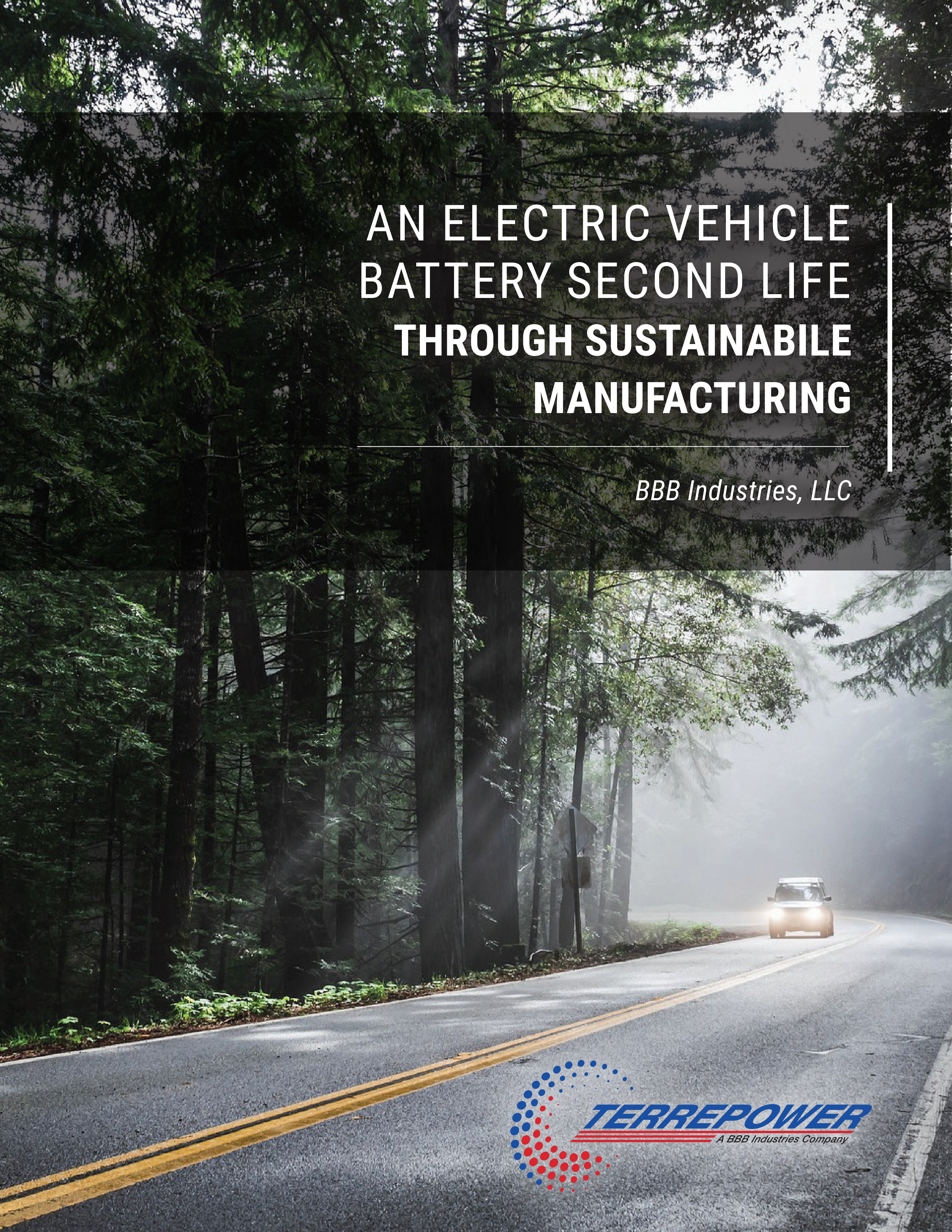
AN ELECTRIC VEHICLE BATTERY SECOND LIFE **THROUGH SUSTAINABILE MANUFACTURING**

BBB Industries, LLC



TERREPOWER
A BBB Industries Company

Introduction

Electric vehicles, though in the use phase have a decreased carbon footprint, it is important to consider the production phase environmental impacts.

Lithium, cobalt, and nickel are three materials that are called upon to meet the future demands of electric vehicle battery production. As the expected consumer choice from traditional vehicles to electric mobility begins to shift, we must consider how we approach production. The challenge to harvest a large number of critical materials has production mines scrambling. So-called "gigafactories" are springing up across the globe and debates are being had about how to properly handle critical material sourcing. Three complications arise. First, as previously stated, the transition from ICE to EV brings a material demand that falls outside the customary automotive scope. Materials will be required that are more difficult to source and are less readily available than traditional vehicle materials. Second, an incredible uptick in adoption means at some point a large number of retired batteries will eventually need to be accounted for, which makes a challenge for waste management, especially due to the hazardous nature of these batteries. Finally, unlike traditional combustion engines, an overwhelming portion of the carbon footprint attributed to a battery can be linked to the production stage (Emilsson, 2019). For an environmentally driven product, the production carbon footprint has been placed under scrutiny and must be taken seriously. The gauntlet has been set up for automotive manufacturers across the globe. Material sourcing, waste management strategy, and carbon intensity across the full product lifecycle must be addressed to ensure a sustainable electric vehicle transition.

TERREPOWER, a subsidiary of BBB Industries, LLC, aims to maximize the environmental impacts of electric vehicles by focusing beyond the

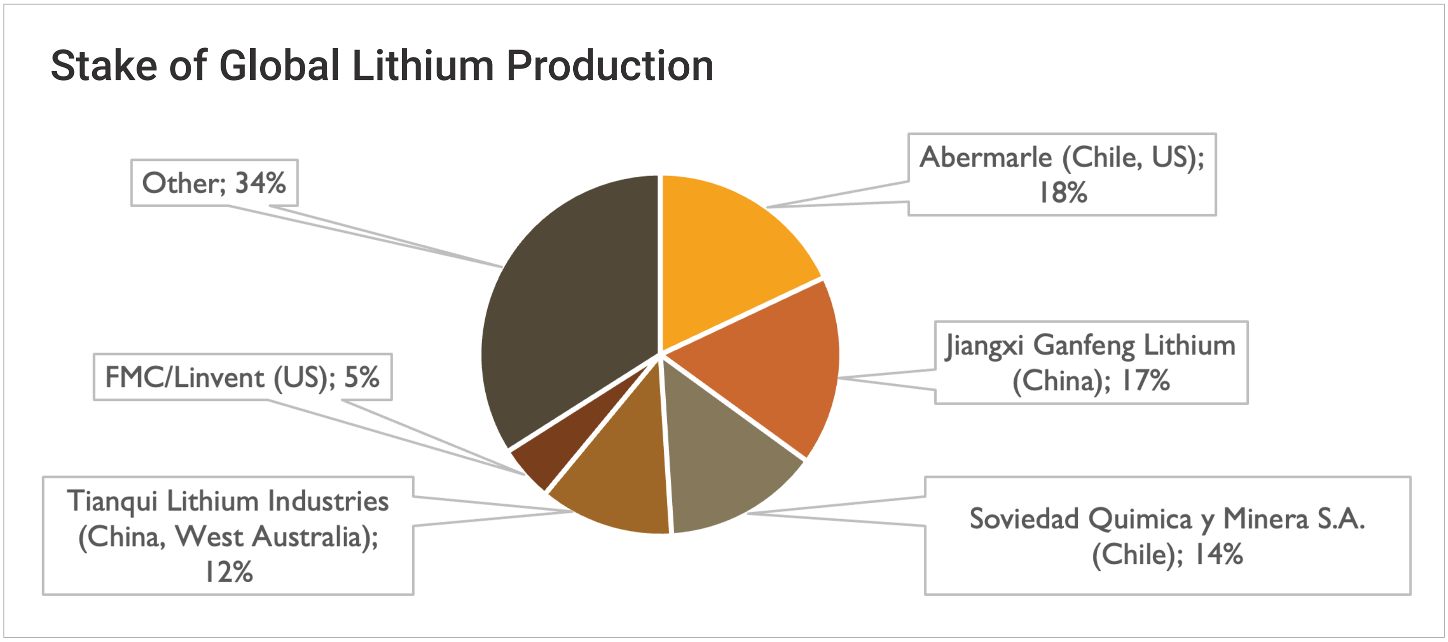
In this case study, TERREPOWER, a subsidiary of BBB Industries, LLC, aims to communicate solutions to address the need for critical materials for BEV production, the uncertainties of disposal, and the environmental impact of battery manufacturing. This has become a prominent issue due to the finite resources the earth has to offer, the negative impacts of excess hazardous waste, and a focus on mitigating carbon emissions to preserve environmental longevity. This research aims to suggest an alternative to the traditional "take-make-waste" business model and sets out to continue a conversation regarding battery second-life options in a Circular Economy. Sustainable Manufacturing is referenced further in this paper and is described as an evolution of the remanufacturing process. Sustainable Manufacturing takes spent core, replaces necessary components, and returns them to the market for a second life. As a differentiator, Sustainable Manufacturing places a strong emphasis on not only the economic basis for a return to the market but also the potential environmental impact. The environmental impact must be considered at the core of future decision-making.

A Transition and the Material Demand it Brings

The manufacturing of Electric Vehicle batteries demands the production of critical materials that the automotive market has not seen before.

At the beginning of 2021, there were 10 million electric vehicles on the road across the globe (Kuchta, 2022) and per the International Energy Agency (IEA), this is projected to increase to 125 million by 2030. While there are environmental benefits to EVs, one challenge to consider is the material necessary to produce the batteries that will be placed in these vehicles. Providing feedstock of Lithium, Nickel, and Cobalt for a 1,250% increase in vehicles is no light endeavor. Lithium demand alone is expected to face shortages by 2025 based on reports from the IEA.

Another factor to consider regarding Lithium is the supply chain constraint due to limited sourcing. Supplied from four major countries; Chile, the United States, China, and Australia, the top 5 lithium mining companies in terms of global market share hold a combined 66% of the total lithium mining supply. See the chart below based on a Seeking Alpha website report.



Lack of diversity in the supply base limits the bargaining power of the customers and puts the rest of the supply chain at risk if they were to fail, not scale fast enough, etc. Various material supply risks can also be found in Cobalt and Nickel, which are integral to battery production. We see a step in the right direction with commentary about critical material recycling and gigafactory waste to be supplemental to material requirements, however, this is only part of a solution.

A Transition and the Material Demand it Brings *(cont.)*

We conclude that manufacturers must be creative when sourcing their critical material feedstock. Before turning to where new material may come from, OEMs must consider how to preserve material already sourced. Keeping these materials at their highest value must be at the forefront of our strategies. As a battery is removed from a vehicle due to performance, the first choice is to make necessary repairs and return it to the vehicle if feasible. If it cannot be serviced and returned to vehicle use, it must be placed in an alternative work function, like stationary storage to hold power for homes, manufacturing facilities, or a plethora of other applications. The least valued strategy before disposal is recycling of materials. A strategy of sustainable manufacturing extends the highest value of materials, provides another product to the market, lowers the demand for new material sourcing, and limits e-waste, which is the next topic of discussion.

Maximized Value From Large Sums of Battery Waste

A large some of the waste is forecasted upon the end-of-life of the demanded EV components being produced today.

Let's consider defining battery waste. What constitutes BEV deemed trash? Contrary to popular opinion, there is significant value in a battery once it ends the initial application. Even when it degrades beyond acceptable use, does this mean that the entire pack is unusable? This concept is challenged by a quote from the Journal of Remanufacturing which states: "The whole idea of cells sorting and repurposing is based on the concept that only few cells are degraded when the battery reaches its end of life. The simulation … estimates that the replacement of 5 –30% of the cells can bring a battery system at a state of health > 95%." This notion showcases the opportunity of repurposing for second-life applications. It challenges the underlying (and often resorted to) statement that batteries below the acceptable use rate of vehicle application are bound for waste or recycling plants. TERREPOWER is focused on utilizing degraded batteries at their highest potential. An efficiency-minded circular economy business model, based on limited energy spent to return the product to the market, creates a segmented class system of value. Underperforming batteries first and foremost are tested for possible reapplication into a vehicle. Secondly, the spent cores are given alternative functions like stationary storage. Finally, fully degraded batteries are turned over to material recyclers to supplement base material demand. We must keep in the forefront of our strategy that material recycling remains to be a last case resort. A commentary may be brought to light regarding the valuable options that recycling brings to the table. Recycling spent batteries does provide an opportunity. However, the lost value of returning specific components to base material form disregards the embodied value of the spent battery, not to mention the energy and emissions required to do so.

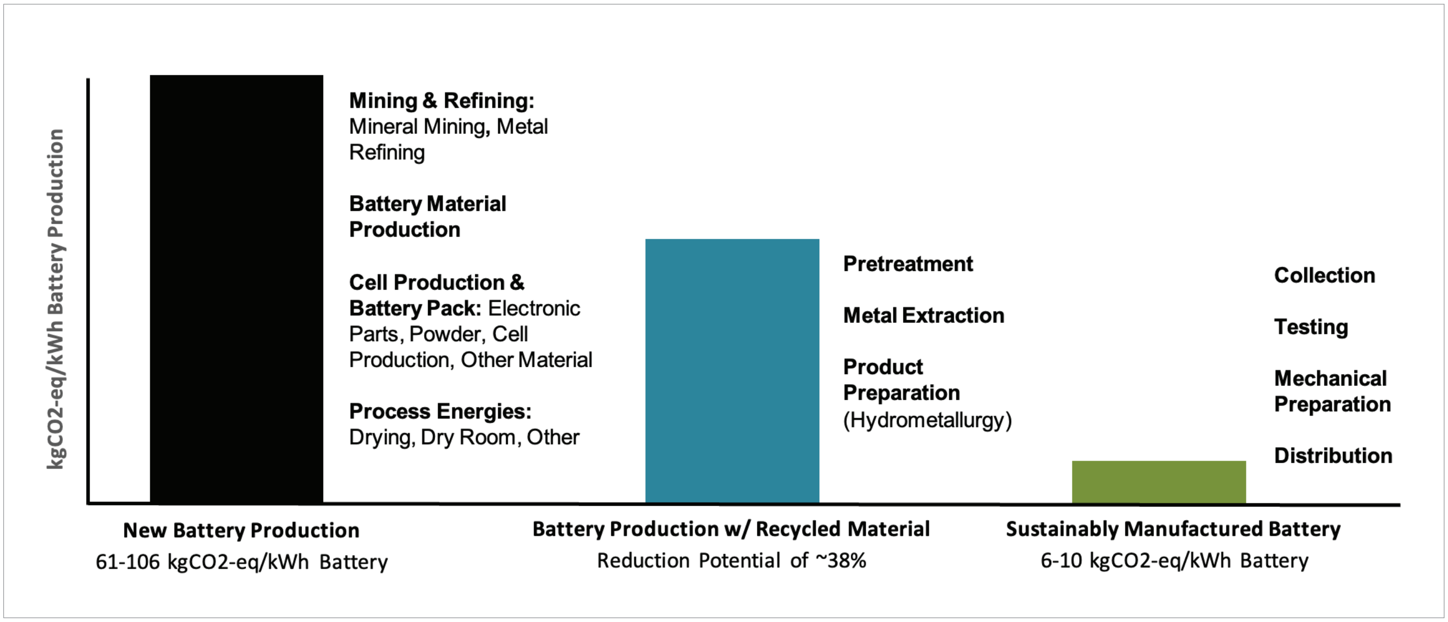
Stationary Storage of underperforming electric vehicle batteries opens the door to peak shaving, emergency power, and a multitude of other opportunities.

There is a clear market for second-life applications for vehicles. Furthermore, stationary storage can assist in electricity peak shaving, emergency power centers, and be placed in tandem with other forms of energy production. All of these options are forgone, and value is lost when 5-30% of a battery pack takes precedence over the 70-95% fully functional portion of the pack.

Marginal Production Footprint with Sustainable Manufacturing

In tandem with maximized value, a conversation about the production carbon footprint of new and spent electric vehicle batteries must also be considered. Though electric vehicles have become the most common solution to decarbonize the transportation industry, we often disregard the emissions produced while manufacturing these vehicles, especially their batteries. Also referred to as embodied carbon, a newly manufactured battery production process emits 61 to 106 kilograms of CO2 equivalents per kilowatt hour (Emilsson, 2019). This process includes mining, refining, fabrication, cell production, and other process energies. This production footprint is far greater than any ICE vehicle components we have seen in the past. This is why full life cycle assessments of EV components are becoming commonplace. Battery production with recycled material does provide a more suitable alternative which poses an embodied footprint of 38% less GHG emissions than virgin production (Rinne, 2021). This figure is based on a hydrometallurgical process that requires metal pretreatments and extraction. Returning critical base materials in BEVs can be no easy task due to their more specific makeup. Finally, the least carbon-emitting solution, the repurpose or sustainable manufacturing process has been studied by the TERREPOWER research team to identify an embodied carbon of 6-10 kilograms of CO2 equivalents per kilowatt hour. This is based on any new material replacement components, energy for testing and sorting, and transportation of spent and finished products. This strategy, when extrapolated to thousands of packs to be produced, not only drastically limits released emissions, but also, reduces energy consumption and effort required to return spent electric vehicles to the market.

The carbon footprint of our drive to work is now extending beyond the pump or charge point. Focusing on sustainability beyond the pavement is TERREPOWER's objective.



Summary

There is a solution to the gauntlet of mass electric vehicle production. The challenges of high material demand, waste management, and production footprint can be alleviated with sustainable manufacturing. Sustainable Manufacturing maximizes the value of spent EV batteries, without expending time, energy, and new materials to get the driver back on the road. As we transition to a cleaner form of transportation, we must consider a cleaner form of production, one that releases minimal emissions into our atmosphere. Though any solution does present its challenges it is important to consider any options that lead to a successful transition to electrification across the transportation industry.

About

BBB Industries, LLC is an industry leader in the sustainable manufacturing of starters, alternators, hydraulic and air disc brake calipers, hydraulic and electronic power steering products, and turbochargers for the OEM, passenger, industrial, and commercial vehicle aftermarket industries. Through TERREPOWER, BBB brings its sustainable manufacturing process to the electric vehicle and renewable energy sectors. TERREPOWER brings new life to electric vehicles and solar modules while improving performance. Through TERREPOWER, an EV battery extends its life expectancy.

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