LED BULB COMPARISON 2020

by

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Incandescent light bulbs have been the gold standard for those of us who are sensitive to dirty electricity (noise on household wiring) and to a 120 Hz fluctuation in light intensity like that produced by fluorescent bulbs. But they are short lived, energy inefficient, and are being phased out by government edict. The mainstream replacement is the Light Emitting Diode (LED) bulb. These produce up to ten times as much light for the same electric power as a 60 W incandescent bulb and last perhaps ten times as long. I reviewed several LED bulbs in a pdf document dated March 2, 2018, along with a number of LED strips.

Prices are dropping and new bulbs are being introduced regularly, so in June, 2020, I bought a fraction of the LED bulbs available at Home Depot, ACE, Walmart, and Kroger for testing. Together with the older bulbs there were a total of 19 different LED bulbs plus two incandescent bulbs for comparison, as shown in Table 1.

The claimed Color Temperature of each bulb is listed under the column heading 'Temp'. The sun is fairly close to being a black body radiator with a temperature in the neighborhood of 6000K. The incandescent bulb with a tungsten filament is also fairly close to being a black body radiator, but operates at temperatures in the range of 2400K to 2700K. At these lower temperatures, the light output contains more red and less blue. It also contains a larger fraction of infrared, light frequencies that cannot be seen directly by the eyes but are sensed by our skin as warmth. Hence, light at these color temperatures is considered to be *warm* white (as opposed to the *cool* white or *pure* white of bulbs operating at 5000K).

Dimmers are notorious for producing dirty electricity. Since I never use dimmers, I bought non-dimming bulbs without even thinking. But Home Depot apparently has made the decision to only carry dimmable bulbs, so the bulbs CREE1, ECO2, and PH4 were purchased there. Regardless of the label, all 19 bulbs were tested on 60 Hz AC voltages from 100 to 140 VAC, and on DC voltages from 130 to 160 VDC. Bulbs that worked well at 130 VDC were tested at voltages down to as low as 90 VDC. (Note that incandescent bulbs start to explode at about 130 VAC and operate at about half intensity at 100 VAC).

AC volts, AC amps, and AC power were measured with an Extech 380801, DC volts with an AideTek VC97 multimeter, and DC amps with a Fluke 117 multimeter. I cannot afford the tens of thousands of dollars required to measure the absolute lumen output of these bulbs, but I believe I was able to measure relative lumen production to within perhaps a 5% error with an inexpensive setup. Each bulb was mounted base down in a simple fixture sitting toward one end and on the bottom of a 48 quart Styrofoam cooler, serving as an 'integrating sphere'. The light sensor was a Pyle PLMT16 Light Meter mounted on the side of the cooler and facing the 'empty' end of the cooler, thus less likely to be unduly influenced by a stray ray from a anisotropic bulb.

Code	Company	Watts	Temp	Dim	Lumens	Model
ACE1	ACE	60	2700K	N	800	A80082710KLED4/ACE
ACE2	ACE	100	2700K	N	1500	A160082710KLED2/ACE
ACE3	ACE	100	5000K	N	1500	A160085010KLED2/ACE
CREE1	CREE	60	2700K	Y	815	08027MDFH25-12DE26-1
ECO1	Ecosmart	60	2700K	N	800	A7A19A60WES01
ECO2	Ecosmart	100	2700K	Y	1600	A7A19A100WESD04
ECO3	Ecosmart	100	2700K	N	1500	A6A19A100WUL01
FEIT1	FEIT	60	3000K	N	800	BPAGOM800/LED
FEIT2	FEIT	100	3000K	N	1500	A1600/830/10KLED/6
GV1	Great Value	100	2700K	N	1500	A191011
GV2	Great Value	100	2700K	N	1600	A19046
GV3	Great Value	100	2700K	N	1500	A191002
GL1	Green Light	60	3000K	N	800	E344320
PH1	Phillips	60	2700K	N	800	9290013154
PH2	Phillips	60	2700K	Y	800	92900111840
PH3	Phillips	60	5000K		800	9290013155
PH4	Phillips	100	2700K	Y	1600	9290022855
PH5	Phillips	100	5000K	N	1500	9290011351A
SA1	Satco	60	5000K	N	800	S9597
ACE60	ACE	60		Y	840	
ACE100	ACE	100		Y	1690	

Table 1: Tested Bulbs

Another quantity of interest is the variation of light intensity with time. A fluorescent bulb, for example, will always produce light that pulses 120 times per second (on a 60 Hz power grid), and some electrical sensitives find that to be a problem. LEDs are inherently high speed devices, so if current is supplied by pulses at say 30 kHz frequency, the light output will also vary at 30 kHz. I made a high speed photodetector from a small photovoltaic panel liberated from a Living Accents Solar LED Mini Pathway Light bought at ACE Hardware, rated at $V_{oc} = 2.66$V and $I_{sc} = 22$mA. A 200Ω resistor was enough load to cause the voltage to follow the bulb photon production without saturation. Waveform across the resistor was examined with a HP 54645A 100 MHz scope. The scope calculated the peak-to-peak voltage V_{pp} and the average voltage V_{ave} of this photodetector output, as shown in Table 2, Table 3, and 4, along with V_{ac}, I_{ac}, P_{ac}, lux, and lux/P_{ac} for each bulb tested on 60 Hz.

There is a great deal of information in these tables. Let us start with the light intensity variation of the two incandescent bulbs. It may come as a surprise to see that even the 'gold standard' bulbs have a 120 Hz fluctuation. The 60 watt bulb has a greater variation than the 100 watt bulb, suggesting lower thermal mass. I think I have heard of people who do not do well with electric lighting, even incandescent. In addition to sensitivity to electric fields and magnetic fields, they might be sensitive to variations in the light itself.

Bulb	V_{ac}	I_{ac}	P_{ac}	V_{pp}	V_{ave}	lux	lux/P_{ac}
ACE1	100.5	0.069	4.2	0.66	0.58	9700	2310
	109.8	0.105	6.9	0.34	0.84	14220	2061
	120.2	0.115	8.2		0.87	14810	1806
	130.2	0.116	8.9		0.87	14660	1647
	140.0	0.118	9.7		0.86	14540	1500
ACE2	100.1	0.065	3.9	1.03	0.63	10290	2638
	110.7	0.145	10.2	0.98	1.40	25600	2510
	120.2	0.177	13.4		1,64	30500	2276
	130.1	0.180	14.6		1.63	30300	2075
	140.9	0.183	15.9		1.62	30100	1893
ACE3	100.0	0.071	4.3	1.17	0.70	13260	3060
	110.5	0.145	10.3	1.03	1.45	30400	2951
	120.0	0.176	13.4		1.68	35900	2679
	130.2	0.179	14.6		1.67	35600	2438
	140.1	0.182	15.8		1.66	35300	2283
CREE1	101.2	0.104	9.6	0.34	0.97	16080	1675
	109.8	0.096	9.7	0.31	0.98	16290	1679
	120.4	0.088	9.7	0.30	0.98	16250	1848
	130.4	0.083	9.6	0.25	0.97	16140	1681
	140.1	0.079	9.6	0.25	0.97	16100	1677
ECO1	100.2	0.133	9.2	0.11	0.96	16610	1805
	110.3	0.120	8.9	0.09	0.94	16360	1838
	119.9	0.111	8.8	0.07	0.93	16170	1837
	130.0	0.103	8.7	0.06	0.92	16010	1840
	140.9	0.096	8.5	0.06	0.92	15910	1872
ECO2	100.1	0.079	4.9	0.44	0.76	12600	2571
	110.0	0.178	14.0	0.84	1.70	33800	2414
	120.7	0.186	16.5	0.75	1.78	36600	2218
	130.0	0.177	17.6	0.69	1.80	36900	2097
	140.1	0.175	19.4	0.62	1.84	38100	1964
ECO3	99.5	0.211	15.0	0.87	1.61	31700	2113
	110.0	0.197	14.7	0.66	1.61	31400	2136
	120.5	0.183	14.5	0.50	1.60	30900	2131
	130.0	0.173	14.3	0.44	1.59	30600	2139
	139.8	0.164	14.3	0.47	1.58	30400	2133
FEIT1	100.0	0.095	7.2	0.16	0.71	12660	1758
	110.4	0.097	8.6	0.19	0.83	14750	1727
	120.9	0.101	10.3	0.25	0.95	17250	1625
	130.0	0.105	11.8	0.28	1.07	19240	1630
	139.5	0.109	13.3	0.31	1.17	23000	1729

Table 2: AC Tests Page 1

Bulb	V_{ac}	I_{ac}	P_{ac}	V_{pp}	V_{ave}	lux	lux/P_{ac}
FEIT2	100.4	0.172	12.4	0.90	1.53	29700	2395
	110.2	0.188	14.5	0.28	1.70	33600	2317
	120.1	0.173	14.2	0.15	1.67	32900	2317
	130.2	0.161	14.1	0.12	1.65	32500	2305
	140.1	0.150	13.9	0.10	1.64	32200	2317
GV1	100.6	0.218	13.8	0.94	1.64	33300	2581
	110.2	0.202	13.5	0.97	1.63	32700	2422
	120.6	0.189	13.3	0.88	1.63	32300	2429
	130.0	0.179	13.2	0.88	1.62	31900	2417
	139.5	0.171	13.1	0.84	1.61	31700	2420
GV2	99.2	0.150	14.1	0.75	1.58	34000	2411
	110.3	0.149	15.5	0.75	1.68	36900	2381
	120.9	0.147	16.6	0.62	1.75	39000	2349
	130.0	0.145	17.3	0.59	1.79	40400	2335
	138.4	0.142	17.9	0.53	1.92	41000	2291
GV3	100.6	0.242	15.4	0.28	1.69	33500	2175
	110.1	0.219	15.1	0.23	1.67	33000	2185
	120.2	0.204	15.0	0.20	1.67	32700	2180
	129.8	0.192	14.9	0.17	1.65	32500	2181
	138.0	0.183	14.8	0.14	1.65	32300	2182
GL1	100.0	0.052	3.1	0.55	0.44	7720	3226
	110.0	0.093	6.3	0.59	0.75	13270	2106
	120.5	0.118	8.8	0.22	0.90	16110	1831
	130.0	0.128	9.7		0.91	16170	1667
	138.2	0.125	10.4		0.89	15940	1533
PH1	101.0	0.027	1.5	0.73	0.25	4670	3133
	110.1	0.056	4.0	0.84	0.59	10390	2597
	120.0	0.080	6.1	0.56	0.81	14430	2366
	130.1	0.088	7.3		0.87	15510	2125
	138.1	0.089	7.9		0.86	15360	1944
PH2	101.2	0.101	9.4	0.22	0.84	14800	1574
	110.1	0.105	10.5	0.26	0.91	16080	1531
	120.2	0.105	11.3	0.25	0.95	16950	1500
	130.0	0.104	11.9	0.25	0.98	17500	1471
	138.5	0.103	12.4	0.25	1.01	17900	1440
PH3	101.2	0.020	1.0	0.40	0.19	3970	3970
	110.0	0.050	3.5	0.75	0.53	10660	3046
	120.1	0.074	5.7	0.53	0.72	15360	2695
	130.0	0.084	6.9		0.83	16890	2448
	138.3	0.085	7.4		0.83	16720	2259

Table 3: AC Tests Page 2

Bulb	V_{ac}	I_{ac}	P_{ac}	V_{pp}	V_{ave}	lux	lux/P_{ac}
PH4	100.8	0.140	13.7	0.08	1.63	32300	2358
	110.1	0.136	14.4	0.11	1.68	33700	2340
	120.4	0.123	14.2	0.11	1.67	33300	2345
	129.8	0.114	14.1	0.11	1.66	33000	2340
PH5	101.2	0.209	12.8	0.25	1.62	35300	2758
	110.0	0.194	12.7	0.20	1.60	34800	2740
	119.8	0.179	12.5	0.16	1.58	34300	2744
	129.8	0.166	12.4	0.12	1.57	34000	2742
	138.3	0.158	12.4	0.12	1.57	33700	2653
SA1	100.9	0.082	4.9	0.67	0.62	11780	2404
	110.1	0.121	7.9	0.39	0.87	16570	2097
	120.4	0.134	9.4		0.92	17620	1874
	129.7	0.135	10.2		0.91	17380	1704
	138.4	0.137	10.9		0.90	17140	1572
ACE60	100.5	0.460	46.2	0.075	0.53	8260	179
	110.6	0.484	53.5	0.11	0.73	11660	218
	120.2	0.507	61.0	0.14	1.00	15750	258
	125.3	0.519	65.0	0.16	1.10	18170	280
ACE100	100.3	0.758	76.6	0.14	1.16	18390	240
	109.9	0.797	88.4	0.16	1.55	28300	320
	120.5	0.839	101.7	0.12	1.87	38000	374
	124.9	0.855	107.6	0.12	1.91	42900	399

Table 4: AC Tests Page 3

The ACE LED bulbs have a light intensity that is constant over a 60 Hz cycle except for two notches, and the notches disappear between 115 and 120 VAC as the voltage increases. That is, if your house has the nominal voltage of 120 VAC, the ACE LED bulbs are *better* than incandescent bulbs in terms of constant light intensity.

The only other bulb that has a constant light intensity over a 60 Hz cycle at 120 VAC is SA1. Bulbs GL1, PH1, and PH3 have a flat light intensity over a 60 Hz cycle at 130 VAC and above, but that is of little interest when we are operating at 125 VAC or less.

The light intensity of the incandescent bulbs ACE60 and ACE100 increases about 35% as the voltage increases from 110 to 120 VAC. The intensity continues to increase with voltage until failure somewhere around 130 VAC. On the other hand all the LED bulbs operate nicely up to at least 140 VAC. The light intensity is more constant than the incandescent bulbs from 110 to 120 VAC except for PH1 and PH3. The CREE1, a dimmable bulb, has light intensity constant to within about 1% over the voltage range 100 to 140 VAC. The other two dimmable bulbs, PH2 and PH4, are almost that constant over that voltage range. The light intensity actually decreases with increasing voltage from 120 to 140 VAC for 14 out of the 19 bulbs.

Efficiency is an important reason people are replacing incandescent bulbs with LEDs. The incandescent bulb ACE60 produces 258 lux/P_{ac} in my experimental setup, while ACE100 produces 374 lux/P_{ac}, at 120 VAC. The ratio is 1.45. That is, the 100 W bulb is 45% more efficient than the 60 W bulb in producing light. Unfortunately, the 100 W bulbs are difficult to find at the big box stores, so we will just compare LED efficiencies to the 60 W bulb. The lux/P_{ac} figure varies from 1500 for PH2, a ratio of 5.81, to 2744 for PH5, a ratio of 10.64. The electric cost for lighting can be reduced by a factor of five to ten, by switching from incandescent to LED!

One concern with LED bulbs is the possibility of dirty electricity produced by the internal electronics. The typical way of quantifying dirty electricity is to use a Stetzer meter, a device that plugs into a wall outlet and displays a three or four digit number in Stetzer units. These are not well defined electrical engineering quantities, but still give a rough measure of how bad things are. It is not uncommon to see a suggestion that 50 units or less will be acceptable to most electrical sensitives. Depending on what the neighbors are doing, the readings in my shop are mostly in the range of 40 to 50. I plugged the Stetzer meter into the same outlet as the variac for the light bulb and watched for a change as the light bulb made contact. For 15 out of the 19 LED bulbs, there was no change at all. The four problem children were FEIT1 (600-700), GV2 (220), PH2 (700-900), and PH4 (300).

DC Operation of LED Bulbs

I am intolerant to 60 Hz magnetic fields, and probably to 60 Hz electric fields and to dirty electricity, yet I really enjoy the benefits of electrification (lighting, cooking, Internet, etc.). Is there any way of having my cake and eating it too? I think for a large majority of we sensitives that the solution is to go totally off-grid. The standard off-grid home today generates and stores electrical energy as DC, but then immediately connects the battery to an inverter, making the electromagnetic environment of the home the same as if it were on-grid. I advocate the omission of the inverter, and instead distributing electricity around the house as just the DC battery voltage. We still have electric and magnetic fields in the house, but no 60 Hz fields.

One major problem with this concept is that conventional switches and breakers require the current to go to zero before a switching generated arc goes to zero. With DC, the arc produced by opening the contacts continues until something fails or the house burns down. It will be necessary to switch a load by using a power MOSFET. A power MOSFET is turned on by applying perhaps 15 VDC to its gate terminal. The 15 VDC is applied with a regular mechanical switch that only needs to carry a few mA for a short period. Those levels of voltage and current are not adequate to maintain an arc, so there is no safety issue.

With the proper solid state switch (sometimes called solid state relay) a nominal 120 VDC system can be used, with basically the same wire sizes and current densities as a 120 VAC system. What exact number we select as 'nominal' will probably be in a state of flux for some time, similar to the situation with 110, 115, or 120 VAC as the nominal rating. For example, the 2017 National Electrical Safety Code states in Article 712.30: “Examples of nominal dc system voltages include but are not limited to 24, 48, 125, 190/380, or 380 volts.” I suspect the suggestion of 125 (rather than 120) is due to the historical use of 12 VDC lead acid batteries. A nominal 12 volt battery has an open circuit fully-charged voltage of about 12.6 V. Ten such batteries in series would have an actual voltage of about 126 V, so we might be inclined to call it a nominal 125 rather than a nominal 120. Individual lead acid batteries for a typical home size would more likely be of 6 V size rather than 12 V size, so if we wanted a fully charged voltage of 120 VDC, we would just buy 19 of these 6 V batteries. In that case, the battery voltage would range from 114 VDC (a reasonable choice for minimum voltage to assure long battery life) to about 137 VDC while being charged.

If we use lithium ion batteries (more efficient and longer life than lead acid batteries) the necessary operating range is even greater. The smallest cell of a lithium ion battery is rated at 3.6 or 3.7 V (as compared with the lead acid cell of 2 V). The stored energy rating is for a discharge from a maximum charge voltage of 4.2 V to a minimum voltage of 2.8 V. One option for a battery bank would be to use recycled electric vehicle batteries. BMW has a battery module of 16 cells in series, available on the Internet for about $250. Two of these modules in series would store a nominal 4 kWh and have a voltage range of 89.6 to 134.4 VDC.

Discharging a battery completely shortens its life. Manufacturers often publish claims about the expected number of cycles at a 50% Depth of Discharge (DOD). That means the BMW battery would have an effective capacity of 2 kWh. The actual voltage range would be in the vicinity of 115 to 134 VDC, not a lot different from the lead acid.

It would be nice if we could just connect our light bulbs directly to the battery (through an appropriate circuit breaker and switch) without any extra electronics. As mentioned earlier, this is not possible for incandescent bulbs because their life expectancy gets *very* short above about 125 V (either AC or DC). Also the light intensity will vary by more than a factor of two if the voltage swings by 20 V, as we saw in Table 4.

I applied a DC voltage (obtained from a variac, a full wave rectifier, and a 1400 μF capacitor) to each of the 19 bulbs and recorded the DC current and the relative lux output, as shown in Tables 5 and 6. Eight of the bulbs worked quite nicely over the voltage range of 110 to 160 VDC, and two of the eight worked over an even wider range of 90 to 160 VDC. The remainder required voltages above 120 VDC for operation.

The filter capacitor would obviously tend to isolate the electronics in the bulb from the building wiring. Indeed, the Stetzer meter did not show any change for any of the 19 bulbs.

Fourteen of the bulbs put out a constant light intensity for a given voltage. The other five had a ripple in the 20 kHz to 50 kHz range. The five bulbs and the ratio of ripple peak-to-peak and average intensity are: ECO1 7%, FEIT2 6.1%, GV1 54.2%, GV3 21%, and PH5 13.5%.

Bulb	V_{dc}	I_{dc}	lux	lux/P	Bulb	V_{dc}	I_{dc}	lux	lux/P
ACE1	130.1	0.029	8710	2309	GV1	111.6	0.112	33300	2664
	140.2	0.052	14670	2012		120.3	0.112	32600	2420
	150.2	0.052	14540	1862		132.2	0.102	32000	2373
	160.9	0.052	14440	1726		140.5	0.093	31800	2434
ACE2	130.7	0.016	5860	2802		150.6	0.087	31500	2406
	140.0	0.075	27000	2571		159.6	0.082	31400	2399
	150.8	0.085	30500	2379	GV2	90.0	0.136	30000	2451
	160.5	0.085	30300	2221		100.0	0.164	38300	2335
ACE3	130.4	0.017	6910	3117		110.4	0.191	46800	2219
	140.7	0.084	35700	3021		121.2	0.215	54700	2099
	151.1	0.085	35800	2787		130.5	0.205	55400	2017
	161.0	0.085	35600	2601		140.0	0.190	54700	2056
CREE1	130.5	0.072	16040	1707		150.3	0.175	54100	2057
	140.0	0.068	16000	1681		159.4	0.166	54300	2052
	150.0	0.063	15950	1688	GV3	150.7	0.043	14850	2292
	160.9	0.059	15940	1679		160.3	0.063	24300	2406
ECO1	130.4	0.068	16720	1886	GL1	130.8	0.022	7070	2457
	141.6	0.062	16510	1881		140.0	0.83	14700	2100
	150.6	0.057	16340	1903		150.0	0.91	16280	1871
	160.5	0.053	16180	1902		159.7	0.058	16030	1731
ECO2	131.3	0.026	8500	2490	PH1	131.6	0.004	1440	1736
	140.8	0.094	33100	2501		141.0	0.044	15700	2531
	150.0	0.174	58400	2238		150.0	0.044	15500	2348
	158.8	0.229	69700	1917		160.4	0.044	15330	2172
ECO3	110.3	0.126	29800	2144	PH2	90.2	0.105	14660	1548
	120.1	0.116	30100	2161		100.2	0.110	16240	1473
	130.0	0.110	31500	2203		110.4	0.114	17600	1398
	140.4	0.101	31000	2186		120.5	0.113	18390	1351
	150.4	0.093	30500	2181		130.5	0.108	18780	1332
	159.2	0.087	30100	2173		140.4	0.102	18960	1324
FEIT1	110.0	0.075	14360	1741		150.0	0.097	19000	1306
	120.2	0.076	15660	1714	PH3	139.6	0.020	8810	3155
	130.7	0.081	17710	1673		150.1	0.042	16960	2690
	140.0	0.088	21800	1769		159.4	0.042	16730	2499
	150.6	0.096	24400	1688	PH4	100.2	0.135	31000	2292
	161.2	0.104	26900	1605		111.7	0.131	33400	2283
FEIT2	111.4	0.061	16400	2403		120.7	0.120	33100	2285
	121.4	0.094	28200	2471		130.8	0.111	33400	2300
	131.4	0.107	33400	2376		140.6	0.103	33200	2293
	140.0	0.100	32800	2343		150.3	0.096	33000	2287
	150.0	0.092	32300	2341		165.0	0.087	32900	2292
	159.0	0.086	32000	2096					

Table 5: DC Tests Page 1

Bulb	V_{dc}	I_{dc}	lux	lux/P	Bulb	V_{dc}	I_{dc}	lux	lux/P
PH5	110.5	0.118	36400	2792	SA1	130.1	0.031	9960	2470
	120.7	0.105	35000	2762		140.2	0.061	17810	2081
	130.3	0.096	34400	2750		150.4	0.060	17260	1913
	140.1	0.088	33900	2750		164.9	0.060	17060	1724
	150.0	0.082	33600	2732					
	165.0	0.75	33300	2691					

Table 6: DC Tests Page 2

CONCLUSION

We have seen that LED bulbs have many advantages:

- Very efficient. May cut energy requirement by factors of five to ten.
- Long lived. 10,000 to 15,000 hours compared with 700 to 1500 hours for incandescents.
- Some operate over a wide voltage range, 110 to 140 VAC or 110 to 160 VDC.
- Some have constant light intensity at a given voltage. No indication of 60 Hz or some switch mode circuit operating in a few tens of kHz.
- Some do not increase the dirty electricity in the house. No change on the Stetzer meter.

I use LED bulbs in my house and lab, with no ill effects. When I build a true off-grid cabin (no inverter, DC only) lighting will be with LED bulbs. Incandescent bulbs just do not have the operating voltage range necessary to work directly on battery voltage, even if we were willing to accept the factor of five to ten on energy requirements. The alternatives are things like propane lamps or coal oil lamps. I was 12 years old before I lived in a house with electricity, so I know about coal oil lamps! Trust me, electric lights are much superior!

Even with all the advantages, I still hear people making blanket statements about LED bulbs being bad for those of us with EHS. It is certainly possible to get a bulb that increases the dirty electricity, or a bulb that has the light intensity pulse at 120 Hz like a fluorescent bulb, but that does not mean that all LED bulbs are bad. If someone reacts to one of the 'good' bulbs, the only possibility I can think of is that the light spectrum of the LED bulb is different from that of the incandescent bulb. The LEDs produce more light in the blue portion of the spectrum, which is then absorbed by various phosphors and reradiated at longer wavelengths, toward the red end of the spectrum. I would hope the fraction of us that are really affected by the difference in spectrum would be small.