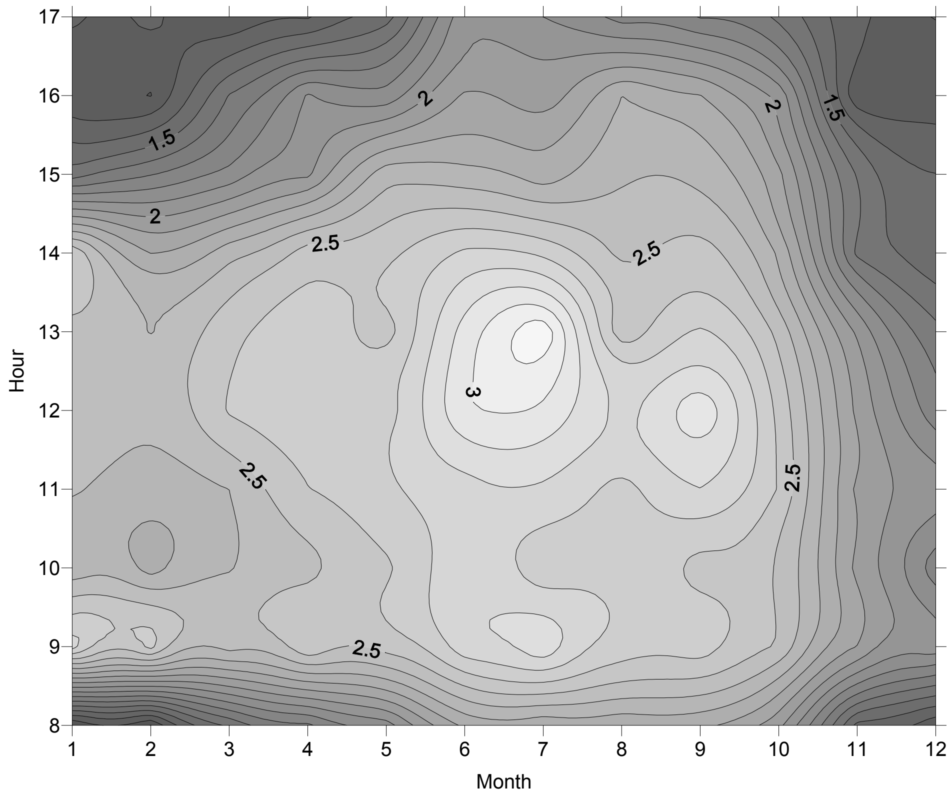


Figure 11. Percentage of people (%) switching lights off for every hour in the year (monthly average) for the interior zones.

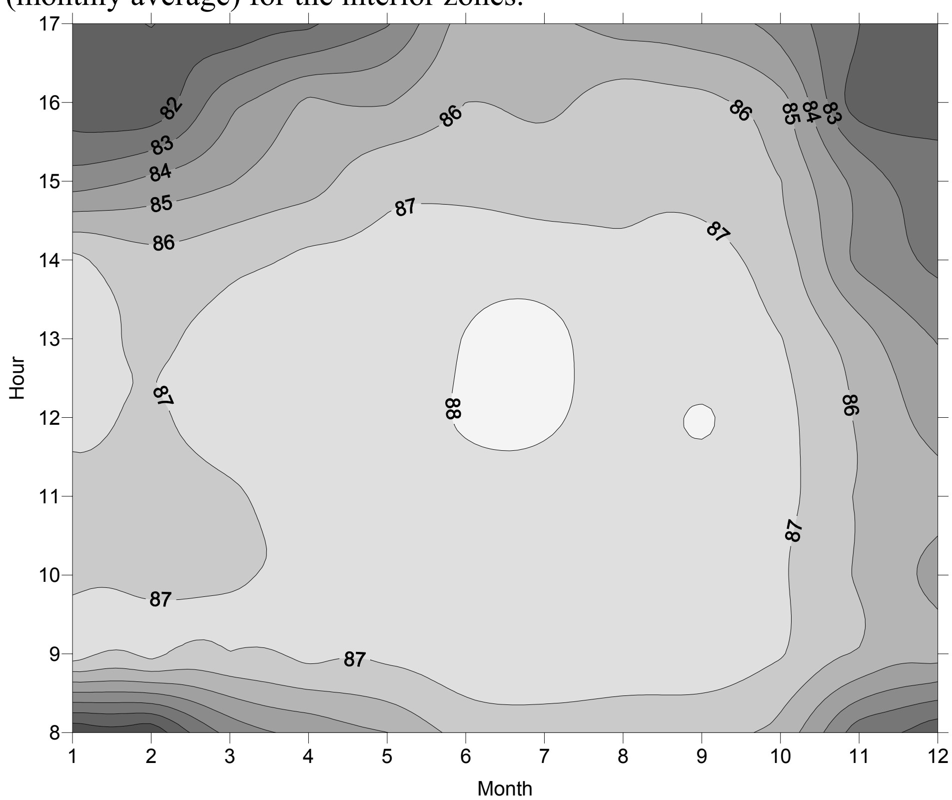


Figure 12. Percentage of people (%) not switching lights (on or off) for every hour in the year (monthly average) for the interior zones.

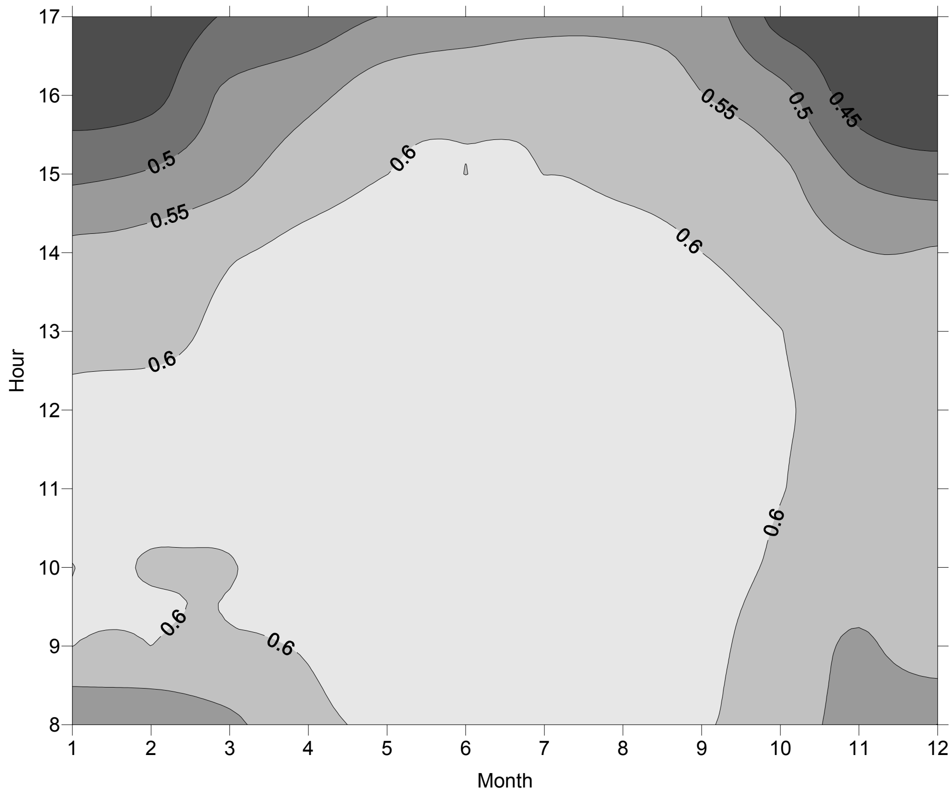


Figure 13. Realistic energy savings due to manual light switching throughout the year for the perimeter zones. Values are percentages (e.g. 0.5 = 50% savings).

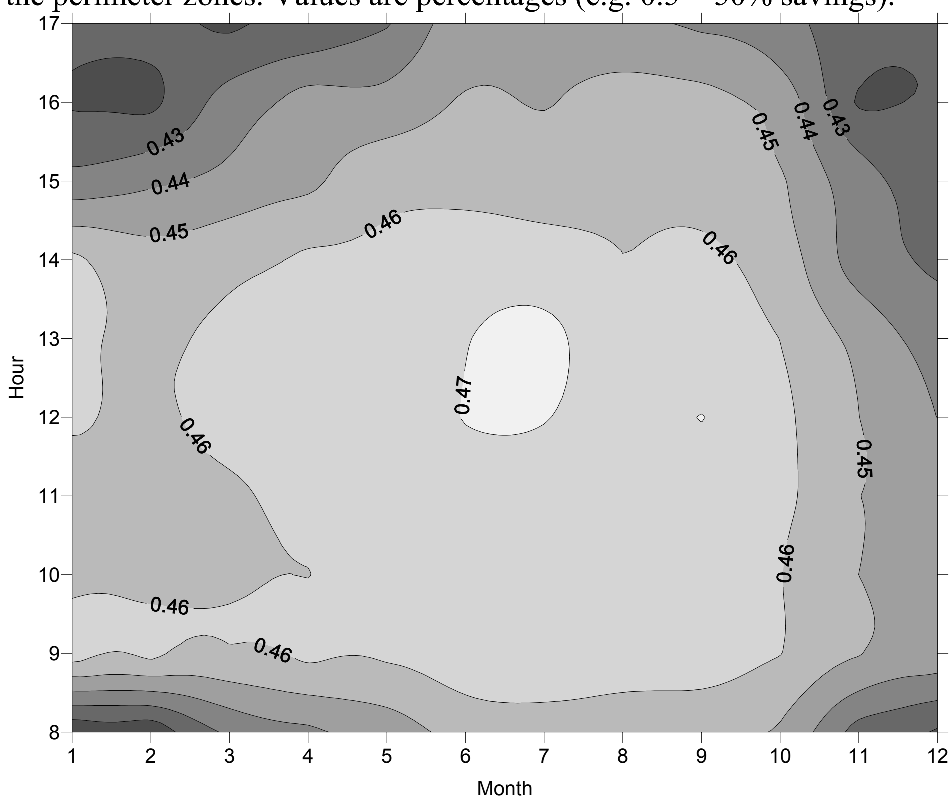


Figure 14. Realistic energy savings due to manual light switching throughout the year for the interior (core) zones. Values are percentages (e.g. 0.5 = 50% savings).

The energy savings using manual switching for the perimeter zones, the interior zones and the entire floor are summarized in Table 1. The results are also compared with theoretical automated stepped lighting control (also shown in Appendix A), which assumes that lights are dimmed to 50% when natural lights levels exceed 500 lux.

Table 1. Comparison of energy savings for different zones and control modes

	Perimeter zones	Core zones	Entire floor
Lighting energy consumption (no controls/switching) (kWhrs)	11457	14414	25871
Lighting energy consumption with manual switching (kWhrs)	4905	7915	12820
Realistic energy savings with manual switching (%)	57%	45.1%	50.3%
Lighting energy consumption with theoretical automatic stepped dimming (kWhrs)	8689	14414	23103
Theoretical energy savings with automatic stepped dimming (%)	24%	0%	10.6%

Conclusion

This study showed the realistic energy savings due to manual light switching (0, 50% and 100% power) for the entire floor of an office building in Chicago. The space was separated in perimeter and core zones for differentiation of the results and better understanding of where the energy savings come from. Behavioral models for light switching were used in the analysis. The percentage of people switching lights was input to the daylighting and energy model, which predicted occupant-area averaged resulting work plane illuminance for each space on each hour of each month. The results showed that realistic lighting energy savings for perimeter zones reach almost 57%, where for the core darker zones 45%. Theoretical savings due to automatic stepped dimming reach 24% for perimeter and zero for the core zones. Considering the potential low price of the switching system, the manual switching system is a very attractive option for offices.

References

- Perez R., Ineichen P., Seals R., Michalsky J., Stewart R., "Modeling daylight availability and irradiance components from direct and global irradiance", Solar Energy, Vol. 44 (5), 1990 and 1992.
- LBNL, Radiance software manual, 2004.
- IES-VE 5.9 software, 2008.
- Nicol F., Wilson M., Chiancarella C., "Using field measurements of desktop illuminance in European offices to investigate its dependence on outdoor conditions and its effect on occupant satisfaction, and the use of lights and blinds", Energy and Buildings, Vol. 38, 2006.
- Lindelof L., Morel M., "A field investigation of the intermediate light switching by users", Energy and Buildings, Vol. 38 (2006).
- Boyce,P.R.,Veitch,J.A.,Newsham,G.R.,Jones,C.C.;Heerwagen,J.,Myer, M.., Hunter, C. M., "Occupant use of switching and dimming controls in offices", Lighting Research and Technology, Vol. 38, 2006.
- Hunt D.R.G., "The use of artificial lighting in relation to daylight levels and occupancy", Building and Environment, Vol. 14, 1979.

APPENDIX A. MODELING DATA AND RESULTS TABLES

1. Results for perimeter zones

Month	Hour	Work plane illuminance (daylight) (lux)	Work plane illuminance (electric lights) (lux)	% of people switching lights off	% of people switching lights on	% of people not switching lights	Energy consumption with manual switching (KWhrs)	Energy consumption without control/switching (kWhrs)	Energy consumption with automated stepped control (kWhrs)
1	8	210	225	5.40	4.87	89.73	47.49	95.48	95.48
2	8	220	225	5.74	4.54	89.72	47.17	95.48	95.48
3	8	320	225	9.69	2.23	88.08	44.18	95.48	95.48
4	8	500	225	18.32	0.62	81.05	39.29	95.48	95.48
5	8	600	225	22.51	0.31	77.18	37.14	95.48	47.74
6	8	600	225	22.51	0.31	77.18	37.14	95.48	47.74
7	8	550	225	20.59	0.44	78.98	38.12	95.48	95.48
8	8	550	225	20.59	0.44	78.98	38.12	95.48	95.48
9	8	570	225	21.41	0.38	78.21	37.70	95.48	47.74
10	8	450	225	15.89	0.89	83.22	40.58	95.48	95.48
11	8	300	225	8.82	2.57	88.60	44.76	95.48	95.48
12	8	200	225	5.07	5.23	89.70	47.82	95.48	95.48
1	9	550	224	20.54	0.44	79.02	38.15	95.48	95.48
2	9	550	222	20.47	0.44	79.08	38.18	95.48	95.48
3	9	550	208	19.86	0.49	79.65	38.50	95.48	95.48
4	9	600	185	21.01	0.41	78.58	37.90	95.48	47.74
5	9	700	175	23.91	0.21	75.87	36.43	95.48	47.74
6	9	710	175	24.11	0.20	75.69	36.33	95.48	47.74
7	9	700	180	24.01	0.21	75.79	36.38	95.48	47.74
8	9	680	180	23.55	0.24	76.21	36.61	95.48	47.74
9	9	650	178	22.60	0.30	77.10	37.09	95.48	47.74
10	9	480	191	15.71	0.91	83.38	40.68	95.48	95.48
11	9	350	211	10.40	1.99	87.60	43.73	95.48	95.48
12	9	500	225	18.34	0.62	81.04	39.28	95.48	95.48
1	10	590	180	20.36	0.45	79.18	38.23	95.48	47.74
2	10	580	180	19.93	0.49	79.58	38.46	95.48	47.74

3	10	580	181	20.00	0.48	79.52	38.42	95.48	47.74
4	10	700	179	23.99	0.21	75.81	36.39	95.48	47.74
5	10	750	172	24.53	0.15	75.32	36.10	95.48	47.74
6	10	760	171	24.56	0.14	75.30	36.09	95.48	47.74
7	10	800	171	24.21	0.11	75.68	36.23	95.48	47.74
8	10	780	173	24.47	0.12	75.41	36.12	95.48	47.74
9	10	700	175	23.91	0.21	75.88	36.43	95.48	47.74
10	10	550	192	19.11	0.55	80.34	38.88	95.48	95.48
11	10	400	206	12.52	1.45	86.04	42.46	95.48	95.48
12	10	510	185	16.88	0.77	82.35	40.05	95.48	95.48
1	11	640	180	22.35	0.32	77.33	37.22	95.48	47.74
2	11	630	181	22.03	0.34	77.63	37.38	95.48	47.74
3	11	620	181	21.65	0.36	77.99	37.58	95.48	47.74
4	11	710	172	24.04	0.20	75.75	36.36	95.48	47.74
5	11	760	170	24.55	0.14	75.30	36.09	95.48	47.74
6	11	800	170	24.24	0.11	75.65	36.22	95.48	47.74
7	11	820	171	23.76	0.09	76.15	36.44	95.48	47.74
8	11	800	170	24.23	0.11	75.66	36.22	95.48	47.74
9	11	700	172	23.84	0.22	75.94	36.46	95.48	47.74
10	11	600	183	20.93	0.41	78.66	37.94	95.48	47.74
11	11	460	200	15.16	0.99	83.86	40.97	95.48	95.48
12	11	550	189	18.97	0.56	80.47	38.95	95.48	95.48
1	12	760	175	24.55	0.14	75.31	36.08	95.48	47.74
2	12	700	176	23.94	0.21	75.85	36.41	95.48	47.74
3	12	680	177	23.49	0.24	76.27	36.64	95.48	47.74
4	12	740	171	24.46	0.17	75.37	36.14	95.48	47.74
5	12	750	170	24.52	0.16	75.32	36.11	95.48	47.74
6	12	800	171	24.23	0.11	75.67	36.23	95.48	47.74
7	12	820	172	23.73	0.09	76.18	36.46	95.48	47.74
8	12	820	171	23.76	0.09	76.15	36.44	95.48	47.74
9	12	710	172	24.05	0.20	75.75	36.36	95.48	47.74
10	12	620	179	21.56	0.37	78.07	37.62	95.48	47.74

11	12	500	193	16.79	0.78	82.43	40.10	95.48	95.48
12	12	540	184	18.26	0.63	81.11	39.32	95.48	95.48
1	13	500	170	15.65	0.92	83.43	40.71	95.48	95.48
2	13	520	172	16.71	0.79	82.50	40.14	95.48	95.48
3	13	650	173	22.44	0.31	77.25	37.18	95.48	47.74
4	13	730	170	24.34	0.18	75.48	36.20	95.48	47.74
5	13	740	170	24.45	0.17	75.38	36.15	95.48	47.74
6	13	760	171	24.56	0.14	75.30	36.09	95.48	47.74
7	13	780	172	24.48	0.12	75.40	36.11	95.48	47.74
8	13	780	172	24.48	0.12	75.40	36.11	95.48	47.74
9	13	700	171	23.83	0.22	75.95	36.47	95.48	47.74
10	13	600	177	20.69	0.43	78.89	38.07	95.48	47.74
11	13	450	189	14.12	1.15	84.74	41.55	95.48	95.48
12	13	480	185	15.42	0.95	83.63	40.83	95.48	95.48
1	14	450	192	14.26	1.12	84.62	41.47	95.48	95.48
2	14	480	189	15.61	0.92	83.47	40.73	95.48	95.48
3	14	580	175	19.72	0.50	79.78	38.56	95.48	47.74
4	14	700	171	23.82	0.22	75.96	36.48	95.48	47.74
5	14	730	170	24.34	0.18	75.48	36.20	95.48	47.74
6	14	750	170	24.52	0.16	75.32	36.11	95.48	47.74
7	14	750	170	24.52	0.16	75.32	36.11	95.48	47.74
8	14	740	170	24.45	0.17	75.38	36.15	95.48	47.74
9	14	600	172	20.45	0.45	79.10	38.19	95.48	47.74
10	14	500	179	16.11	0.86	83.03	40.46	95.48	95.48
11	14	400	196	12.03	1.56	86.42	42.74	95.48	95.48
12	14	420	192	12.82	1.38	85.79	42.28	95.48	95.48
1	15	200	195	4.17	6.45	89.37	48.83	95.48	95.48
2	15	250	192	5.63	4.64	89.73	47.27	95.48	95.48
3	15	350	182	9.11	2.45	88.44	44.56	95.48	95.48
4	15	500	172	15.74	0.91	83.35	40.66	95.48	95.48
5	15	600	171	20.40	0.45	79.15	38.22	95.48	47.74
6	15	600	170	20.38	0.45	79.17	38.23	95.48	47.74

7	15	600	170	20.38	0.45	79.17	38.23	95.48	47.74
8	15	550	170	18.10	0.64	81.25	39.40	95.48	95.48
9	15	500	180	16.14	0.86	83.00	40.44	95.48	95.48
10	15	450	191	14.20	1.13	84.67	41.50	95.48	95.48
11	15	200	201	4.35	6.18	89.47	48.62	95.48	95.48
12	15	150	199	2.96	8.96	88.08	50.60	95.48	95.48
1	16	30	230	1.30	16.87	81.84	55.17	95.48	95.48
2	16	50	223	1.48	15.42	83.10	54.39	95.48	95.48
3	16	270	210	7.01	3.54	89.45	46.08	95.48	95.48
4	16	350	192	9.54	2.29	88.17	44.28	95.48	95.48
5	16	550	180	18.57	0.60	80.83	39.16	95.48	95.48
6	16	560	180	19.04	0.56	80.41	38.92	95.48	47.74
7	16	570	180	19.49	0.52	79.99	38.68	95.48	47.74
8	16	500	186	16.42	0.82	82.76	40.29	95.48	95.48
9	16	400	191	11.78	1.61	86.61	42.89	95.48	95.48
10	16	300	196	7.61	3.17	89.22	45.62	95.48	95.48
11	16	20	229	1.15	18.24	80.62	55.90	95.48	95.48
12	16	0	238	1.01	19.67	79.32	56.65	95.48	95.48
1	17	0	260	1.29	16.88	81.83	55.18	95.48	95.48
2	17	0	256	1.24	17.33	81.43	55.42	95.48	95.48
3	17	100	217	2.26	11.25	86.49	52.03	95.48	95.48
4	17	130	209	2.72	9.66	87.62	51.05	95.48	95.48
5	17	250	185	5.38	4.89	89.73	47.50	95.48	95.48
6	17	300	183	7.14	3.46	89.41	45.98	95.48	95.48
7	17	350	182	9.14	2.44	88.42	44.54	95.48	95.48
8	17	350	190	9.47	2.31	88.22	44.33	95.48	95.48
9	17	330	202	9.13	2.45	88.43	44.55	95.48	95.48
10	17	50	215	1.37	16.29	82.34	54.87	95.48	95.48
11	17	0	263	1.34	16.47	82.18	54.96	95.48	95.48
12	17	0	267	1.39	16.07	82.54	54.75	95.48	95.48

2. Results for interior (core) zones

Month	Hour	Work plane illuminance (daylight) (lux)	Work plane illuminance (electric lights) (lux)	% of people switching lights off	% of people switching lights on	% of people not switching lights	Energy consumption with manual switching (KWhrs)	Energy consumption without control/switching (kWhrs)	Energy consumption with automated stepped control (kWhrs)
1	8	20	225	1.1	18.78	80.1	70.7	120.1	120.1
2	8	20	225	1.1	18.78	80.1	70.7	120.1	120.1
3	8	50	225	1.5	15.18	83.3	68.3	120.1	120.1
4	8	60	225	1.7	14.14	84.2	67.5	120.1	120.1
5	8	70	225	1.8	13.17	85.0	66.9	120.1	120.1
6	8	90	225	2.2	11.43	86.4	65.6	120.1	120.1
7	8	90	225	2.2	11.43	86.4	65.6	120.1	120.1
8	8	90	225	2.2	11.43	86.4	65.6	120.1	120.1
9	8	90	225	2.2	11.43	86.4	65.6	120.1	120.1
10	8	80	225	2.0	12.27	85.7	66.2	120.1	120.1
11	8	40	225	1.4	16.30	82.3	69.0	120.1	120.1
12	8	30	225	1.2	17.49	81.3	69.8	120.1	120.1
1	9	75	265	2.7	9.58	87.7	64.2	120.1	120.1
2	9	70	265	2.6	9.93	87.4	64.4	120.1	120.1
3	9	70	256	2.4	10.59	87.0	65.0	120.1	120.1
4	9	80	253	2.6	10.05	87.4	64.5	120.1	120.1
5	9	80	250	2.5	10.24	87.2	64.7	120.1	120.1
6	9	95	246	2.8	9.52	87.7	64.1	120.1	120.1
7	9	100	246	2.9	9.19	87.9	63.8	120.1	120.1
8	9	90	246	2.7	9.86	87.5	64.4	120.1	120.1
9	9	90	246	2.7	9.86	87.5	64.4	120.1	120.1
10	9	80	248	2.5	10.42	87.1	64.8	120.1	120.1
11	9	50	259	2.1	11.96	85.9	66.0	120.1	120.1
12	9	40	262	2.0	12.57	85.5	66.4	120.1	120.1
1	10	80	240	2.3	11.00	86.7	65.3	120.1	120.1
2	10	75	241	2.2	11.31	86.4	65.5	120.1	120.1

3	10	80	243	2.4	10.77	86.8	65.1	120.1	120.1
4	10	85	242	2.5	10.51	87.0	64.9	120.1	120.1
5	10	90	242	2.6	10.10	87.3	64.6	120.1	120.1
6	10	100	240	2.8	9.55	87.7	64.1	120.1	120.1
7	10	95	239	2.6	9.97	87.4	64.5	120.1	120.1
8	10	95	241	2.7	9.83	87.5	64.4	120.1	120.1
9	10	90	241	2.6	10.18	87.3	64.6	120.1	120.1
10	10	85	243	2.5	10.43	87.1	64.8	120.1	120.1
11	10	60	247	2.1	12.08	85.9	66.1	120.1	120.1
12	10	40	249	1.7	13.76	84.5	67.3	120.1	120.1
1	11	80	245	2.4	10.68	86.9	65.0	120.1	120.1
2	11	75	245	2.3	11.00	86.7	65.3	120.1	120.1
3	11	80	244	2.4	10.73	86.9	65.1	120.1	120.1
4	11	90	243	2.6	10.05	87.4	64.5	120.1	120.1
5	11	95	242	2.7	9.78	87.5	64.3	120.1	120.1
6	11	100	240	2.8	9.55	87.7	64.1	120.1	120.1
7	11	100	242	2.8	9.46	87.8	64.1	120.1	120.1
8	11	95	241	2.7	9.83	87.5	64.4	120.1	120.1
9	11	100	242	2.8	9.42	87.8	64.0	120.1	120.1
10	11	90	243	2.6	10.06	87.3	64.5	120.1	120.1
11	11	60	248	2.1	12.05	85.9	66.0	120.1	120.1
12	11	50	252	2.0	12.53	85.5	66.4	120.1	120.1
1	12	85	244	2.5	10.37	87.1	64.8	120.1	120.1
2	12	80	245	2.4	10.68	86.9	65.0	120.1	120.1
3	12	90	244	2.6	10.00	87.4	64.5	120.1	120.1
4	12	95	242	2.7	9.79	87.5	64.3	120.1	120.1
5	12	95	241	2.7	9.85	87.5	64.4	120.1	120.1
6	12	110	240	3.0	8.89	88.1	63.6	120.1	120.1
7	12	110	240	3.0	8.91	88.1	63.6	120.1	120.1
8	12	100	241	2.8	9.49	87.7	64.1	120.1	120.1
9	12	110	240	3.0	8.92	88.1	63.6	120.1	120.1
10	12	90	242	2.6	10.14	87.3	64.6	120.1	120.1
11	12	60	247	2.1	12.06	85.9	66.1	120.1	120.1

12	12	40	249	1.7	13.77	84.5	67.3	120.1	120.1
1	13	85	243	2.5	10.44	87.1	64.8	120.1	120.1
2	13	80	244	2.4	10.75	86.9	65.1	120.1	120.1
3	13	90	242	2.6	10.15	87.3	64.6	120.1	120.1
4	13	95	241	2.7	9.84	87.5	64.4	120.1	120.1
5	13	90	241	2.6	10.19	87.3	64.6	120.1	120.1
6	13	110	238	2.9	9.02	88.0	63.7	120.1	120.1
7	13	120	238	3.2	8.40	88.4	63.2	120.1	120.1
8	13	90	240	2.5	10.26	87.2	64.7	120.1	120.1
9	13	100	238	2.7	9.68	87.6	64.2	120.1	120.1
10	13	85	242	2.5	10.49	87.0	64.9	120.1	120.1
11	13	55	247	2.0	12.49	85.5	66.4	120.1	120.1
12	13	30	252	1.6	14.44	83.9	67.8	120.1	120.1
1	14	90	243	2.6	10.06	87.3	64.5	120.1	120.1
2	14	70	244	2.2	11.52	86.3	65.7	120.1	120.1
3	14	80	242	2.4	10.87	86.8	65.2	120.1	120.1
4	14	90	241	2.6	10.19	87.3	64.6	120.1	120.1
5	14	90	242	2.6	10.11	87.3	64.6	120.1	120.1
6	14	100	239	2.7	9.66	87.6	64.2	120.1	120.1
7	14	100	237	2.7	9.79	87.5	64.3	120.1	120.1
8	14	85	242	2.5	10.46	87.1	64.9	120.1	120.1
9	14	90	241	2.5	10.22	87.2	64.7	120.1	120.1
10	14	75	243	2.3	11.18	86.5	65.4	120.1	120.1
11	14	30	249	1.6	14.79	83.6	68.0	120.1	120.1
12	14	15	254	1.4	15.86	82.7	68.7	120.1	120.1
1	15	35	242	1.5	14.98	83.5	68.1	120.1	120.1
2	15	40	246	1.7	14.04	84.3	67.5	120.1	120.1
3	15	50	244	1.8	13.25	84.9	66.9	120.1	120.1
4	15	60	242	2.0	12.52	85.5	66.4	120.1	120.1
5	15	80	242	2.4	10.87	86.8	65.2	120.1	120.1
6	15	80	241	2.3	10.98	86.7	65.3	120.1	120.1
7	15	75	241	2.2	11.34	86.4	65.5	120.1	120.1
8	15	80	243	2.4	10.80	86.8	65.1	120.1	120.1

9	15	80	242	2.4	10.85	86.8	65.2	120.1	120.1
10	15	65	245	2.1	11.84	86.0	65.9	120.1	120.1
11	15	25	255	1.6	14.68	83.7	67.9	120.1	120.1
12	15	10	257	1.4	16.01	82.6	68.8	120.1	120.1
1	16	0	255	1.2	17.46	81.3	69.8	120.1	120.1
2	16	0	253	1.2	17.77	81.0	70.0	120.1	120.1
3	16	30	251	1.6	14.58	83.8	67.9	120.1	120.1
4	16	50	249	1.9	12.83	85.3	66.6	120.1	120.1
5	16	50	244	1.8	13.25	84.9	66.9	120.1	120.1
6	16	65	244	2.1	11.88	86.0	65.9	120.1	120.1
7	16	60	245	2.0	12.22	85.7	66.2	120.1	120.1
8	16	75	244	2.3	11.11	86.6	65.4	120.1	120.1
9	16	70	244	2.2	11.50	86.3	65.6	120.1	120.1
10	16	55	247	2.0	12.54	85.5	66.4	120.1	120.1
11	16	0	254	1.2	17.56	81.2	69.9	120.1	120.1
12	16	0	258	1.3	17.14	81.6	69.6	120.1	120.1
1	17	0	262	1.3	16.70	82.0	69.3	120.1	120.1
2	17	0	262	1.3	16.61	82.1	69.2	120.1	120.1
3	17	0	254	1.2	17.60	81.2	69.9	120.1	120.1
4	17	10	250	1.3	16.94	81.8	69.5	120.1	120.1
5	17	20	251	1.4	15.65	82.9	68.6	120.1	120.1
6	17	55	247	2.0	12.53	85.5	66.4	120.1	120.1
7	17	50	248	1.9	12.90	85.2	66.7	120.1	120.1
8	17	45	245	1.8	13.66	84.6	67.2	120.1	120.1
9	17	40	246	1.7	14.05	84.3	67.5	120.1	120.1
10	17	30	249	1.6	14.78	83.6	68.0	120.1	120.1
11	17	0	262	1.3	16.67	82.0	69.3	120.1	120.1
12	17	0	261	1.3	16.80	81.9	69.4	120.1	120.1