Viral Batteries

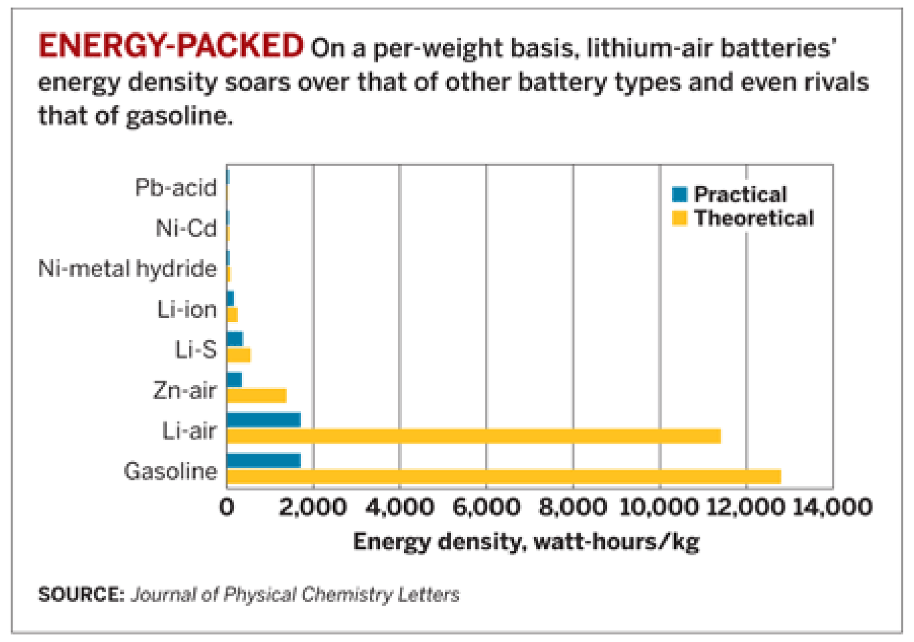
For Green, Inexpensive Energy Storage

Leah Beveridge
Evan Eisenhart
Marisa Kouma

The Problem

Today's societies are heavily technology-based, yet even with all the technological advances, battery advancements have been stagnant for decades, which is affecting our ability to create efficient, sustainable technologies. For example, one current major technology that utilizes rechargeable batteries is the electric vehicle; however, lithium-ion batteries have limited power, which limits the distance an electric vehicle can travel using one charge, limiting how much the consumer can enjoy the product. On top of general lack of improvements for lithium-ion batteries, lithium-ion batteries are a generally unsustainable power source. In lithium-ion batteries, the lithium must be bonded to a metallic polyatomic ion, where the metal is cobalt, which is a limited resource that is mined in a politically unstable and corrupt nation.

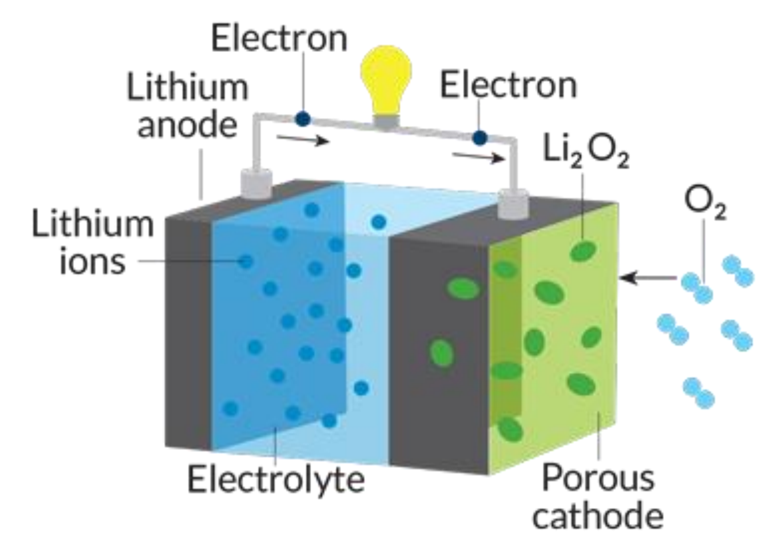
Various groups have been researching alternatives for decades. While researchers have determined the top replacement possibilities, there has been minimal success in finding a combination of reactions and other battery materials, such as casings and electrolytes, that lead to a useful power output.



Lithium-Air Batteries

Currently, the leading rechargeable battery is the lithium-ion battery, a reversible reaction based around lithium bonded to a polyatomic ion, typically including cobalt. Unfortunately, the maximum potential of lithium-ion batteries is too low to be useful as a power supply in future technological advances. As such, there is a demand for a new rechargeable battery with a greater maximum power potential with a higher level of sustainability. The most commonly researched alternative for a future power source is the lithium-air battery, which involves a reversible reaction based around lithium peroxide. Theoretically, lithium-air batteries have a much higher maximum potential than lithium-ion batteries; however, there have been numerous complications in finding all the proper reactions and materials to successfully cause a lithium-air battery reaction that outputs a useful amount of power, has a sufficient recharge cycle, and produces few, if not no, byproducts.

With the current electrolytes researchers are testing in lithium-air batteries, there is a large gap between the voltages of the first discharge and the first recharge, showing that there is still a much more efficient electrolyte that can be found and used in lithium-air batteries to maximize that lithium-air battery's potential. Unfortunately, all the obvious electrolyte options have had at least one issue that makes them unusable in the lithium-air battery system. Without the correct electrolyte, the lithium-air battery discharge will remain insufficient for practical use. Beyond the research finding the correct electrolyte for this reaction, the lithium-air batteries also have issues concerning molecular byproducts of the forward and reverse reactions. The main problem with the byproducts is that the reactions are irreversible organic reactions.



Viral Nanostrucutres

Viral nanostructures utilize the virus capsid, a coat of proteins that surrounds the viral DNA. These capsids have a well defined structure, making them useful for creating nanostructures. In the production of nanostructures for lithium-air batteries, the M13 virus was used. The M13 major coat protein, phage gene 8, makes the virus a good candidate for nanostructure production, as it creates a high number of bonding sites, allowing for a higher aspect ratio of structures.

To produce the nanowires, a manganese oxide (MO) base had to be created. First, manganese(II) ions were added to the p8 proteins. The virus with the manganese(II) ions then reacted with KMnO4. Next, the nanowires were coated in a noble metal, Pd, to increase catalytic activity and efficiency. To obtain Pd, the wires were wrapped in polyacrylic acid, then ethylene glycol was applied to eliminate excess Pd. The end result was an effective, virally created MO nanowire with Pd composite.

The new lithium-air battery was able to improve upon the gravimetric energy density (measured in power per weight) of lithium-ion batteries by two to three times. In an MIT study, biologically assembled manganese oxide nanowires showed a 40% improvement of Li2O2 storage capability. Additionally, the gap between the discharge voltage and charge voltage decreased significantly from non-virus assembled MO nanowires, meaning the efficiency improved. The enhanced discharge capacity of the biological MO nanowires is believed to have come from improvement in the conductivity and magnitude of the electrode surface area.

Electric Cars

Today, electric vehicles (EVs) typically run on lithium-ion batteries, but lithium-air batteries with the help of the M13 virus may soon be replacing them. One problem with EVs is lithium-ion batteries do not provide the same kind of energy density as gasoline, so electric car users need to recharge frequently. Fortunately, the practical energy density of lithium-air batteries, at about 1700 Wh/kg, is much higher than the energy density of lithium-ion batteries and is comparable to that of gasoline. Furthermore, lithium-air batteries have a larger power per weight ratio, meaning they are lighter and smaller than the equivalent lithium-ion batteries. Therefore, more batteries can fit within the vehicle powerpack, allowing users to travel farther. High energy density also lowers the cost of the batteries, the annual cost of recharging, shipping costs, and the upfront cost of lithium-air powered vehicles, making green travel more accessible and affordable. Furthermore, larger scale use of electric vehicles has the potential to create more jobs. Additionally, creating a new market for electric vehicles will have a positive impact on our economy and reduce our foreign dependence on oil.

Sustainability

ENVIRONMENTAL: Lithium-air batteries do not use cobalt—a limited resource. Lithium-air batteries also have a higher overall power potential, so they last longer than lithium-ion batteries, which decreases production of waste. Moreover, virus-assembled lithium-air batteries with their compacted size will be a highly useful power source for electric vehicles, which produce less pollution.

ECONOMIC: A better recharge cycle means lithium-air batteries will lneed to be replaced less frequently thaner than lithium-ion batteries. Furthermore, with the M13 virus compacting the battery size, transportation costs will be lower, since more batteries can be stored in a specific fixed volume. Once implemented in electric vehicles, oil usage in the United States will decrease, and overall spending on oil from foreign nations will decrease.

SOCIAL: Lithium-ion batteries use cobalt, which is mined using child labor in an unstable nation, but lithium-air batteries do not. Additionally, decreased dependence on foreign oil with implementation of electric vehicles means a decrease in funding toward hostile nations.