Modern Day Electricity Advantages: LEDs, vs Incandescent?

Lexus Carton

Energy Economics 303

Dr. Steven Piper

April 25, 2022

Introduction

In the increasing expansion of the energy market in the last decades, consumers must be conscious of the associated cost with their lighting sources. The following discusses the monetary saving impacts of switching incandescent bulbs from LED bulbs. the economic value it could pose as some of its competitors in the market. Currently, sought-after bulbs are halogen, florescent, vapor, and incandescent; yet, many of the comparisons will be made to incandescent bulbs because they are the most readily available on the market. Since their invention in 1880, and relevance conjoining the development of electricity, it was difficult for a substitute to enter the market until 2002. (DOE, 2013) Beforehand, only primary color LEDs were issued in circuit boards in the 60 and 70s. In Contrast, LEDS, "emit a mixed monochromatic light" (Energy Saving Lighting, 2022), and do not have filaments that break or burn. Then, LEDs became prevalent in traffic signs and outdoor arrangements and made their way into interior spaces. Nonetheless, they are becoming readily accessible for interior settings; "nearly half of US. Use LED bulbs for all or most of their indoor lighting. "By 2018 LED had become the second-most common lightings in buildings" (EIA, 20121). However, it is important to consider why one would not choose and LED bulb over one of its competitors. In order to do this, retail consumers must be aware of the future and present cost of both options so they can make optimal monetary savings. This paper exchanging LEDS in a retail setting, the before tax cost of both types of receive fixtures, and forecasting data based on pollution and inflation rates. The Consumer Pricing Index Consumer pricing index was on 7% in 2021 (Statistia,2022); therefore, it became the rate of interest unless specified otherwise.

<u>Product Life</u>

The table below summarizes the cost benefit analysis Incandescent LED and CFL

As presented, the savings of installing an LED bulb is much greater than incandescent over ten years largely because of the lifespan; one spends 4.5 times less per year on LED bulbs than incandescent because of the replacement cost. This is because Incandescent bulbs have a life span of 1000 hours.

	INCANDESCENT	LED
LIFE SPAN (Hrs) (Sheinlong, 2017)	1,000	50,000
Wattage/per Hr	6okWh/1000 hr	12kWh/1000 hr
Cost to Operate	6.60/1000	1.32/1000hr
Number Purchased over Ten years	10	1
Color Options (USA,2017)	Warm yellow	White/ daylight
Initial cost	$2.70	$3.25
Cost over 10 years	93	13.2
COST PER YEAR (USA,2017)	$78.80	$17.25

Based on a survey conducted in 2012, only 1,957 of commercial floor spaced utilized LEDs, therefore their entrance to the electric market was still small. The Chart below shows the Cost benefit analysis of switching from and Incandescent future to for a retail space of 68,729 square feet with available revenue for lighting of 100,000 dollars. The average cost of Incandescent bulbs was $1.00 and the average cost of and LED is 3.50 dollars. The most common type of lighting fixture for retail spaces are tack lighting, overhead fluorescent light, and recessed lighting." (CBECS, 2017). For this purpose, recessed fixture was chosen; each one cost 175 dollars regardless of bulb type (Shinelongled, 2017). The most appealing reasons to switch to

LED bulbs is due to tax code section 179 D which, “encourages businesses to make energy efficient improvements to property” (EPA, 2022). According the section, LED lighting qualifies for a tax deduction if commercial spaces make efforts to become more energy efficient. This deduction is permeant and the $1.80 per square foot tax deduction grows each year due to inflation. (Heerema,2021). In this case, the electricity tax credit does not kick in until time period 4 when the operational cost is $69.12 The average cost of energy in a commercial retail space in 2021 was $11.27ct/KwHr, but for annual computations, it was converted to 98725.2 Kw/yr(EIA, 2022). Each lightbulb also has its own unique depreciation rate; Lumen depreciates rate (LLD) is the loss of the original light output of the bulb over time. “Fluorescents and halide fluorescent have a LLD of 50%” Over the rated life and “LED have a rating of 70%” (LEDs Magazine, 2011). This value multiplied in the depreciation rate of the initial fixture price in both scenarios.

Switch to LED from Incandesce Retail Space (2021)											
Year	0	1	2	3	4	5	6	7	8	9	10
Revenue		$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Building Square foot (mil square feet)	68,729										
$/square foot	-1										
Operation (Hr)	10	3650	Hours per year								
$/per fixture	-175										
# Incandenct	400	300	200	100	0	0	0	0	0	0	0

Capital Cost In	-392.74	0	0	0	0	0	0	0	0		
Bulb Lifetime (Hr)	1000.00										
(-) Incan. Depreciation		-196.37	-98.18	-49.09	-24.55	-12.27	-6.14	-3.07	-1.53	-0.77	-0.38
Operation Cost		-3285	-2190	-1095	0	0	0	0	0	0	0
Maintenance Fees			-200.00								
$/square foot	-3.5										
# of LED	0	100	200	300	400	400	400	400	400	400	400
Capital cost LED	0	-17500	-35000	-52500	-70000	-70000					
Bulb Lifetime	50,000										
$/per fixture	-175										
Installation cost		-70000									
Operation Cost		-183	-366	-549	-732	-732	-732	-732	-732	-732	-732
(-)LED Depreciation			-12250	-3675	-1102.5	-330.75	-99.225	-29.7675	-8.93025	-2.679075	-0.8037225
Replacement Cost	0	-350	-250	-150	-50	50	0	0	0	0	0
(-) maintenance Fees							-1400				

Retail electricity Price		-97936.8	-97936.8	-97936.8	-97936.8	-97936.8	-97936.8	-97936.8	-97936.8	-97936.8	-97936.8
(+) Electricity tax Credit					123712.2	123712.2	123712.2	123712.2	123712.2	123712.2	123712.2
(+) Incan Depreciation		196.37	98.18	49.09	24.55	12.27	6.14	3.07	1.53	0.77	0.38
(+) LED Depreciation		0	12250	3675	1102.5	330.75	99.225	29.7675	8.93025	2.679075	0.8037225
Salvage Value In											-397.74
Salvage Value											-70007
ATCF	-392.74	-71375.43	11971.38	4542.29	126852.45	126168.42	125880.76	125808.24	125785.86	125778.85	125776.59
Net Revenue	197766.38										
NPV	$371,945.71		i*=0.10%								
PV	$2,413.20										
FV	$6,259.22										

Generally, retail operational hours are 9-10 hours of the day. Keeping this in mind, it should be considered how many lumens each bulb will dissipate over each per day i leading a retail operation to replace the bulb. Bases on this assumption Incandescent fixture will be need to be replaced every 2.7 years and a LED will need replacing every 5.7 years.

Price assumptions and Value of Time

As mentioned in the previous section, the price per LED bulb is 3.5 times higher than an Incandescent. This may deter commercial space owners from utilizing them in lighting fixtures, however, the “quality lighting design reduces energy use and energy dependence” (DOE,2022). The following section views the energy savings associated with installing one resistant fixture. Although “Energy consumption of lighting system differs based on season” (DOE, 2022) during the winter, customers utilize more energy because the days are shorter and less during the spring and summer. In the calculations, the weather was assumed to be constant.

BTCF of LED Recessed Fixture (2021)						
Year	0	1	2	3	4	5
REVENUE		200	200	200	200	200
capital cost (+)	-175					
Depreciation (-)		-52.5	-36.75	-25.725	-18.0075	-12.6053
Repair cost (Replace) (-1)		0	-175	0	0	-175
Operation Expenses		-172.8	-172.8	-172.8	-172.8	-172.8
Net Revenue		-25.3	-184.55	1.475	9.1925	-160.405
Depreciation (+)		172.8	172.8	172.8	172.8	172.8
Salvage Value						689
BTCF	-175	147.5	-11.75	174.275	181.9925	12.39475
NPV	($407.60)					
PV	$767.76					
FV	$1,076.83					
ROR	7%					

BTCF of LED Recessant Fixture(2021)						
Year	0	1	2	3	4	5
REVENUE		200	200	200	200	200
capital cost (+)	-175					
Depreciation (-)		-52.5	-36.75	-25.725	-18.0075	-12.6053

Repair cost (Replace) (-1)		0	0	0	0	-175
Operation Expenses		-28.8	-28.8	-28.8	-28.8	-28.8
Net Revenue		118.7	134.45	145.475	153.1925	-16.4053
Depreciation (+)		28.8	28.8	28.8	28.8	28.8
Salvage Value						-31
BTCF	-175	147.5	163.25	174.275	181.9925	12.39475
NPV	$335.68					
PV	$767.76					
FV	$1,076.83					
ROR	7%					

The Before Tax cash flows depicts a net present value of $335.68 with the installation of one recusant LED fixture as opposed to the incandescent fixture with a negative Net Present value of ($407.60) both with a rate of return of 7%. “Maintenance costs for LED lights are generally low” (Shinelongled,2017) and have a high upfront cost. LED have lower operatorial cost per year; making them more cost efficient for retail use.

The following example evaluate the marginal cost of purchasing an additional light bulb fixture. the monthly energy cost of operating a LED $2.40 was multiplied by twelve per number of bulbs. The same operation was carried out for the number of Incandescent. The operation cost for Incandescent was $14.40 per month (Shinelongled, 2017). This information was taken into account when generating the repair cost a corporation may pay over ten years. The price of purchasing an additional lightbulb was multiplied of the inflation rate of 7% (Statistica, 2022). It is depicted that the marginal cost for per incandescent bulbs is greater than LED bulbs over a five-year period.

Marginal Analysis LED				
Fixtures	Inflated Price	Revenue	Annual Energy Cost	Marginal Cost
1	$	$	$	$

	3.50	3.50	100.80	-
2	$ 3.75	$ 7.25	$ 208.66	$ 107.86
3	$ 3.99	$ 11.48	$ 330.62	$ 121.97
4	$ 4.24	$ 16.21	$ 466.70	$ 136.08
5	$ 4.48	$ 21.42	$ 616.90	$ 150.19

Marginal Analysis Incandescent				
Fixtures	Inflated Price	Revenue	Annual Energy Cost	Marginal Cost
1	$1.00	$1.00	40.32	0
2	$ 1.07	$ 3.00	120.96	$ 80.64
3	$ 1.14	$ 7.00	282.24	$ 161.28
4	$ 1.21	$ 13.00	524.16	$ 241.92
5	$ 1.28	$ 21.00	846.72	$ 322.56

As depicted form the Marginals Analysis of individual LED and Incandescent bulbs. The marginal cost of Incandescent is much greater than LEDs; each year almost 100 dollars is added to the overall cost per year. This is largely to do with the operational cost associated with each incandescent bulb as they pose a major modern day engineering flaw. “Incandescent bulbs release 90% of energy as heat” (USA today, 2017) while the light sources of LEDs can be “the size of a fleck of pepper”, and are available in “multidirectional styles” USA today, 2017).

<u>Future impact and Environmental Concerns.</u>

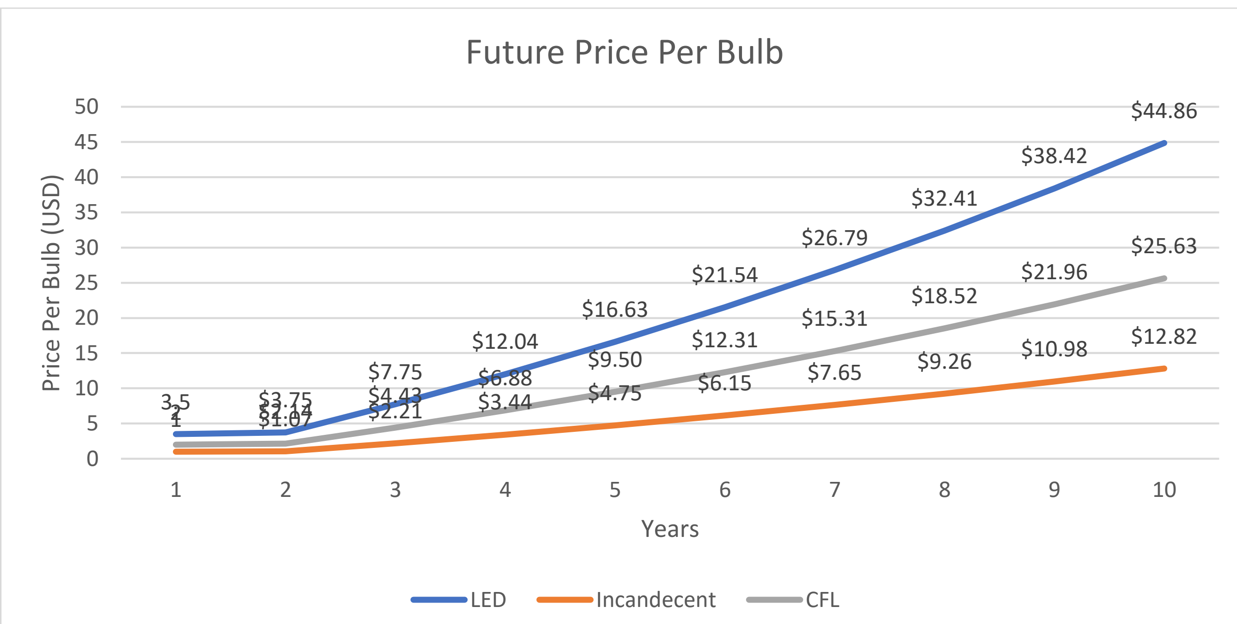
It 2020, “the commercial segment dominated the market and held 50%” (Firor Markets, 2021). The indoor lighting held 70% of the market because there was an increase usage of LED lights in retail stores. Although LEDs are gaining popularity, one must consider any negative externalities associated with their benefits. Therefore, one might ask; Do the bulbs produce an equal amount of damage to the environment? The following section addresses the environmental concerns surrounding light pollution emitted per single bulbs. Light pollution is becoming fairly common issue throughout the globe; “more than 80% of the world's population live under light-polluted skies” (Morelle, 2016). LEDs have a lifespan of 1000 hours, this begs the question if the extended Lumosity could cause more environmental damage to the atmosphere. In the following sensitivity analysis, a poison distribution was utilized to model the realistic exponential rate a which light pollution grows due to human intervention and new construction. Forest Preserve District Will County have reported that between the years 2012- 2016 light pollution increased by 2.2%. The equation was $P(x) = e^{-0.02}\,\frac{0.02^4}{4!}$ This became the Probability of Occurrence is both tables below.

Sensitivity Analysis LED						
Cash Flows	0	1	2	3	4	5
Revenue		10000	10000	10000	10000	10000
# of Fixtures		400	400	400	400	400
installation cost	-5600					
Operation Cost (Kw/Hr)		-4380	-4380	-4380	-4380	-4380
Maintenance Cost	0	0	0	0	0	-1400
Probability of Occurrence		9.54828E-09	1.33139E-18	2.62531E-29	1.40796E-40	2.83645E-52
Net Value (w/o	-5600	5620	5620	5620	5620	4220
Net Value	-5600	5.36613E-05	7.48243E-15	1.47542E-25	7.91271E-37	1.19698E-48
NPV Pollution	($5,233)					
NPV (No Pollution)	$15,369.09					

Sensitivity Analysis Incandescent						
Cash Flows	0	1	2	3	4	5
Revenue		10000	10000	10000	10000	10000
# of Fixtures		400	400	400	400	400
installation cost	-1600					
Operation Cost (Kw/Hr)		-4380	-4380	-4380	-4380	-4380
Maintenance Cost	0	0	-200	0	0	0
Probability of Occurrence	0	9.54828E-09	1.33139E-18	2.62531E-29	1.40796E-40	2.83645E-52
Net value (w/o Probability)	-1600	5620	5420	5620	5620	5620
Net Value (Probability)	-1600	5.36613E-05	7.21615E-15	1.47542E-25	7.91271E-37	1.59408E-48
NPV Pollution	($1,495.33)					
NPV (No pollution)	$19,877.03					

In both scenarios, the net present value of pollution is negative but in Incandescent scenario it is smaller. It indicates that there is a correlation with the number of LEDs installed over time; This could be due to the fact that LEDs are built to be more energy efficient and have a higher Wattage. Yet, this problem can be mitigated, with proper city planning. Solutions to mitigate this issue with LED may include extensive city planning so there could be an even distribution of light traffic in the sky. In the past century there was a global shift from rural to urban living commodity demands and this caused; “about 15 million tons of CO2 to be emitted each year’ in order to power outdoor lighting and “3 million is lost to sky glow” (IDS, 2019). The International Dark sky association cautions “only warm white LED bulbs should be used,” in order to be effective (IDS, 2019). Installing dimmers and motion sensors to “reduce average illumination levels to save more energy” (IDS, 2019), would also be helpful in reducing skyglow. Governmental influence to phase out non energy efficient bulbs started to take effect on January 2012 initiated by the Energy Independence and Security Act of 2007. In general, it does not ban the sale of incandescent bulbs but they must meet an energy efficiency standard that is “25 percent less energy use” (EPA, 2017). Thus, it is pushing for more sales of LED bulbs, as they do “hold a longer shelf life”, and emit less heat than other bulbs on the market.

Because of the contrast in prices, one must recognize the potential effect of inflation. The following chart forecast the prices of individual lightbulbs using an inflation rate of 7%. The Energy Information Administrations reported, “Retail electricity prices rose at fastest rate since 2008” (EIA, 2022), due to the fact that many renewable resources became incapacitated because of the severe weather in 2021. Time period one starts in year 2021 and using the inflation rate of 7% from the ear 2021, by 2028 it is projected that the price of LED lightbulbs will be about $21.54.



Although the rising individual bulb prices are a concern, it is important to consider the fact many Incandescent bulbs may not be in circulation 2028 because they do not meet the efficiency standard. This could cause the price of LEDs to fall, causing LEDs to become the dominate product, because the demand for the substitute would be larger. Both section 179 D and Energy Independence and Security Act of 2007; are enforcing greener tactics for retail and general consumers so this could become possible. On the other hand, market of Incandescent bulbs may continue to be prosperous since, “36% of consumers did not know about the benefits associated with LEDs” (USA, 2017). Incandescent still have a large grasp on the electricity because of uninformed consumers and their acclaim associated with the invention of electricity. It consumers will not have to make the conscious effort to make greener choices because of the government intervention. Nonetheless, those retailers who make use of LEDs in a secure way can produce beneficial energy savings.

Sources

1. Hutton Power and Light. (2019, October 3). LED vs. Incandescent Lighting: A Cost Comparison. Hutton Power and Light. Retrieved from: https://www.huttonpowerandlight.com/blog/2019/october/led-vs-incandescent-lighting-a-cost-comparison/
2. DOE. (2021). LED Adoption Report. The Office of Energy Efficiency and Renewable Energy. Retrieved from: https://www.energy.gov/eere/ssl/led-adoption-report
3. Ell, K. (2017, June 9). Household Savings: LED bulbs Gaining in Cost Efficiency. USA Today. Retrieved from: https://www.usatoday.com/story/money/personalfinance/2017/06/09/household-savings-led-bulbs-gaining-cost-efficiency/375699001/

4. Thomas, M. (2019). How Much Can You Save by Switching to Led Lighting? Carbon Switch. Retrieved from: https://carbonswitch.com/led-savings/#:~:text=At%20the%20national%20average%20of,projects%20go%2C%20that's%20a%20lot!
5. The Department of Energy. (2015, December 18). Future Home Tech: 8 Energy Saving Solutions on the Horizons. Energy Gov. Retrieved from: https://www.energy.gov/articles/future-home-tech-8-energy-saving-solutions-horizon
6. DOE, (2022). LED Basics: Solid State Lighting . The Office of Efficiency and Renewable Energy. Retrieved from: LED Basics | Department of Energy
7. Fior Markets. (2021, June 24). Global LED Lighting Market is Expected to Reach 122.51 billion by 2028: Fior Markets. Retrieved from: https://www.globenewswire.com/news-release/2021/06/24/2252748/0/en/Global-LED-Lighting-Market-Is-Expected-to-Reach-USD-122-51-billion-by-2028-Fior-Markets.html#:~:text=Newark%2C%20NJ%2C%20June%2024%2C,the%20forecast%20period%202021%2D2028.

8. Shinelongled. (2017). Lighting Guide: All You Need to Know About LED Light Cost. ShineLong Technology. Retrieved from: https://www.shinelongled.com/led-lights-costs/

9. DOE. (2022). Lighting and Design. The Department of Energy. Retrieved from: https://www.energy.gov/energysaver/lighting-design

10. EIA.(March 2022). *Electricity Explained: Factors Affecting Influence Electricty Prices.* Energy Information Administration. Retrieved from: https://www.eia.gov/energyexplained/electricity/prices-and-factors-affecting-prices.php
11. Department of Energy. (2013, November 22). *The History of the Lightbulb*. The Department of Energy. Retrieved from: https://www.energy.gov/articles/history-light-bulb
12. Energy Saving Lighting. (2022). *The History of LED Lighting*. Retrieved from: https://www.energysavinglighting.org/the-history-of-led-lighting/
13. Heerema. M, (2021, Jan 7). Good News for LED Lighting Upgrade: What EPAct 179D Really Means. Lighting Insights Blog. Retrieved from: https://insights.regencylighting.com/lighting-retrofits-what-epact-179d-really-means
14. The Office of Energy Efficiency and Renewable Energy. (2021, January 1*). 179d Commercial Buildings Energy-Efficiency Tax Deduction*. The Department of Energy.Retrieved from: https://www.energy.gov/eere/buildings/179d-commercial-buildings-energy-efficiency-tax-deduction
15. Statista. (2022, Feburary). *Monthly Percentage of Change in the Consumer Price Index 2021/22).* Statista Research Department. Retrieved from: https://www.statista.com/statistics/216037/monthly-percentage-of-change-in-the-cpi-u-in-the-us/
16. Brady H, (2017, November 22). *These Energy-Saving Bulbs Are Making One Pollutant Much Worse*. National Geographic. Retrieved from: https://www.nationalgeographic.com/science/article/light-pollution-energy-LED-bulbs-spd

17. The World Bank. (2021. October 21), *Soaring Energy Prices Pose Inflation Risk As Supply Constraints Persist*. The World Bank. Retrieved from: https://www.worldbank.org/en/news/press-release/2021/10/21/soaring-energy-prices-pose-inflation-risks-as-supply-constraints-persist#:~:text=The%20World%20Bank's%20latest%20Commodity,year%20as%20supply%20constraints%20ease.
18. CBECS, (2017, May 17). *Trends in Lighting in Commercial Buildings.* Us Energy Information Administration. Retrieved from: https://www.eia.gov/consumption/commercial/reports/2012/lighting/
19. DOE. (2022). *When TO Turn Off Your Lights*. The Department of Energy. Retrieved from: https://www.energy.gov/energysaver/when-turn-your-lights
20. Mordor Intelligence(2021). *LED Lighting Market – Growth, Trends, COVID-19 Impact and Forecasts (2022-2027).* Mordor Intelligence. Retrieved from: LED Lighting Market Size, Share, Growth, Trends | 2022 - 27 (mordorintelligence.com)
21. LEDs Magazine. (2011. October, 200). *Understanding the Difference Between LED Rated Life and Lumen Maintenance Life*. LEDs Magazine. Retrieved from Understanding the difference between LED rated life and lumen-maintenance life (MAGAZINE) | LEDs Magazine
22. EPA. (2017, January). *How the Energy Independence and Security Act of 2007 Affects Light Bulbs. United States Environmental Protection Agency.* Retrieved from https://www.epa.gov/mercury/how-energy-independence-and-security-act-2007-affects-light-

bulbs#:~:text=Basics%20of%20the%20Energy%20Independence,that%20are%20not%20energy%2Defficient.

23. EIA. (2017, May 18*). Large Commercial Buildings are More Likely to use Lighting Control Strategies.* Retrieved from: U.S. Energy Information Administration - EIA - Independent Statistics and Analysis
24. Morelle. R, (2016, June 10). *Light Pollution 'Affects 80% of Global Population'* . BBC News. Retrieved from Light pollution 'affects 80% of global population' - BBC News
25. Forest Preserve District Will County. (2021. October 19). *The World is Aglow; Light Pollution Alter Our View and Our Health.* Reconnect with Nature. Retrieved from https://www.reconnectwithnature.org/News-Events/The-Buzz/Light-pollution#:~:text=Research%20conducted%20between%202012%20and,study%20published%20in%20Science%20Advances.
26. IDS. (2019). *Light Pollution Waste Energy and Money. International Dark-Sky Association*. Retrieved from: Light Pollution Wastes Energy and Money - International Dark-Sky Association (darksky.org)