

## Lighting Analysis

The current lighting system in the Hilton Hotel at BWI Airport encompasses a variety of spaces and uses many different types of light fixtures and lamps. The main reason for studying the lighting systems of the guest rooms was to decrease the amount of electrical energy used. Economics were also an issue with choosing between various lighting design options. An analysis was done comparing several different lighting schemes to find the one that used the least amount of energy. An economic analysis was done on the same schemes to determine the most cost effective means of properly lighting the guest rooms.

### Original Guest Room Lighting Design

Each guest room consists of the living space, entry, and bathroom. The lighting design in the entry and bathroom was not studied or altered, so the costs of the fixtures, lamps, and energy usage did not change from the original design. Therefore any of the energy and economical analyses done for the guest rooms did not include these two spaces. The analyses were done first for just the living space of one typical guest room, and then those results were multiplied by 279 to examine the results for all the guest rooms in the guest room tower of the BWI Hilton. Information on a typical size guest room used for all the analyses is shown in Table 32 – Guest Room Info.

The original lighting design of the living space in each guest room consisted of two table lamps, one floor lamp, and one desk lamp. The “Hilton Design and Construction Standards” specified that each lighting fixture was to be lamped with a 100 W incandescent bulb. A typical A19 100 W incandescent lamp was found on the Philips website to be used as the base case of the original design. The “Hilton Design and Construction Standards” also specified that 30 footcandles (fc) be provided at the work plane (2.5 ft above floor) for reading tasks.

**Table 32 - Typical Guest Room**

Length	18 ft
Width	13 ft
Area	234 sq ft
Total No of Guest Rooms	279 rooms

### Lighting Design Alternatives

In almost all applications, incandescent lamps use more energy, give off more heat to their surroundings, and need replaced more often than compact fluorescent lamps. For these reasons, a replacement of all the incandescent lamps in the guest rooms was studied. The other problem with the incandescent fixtures was that the lighting power density was greater than that allowed by ASHRAE Standard 90.1-2004. The calculated value for the original design was 1.73 W/sf, and the maximum allowable for hotel guest rooms was listed as 1.1 W/sf in Table 9.6.1.

Several options were available to be used as alternative designs to the original incandescent lamps. The effects of the lamp color rendering index, color temperature, and lumen output were all studied to ensure that the new lighting schemes were just as good, if not better, than the original designs. Philips lamps were used for all the options. Prices for all the Philips lamps were found online at bulbs.com. To see renderings for some of the lighting design options, please see Appendix H – Typical Guest Room Lighting Renderings.

The first design option was to simply replace all the incandescent lamps with compact fluorescent lamps with screw-in bases. This method would simply use the four existing fixtures and just change the lamp type. Philips 27 W Mini-Deco Twister lamps were found to be suitable replacements for the A19 incandescent bulbs. The lumen output of these lamps was more than the original incandescent ones, and they also had the same color temperature of 2700 K. The color rendering index (CRI) of the compact fluorescents was 82, and they had a warm white finish. This was all done to ensure that the light would look the same as if there were traditional incandescent lamps being used.

The other alternatives all incorporate the use of other lighting design schemes. One possibility involved compact fluorescent recessed downlights. However, this was found to be unfeasible because of the guest room tower structure. The floor-to-floor height of each floor was 9 ft, and there was a 7-1/2 in post-tensioned concrete slab between floors, as was described in the Structural Systems section of the Building Systems Overview. With this type of structure, it was determined that using recessed fixtures would be a poor decision. Therefore, other means of using ceiling lighting was studied, namely using surface mounted fixtures.

The second and third design options involved using small surface mounted downlights with two compact fluorescent lamps in each fixture. The second option used a layout of four fixtures, and the third option used a layout of six fixtures. However, in both cases, the lighting levels were much below the required 30 fc minimum. Since these two options still did not provide adequate amounts of light, additional lighting options were studied.

The fourth and fifth design options used ceiling surface mounted fluted disk fixtures. One of these Lightolier fixtures could be used in each guestroom because of their high light output. This option replaced all the table lamps and floor lamp fixtures with a single ceiling fixture. Two options existed for the spectral fluted disk fixtures. The first option used two T5 circular fluorescent lamps (option 4), and the second option used four 18 W compact fluorescent lamps for in the fixtures (option 5). These two options were compared to see which had the better light output, lamp replacement costs, and energy costs. However, with both of these options, the light levels were still too low.

One final design option was considered after all the other options failed to meet the minimum of 30 fc at the working plane. This sixth design option involved using one Lightolier ceiling fluted disk fixture along with the four compact fluorescent fixtures for task lighting. This method increased the amount of light in the room, as well as the energy usage, energy costs, and lamp costs.

Cut sheets for some of the lamps and fixtures used can be found in Appendix J – Lighting Selection. More information on energy and cost comparisons made between all six lighting design options can be found in the following sections. For a summary of all six lighting design options with the lamp and fixture information, please see the table shown below, Table 34 – Lamp and Fixture Info. All the abbreviations used for each lighting option are listed in Table 33 – Option Abbreviations.

A few assumptions were made consistently for all the different options. An estimated light loss factor (LLF) of 0.65 was used. Also, average reflectances were assumed for the guest room surfaces: walls = 0.50, ceiling = 0.86, and floor = 0.20.

**Table 33 - Option Abbreviations**

Inc	Incandescent
CFL	Compact Fluorescent
SM	Surface Mounted
Combo	Both Compact Fluorescent and Surface Mounted

**Table 34 - Lamp and Fixture Info**

Option No	Option	Fixture Qty	Lamp Qty	Watts Ea	Total Watts	Watts per sf	Lumens ****	Total Lumens	Lumens per sf	Avg fc	Avg Life (hr)	Avg Life (yr)	Lamp Cost Ea
Base	Inc	4	1	100	400	1.71	1550	6200	26.50	2.37	1500	1.0	\$0.59
1	CFL	4	1	27	108	0.46	1750	7000	29.91	2.61	10,000	6.8	\$4.59
2	SM 1	4	2	13	104	0.44	825	3300	14.10	9.02	10,000	6.8	\$1.99
3	SM 2	6	2	13	156	0.67	825	4950	21.15	13.63	10,000	6.8	\$1.99
4	SM Disk 1	1	1	-	62	0.26	4830	4830	20.64	17.95	16,000	11.0	\$31.98
5	SM Disk 2	1	4	18	72	0.31	4300	4300	18.38	15.99	16,000	11.0	\$7.69
6	Combo	5	6	-	170	0.73	-	11830	50.56	20.56	-	-	-

\*\*\*\*Based on initial lumens

### Typical Guest Room Lighting Rendering

In order to have an idea of what each lighting design option actually looked like, Lighting Analysts AGI v1.8 was used to calculate the average illuminance levels at the work plane. A plan view of a typical guest room was drawn and the footcandles at various points were shown on each plan. Isometric views of a typical guest room were also developed, and a rendering of the space, illuminance levels, and luminance levels were all created for some of the design options. These renderings can be found in Appendix H - Typical Guest Room Lighting Renderings.

For the typical guest room layout, a single king bed guest room was used as the basis since it is the most common room type in the hotel. Other guest rooms are very similar, except for the exact placement of the beds and nightstand tables on the floor plan. All furniture was taken directly from the original plans for the BWI Hilton. For simplicity, each piece of furniture was simply assumed to have a geometric cubic shape. The only problem with this was with the two chairs in the room. It shows that the illuminance levels are very low, but in actuality, they would be much closer to those on the ottoman at the foot of the chair or the desk.

It was very difficult to find any .ies files on the internet for any kind of desk lamp or floor lamp. Ones were finally found and used for the AGI renderings of the typical guest room. But the way the fixtures were shaped automatically by the program was not the shape in the original design. This was just a minor detail, and the main concern was with the actual light output of the light fixtures. However, illuminance levels may not be exactly the same as was intended by the architect. This most likely was because of the .ies file used. A more accurate representation of the actual light fixtures selected for the guest rooms would give better results than the approximations made in this case.

Despite these approximations, significant differences can be seen the light levels between many of the options. It can also be seen that the original design with only incandescent fixtures does not adequately meet the 30 fc minimum requirement. However, many of the proposed lighting design options also do not fully meet the illuminance level of 30 fc, as for reasons given above.

### Energy Savings

The primary reason for altering the design of the guest room lighting was to decrease the amount of electrical energy used in the Hilton Hotel at BWI Airport. The original design with the incandescent lamps used the most electrical energy out of all the options studied. Calculations were done to compare each of the six design options with the base case. It was assumed that each fixture was

only used for four hours each day. As can be seen in the table below, Option 4 with the surface mounted fluted disk with two circular fluorescent lamps had the greatest amount of energy savings as compared to the incandescent base case. For a comparison of the energy usage of all six options, please see below in Table 35 – Energy Use Comparison.

**Table 35 - Energy Use Comparison**

Option No	Option	Watts per Room	Total Elec Use (kW)	Avg hr per day	Avg hr per yr	Total Elec Use (kWh per yr)	Energy Savings (kWh)**
Base	Inc	400	111.60	4	1460	162,936	-
1	CFL	108	30.13	4	1460	43,993	118,943
2	SM 1	104	29.02	4	1460	42,363	120,573
3	SM 2	156	43.52	4	1460	63,545	99,391
4	SM Disk 1	62	17.30	4	1460	25,255	137,681
5	SM Disk 2	72	20.09	4	1460	29,328	133,608
6	Combo	170	47.43	4	1460	69,248	93,688

\*\*vs Base

Cost Comparisons

Several cost comparisons were also done between the six different lighting design options. They are all described next. Based on the energy usage savings above, energy cost savings were calculated next. An energy cost analysis was done using an average calculated cost of electricity at \$0.071/kWh. Consistent with the previous table, Option 4 again had the greatest amount of savings compared to the base case. Please see the table below, Table 36 – Energy Cost Comparison.

**Table 36 - Energy Cost Comparison**

Option No	Option	Avg Elec Cost (per kWh)***	Elec Cost (per yr)	Elec Cost Savings**
Base	Inc	\$0.071	\$11,568.46	-
1	CFL	\$0.071	\$3,123.48	\$8,444.97
2	SM 1	\$0.071	\$3,007.80	\$8,560.66
3	SM 2	\$0.071	\$4,511.70	\$7,056.76
4	SM Disk 1	\$0.071	\$1,793.11	\$9,775.35
5	SM Disk 2	\$0.071	\$2,082.32	\$9,486.13
6	Combo	\$0.071	\$4,916.59	\$6,651.86

\*\*\*Calc avg from rates

\*\*vs Base

A comparison of the costs of the lamps was also done. The costs only included the cost of the bulb itself; it did not account for the cost of the fixture, labor rates for relamping all the fixtures, and labor rates for installation and wiring of the fixtures. The information required for those things was not done because

only a basic comparison of lamp prices was desired. As can be seen below, each of the six options resulted in no lamp cost savings. Instead, each option cost more money per year since the compact fluorescent lamps were still much more expensive than the incandescent lamps. However, the average life of each of the compact fluorescent lamps was much longer. An average relamp cost per year was calculated based on the four hours per day operation and the specified lamp life by Philips. Please refer to Table 37 – Lamp Cost Comparison below.

**Table 37 - Lamp Cost Comparison**

Option No	Option	Total Lamp Cost	Avg Relamp Cost (per yr)*	Total Cost (per yr)	Lamp Cost Savings**
Base	Inc	\$2.36	\$2.30	\$640.88	-
1	CFL	\$18.36	\$2.68	\$747.88	-\$106.99
2	SM 1	\$15.92	\$2.32	\$648.49	-\$7.60
3	SM 2	\$23.88	\$3.49	\$972.73	-\$331.85
4	SM Disk 1	\$31.98	\$2.92	\$814.17	-\$173.29
5	SM Disk 2	\$30.76	\$2.81	\$783.11	-\$142.23
6	Combo	\$50.34	\$5.60	\$1,562.05	-\$921.17

\*(Total lamp cost)/(avg life)      \*\*vs Base

After calculating both the energy cost savings and the lamp costs, a total cost comparison was made. After comparing all the numbers, the greatest cost savings per year was with Option 4. This option used two circular fluorescent lamps in each fixture. Please see Table 38 – Total Cost Comparison below for the details of this comparison.

**Table 38 - Total Cost Comparison**

Option No	Option	Yearly Total Cost Savings**
Base	Inc	-
1	CFL	\$8,337.98
2	SM 1	\$8,553.05
3	SM 2	\$6,724.91
4	SM Disk 1	\$9,602.06
5	SM Disk 2	\$9,343.90
6	Combo	\$5,730.70

\*\*vs Base

### Lighting Conclusions

To make a proper recommendation on the guest room lighting design, it is necessary to analyze all the information and data from all six design options. This includes looking at the electrical energy usage, energy costs, lamp costs, and light levels.

The effects of these different lighting schemes can be realized in both the amount of energy consumed by the hotel and with the heat generated by the lighting fixtures. The lower amount of heat generated by the lamps could potentially reduce the block loads of the guest rooms on the fan coil units that condition those spaces. However, since this amount of generated heat is such a small fraction of the total room block load, the differences between the base case and new design will be negligible. This is especially true when re-sizing a new fan coil unit is considered.

However, the amount of energy consumed is a much bigger deciding factor. Significant amounts of energy can be reduced by using different lamps and light fixtures. Simply interchanging compact fluorescent lamps for the incandescent lamps has a significant reduction in energy consumption, but additional savings can be found using ceiling light fixtures.

The other major factor deals with the light output of the selected fixtures. To properly analyze the light output of the originally selected fixtures, a more exact photometric (.ies) file should be used. Also, using the exact shapes of the chairs and other furniture may have some benefits.

If the illuminance levels in the guest rooms were not set in stone, the surface mounted fluted disk option with two circular fluorescent lamps would be the best option to use. This is because it has the greatest amount of energy savings. However, if the 30 fc is more rigid, then additional fixtures should be added to the space that can be used as task lights for reading. This way, the energy consumption would be decreased and the proper light levels would also be met.