GREEN CUBES
THE POWER TO PERFORM

Lithium-ion Technology for Electric Ground Support Equipment

With the emergence of more and more electric Ground Support Equipment (eGSE), there is potential for great savings in Total Cost of Ownership (TCO) versus Internal Combustion Engines (ICE) and airports and airlines can come closer to meeting their Greenhouse Gas (GHG) emissions goals. Li-ion technology is expected to grow exponentially within this market due to the efficiency gains, lower maintenance, and environmental benefits over Lead Acid batteries. Green Cubes offers clean lithium power systems to support existing and new eGSE deployed around the globe. For more than a decade, Green Cubes has specialized in lead acid and internal combustion replacement solutions for material handling equipment, and we've taken that knowledge and expertise and applied it to the rapidly growing market of eGSE.

IN THE ELECTRIFICATION OF GSE,

Green Cubes Technology estimates that Lead Acid batteries will gain some market share over Internal Combustion Engines, but modern, Lithium ion (Li-ion) batteries will grow in this market from about 3% market share to 20% market share in the next five years and will continue to grow exponentially as further regulations are enacted.

Worldwide Adoption of eGSE

Ground-based airport Green House Gas (GHG) emissions are caused by gasoline and diesel fuel for airport vehicles and ground support equipment (GSE), fossil fuel for electricity and heating, jet fuel for auxiliary power units (APUs) that power aircraft at airport gates. Federal, state, and local governments are setting GHG reduction goals to reduce their local contributions to global GHG levels and airports stand to gain from the financial efficiencies of green energy. Many airlines, such as Alaska, Delta and United have publicly identified electric GSE (eGSE) as a first step to carbon reductions in their sustainability reports. Airports can also purchase renewable energy, install airport renewable energy systems, reduce energy consumption, monitor the efficiency of heating, ventilation, and cooling systems in a multi-pronged approach.

There are now 152 airports worldwide certified for mapping their carbon footprints and the process of Airport Carbon Accreditation. Reaching Level 4+ "Transition" means that the airport has aligned its CO2 management with global climate goals and compensated for the remaining residual emissions with high quality carbon credits. There are now 13 airports in the world that have achieved this level. So far only one in North American, Dallas Fort Worth International Airport, has achieved Level 4+, "Transition" status, representing just 3.7% of air passenger traffic. With this large untapped market, Green Cubes Technology (Green Cubes) estimates that Lead Acid batteries will gain some market share over Internal Combustion Engines (ICE), but modern, Lithium ion (Li-ion) batteries will grow in this market from about 3% market share to 20% market share in the next five years and will continue to grow exponentially as further regulations are enacted.

Power Technology Challenges

All power technology requires some maintenance to keep it operating efficiently. With diesel engines, handlers need to perform preventive maintenance (PM) on a regular basis – using petrochemicals in the process and generating a waste stream. Handlers also need to refuel these engines with diesel fuel that is getting increasingly more expensive year over year. With flooded lead acid (FLA), handlers need to regularly water them, perform equalization charges on a set schedule, and rebalance the pH in the battery. This can become a costly process over the life of the battery and maintenance costs need to be accounted for along with battery watering and equalization cycles that need to be tracked in order to comply with manufacturer warranties.

FLA can also emit hydrogen when charging due to heating, so it needs to be charged in a properly ventilated space for safety. This can be an issue in enclosed spaces such as baggage rooms or charging rooms. Costly ventilation systems need to be utilized to ensure that the off-gassing during charging does not cause hydrogen buildup. Some eGSE fleets have implemented Sealed Lead Acid (SLA) batteries, which do not require monitoring and only vent if there is an issue with the battery. There is still the possibility that SLA can vent hydrogen if it is charged improperly, or if a cell is going bad.

Both FLA and SLA batteries are limited in how fast they can charge before cell damage happens. Many manufacturers only recommend up to a 3C charge rate. However, this is not for the entire charging cycle, which means that a full charge can take five or more hours depending upon the charging infrastructure, and the environment in which it's used. Most Lead Acid batteries charge at about 80% efficiency, so there is a significant waste of electricity.

Levels of Airport Carbon Accreditation

+ **MAPPING**
  Footprint measurement
+ **REDUCTION**
  Carbon management towards a reduced carbon footprint
+ **OPTIMISATION**
  Third party engagement in carbon footprint reduction
+ **NEUTRALITY**
  Carbon neutrality for direct emissions by offsetting
+ **TRANSFORMATION**
  Transforming airport operations and those of its business partners to achieve absolute emissions reductions
+ **TRANSITION**
  Compensation for residual emissions with reliable offsets

Lithium Iron Phosphate

Green Cubes lithium power systems use Lithium Iron Phosphate (LFP) which It is a very reliable chemistry with decent energy density; but, more importantly, it is a very safe and stable chemistry that doesn't include toxic metals and has an unparalleled cycle life and power output. No changes in safety equipment need to be made because ramps and GSE, which meet SDS, all have fire extinguishers already.

LFP is compatible with airfield operations because and discharging properties that match up with eGSE usage. It can handle spikes of draw in electric loaders and pushbacks without generating large amounts of heat waste throughout the system and allows for faster recharging. This faster recharging allows airside operations personnel to opportunity charge between flights and during personnel break periods. Li-ion batteries can be charged at up to 1C with 95% efficiency, allowing for a reduction in down time, and depending on its charging infrastructure, could charge in as quickly as one hour. Li-ion batteries, unlike Lead Acid, do not require equalization charges and are virtually maintenance free. When adding the elimination of watering, equalization, and higher charging efficiency, Li-ion becomes a much better operational cost option than either FLA or SLA.

LFP VS. NMC

Parameter	Lithium Iron Phosphate (LFP)	Nickel Manganese Cobalt (NMC)	Comparison
Voltage	3.2 V	3.6 or 3.7 V	NMC Batteries are lighter and more compact
Weight Energy Density	90-120 Wh/Kg	150-250 Wh/Kg	
Volume Energy Density	300-350 Wh/L	500-700 Wh/L	
Max Discharge Rate	30C	2C	LFP Batteries provide more power over a shorter period, and can be charged faster
Max Charge Rate	10C	0.5C	
Typical Cycle Life (@80%)	2000-3000 Cycles	500-1000 Cycles	LFP Batteries will deliver more cycles over a longer calendar life
Calendar Life (@80%)	8+ Years	3~ 4 Years	
Thermal Runaway Onset*	~195 °C	~170 °C	NMC Batteries have lower thermal runaway thresholds and will burn hotter
Thermal Runaway Increase*	210 °C	500 °C	

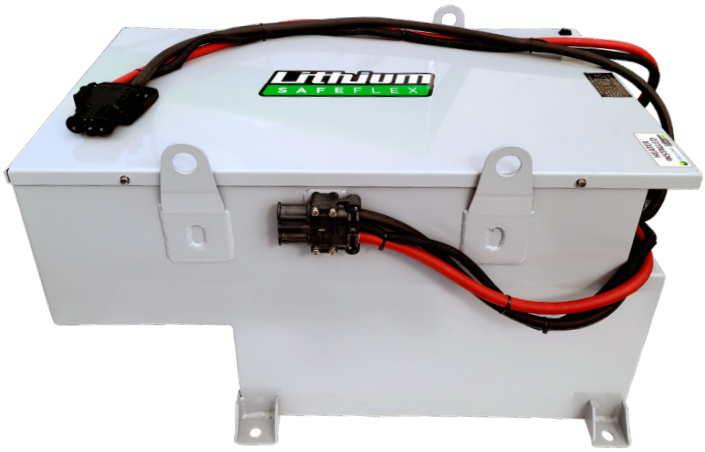
* Royal Society of Chemistry, 2014

LFP has the added advantage of being based on iron ore, which is readily abundant and non-toxic, unlike other Li-ion chemistries that contain Cobalt, Nickel, Aluminum and/or Manganese. These compounds are often unethically mined in Africa at locations that are monopolized by Chinese investors, so the supply chain for LFP is much more stable than other variants of Li-ion.

Communication and Optimization

In order to fully optimize the use of LFP batteries, we work to implement state of the art communication and charging protocols. We've worked with several eGSE Original Equipment Manufacturers (OEMs) to supply a controller area network CAN bus standard allowing communication between devices for their eGSE to optimize performance between the battery and the eGSE in which it is installed. Similarly, we've worked with different charging solutions to charge batteries using full CAN communication. Utilizing CAN protocols from a Battery Management System (BMS) to integrate with the charging infrastructure allows lithium batteries to charge at an efficiency rate of up to 98%. This translates to less energy consumption and waste from the chargers to the battery, enabling faster charging and more efficient opportunity charging.

This is critically important for airports with overtaxed electrical grids. Though there are still limitations to how fast lithium-ion batteries can be charged, it is possible to charge a battery 200% faster with using lithium-ion over lead acid.



ABOUT GREEN CUBES TECHNOLOGY

Harnessing our 35 years of industry experience, Green Cubes Technology is committed to designing, manufacturing, and implementing Lithium-ion platforms that give you The Power to Perform. Our battery packs are sustainable, maintenance-free, environmentally friendly, and superior performing.

For more information, email **info@greencubes.com** or visit **greencubes.com.**

GREEN CUBES
THE POWER TO PERFORM