

TLEDs: The challenges in opportunity

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Introduction

This paper provides an overview of trends in the Tubular LED (TLED) market. It covers the technical differences found across several types of TLEDs, describes the marketplace in which TLEDs are being manufactured and sold, and explores the large opportunities and challenges for energy efficiency programs within this dynamic and rapidly changing market. This technology is of particular interest as its popularity has grown significantly in a short amount of time. Initial findings from BPA's market research work indicate that northwest regional sales of TLEDs more than doubled between 2014 and 2015, making it the fastest growing category of lighting.

There are three main ideas presented in this paper: (1) There are rapidly changing technical advancements and nuances to understand when discussing TLEDs; (2) The market for TLEDs is hyper-competitive with numerous new manufacturers disrupting the market, resulting in steep price drops that are likely to continue into the near future; (3) The combination of TLED's per-unit energy savings, the low barriers to installation, their relative long life, and the overall size of the linear market could result in fast and significant movement to market adoption, despite the energy-efficiency community's concern that TLEDs are not always the best option relative to other LED solutions.

Background

TLEDs emerged because manufacturers saw the potential for putting LED technology into millions of fluorescent fixtures without the costs and burdens of a comprehensive retrofit needed for LED luminaires. TLEDs are still a fairly nascent technology today, having come on the market only in the last three to four years. Cree, a major LED manufacturer, announced its first TLED as recently as May, 2014¹. But the technology has come a long way in such a short time. The Design Lights Consortium (DLC) has seen a surge of new TLED products on its Qualified Product List (QPL), growing exponentially since 2013 when TLEDs first appeared on the QPL. In just the last three years, TLEDs have generated a lot of interest as different variations of the technology are developed, new manufacturers emerge, and energy-efficiency programs consider them as a potential method of achieving energy savings.

The sales of TLEDs are still small compared to linear fluorescents, with linear fluorescents the overwhelming majority of lamps sold. Yet, linear fluorescent sales in the Northwest have been steadily declining since 2011, while TLED sales have increased; recent research shows 2015 TLED sales are 2.7 times greater than 2014 sales². This growth in the face of the larger decline in the fluorescent market has created disruption for the market, as the market switches from the dominant technology at a rapid pace.

Understanding the types of TLEDs

Technically speaking, TLEDs can be grouped into four categories, each with its own unique characteristics. UL, a safety certification organization, provides definitions for three of these categories:

¹ "Cree Delivers the First No-Compromise LED T8 Replacement Tube": <http://www.cree.com/News-and-Events/Cree-News/Press-Releases/2014/May/T8-tube-release>

² Forthcoming: "2015 Non-residential Lighting Market Research and Momentum Savings Report" Bonneville Power Administration, available at www.bpa.gov/goto/MomentumSavings

type A (“Plug-and-play”), type B (“Line Voltage”), type C (“External Driver”)^[3]. A fourth type, “Hybrid” or “Universal”, found in the market but not officially classified by UL, can function both as a plug-and-play and line voltage lamp.

Plug-and-Play (UL type A): This lamp type is defined as one that operates off of the existing fluorescent ballast in the fixture. Installation only requires replacing the lamp. Plug-and-play TLEDs represent the focus on convenience in the lighting retrofit market. Having to do no rewiring or even minor work to the fixture means nearly anyone familiar with linear fluorescent fixtures can replace this lamp quickly and easily. Additionally, as lamp prices drop, labor costs become an increasingly important factor, giving plug-and-plays even greater appeal.

Line Voltage (UL type B): This lamp type is installed directly into the existing sockets, after the existing ballast is disconnected or removed from the fixture. Since the lamp runs on line voltage, the sockets often need to be replaced with ones specifically designed for these lamps. Within line voltage TLED lamp models, there are numerous possible wiring configurations that use voltage through one or both of the sockets, and one or two pins on each end of the lamp. This lamp operates on an LED driver that is housed inside the lamp itself. It should be noted some major manufacturers, such as Osram Sylvania and Philips, have specifically made the decision to not produce line voltage lamps, due to the possibility of safety risks.

“External Driver” (type C): As with line voltage lamps, the ballast is disconnected or removed from the fixture. This lamp operates on an LED driver that sits outside the lamp somewhere in the fixture, meaning that the sockets are not wired with line voltage but rather low voltage DC.

“Hybrid”, “Universal” (unofficial type ‘AB’): Not officially defined by UL, this lamp functionally operates as either a type ‘A’ lamp or a type ‘B’ lamp, depending on how it is installed. The same lamp can operate using an existing fluorescent ballast (type A), or the lamp can be wired directly to line voltage sockets (type B).

Diagrams showing the various possible wiring configurations can be found in the appendix.

Technical and business advancements

There are rapid technology developments that have consequences for the quality and price of TLEDs. A team from BPA visited Light Fair in San Diego in April 2016 and observed several consistent trends across manufacturers. First, manufacturers were ‘leap-frogging’ their own TLED technology with a new lamp model every few months. A common refrain from manufacturers was that they offered a basic TLED model fall of 2015, in the winter they refined it, and the summer of 2016 there will yet another variation of lamp. Technically, this means that within nine months a TLED lamp could be two generations old.

Secondly, TLEDs are quickly becoming commodity products, though some manufacturers are finding niche markets for specialized TLEDs (some are highlighted below). With over 200 manufacturers producing a technically simple product, it will be difficult for producers to differentiate their TLEDs from

³ UL 1598c “Standard for Light-Emitting Diode (LED) Retrofit Luminaire Conversion Kits”: <http://ulstandards.ul.com>

those of their competitors. In theory, consumers who see uniform, commoditized products will only base their buying decisions on price, and thus prices will all converge where supply meets demand.

Lastly, many manufacturers, especially large ones, are choosing to produce TLEDs in tiers of quality; a manufacturer will produce expensive TLEDs with higher quality components and materials, and at the same time produce value TLEDs, with cheaper components, and that may not be DLC listed. Producing lamps at varying quality and price tiers is reflecting two possible strategies on the part of manufacturers. One, the market has not yet determined how consumers value quality versus price and is gauging demand for each tier; and two, manufacturers believe that, like cars, consumers value variety and selection; offering a 'good, better, and best' TLED might appeal to different market segments with different priorities.

There are also technological changes occurring across TLED types. A few specific advancements observed at Light Fair include:

Universal lamps: Also known as 'hybrid' TLEDs; these lamps are a relatively new model of TLED. With the amount of market share a versatile product like this could tap into, manufacturers are improving type AB lamps to operate on both magnetic and electronic ballasts. A potential pitfall of this lamp's strategy is that it may work in many applications, but also perform poorly in many applications. If the technology can prove that it performs well on many types of ballasts as well as line voltage, this lamp type has a lot of potential for growth in the retrofit market.

Integrated Controls: There are a small number of TLEDs on the market today that come with integrated controls. A wire runs out the end of the lamp and can be connected to a control network. Currently this technology is not ubiquitous but may be gaining popularity.

Heatsinks: A couple manufacturers said they were planning on producing a TLED model with an aluminum heatsink on the back of the bulb to avoid heat getting trapped inside the lamp, potentially harming the LED components. This solution makes this particular TLED a poor candidate for fixtures that require omnidirectional lighting. However, it would be very effective in applications that make use of directional lighting and where a long operating life is highly valued, such as high-bays.

Niche Applications: A couple manufacturers shared that they had or planned to produce TLEDs for applications which require specific material and quality standards. One example of this is TLEDs that are encased in shatter-resistant glass. Shatter-proof glass is a requirement for any lighting in a food preparation area. Another example seen was a TLED that had a coating that blocked all UV light emanating from the lamp; the specific application for this TLED was a computer components processing area. As TLEDs mature, we are likely to see more variations like these that allow the lamps to permeate into more applications.

Less directionality: TLEDs used to be a very directional light source, but some new models are nearly omnidirectional.

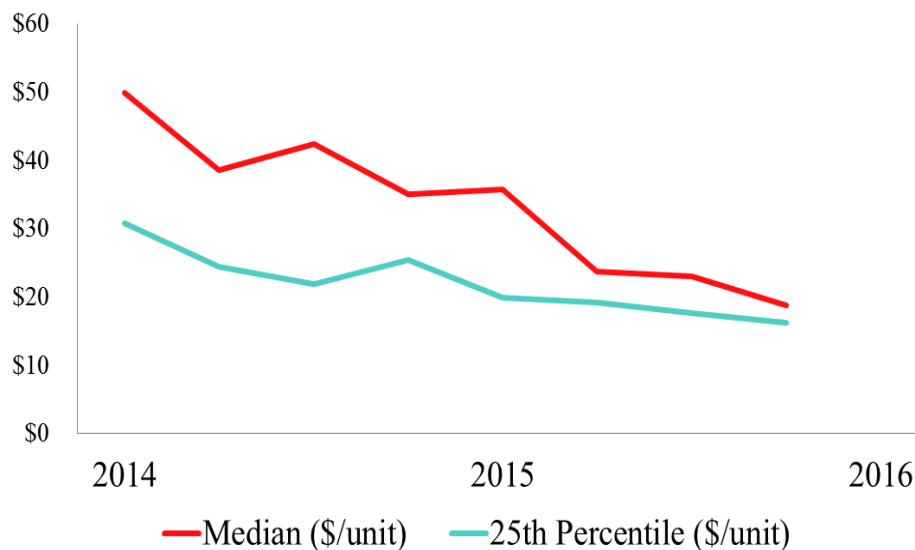
Together, these refinements in TLEDs demonstrate that the market is neither nascent nor mature; TLEDs are at the stage where the technology is established and manufacturers are working to refine the technology and its applications.

TLEDs are a highly competitive market

The marketplace for TLEDs is hyper-competitive currently, meaning change happens quickly and assumptions about TLEDs need to be often rechecked for accuracy. This level of competition is in part due to the fact that there are so many manufacturers fighting for market share, with over 200 manufacturers represented on the DLC alone ^[4]. So many firms exist because it was easy for small, mostly Chinese firms to begin to produce TLEDs because TLEDs were essentially reengineering existing components and materials. With such a low technological barrier to market entry, a bottoms-up business model encouraged dozens of newly-founded companies to produce TLEDs. This set off a competitive race to produce TLEDs at lower and lower costs.

This level of competition has resulted in prices dropping precipitously, but it ultimately cannot be sustained. As prices drop, many manufacturers will not be able to sustain profits and only those with significant economies of scale, or those that can effectively demonstrate product differentiation, will ultimately survive. However the TLED market may look when it has matured, consolidation is very likely in the marketplace.

Figure 1: Historical Price of TLEDs^[5]



⁴ Design Lights Consortium, April 2016; Analyzed by Cadeo Group.

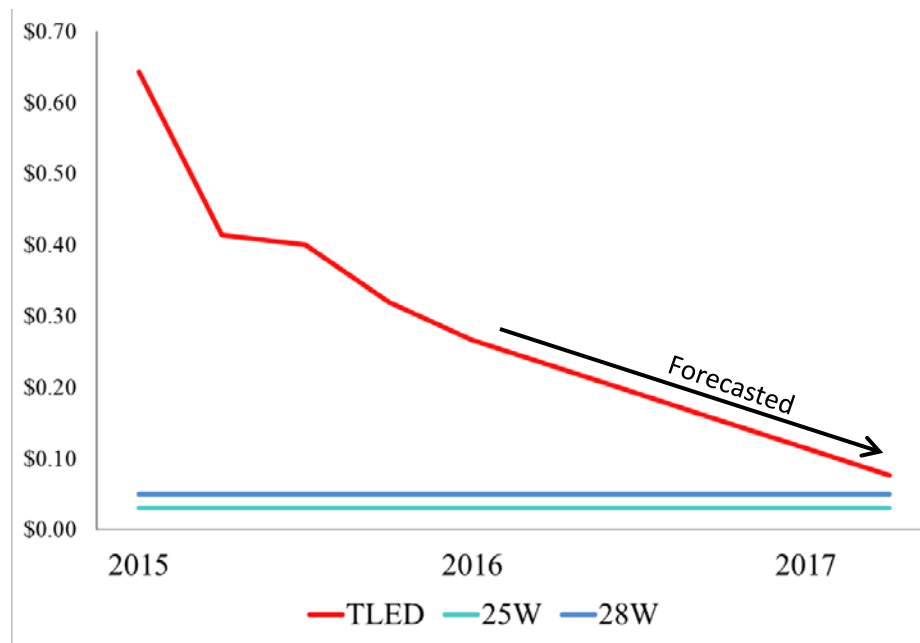
⁵ Navigant Consulting Analysis.

Costs and cost-effectiveness parity

The cost of energy saved from TLEDs is getting closer to that of linear fluorescents. In just the last two years, from 2014 to the end of 2015, the average retail price of a TLED lamp has plummeted from around \$50 to \$18 as shown in Figure 1, and the price drop will continue. As of June, 2016, TLEDs can be found at some big box home improvement stores for around \$10 per lamp. Some manufacturers shared at Light Fair that we may very well see prices as low as \$6 by mid-2017.

As prices drop, the cost per kWh for TLEDs gets closer to that of low-wattage fluorescent bulbs, as seen in Figure 2. The latest complete cost data on TLEDs from late-2015 shows that TLEDs cost \$18 a lamp, which is still relatively expensive, at \$0.30 per kWh (compared to a 28W T8, at \$0.05 per kWh). But at a \$6 a lamp, which may occur in 2017 or 2018, TLEDs are edging in on T8s at \$0.07 per kWh. It is important to highlight that the end-user will still see a retail price of TLEDs that is twice that of fluorescents, but the difference in the cost of a kWh saved will be negligible.

Figure 2: Historical and Forecasted Price Per kWh^[6]



TLEDs could drive significant future energy savings

Because TLEDs are highly efficient and can access the total retrofit market they could be a large source of energy savings in the future. Linear lamps in the Pacific Northwest account for 72% of installed commercial wattage⁷. TLEDs have the unique ability within the broader technology of LED lighting to reach a significant portion of this market because TLEDs, like low-wattage T8s, can be used in both the maintenance market (lamp change-outs) *and* the system-wide retrofit market (complete fixture and lamp change-out). In contrast, LED luminaires require an entire system retrofit, which has more up-front costs

⁶ Analysis by Ray Hartwell, using Navigant historical price analysis. Assumes 25W and 28W costs and kWh savings are constant.

⁷ Commercial Building Stock Assessment, 2013, Northwest Energy Efficiency Alliance.

and challenges for the end-user. Plug-and-Play, hybrid, and to some extent line voltage TLEDs can be installed with very little time and effort on the part of a contractor and all TLEDs make use of the existing fixture.

Of all retrofit projects each year, estimates show that system-wide retrofits account for 25-30% of projects and that the maintenance market accounts for 70-75% of projects⁸. Since TLEDs can access both the system-wide, and maintenance projects, they can penetrate four-times as many projects than LED luminaire technology which is limited to system-wide retrofits. That potential coupled with the fact that TLEDs use an average 17W (relative to a T8's 32W) means that TLEDs can deliver significant savings in the commercial sector, and in a much shorter amount of time than LED luminaires.

However, as other non-TLED retrofit options develop, LED luminaire advancements may compete with TLED on convenience. Some manufacturers at LightFair 2015 were showing LED retrofit kits (some with controls) that could fit into an existing fixture relatively simply.

Some in the Energy Efficiency Industry's worry that TLEDs leave savings on the table

Some energy efficiency industry professionals have reservations about TLEDs. Three of the most common concerns are that TLEDs are a 'band aid' solution to the adoption of LED technology, that TLEDs are not a quality product, and that some types of TLEDs carry significant safety risks.

Band aid product: One of the biggest concerns some have is that TLEDs are forestalling many consumers from making the leap to LED luminaires and controls. Some believe the goal of lighting programs should be to promote comprehensive system retrofits that make use of highly-efficient and advanced-controlled LED luminaires that are not reliant on incumbent technology or hardware, like ballasts and fixtures. Because TLEDs are cheaper, end-users may be tempted to install TLEDs, which once installed, may prevent the lighting system from using advanced lighting controls in the future. Since lighting controls are a source of additional savings for programs, TLEDs would be seen as a significant obstacle even after they are installed and functioning.

Quality: With so many TLEDs being produced by new and foreign firms with no reputation or experience in the industry, there is concern that there is not a rigorous standard of quality for TLEDs. Anecdotal stories of failing TLEDs are sometimes backed up by actual recalls of lamps, though it is hard to say definitively if TLEDs experience more failures than other technologies. Some have speculated that there may be issues in the future with warranties that may not be honored if the manufacturer goes out of business. Program managers have shared concerns about ballast compatibility and ballast failure being a weak link in TLED lighting.

Fluorescent and TLED lamps also produce and disperse light in very different ways. Unlike fluorescents which are omnidirectional, TLEDs are directional. This means that retrofitted fluorescent fixtures, which were made to distribute lighting from an omnidirectional lamp, now

⁸ Navigant Consulting and Cadeo Group analysis, 2016.

have to accommodate the directional light from a TLED. This can create poor quality lighting conditions with over-lit and under-lit spaces.

Safety: Both line voltage and hybrid TLED types operate on sockets that have been rewired to use line voltage. At Light Fair 2015, Osram Sylvania and Philips reported that they are not producing line voltage lamps because of concerns about electrocution. Those that do produce line voltage lamps include stickers that must be put in the fixture to alert any maintenance person that the sockets have been rewired to line voltage.

Some of the disagreement about TLEDs could come from the fact that the technology is changing so rapidly; with models of TLEDs with new refinements coming out every few months, what was true six months ago may not be true today. Do TLEDs have a higher failure rate? Perhaps TLEDs of two generations ago did, is it a different story when we talk about TLEDs being produced today? Some of the debate it is potentially also based on a philosophical divide in the industry that goes beyond TLEDs. What is the role of programs to ensure and maintain quality products in our region? How much can and should utility programs alter these market forces?

TLEDs create opportunities and challenges for programs

A market in a period of rapid change makes it difficult for any energy efficiency program to stay in step; dropping prices, rapid technology evolution, and two-hundred manufacturers make quality concerns difficult to manage. The pace fundamentally challenges the conventional energy efficiency program model of setting fixed incentives for long durations of time. As soon as the incentive is set, the price has changed. With some TLED lamps possibly reaching \$6 within a year, those lighting programs without incentive caps may be paying a five times the cost of the product. On the technical side, if a program manager writes a specification that addresses a particular problem, the market could solve that problem or alleviate it in a matter of months.

Additionally, most programs in the region recognize TLEDs as a single technology in their incentive structure, when there are four distinct types of TLEDs. Each TLED type carries with it very different consequences for quality, specifications, and energy savings, as outlined earlier. And even within a single type of TLED, manufacturers are beginning to create tiers of quality, with corresponding prices. Of course, this creates more work for a program manager trying to promote quality TLEDs while also running a streamlined program.

One of program's levers in the market is to influence quality. With two-hundred manufacturers in the market, who holds responsibility for lamp warranties when the manufacturer has gone out of business? It is too early to know who the winners and losers in the TLED market will be. As soon as a quality concern is identified, the market could have moved to fix or circumvent it, while a new quality concern may emerge.

Conclusion

TLED technology is rapidly changing, making it paramount that we continue to monitor and study TLEDs to stay up to speed with the reality of the marketplace. The hyper-competitive manufacturing environment of TLEDs is creating downward price pressure which will likely lead to a consolidation in

the number of manufacturers, and a more cost-effective source of energy savings. Energy-efficiency programs could capture significant savings from TLEDs because of their efficiency and retrofit potential, despite some in the energy efficiency community having concerns that TLEDs are not always the best option. The savings opportunity that TLEDs offer could be exploited through strong regional program coordination to leverage the benefits and mitigate the difficulties that TLEDs pose. Regardless of how the energy efficient industry feels about TLEDs though, they are likely to continue to grow as an important lighting solution for the near-future as the technology matures and becomes more cost-effective.

Given this, we recommend:

1. **Regional energy efficiency program coordination on consumer message and education on TLEDs:** End-users are facing a tough job as they decide what lighting solution is appropriate to meet their needs. A coordinated approach could help consumers get the light quality they desire at the best price point that will save them the most energy in the long-run.
2. **Regional coordination, where possible, on incentive design:** Utilities and energy efficiency organizations have different needs which drive their incentive design. However, these needs should be weighed against the market impacts of uncoordinated incentive design. Disparate incentive design creates less influence in the wider market and market actor and consumer confusion. Coordinated incentive designs would simplify programs for many market actors while providing a clearer and more persuasive signal to the market to influence efficiency.
3. **Incorporation of price declines in incentive levels:** We recommend checking prices on TLEDs twice a year. A regional “price index” could economically be developed which would look at the rate of change in the prices for a few distributors, and provide that rate of change to program administrators. While this price index would have limitations due to a reliance on a few large distributors pricing, it would be an achievable method for measuring the drop in average prices. As the prices decline, incentives should keep pace. Rapidly falling prices frequently “outrun” incentives set by programs, and keeping incentives in line with the market helps contain cost; avoids overpayment windfalls to contractors, manufacturers, and customers, and limits interference with natural competition and price declines in the lamp market.
4. **The consideration of market segments when designing TLED program strategy.** TLED adoption has varied widely by market segment, and different program and incentive strategies are needed depending on the circumstance. Small businesses with limited capital tend to be late adopters, whereas large businesses have anecdotally been much quicker to adopt TLED.
5. **Increased information on market penetration of TLED:** Collecting data on market changes is a complex undertaking with many moving parts. TLED sales data collection is even trickier, as TLEDs might not always follow the traditional path to market. The team recommends: (1) twice yearly full-category sales data collection embedded into any mid-stream program requirement; (2) full-market sales data collection conducted annually for all distributors; (3) frequent qualitative research to identify new channels to market for linear lamps; (4) following new technology availability in order to track emerging products which may change the landscape.

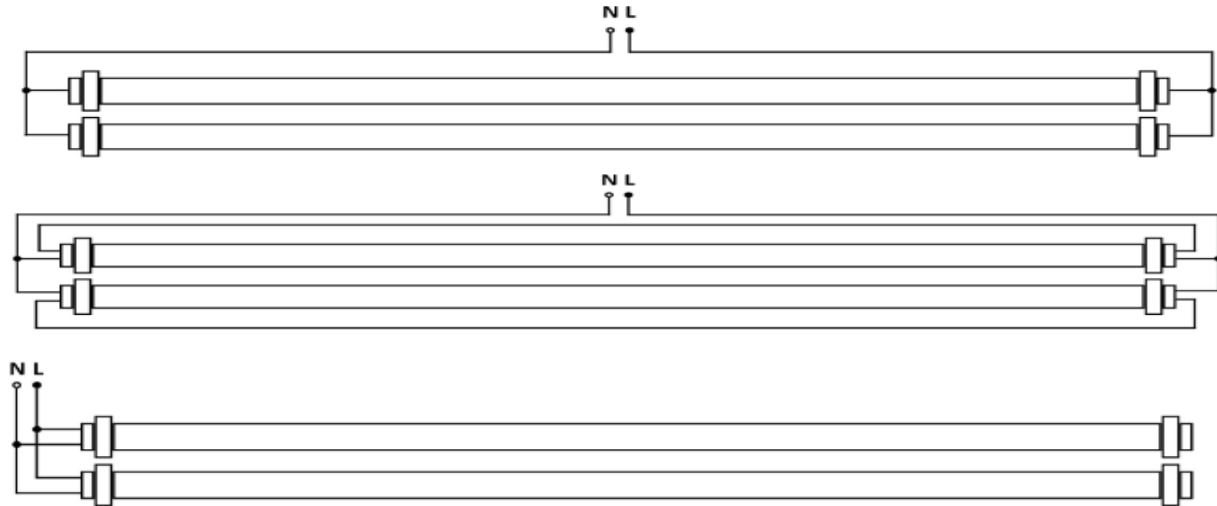
Appendix

TLED Technical Diagrams - Courtesy of Jeff McCullough, Pacific Northwest National Lab

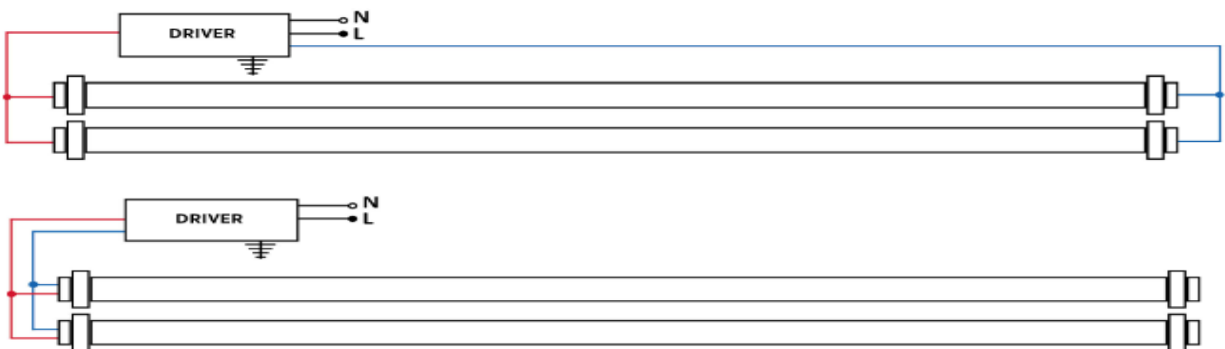
Plug-and-Play (UL Type A)



Line Voltage (UL Type B)



External Driver (UL Type C)



Hybrid, Universal (*Not pictured* – operates as either a plug-and-play or a line voltage lamp)