Eneref Institute

PR FOR PLANET EARTH™

A REPORT ADVOCATING FOR SOCIALLY RESPONSIBLE SUSTAINABLE DEVELOPMENT

EMPLOYING POLYCARBONATE COMPONENTS TO DESIGN **SUSTAINABLE LUMINAIRES**

ENEREF INSTITUTE EXAMINES THE SUSTAINABILITY BENEFITS OF POLYCARBONATE IN PLACE OF ALUMINUM IN LED LUMINAIRES.

For several years, the lighting industry has moved aggressively into lighting controls—making a play for the Internet of Things. Yet, unlike the computer industry that is now competing to offer home controls, the lighting industry has been slow to advocate for sustainability. According to the United Nations University Solving the E-Waste Problem Initiative, about 85 million tons of damaged, obsolete or simply unwanted electronic devices were discarded as e-waste in 2017 alone.

- Similar to the personal computer manufacturing industry, lighting manufacturers need to design their products in a responsible way to more easily recover and recycle their goods and provide convenient recycling options for customers to safely dispose of their end-of-life product.

- The industry should not wait for the government to step in and regulate—the EPA's National Strategy for Electronics Stewardship is already working with governments and environmental officials around the world on e-waste management.

In closed-loop recycling, both aluminum and thermoplastic can be taken apart, cleaned and reused as postconsumer recycle material. However, thermoplastics do have advantages; for example, the energy needed to melt thermoplastics such as polycarbonate is one-fourth that of aluminum.

As part of our "Don't Burn. Build." campaign, Eneref Institute examines opportunities to replace metal component parts in LED luminaires with polycarbonate, with the overarching goal of reducing the environmental footprint of the lighting industry.

POLYCARBONATE IS LESS ENVIRONMENTALLY HARMFUL

While no panacea, drilling for petrochemical hydrocarbons—the raw material of plastics—is far less destructive to the environment than mining for aluminum. Metal mining is linked to water contamination, deforestation and environmental degradation, as well as conflict and violence due to land grabbing. In fact, in 2017, El Salvador voted to prohibit the mining of all metals, making the country the first in the world to impose a nationwide ban on metal mining.

Hydrocarbon combustion is the primary driver of global warming. Transitioning petrochemicals into plastic materials—rather than burning the fossil fuels as energy—is one more tool available to reduce the cataclysmic results of adding carbon to the atmosphere. Atmospheric carbon levels are already at 411 ppm, up from 265 ppm at the beginning of the Industrial Revolution.

Eneref is *not* advocating for the use of polymers like plastic bags or bottles, which can be recycled but more often end up as unrecycled waste. Instead, we are advocating for the use of polymers as reclaimable, reusable and recyclable products.

While a comparison of the full lifecycle assessment between aluminum and plastic is difficult, according to MIT's Environmentally Benign Manufacturing Group, in general, plastics from crude oil require under 100 MJ of energy to produce, whereas virgin aluminum requires close to 250 MJ. These numbers are extrapolated from work by MIT Professor Tim Gutowski.

A large portion of GHG emissions come as a result of resource acquisition, manufacturing, transportation and end-of-life lifecycle stages. It requires energy to mine expanses of earth to reach bauxite, the primary ore of aluminum, as well as to transport it. Most bauxite is found in metal-rich areas of the world and then transported to industrialized countries for mineral extraction.

Compared to the same volume of aluminum, polycarbonate requires less energy to ship, because it is less dense and therefore weighs less. In fact, polycarbonate weighs less than half as much as aluminum, which weighs 2.7 grams per cubic centimeter.

Moreover, nearly all extracted oil and natural gas is usable for making plastic, whereas only a small percentage of mined ore can be used to make aluminum. Of the millions of tons of ore processed every year, over 95% is disposed of as waste, according to a May 2017 report published in Minerals Engineering Journal, a white paper funded by the Natural Environment Research Council.

APPLICATIONS FOR PLASTIC

Presently polycarbonate is used to replace metal in numerous applications: housings for medical equipment, electric vehicle charging stations, network devices, junction boxes, sensors and security cameras. Within the lighting industry, polycarbonate is already common in optics and lenses of lamps and luminaires, but it has also been used to replace metal in heat sinks, reflectors and housings.

In addition to its use in various products, polycarbonate, a thermoplastic, can be economically recycled into secondary, post-industry applications. Within the electronics industry, reclaimed polycarbonate is ground and cut with virgin material to make desktop computers, printers and electronic chargers. Building material companies down-cycle polycarbonate for noncritical applications in everything from park benches to pallets to decks.

THE BENEFITS OF CONSOLIDATION

Optimizing design by consolidating components of the same material streamlines both the manufacturing and recycling of luminaires. With fewer components made from fewer materials, the purchasing, shipping and warehousing processes are simplified. Polycarbonate parts can be co-injection-molded or joined together by various techniques, eliminating assembly steps. Waste and scrap rates are also reduced. And recycling various parts made from the same material is far more efficient than negotiating multiple recycling resources.

"I once actually molded a heat sink around the LED module, so it was pretty close to just one shot and it's done. The lens snapped in place," said Andy Beregszaszi, Innovation and Development Engineer of Luxtech LED. "You can't do that with aluminum."

One obstacle to introducing new materials into any industry is that the engineering requires additional and sometimes more sophisticated development. In lighting, engineers are accustomed to aluminum and might be skeptical of polycarbonate's benefits.

The back enclosure of A.L.P. Lighting's Recruit™ wall mount fixture is injection molded from Makrolon® TC polycarbonate.

THERMAL MANAGEMENT AND HEAT SINKS

Despite potential skepticism, Eneref has found polycarbonate heat sinks successfully deployed in luminaires across the United States, Asia and Europe, including in outdoor wall sconces, emergency lighting, high-bay systems and automotive components. It's an application-specific decision that depends upon the package space and desired steady-state operating temperature. As LEDs grow more efficient, future designs should better accommodate polycarbonate heat sinks that are injection-molded or extruded from thermally conductive polycarbonate.

A large percentage of the aluminum in any LED luminaire is used as a heat sink, which could be replaced by polycarbonate. In some heat sink applications, the use of aluminum may simply be over-engineered. Although thermal conductivity for aluminum (90 W/mK for cast aluminum; 200 W/mK for extruded aluminum), is far more conductive than polycarbonate, higher thermal conductivity is not necessarily better. In testing, there was no significant improvement in thermal management for LED case temperatures above 20 W/mK. With additives, polycarbonate's conductivity can be increased 100-fold, up to 22 W/mK.

In addition to good thermal management through conduction, thermally conductive polycarbonate offers design freedom to further multiply heat dissipation by convection. Because polycarbonate heat sinks are typically injection-molded, intricate designs can be fabricated to increase surface area, which in turn increases convection. Polycarbonate parts can be designed to occupy the same package space with considerably more surface area than aluminum. While adding mass to any heat sink makes it more effective, designing more surface area into the heat sink is really what drives thermal management. And some designs that increase surface area may result in a further reduction of weight and material.

In fact, in poor convection

The housing of SLP Lighting's CircLED™ high bay fixture acts as a heat sink and is injection molded with Makrolon® TC8030 polycarbonate.

environments, better conductors offer negligible advantage. For example, in a kitchen downlight with little airflow—or natural convection—all the conductivity of aluminum beyond, say, 10 W/mK, is wasted. Heat can't be pulled away from the heat sink any faster than airflow allows. Additionally, greater heat dissipation can be achieved with thermally conductive polycarbonate through radiation as a result of its high emissivity compared to most aluminum grades and surface treatments.

REDUCING COMPONENTS

Thermal interface materials, such as grease, that adhere LED modules to the aluminum heat sink and eliminate any irregularities that reduce heat transfer, could instead be accomplished simultaneously with an in-mold polycarbonate assembly. This increases the conductivity of a polycarbonate heat sink, while reducing costs.

In fact, conductive grease has a conductivity in the range of 1 to 3 W/mK—lower than thermally conductive polycarbonate—and can grow brittle over time, further reducing conductivity, even to the point of failure.

Polycarbonate can also be used to replace metal reflectors, moving luminaires closer to being nearly metal-free. To create reflective properties, polycarbonate is blended with a light-reflecting pigment package.

Before ever finding their way

into a luminaire, metal reflectors often require complex processes such as vacuum coating or wet-chemical electroplating. Specular aluminum reflector surfaces are coated by running five-ton aluminum substrate coils through a vacuum line. Replacing multi-faceted or parabolic aluminum reflectors with polycarbonate can reduce these high manufacturing costs.

POLYCARBONATE ALLOWS FOR FREEDOM OF DESIGN

In order to alter the paradigm, engineers need to change their thinking about the geometry of the components they design. For example, although screwing threaded fasteners directly into thermally conductive plastic materials isn't feasible, durable plastic attachments can snap precisely into place, simplifying assembly and dismantling. While manufacturing with plastic requires higher volumes to amortize tooling costs, molds for plastic heat sinks can offer longer tool life and higher production volume compared with molds for aluminum.

Aluminum heat sinks are typically die-cast, whereas polycarbonate heat sinks are injection-molded. The cycle time for injection-molded polycarbonate (filling, cooling, etc.) is slightly longer than the aluminum molding process—influencing the piece price of finished goods—however die-cast aluminum heat sinks often require secondary finishing operations to achieve a final part. And because the additives to increase the thermal conductivity of polycarbonate are nonmetallic and nonabrasive, the injection molds can outlast the molds for aluminum heat sinks by as much as five to one. Moreover, plastic materials allow designers to create shapes that would not otherwise be possible. In fact, many light fixtures are linear, making extrusions of plastic a natural manufacturing process of luminaires.

MEASURING THE STRENGTH OF PLASTICS

The high impact strength of polycarbonate lenses protects components from abuse, impact and vandalism over a wide temperature range. And polycarbonate is less sensitive to corrosion than aluminum from saltwater near ocean locations. However, when designing with polycarbonate, like any polymer, consider that altering its characteristics with additives will also change its properties. Improving one property sacrifices another. The same trade-offs occur in metals and alloys as well.

REDUCING WEIGHT INCREASES SUSTAINABILITY

Per pound, polycarbonate is more expensive than aluminum. But because polycarbonate is half the density, more parts can be manufactured from the same volume. That's why polycarbonate heat sinks are half the weight of their aluminum counterparts.

This weight reduction contributes to a more sustainable environment worldwide; from initial OEM component shipping to end-user installation, less energy is needed. Installing fixtures with less weight also increases worker safety, especially with large or outdoor systems. For the installers, holding a 50-pound fixture over their heads while 30 feet up on a ladder is much less safe than working with one that's lighter-weight.

PLASTIC IS RECYCLABLE

Despite the ability to recycle plastics to very high purity levels, some mechanically recycled plastics do not hit the same physical properties of their virgin counterparts. However, new additives are being introduced to help boost the properties of recycled plastics. Ultimately, the plastics industry is working toward making plastic infinitely recyclable with limitless applications—and with emerging technologies like chemical recycling and solvent extraction, what was once just a lofty goal could become the new reality.

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Every organization possesses the opportunity to improve our planet and society.

Our initiatives encourage organizations to grow sustainably and act responsibly by raising awareness for clear, specific solutions that offer an efficient use of natural resources, demonstrate social responsibility and foster a peaceful, earth-friendly economy.

We launch initiatives designed to encourage the best that commerce has to offer—for people and for our planet. We promote the idea that being resource-efficient and socially responsible, is also profitable. Our Advocacy Reports demonstrate the benefits of successful solutions.

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