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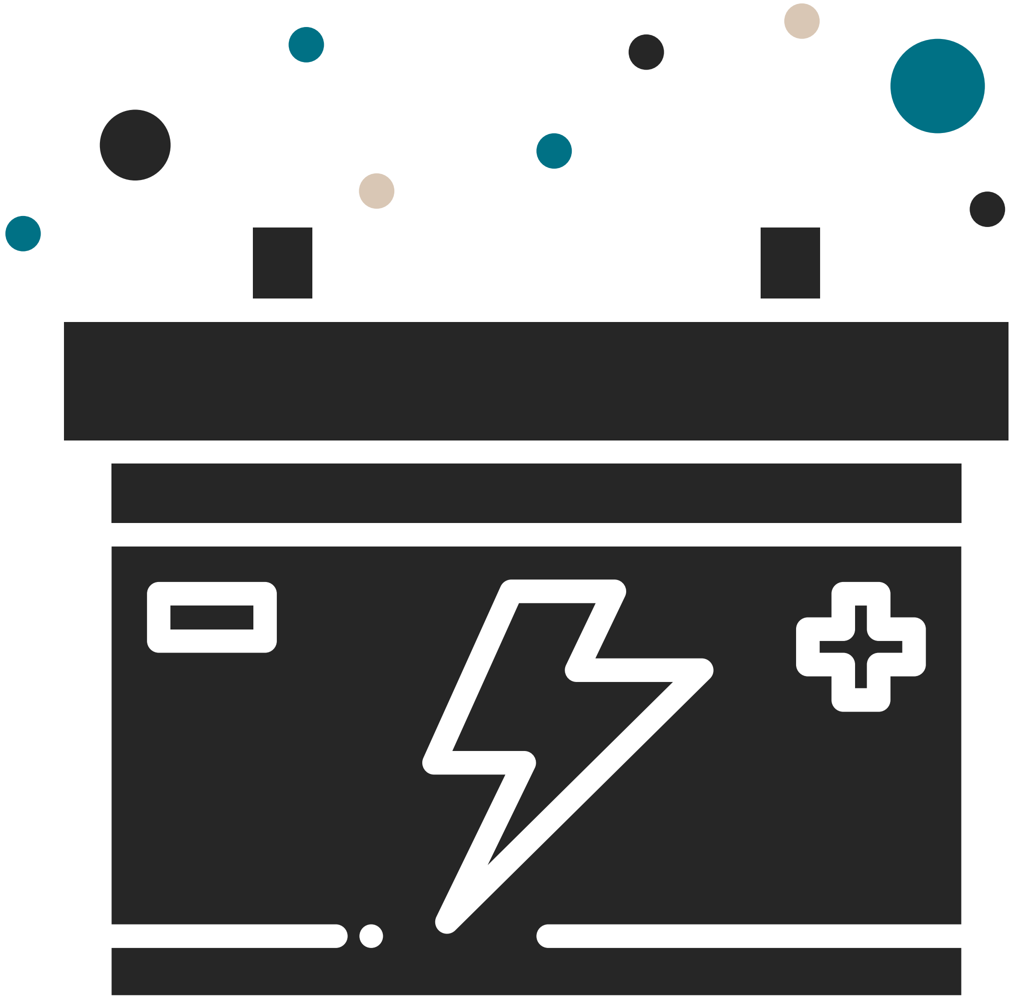


THE LEAD ACID BATTERY INDUSTRY AND THE EV TRANSITION

www.DynamicsLab.org

Researching the Risks and Opportunities of the Global Sustainability Transition

Bulletin No. 20220304

CONTENTS

introduction.

With a rapid increase in electric vehicle demands, lithium-ion batteries are proportionally increasing in popularity and demand. Electric vehicles are able to provide a cleaner atmosphere in comparison to the typical combustion vehicle that maintains the majority of the automotive industry as of now, alongside, their energy source – lead acid batteries.

With this transition, we are able to navigate through multiple impactful factors such as how lead-acid batteries could become a thing of the past, or if continuing innovation could revamp lead-acid batteries to be able to compete with lithium-ion batteries and its variations (i.e. lithium iron phosphate batteries) - as well, as the environmental, socioeconomic, and human impact on surrounding communities where the mining, production, and application of this new technology is being enacted.

The electric vehicle transition has taken the mature lead acid battery industrial sector by storm with phenomenal charging/efficient energy use that the lead-acid battery has never held as an attribute. However, this is still a brand new rising industry, and furthermore, we will examine the differences, similarities, and possible risks to this transition.

FAST FACTS

The Dynamic Sustainability Lab™

99%

99% of lead-acid batteries are recycled within the United States of America. 97% of lead-acid batteries are recycled internationally.

$52B

According to the Grand View Research Market report, the global lead-acid battery industry is estimated to reach $52 billion by 2024, from its current amount of $41 billion.

The initial use of the lead-acid battery was to power train car lights while stopped intermittently at their respective stations.

1859

The lead-acid battery was first invented in 1859 by Gaston Planté, where it was the first rechargeable battery of its kind by being able to reverse its current to recharge.

3-5

The typical lifespan of a lead-acid battery is 3-5 years.

the lead acid battery

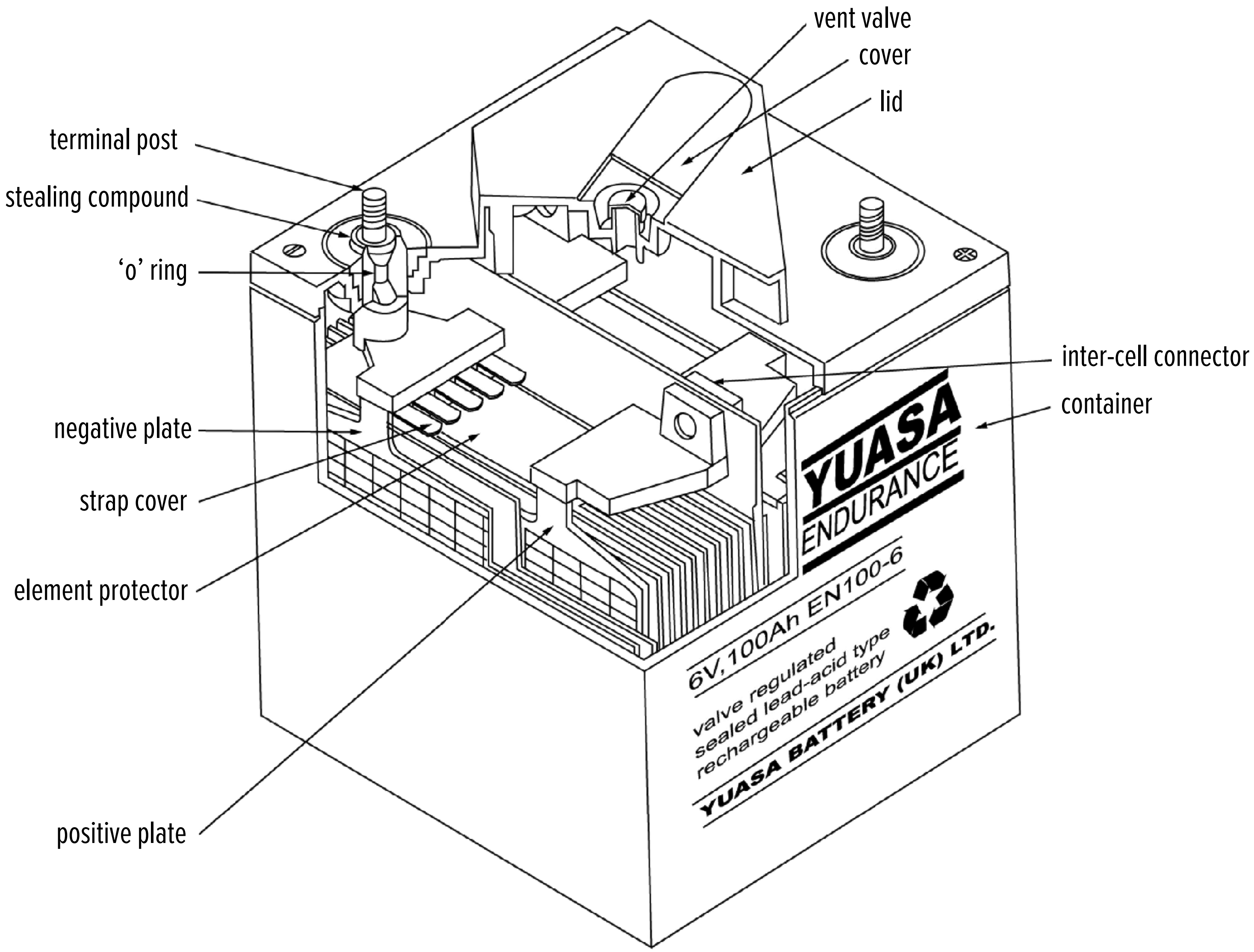


Figure 1: Intricate Exploded Drawing of a Lead-Acid Battery [ref. 1].

the lead acid battery.

The lead-acid battery is a mature technology that is well established and widely adopted. Lead-acid batteries remain as the most preferred and performance-proven backup power solution for most traditional industrial applications despite the growth in popularity for lithium-ion batteries. Lead acid battery life has increased by 30–35% in the last 20 years.

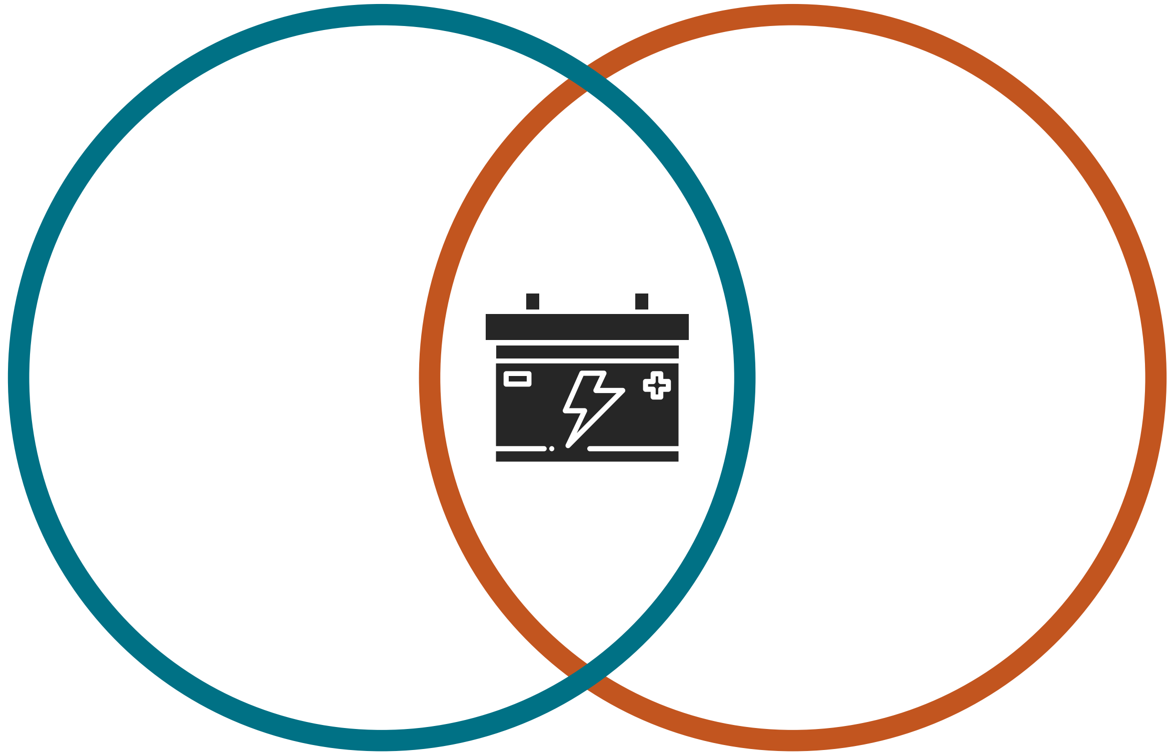
The major uses of LABs are as a starter battery, motive power battery, and stationary battery. Automotive batteries for starting, lighting, and ignition (SLI) and traction/stationary batteries (used for standby and emergency power supply) account for approximately 75% and 25% of the total lead acid battery usage.

FUNCTIONS & TECHNOLOGY

75%

AUTOMOTIVE

Typically used as a starter and motive battery for starting, lighting, and ignition (SLI)



25%

TRACTION/STATIONARY

Typically used for standby and emergency power supply to generate electricity stored

Figure 2: Venn Diagram of Comparative Percentages of Lead-Acid Battery Usage [ref. 2].

These batteries are categorized as deep cycle batteries or starter systems. The deep cycle battery includes two distinct subcategories including flooded lead acid (FLA) and valve regulated lead acid (VRLA) batteries with the VRLA type further subdivided into two types, absorbed glass mat (AGM) and gel.

THE LOCAL MARKET

THE TOP 4 LEAD-ACID BATTERY MANUFACTURERS IN THE U.S.
2016-2021

1. CLARIOS
2. ENERSYS
3. ENERGIZER
4. PANASONIC

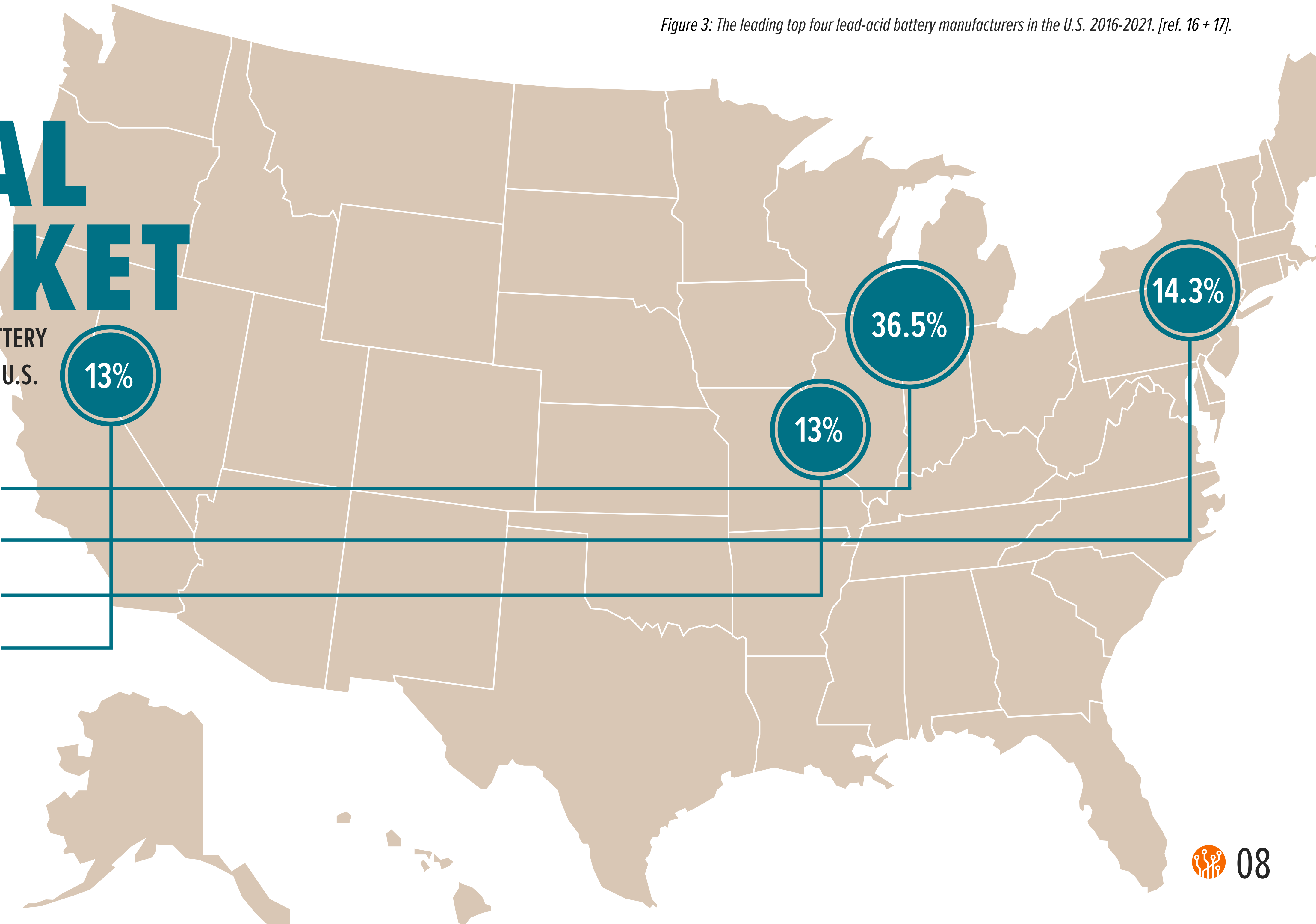
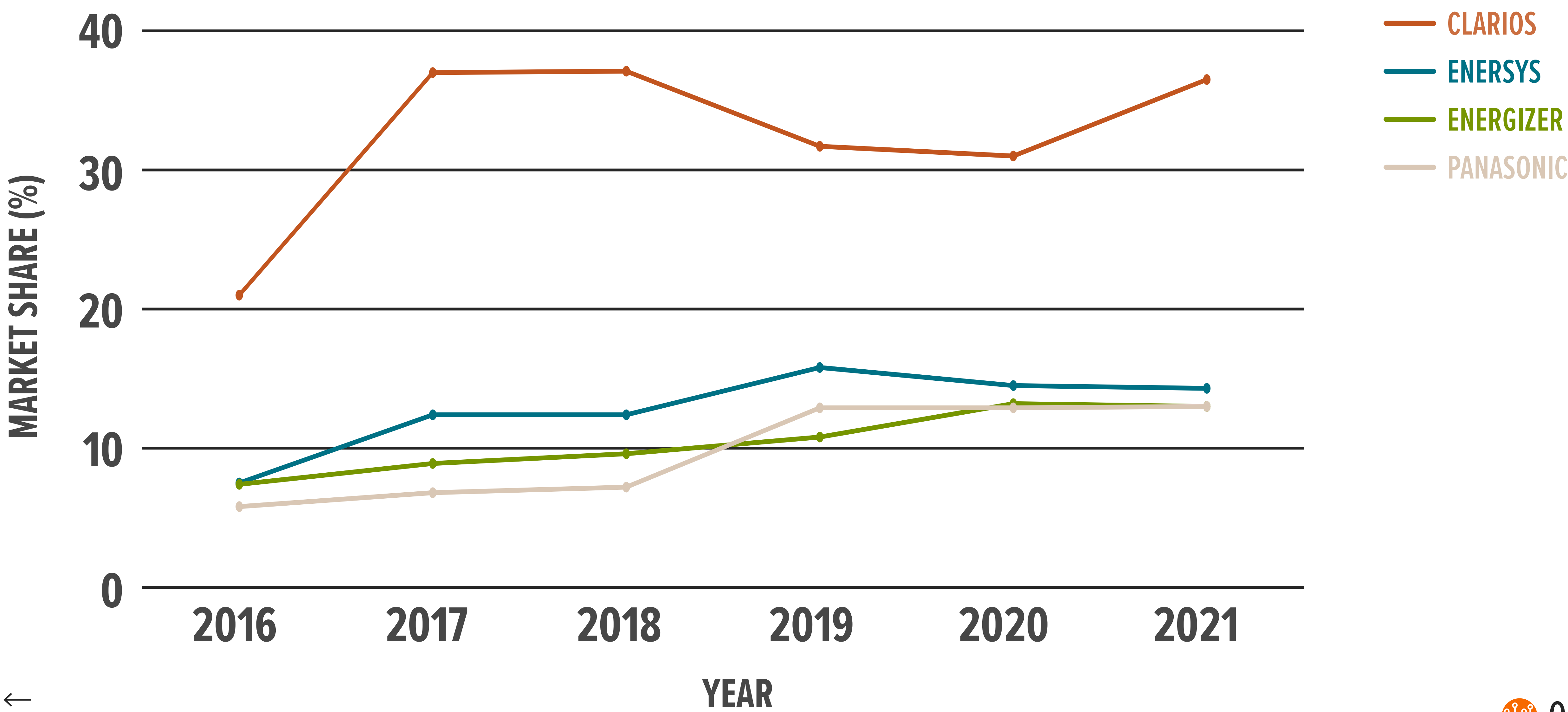


Figure 3: The leading top four lead-acid battery manufacturers in the U.S. 2016-2021. [ref. 16 + 17].

LEADING LEAD-ACID BATTERY MANUFACTURERS & MARKET SHARES

2018 - 2021

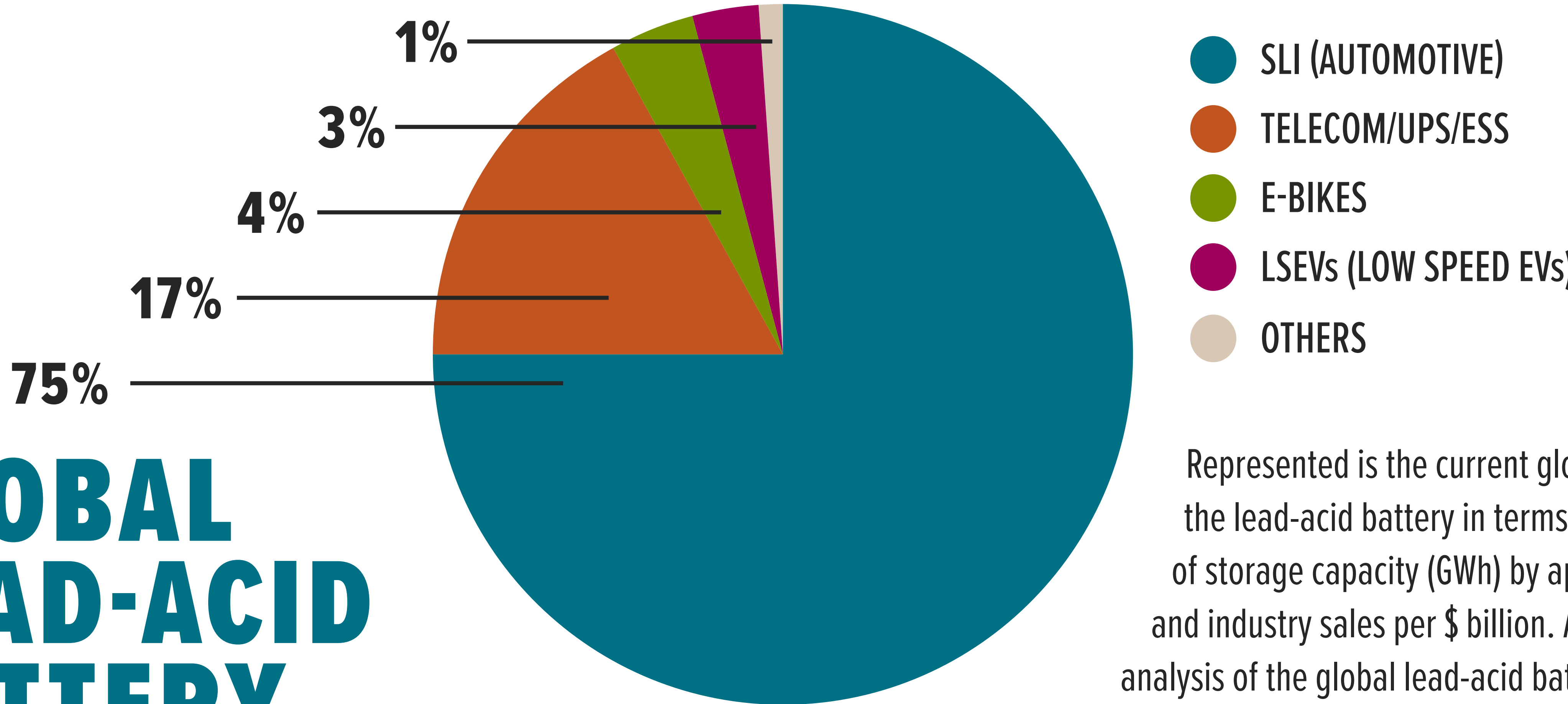
Figure 4: The leading top four lead-acid battery manufacturers market share percentages over the years 2016-2021 [ref. 16 + 17].



DEMAND FOR AUTOMOTIVE BATTERY

Automobiles are continuing their trend to depend on more and more electronics as they become more energy efficient, offer more accessories and safety features while handling the electrical load of simultaneously charging multiple devices.

The power consumed by these devices has doubled in the past 10 years and is projected to double again in the next five years. In simpler terms, the climbing trend in popularity of electric vehicles is proportional to the amount of vehicles being produced/ their power consumed. This will require increased demand of battery storage.



GLOBAL LEAD-ACID BATTERY DEPLOYMENT BY UTILIZATION

THE LEAD-ACID BATTERY MARKET SATURATION

Represented is the current global market for the lead-acid battery in terms of percentage of storage capacity (GWh) by application and industry sales per $ billion. An annual analysis of the global lead-acid battery industry determined that sales grew by over 20% from 2013-2018 to $37 billion. This industry currently saturates more than 70% of all rechargeable battery markets; 75% of sales being within the Automotive SLI sector, which is primarily dominated by Clarios (formerly Johnson Controls) with $23.3 billion; Second is EnerSys, within the industrial sector at $14.2 billion.

Figure 5: Leading Global Application of Lead-Acid Batteries [ref. 16 + 17].

sulfur production worldwide

by country, 2020

Figure 6: The current global sulfur production industry for the lead-acid battery measured in thousand metric tons as of 2020 [ref. 16 + 17].

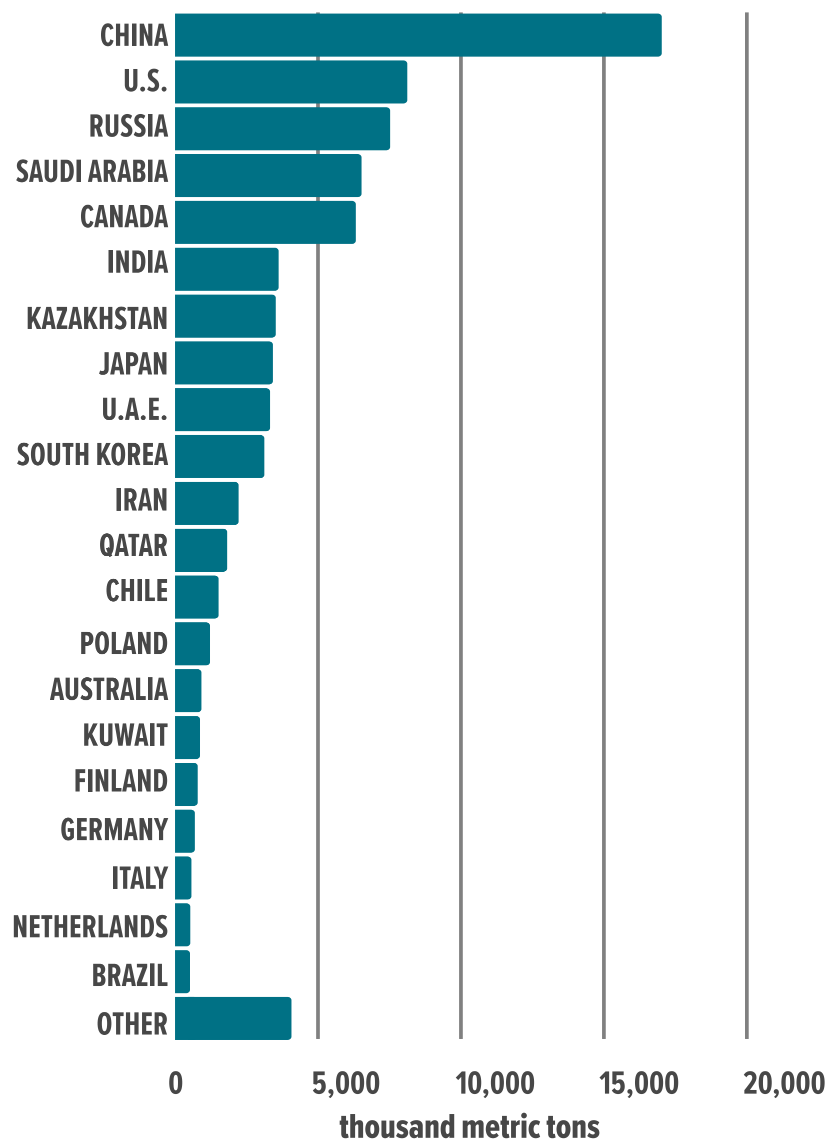
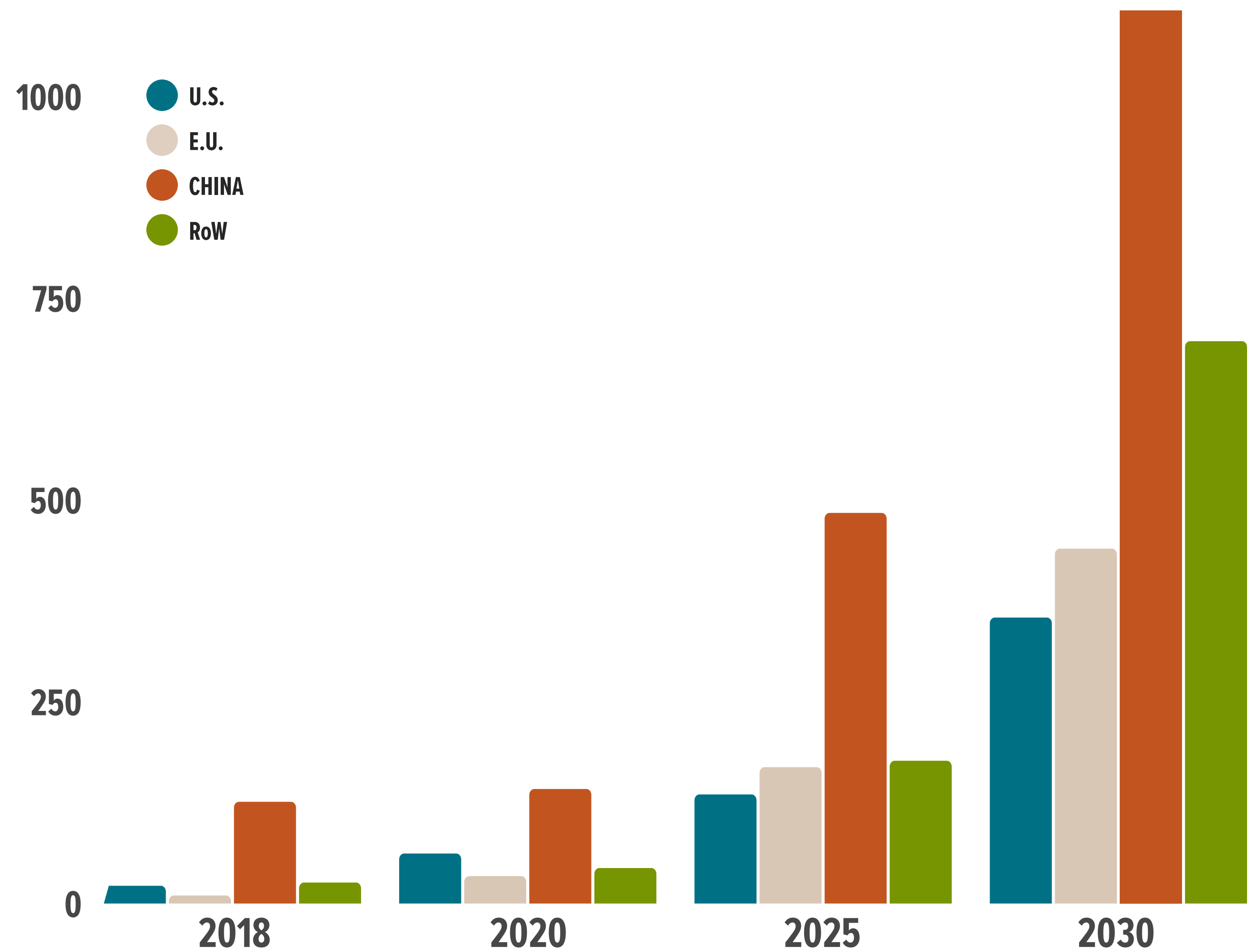


Figure 7: The current global market demand for the lead-acid battery in terms of storage capacity (GWh) by year and the regions of the US, China, EAU and RoW [ref. 16 + 17].



global lead-acid battery market demand

estimated by region, 2018 - 2030

strategic partnerships.

the lead-acid battery market global partners

In November of 2021, Clarios, producer of one in three of the world's car batteries, will enter a strategic collaboration with a high tech enterprise, China Lithium Battery Technology Company (CALB) which specializes in R&D and development of lithium batteries & battery materials, to develop low-voltage lithium-ion battery systems to address the growing electrical needs of global automakers

At present, we have established six major production bases in Changzhou, Luoyang, Xiamen, Wuhan, Chengdu and Hefei. Meanwhile, CALB Research Institute, which is operated as a national recognized enterprise technology center, aims to study and transform the key technologies of power battery into application and to create a new energy technology innovation platform with global influence. CALB plans to increase the production capacity to 500GwH+ during the 14th Five Year Plan period and expands production according to the change of the market and customer demand. We are now striving to be a world leading power battery manufacturer and the most reliable partner for the global excellent enterprises.

Clairos estimates that out of the 1.7 billion cars expected to be on the road by 2040, up to 50 percent will be a combination of full and plug-in hybrids, as well as electric vehicles. Each vehicle will require an advanced low-voltage battery as a key component of a multi-battery system to help provide constant power and ensure crucial safety functionality. As more autonomous features are added to vehicles, there is even greater reliance on the 12V to protect against failures that put occupants at risk.

materials & processing

Lead-Acid battery has been seen to be frequently in use for storage application. The components in Lead-Acid battery includes; stacked cells, immersed in a dilute solution of sulfuric acid (H2SO4), as an electrolyte, as the positive electrode in each cells comprises of lead dioxide (PbO2), and the negative electrode is made up of a sponge lead. At the point of discharge, both positive and negative electrode will transform to PbSO4, an also return to their initial state during charge cycle. They have same characteristics whiles valve regulated batteries requires more research development. Also, reversible redox reactions cause a decline in the battery electrodes. This leads to a high cycle life of 1200–1800 cycles.

The high cycle life is based on the DOD at efficiency of 75%–80%, with approximately 5–15 years life time. These characteristics are all dependent on the operating conditions of the system. An increase in temperature to 45°C increases the performance of the battery, its capacity and decreases the life time of the system. One of the basic properties of Lead-acid batteries is the ability to store energy for a longer time. Lead-Acid battery storage are known to have slow performance at a low and high ambient temperature, as well as short life time.

←
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Figure 10: Add description here. [ref. 2 + 4].

01	paste	Pasting electrically active mass onto grids, plate sets respectively charged into separators
02	insertion	Connectivity with plates for same polarity, intercell connectors, and plate sets (+/-)
03	welding & acid filling	Welding cell-to-cell with connectors, injection molding with positive terminals
04	formation & discharge test	Initial battery charging
05	label & finish	Addition of barcodes with Impedance Baseline tracked via serial number/ identifier

global battery trade.

top battery exporting countries 2019

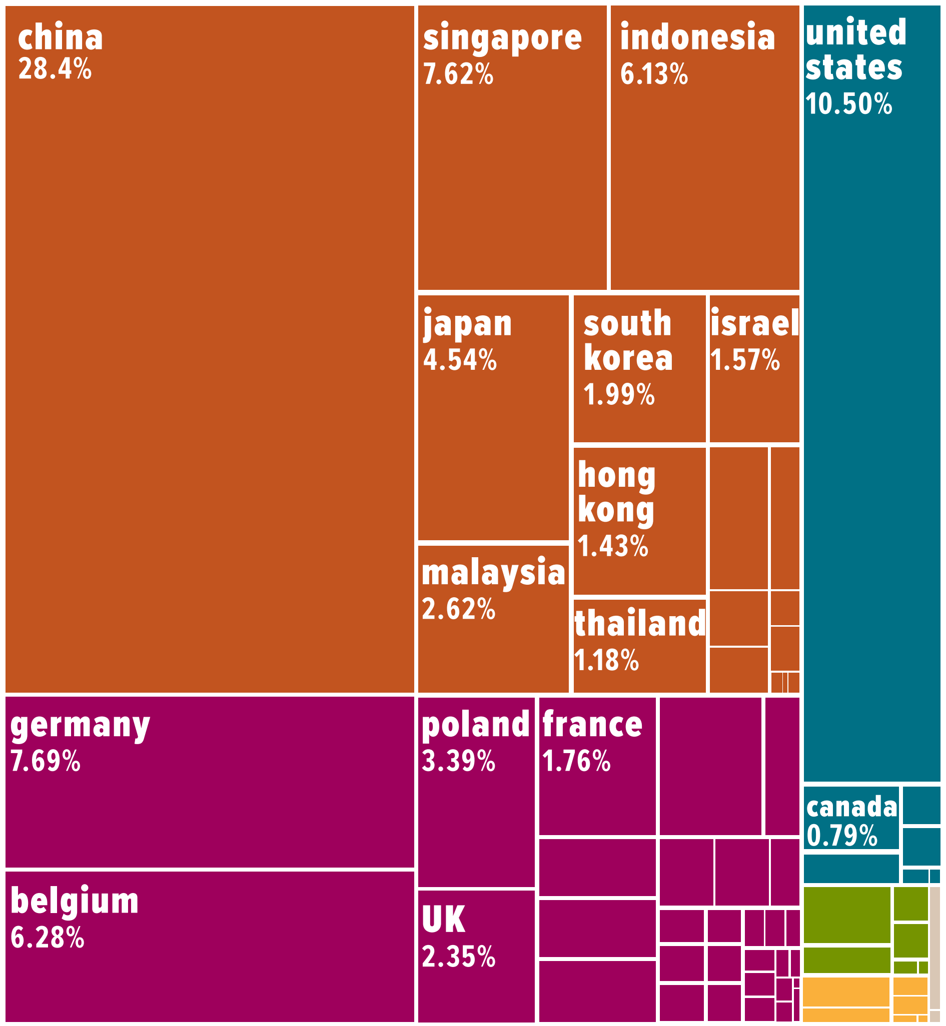


Figure 8: Add description here. [ref. 18].

top battery importing countries 2019

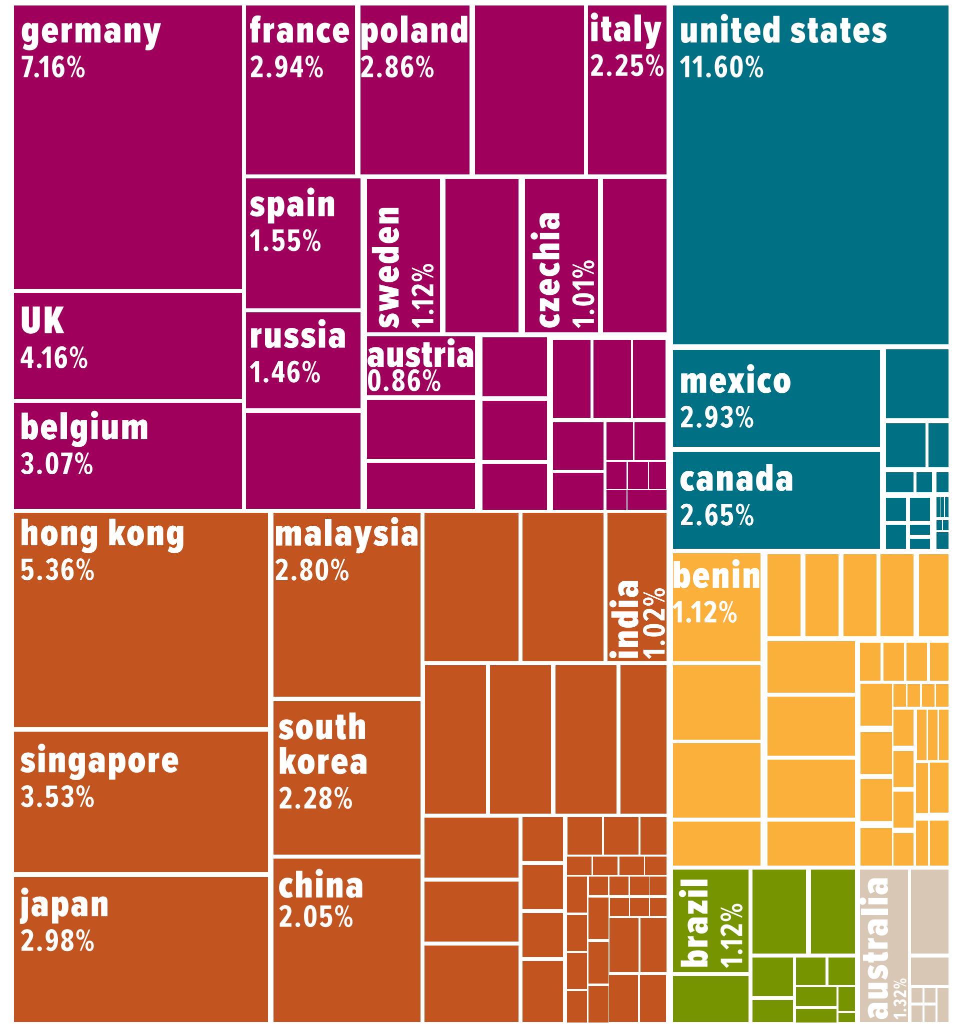
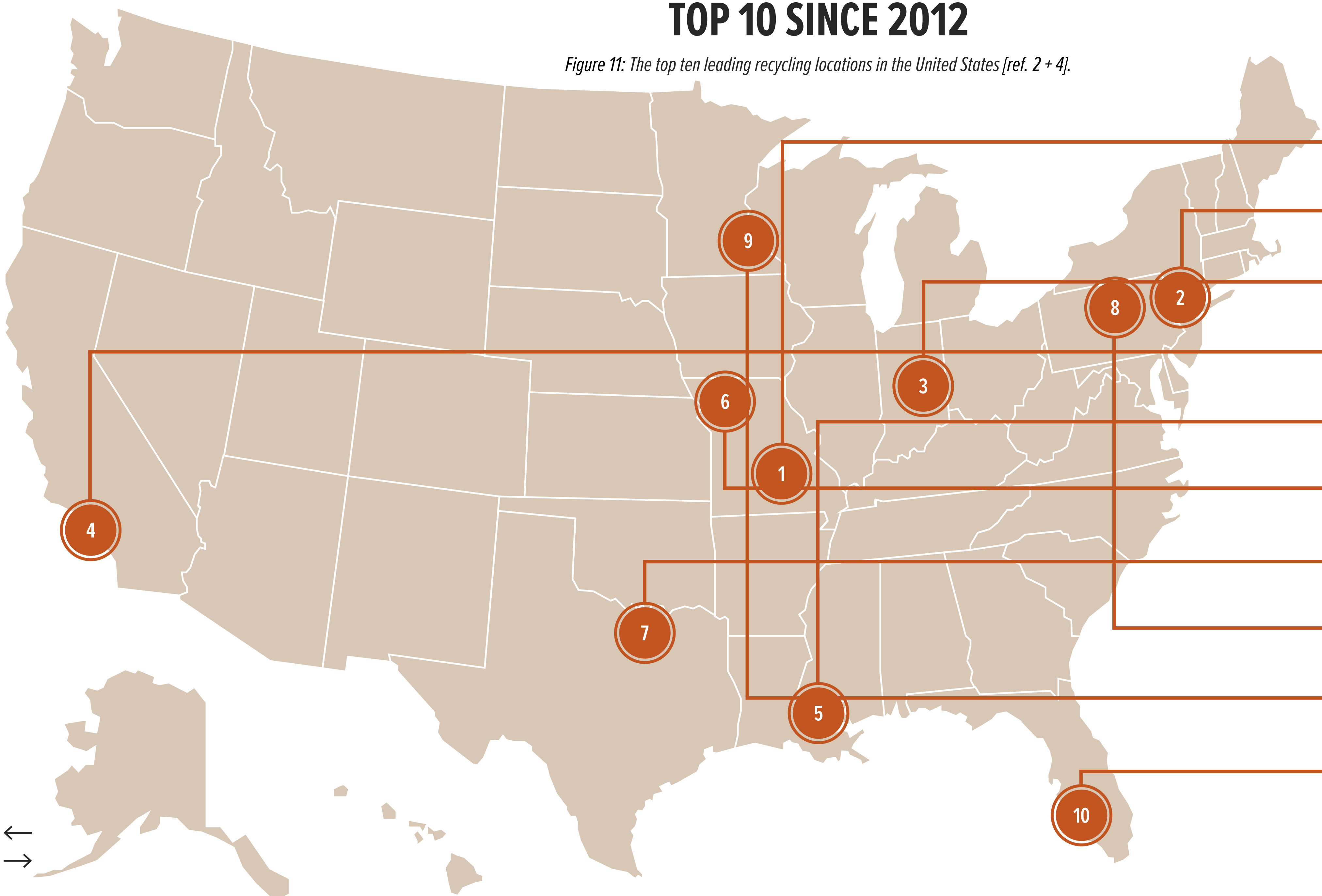


Figure 9: Add description here. [ref. 18].

LEADING LEAD ACID BATTERY RECYCLING LOCATIONS IN THE U.S.

TOP 10 SINCE 2012

Figure 11: The top ten leading recycling locations in the United States [ref. 2 + 4].

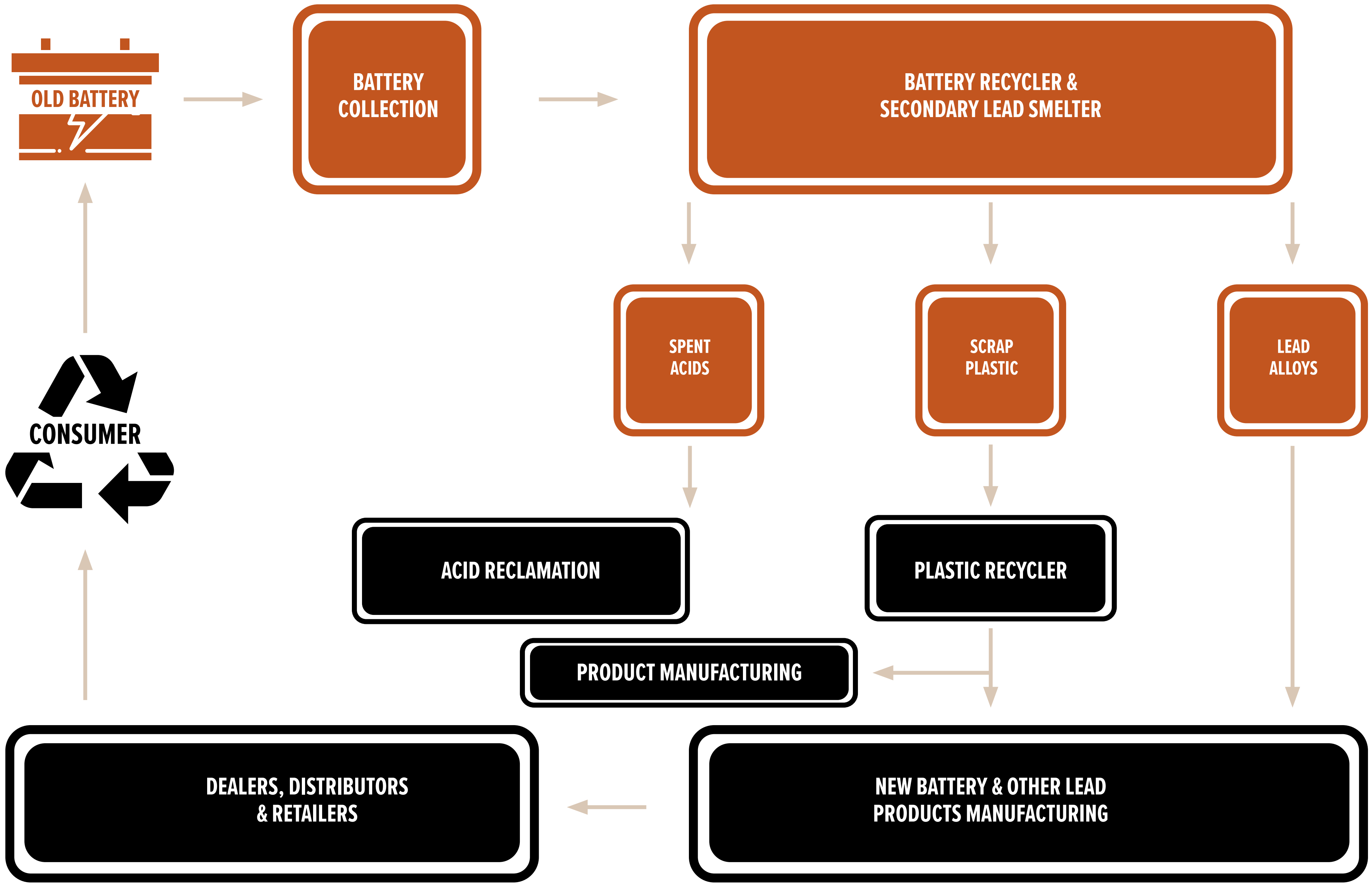


1. **BUICK RESOURCE**
   Boss, MO
2. **EAST PENN MANUFACTURING**
   Lyon Station, PA
3. **EXIDE TECHNOLOGIES INC.**
   Muncie, IN
4. **EXIDE TECHNOLOGIES INC.**
   Vernon, CA
5. **EXIDE TECHNOLOGIES INC.**
   Baton Rouge, LA
6. **EXIDE TECHNOLOGIES INC.**
   Cannon Hollow, MO
7. **EXIDE TECHNOLOGIES INC.**
   Frisco, TX
8. **EXIDE TECHNOLOGIES INC.**
   Reading, PA
9. **GOPHER RESOURCE**
   Eagan, MN
10. **GOPHER RESOURCE**
    Tampa, FL

RECYCLING PROCESSES OF LEAD-ACID BATTERIES

recycling systems

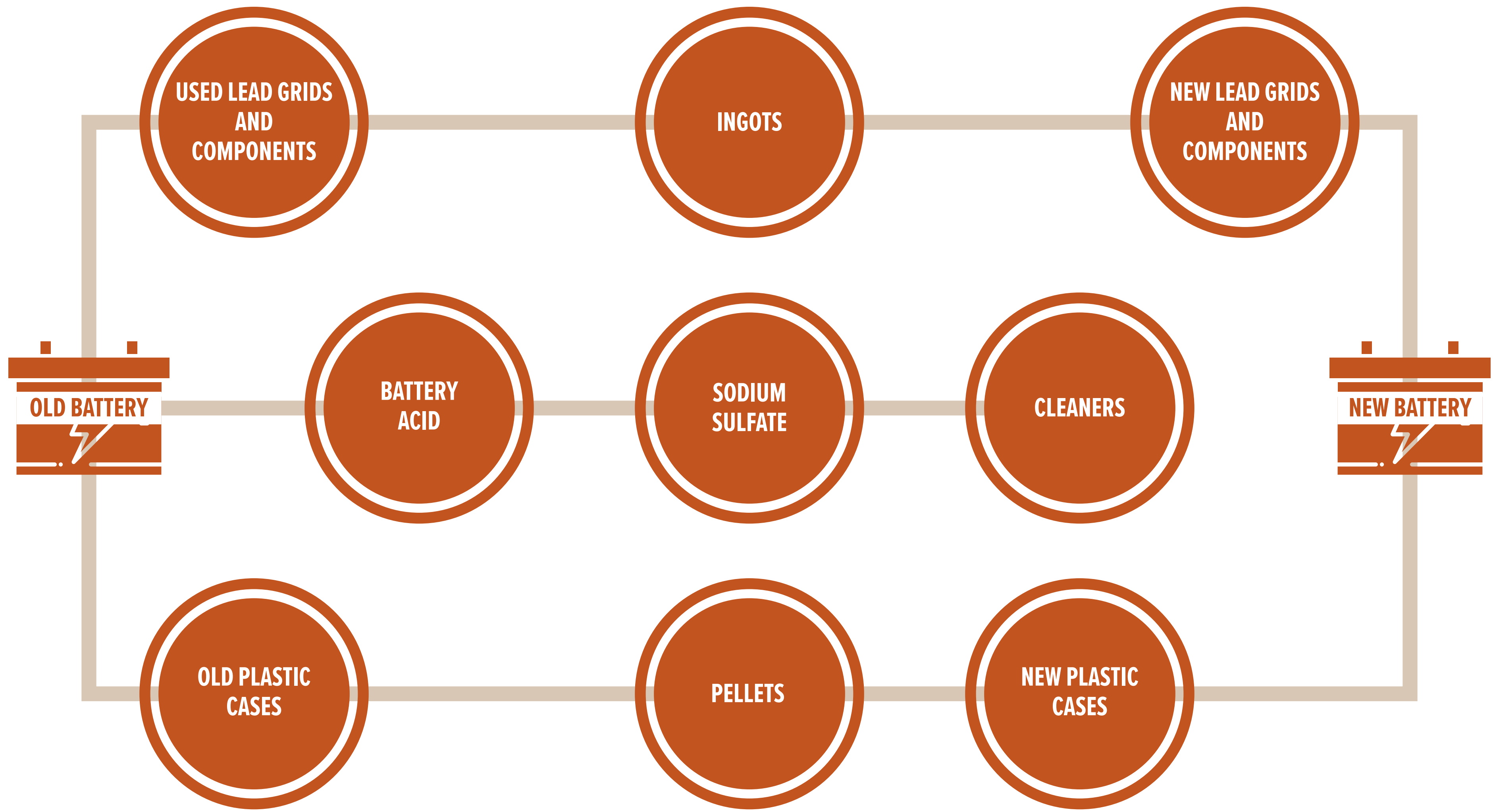
Figure 12: Recycling lifecycle of lead-acid batteries from beginning to end [ref. 2 + 4].



TYPICAL RE-USAGE OF LEAD-ACID BATTERIES WITHIN THE U.S.

recycling systems

Figure 13: Average repurposing applications of lead-acid batteries [ref. 2 + 4].



economic impacts

of the U.S. lead battery industry, 2018

1

The lead–acid industry has an annual output or economic impact of $26 billion in the U.S. ($11 billion in GDP; $26 billion in output.)

2

The lead battery industry created nearly 25,000 direct jobs (manufacturing, recycling, transport, distribution, and mining) in 38 states in the U.S.

3

Compared to other private sector jobs, average salaries in the lead acid battery industry are 96% higher for recycling and mining works, and 28% higher for manufacturing workers.

DIRECT & INDIRECT ECONOMIC IMPACTS OF THE U.S. LEAD-ACID BATTERY INDUSTRY
2018

DIRECT ECONOMIC INFLUENCE ON JOBS

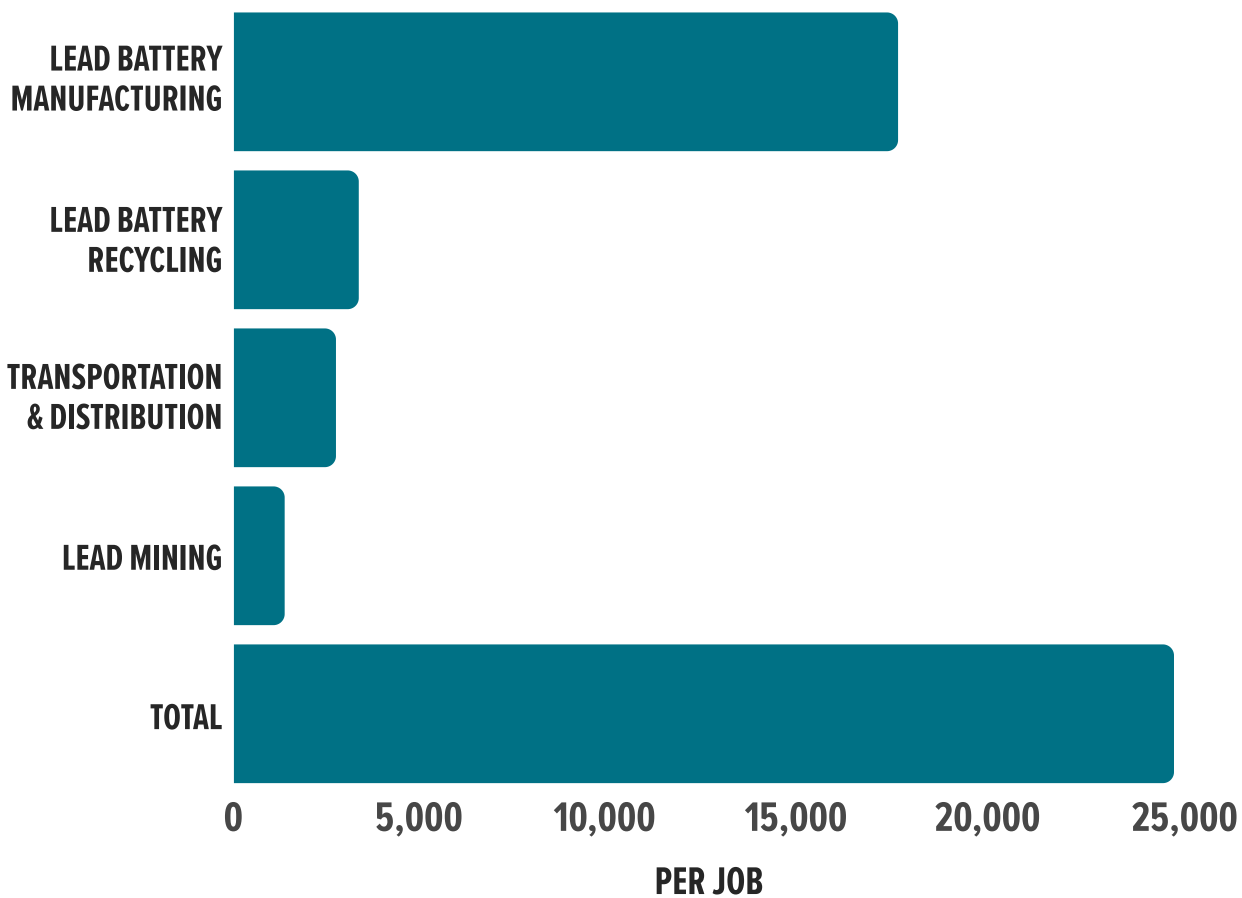


Figure 14: The U.S. lead-acid battery companies' direct economic influence on jobs in 2018. [ref. 2 + 4].

DIRECT ECONOMIC INFLUENCE ON PAYROLL

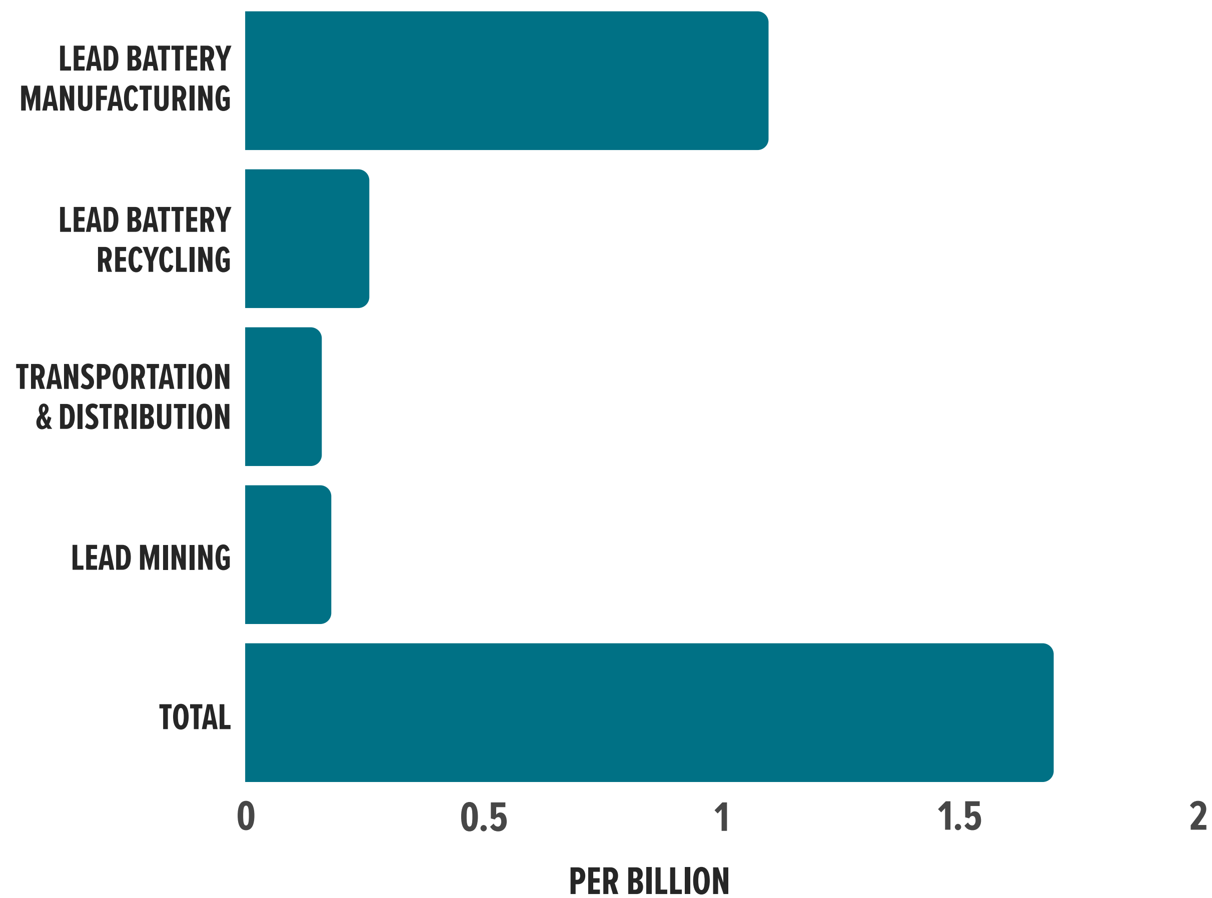


Figure 15: The U.S. lead-acid battery companies' direct economic influence on payroll in 2018. [ref. 2 + 4].

DIRECT & INDIRECT IMPACTS OF THE US LEAD BATTERY INDUSTRY

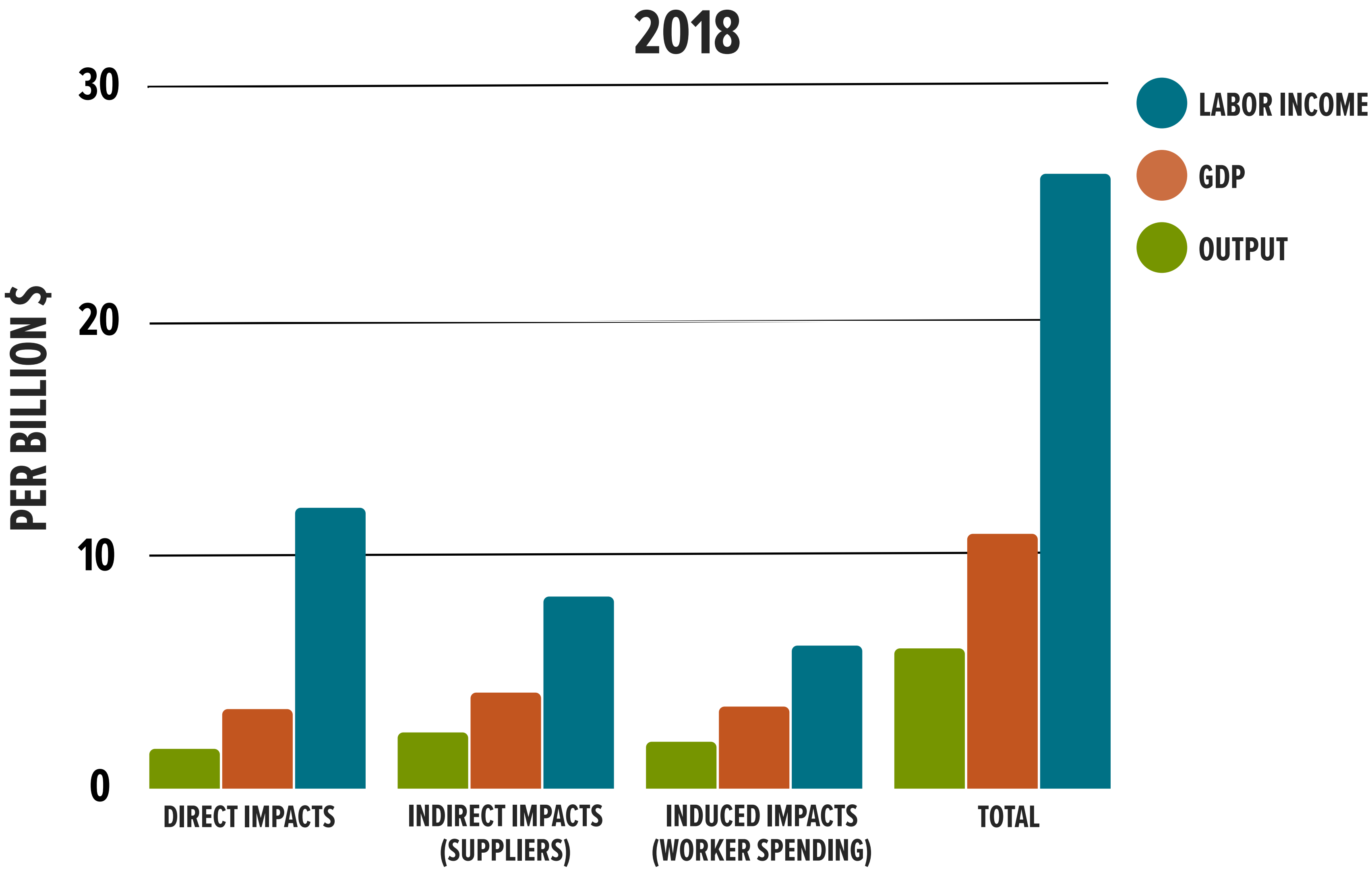


Figure 16: The US lead-acid battery industry economic impact distribution [ref. 2 + 4].

The U.S. lead-acid battery industry supports tens of thousands of jobs and generates billions of dollars in economic impact. However, because lead-acid battery manufacturers use both virgin and recycled lead, some lead mining and recycling companies support manufactures within the same industry. The rest support other industries. The supplied impact from battery manufacturing reflects this fact by not counting jobs twice, and other impacts resulting from the purchase of virgin and recycled lead content.

The Gross Domestic Product (GDP) represents the total value of goods produced by the U.S. lead acid battery industry. Output represents total sales made by the industry. GDP is smaller than output because it excludes payroll, profits, and the cost of supplies. Labor income is a subset of GDP and GDP is a subset of output. Therefore, these figures should not be combined.

environmental impact

More than 90% of global lead consumption is for the production of lead-acid batteries. However, lead-acid batteries contain sulfuric acid and large amounts of metallic lead. The characteristics of these materials are highly corrosive and dissolves lead and lead particulate matter.

According to the UNC Institutional Integrity and Risk Management sector in Environment, Health, and Safety- Lead itself is a highly toxic element that can accumulate in hazardous amounts in the environment and can cause a range of negative health effects. Prolonged exposure to these possible excessive levels can cause damage to brain and kidney, nerve systems, impaired hearing, impaired hearing, and more. It is extremely important and vital to minimize any contamination from these materials by continuing to effectively collecting and recycling these batteries which has been regulated and emphasized in many countries.

environmental impacts
of the U.S. lead battery industry

- 80% of lead acid batteries die due to the sulphation of their lead plates caused by chemical reaction between lead and sulphuric acid
- 20% of lead acid batteries die due to other causes such as incorrect charging, short circuit, corrosion, misuse etc.
- Removal of sulphation results in reviving the battery to complete its remaining cycles and enhance its backup time
- Saves the environment from hazardous pollution and is a benefit to the economy

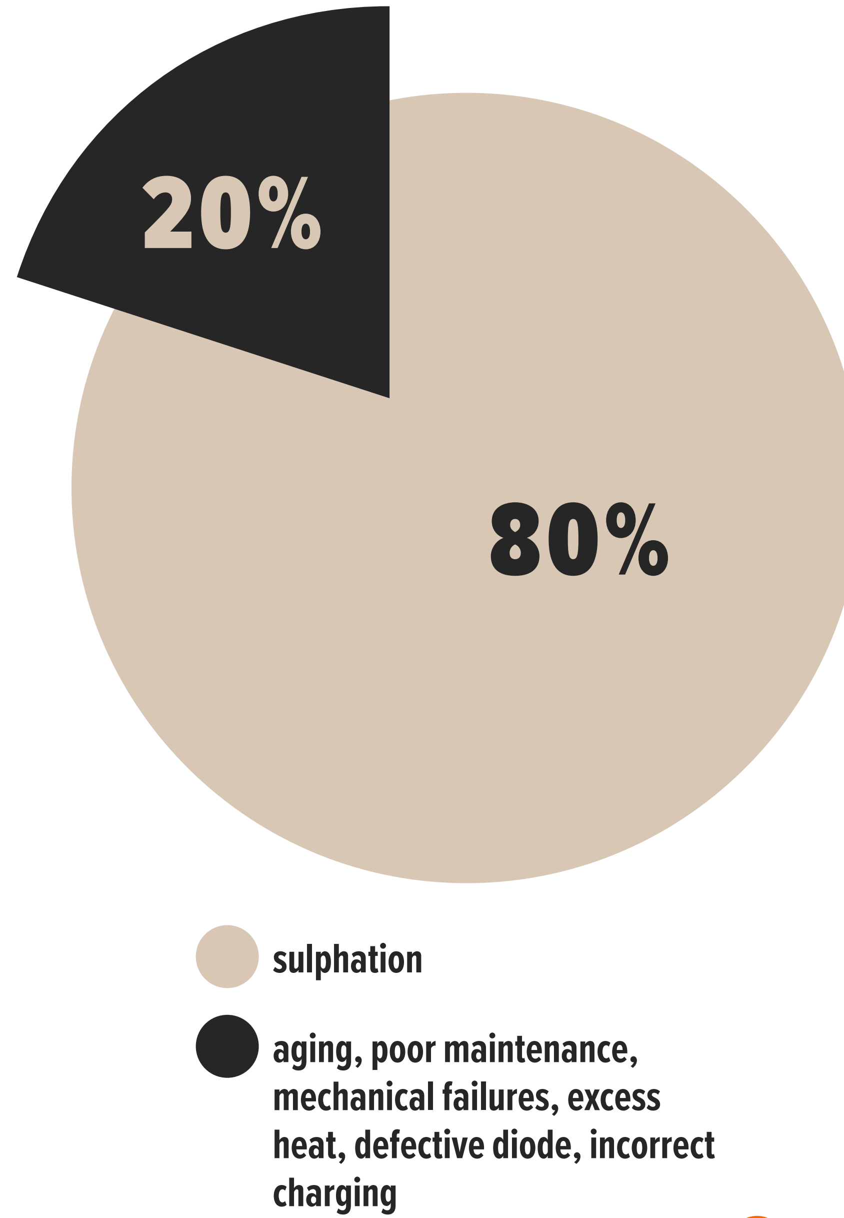


Figure 17: The US lead-acid battery industry percentage comparison of environmental impact [ref. 14].

environmental protection agency (EPA) recycling & composting rates

2018

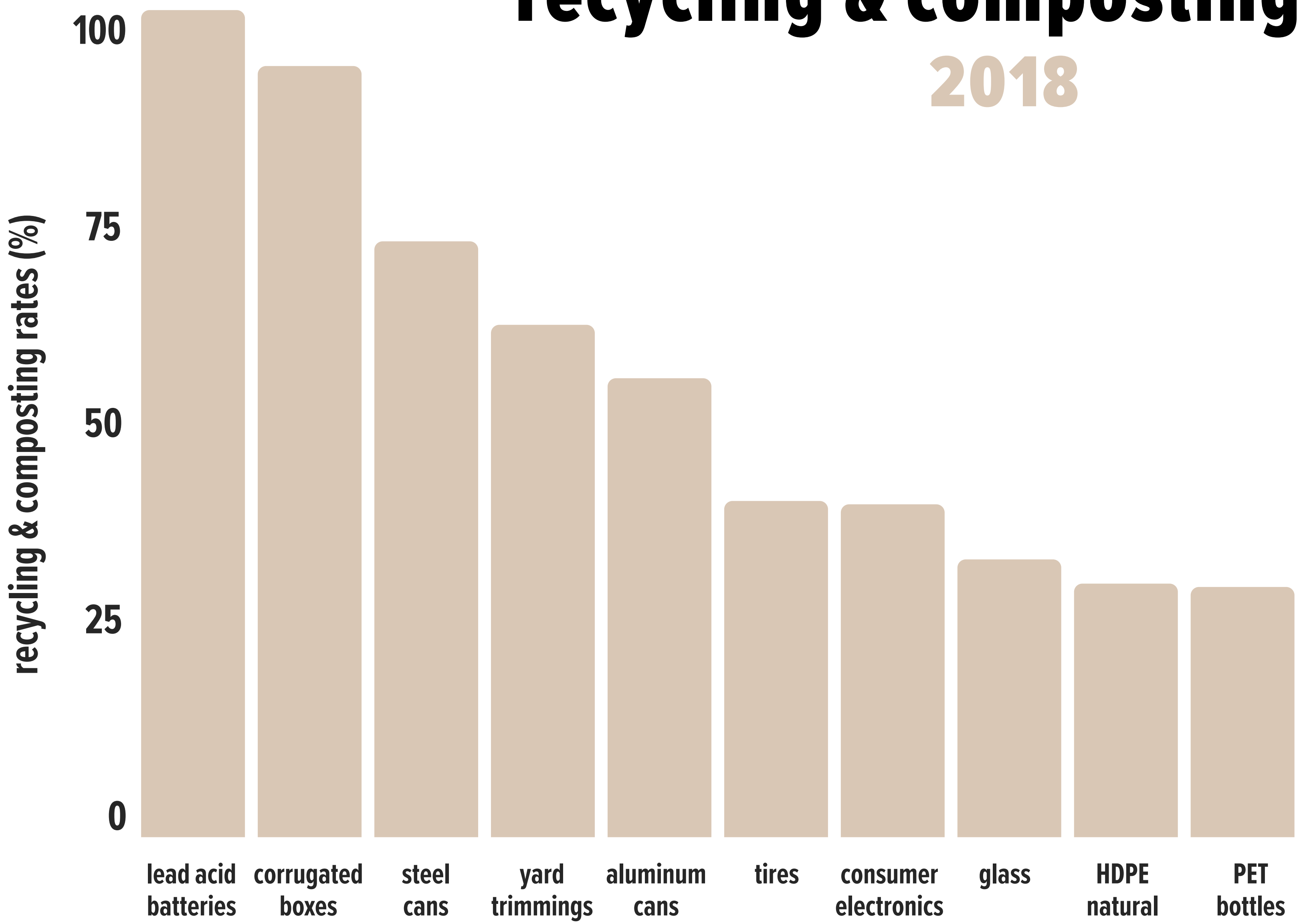


Figure 18: The top ten most globally recycled items compared to lead-acid batteries [ref. 2].

CORRECT WAYS
to dispose of lead-acid batteries

01 properly manage used batteries by having them picked up by

Wholesaler/retailers where you purchased the batteries from, collection center that sends batteries to smelters or recyclers, facilities that recycle the batteries by extracting the lead, or smaller lead-acid batteries can be picked up by submitting and EHS request

02 avoid long term storage of batteries

03 store batteries correctly

In a secure, covered location on a sealed surface, and check often for leaks

04 tape or cap all terminals

Get a receipt from the recycling company and maintain records for at least five years in case of emergency

INCORRECT WAYS
to dispose of lead-acid batteries

01 do not place lead-acid batteries in garbage

02 do not pour battery acid onto the ground or into a drain

03 do not take lead-acid batteries to a landfill

04 do not store batteries outside, unprotected from the weather

05 do not pile batteries more than four high- unstable and prone to spillage of battery acid

electrified power battery chemistries

lithium ion vs. lead acid batteries

lithium ion	vs.	lead acid
	cost	
$$$	up front	$$
$$	per mile	$$$
$$	battery life	$$$
$$	maintenance	$$$
	use cases	
forklift, urban bus		aterials handling, stationary storage
	energy & range	
	energy density	
125 - 600 Wh/L		50 - 90 Wh/L
	battery size: passengers	
x1		x10
	range between charges	
	size & storage	
	charging time	
3 hours		10 hours

solar battery cost comparison

first 10 years of ownership

Figure 19: The global lead-acid battery industry in comparison to lithium-ion battery transition [ref. 12].

	crown (FLA)	crown (SLA)	discover (lithium)
up-front system cost	$12, 899	$12, 899	$12, 899
up-front battery cost	$2,854	$3,954	$13,195
total battery cost (10 yrs)	$8,562	$11,862	$13,195
total cost to own (10 yrs)	$21,461	$24,671	$26,094
battery warranty	3 years	3 years	10 years
number of batteries	8	8	2
battery bank weight	976 lbs.	1,016 lbs.	384 lbs.
regular maintenance?	yes	no	no
cycles	1,200	1,000	unlimited*
depth of discharge	50%	50%	80%

* Discover Li-Ion batteries are warranted for 10 years with an unlimited amount of cycles. The warranty is based on total energy in/out. Refer to the battery warranty for details.

the battery storage transition

what is driving the transition in the battery storage sector from LABs to LIBs?

When considering battery selection it is important to consider use such as for an electric vehicle vs. energy storage for renewables. Many factors come into consideration. For example, Lithium-Ion batteries delivers the same amount of power throughout the entire discharge cycle while Lead Acid batteries starts strong but dissipates during the cycle. With a great variety of LABs and LIBs being put into the global market, there are a greater amount of variables present to be able to help determine which is the most appropriate and efficient battery for its application.

indices	Li-ion (average value)	lead-acid (average value)
costs – using 5.13 kW off-grid solar system storage		
up-front battery costs (sealed lead acid)	$13,195	$3,954
10-year total battery costs	$13,195	$11,862
specific energy (Wh/kg)	151	30.58
specific power (W/kg)	229	181
roundtrip efficiency (%)	87.37	76.36
lifespan in cycles	2,000 - 3,000	1,000 - 1,500
service life (years)	12.67	8.75
daily self-discharge rate (%)	0.17	0.2666
energy density (kWh/m3)	311.67	65
power density (kW/m3)	1250	75
environmental impact	medium/low	high
weight	Li-ion 55% lighter than lead-acid on average	
charge times	Li-ion is 4x faster than lead-acid	
high temperature performance (55 °C)	Li-ion is 2x better than lead-acid	
low temperature performance (32 °F)	cannot accept charge	can accept low charges

li-ion vs. lead-acid differentiation

differences across multiple variables

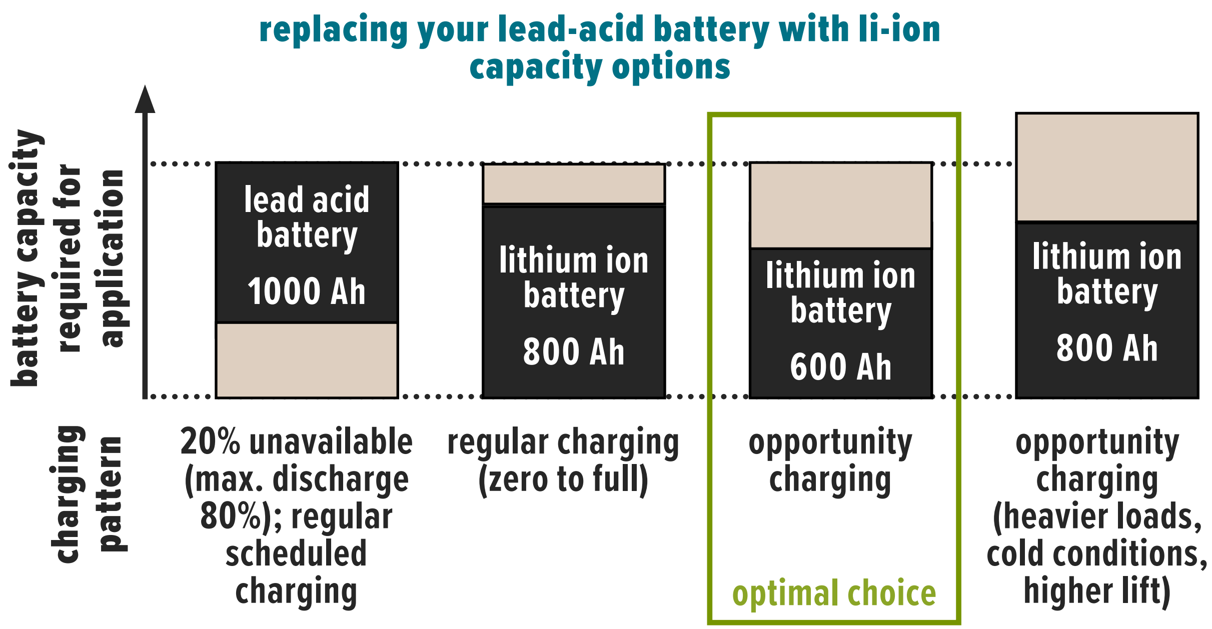
Figure 20: The global lead-acid battery industry in comparison to lithium-ion battery transition [ref. 12 & 11].

the battery storage transition

what is driving the transition in the battery storage sector from LABs to LIBs?

will lead acid batteries be a thing of the past?

Primary cells and primary batteries are used to store electrical energy. They can be made from a variety of materials, including lead-acid, nickel-cadmium, and lithium-ion. Batteries were the world's 367th most traded product, with a total trade of $8.44B in 2019.



The variables to consider when choosing a battery for a specific truck and application: lift truck make, model, voltage, ah capacity in use and max of the lift, compartment size, lift height, weight, attachments in use, length of run, numbers of shifts, length of breaks/lunch.

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ABOUT THE LAB

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MISSION STATEMENT

Provide support to public and private organizations on the risks, unintended consequences, and opportunities of the global sustainability transition

PRIMARY TRANSITION AREAS OF FOCUS

Technology Transitions – Energy Transitions – Biobased Transitions Economy

COMPONENTS OF THE TRANSITION

Supply Chains – Green Finance – Critical Minerals – ESG – National Security

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SUSTAINABLE FUELS & THE AVIATION SECTOR

BULLETIN NO. 20220101

The transition to Sustainable Aviation Fuels (SAF) has the potential to significantly benefit both the domestic economy and environment. SAF can reduce the risks of the Electric Vehicle Transition which is expected to have significant implications for the production and demand of sustainable/renewable fuels such as Ethanol of renewable diesel.

https://www.dynamicslab.org/sustainable-aviation-fuels-technical-bul

CRITICAL MINERALS & THE EV TRANSITION

BULLETIN NO. 20220102

The production of a typical lithium-ion battery requires five minerals dubbed "critical minerals" by the USGS - lithium, cobalt, manganese, nickel, and graphite. These critical minerals each face potentially significant supply chain bottlenecks and disruptions, such as: inadequate supply, dominance by select countries in production and refining, an oligopoly of producers, and more. Additionally, the extraction of critical minerals includes environmental and socio-political impacts that must be addressed for a sustainable and just EV transition.

https://www.dynamicslab.org/critical-minerals-ev

REFERENCES

1. Different types of UPS Batteries. Riello UPS. (n.d.). Retrieved December 30, 2021, from https://www.riello-ups.com/questions/60-different-types-of-ups-batteries
2. Energy Storage Market Report 2020 - Department of Energy. (n.d.). Retrieved December 31, 2021, from https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf
3. Lead acid batteries. PVEducation. (n.d.). Retrieved December 31, 2021, from https://www.pveducation.org/pvcdrom/batteries/lead-acid-batteries
4. Lead acid battery market. Market Research Firm. (n.d.). Retrieved December 31, 2021, from https://www.marketsandmarkets.com/Market-Reports/lead-acid-battery-market-161171997.html
5. The rechargeable battery market and main trends. (n.d.). Retrieved December 31, 2021, from https://assets.niobium.tech/-/media/niobiumtech/documentos/2019-formula-e---berlin/nt_the-rechargeable-battery-market-and-main-trends.pdf
6. Sustainable chemistry | free full-text | A review ... - MDPI. (n.d.). Retrieved December 31, 2021, from https://www.mdpi.com/2673-4079/2/1/11/htm
7. Sustainable chemistry | free full-text | A review ... - MDPI. (n.d.). Retrieved December 31, 2021, from https://www.mdpi.com/2673-4079/2/1/11/htm
8. Will lead batteries soon drive off into the sunset? no, they still have power left in them. The Economic Times. (n.d.). Retrieved December 30, 2021, from https://economictimes.indiatimes.com/prime/transportation/lead-batteries-driving-off-into-the-sunset-no-they-still-have-power-left-in-them-/primearticleshow/65345902.cms

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REFERENCES

9. https://unboundsolar.com/blog/lead-acid-vs-lithium-batteries

10..https://www.forbes.com/sites/rrapier/2019/10/13/lead-acid-batteries-are-on-a-path-to-extinction/?sh=1c6d037fca9a

11. https://www.power-sonic.com/blog/lithium-vs-lead-acid-batteries/.

12.https://www.cummins.com/news/2019/06/17/spot-difference-lithium-ion-versus-lead-acid-battery-electric-technology

13.https://www.livemint.com/brand-post/tesla-power-usa-introduces-affordable-battery-revival-technology-in-india-11629104065913.html

14. https://essentialenergyeveryday.com/community/economic-impact/

15. https://www.riello-ups.com/questions/60-different-types-of-ups-batteries

16. https://my-ibisworld-com.libezproxy2.syr.edu/download/us/en/industry-specialized/4511/1/0/pdf

17. https://my-ibisworld-com.libezproxy2.syr.edu/us/en/industry/33591/about

18. https://oec.world/en/profile/hs92/batteries

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