The Lithium-Ion Economy

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Fast Facts:

- The expansion of the electric-vehicle market and clean-energy production has served as a catalyst for the lithium-ion battery industry.
- Forecasts predict a fivefold increase in the global lithium-ion battery market through 2030, from $21.95 billion in 2020 to $115 billion by 2030.[1]
- A primary driver is the demand for electric vehicle (EVs) with an additional 54 million passenger electric vehicles forecasted to be on roads globally by 2025, up from 12 million today.[2]
- Total global deployment of home and utility energy storage is predicted to grow 122-fold: from 9 gigawatts (GW)/ 17 gigawatt hours (GWh) in 2018 to 1,095 GW/2,850 GWh by 2040.[3]
- The number of lithium-ion battery manufacturers of all types in the United States is forecasted to expand at a 2.6 percent annual pace reaching 41 enterprises by 2025.[4]
- 15 new lithium-ion battery cell facilities for all electric vehicles in the United States are planned for completion by 2025.[5]
- Nevada is the only U.S. state that encompasses every facet of the lithium-ion battery economy and life cycle, from the mining of natural Lithium deposits to the research and development to production and assembly, and finally to recycling.
- The entire Lithium-ion economy in Nevada employs between 8,282 to 9,116 workers in Nevada, roughly the same number of people as a mid-sized gaming company in Las Vegas.
- The lithium-ion battery manufacturing industry alone currently employs almost 5,000 people in the United States, over 59 percent of whom are here in Nevada.[6]

Acronyms:

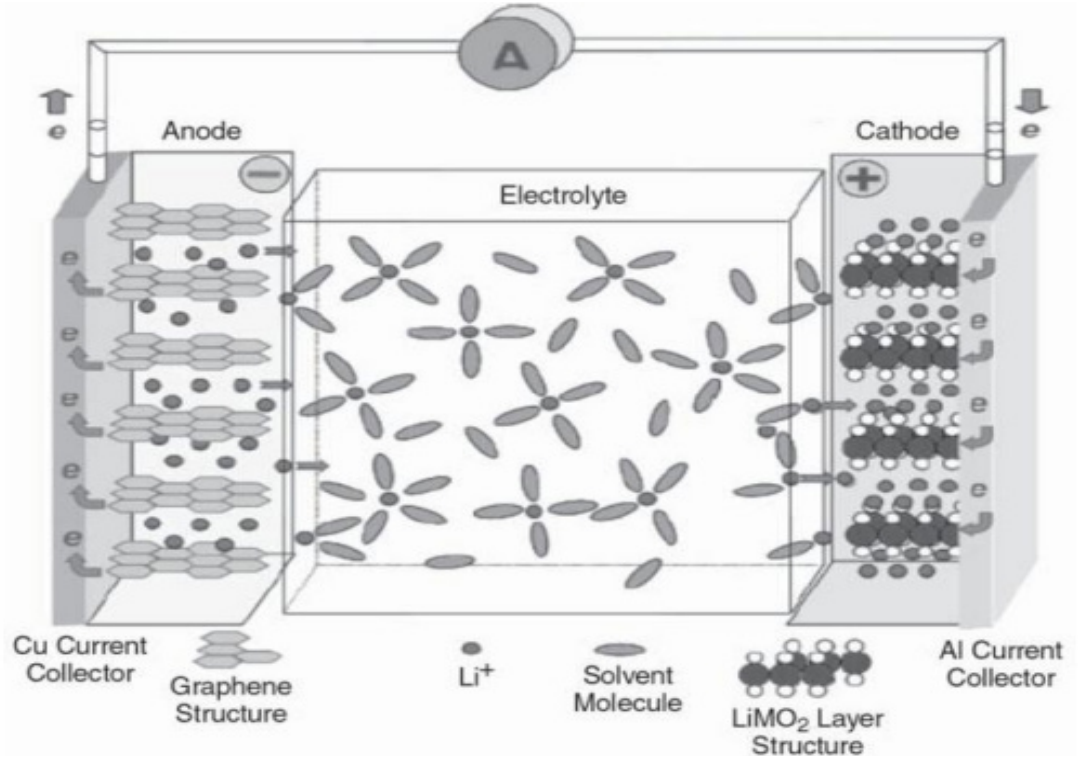
EV	Electric Vehicle		
GW	Gigawatt	**ARC**	Applied Research Collaborative
GWh	Gigawatt hour	**UNLV**	University of Nevada, Las Vegas
IIJA	Infrastructure Investment and Jobs Act	**UNR**	University of Nevada, Reno
NCAR	Nevada Center for Applied Research	**eVTOL**	Electric Vertical Take-off & Landing
TMCC	Truckee Meadows Community College	**GED**	General Educational Development

1 Financial News Media; **2** BloombergNEF Electric Vehicle Outlook Long-Term fbloomb; **3** Bloomberg, Energy Storage Investments, 2019 https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/; **4** IBISWorld, Page 15; **5** Fred Lambert, 2021; **6** IBISWorld, Page 15

I. History of the Lithium-ion Battery

Batteries, or electrochemical cells, are devices that convert the energy created by chemical reactions into electricity. Cells made from lithium were developed in the mid-20th Century, providing lighter and more dense battery cells, thus longer lifespans. Early on lithium-ion batteries served the market for mobile electronic devices – such as medical device implants, military equipment, and an array of consumer goods.[7] In 1991, Sony released a camcorder that featured the first commercial rechargeable lithium-ion battery, beginning a wave of battery -powered products that are now ubiquitous to modern life.

Today, lithium batteries are the battery cell of choice for powering the world's fleet of cell phones, electric vehicles, and electric storage units because of their ability to charge faster and store more electricity than other types of batteries. Unlike wet batteries, such as automotive batteries that use an electrolyte fluid, lithium-ion batteries are dry, meaning they use an electrolyte paste of lithium-ion salt to create chemical energy, and therefore are lighter, easier to handle, and can be easily recharged. In comparison to other rechargeable batteries, lithium-ion batteries possess a higher energy density, a higher voltage capacity, and a lower self-discharge rate. Because a single cell can hold a charge for longer than other battery types, this results in higher electrical efficiency.[8] As commercialization has caught up with technological advancements, lithium-ion batteries have become the preferred choice of battery in everything from consumer electronics, to automobiles, power grids, and home power storage.



Source: Daniel, "Materials and Processing for Lithium-ion Batteries," September 2008.

7 Scrosati, "History of lithium batteries",.5; **8** What are the Benefits of Lithium-Ion Batteries?

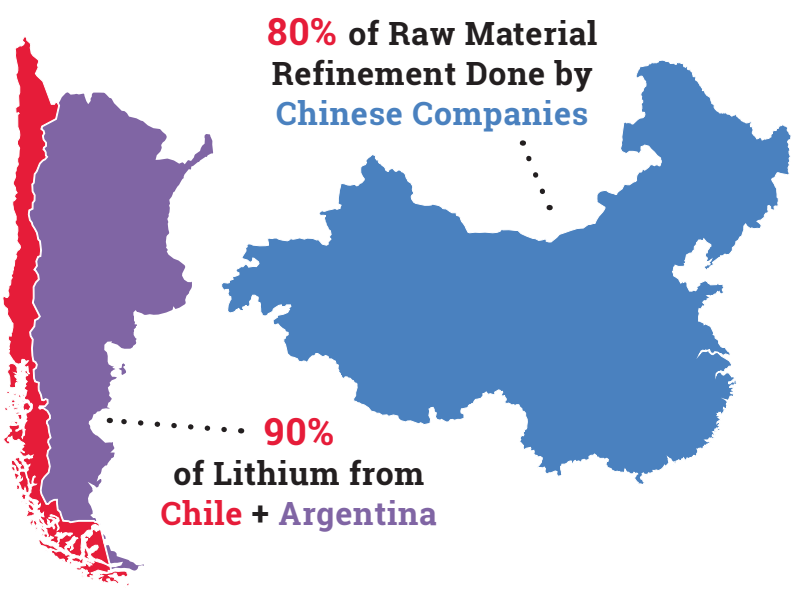
II. The Lithium-Ion Battery Economy in Nevada

When the Panasonic Corporation agreed to partner with the electric auto manufacturer, Tesla, at the Tahoe-Reno Industrial Center in 2015, the electric automobile industry was changed almost overnight. The size of the facility, called a "Gigafactory", and advanced production and scaling techniques allowed Panasonic and Tesla to lower the per-unit cost of each battery cell while packing cells in more efficient ways that allowed for more electricity storage.The partnership brought the per-unit price of electric vehicles down and increased their ability to compete with traditional gasoline-powered automobiles. Nevada brings many other assets to the table when it comes to the lithium-ion battery economy beyond just the Tesla Gigafactory. These additional assets include the mining of lithium-ion and other rare earth minerals in and near our state boundaries, partnerships between the private selector and academic entities dedicated to research and development, e.g. University of Nevada, Reno (UNR) Nevada Center for Applied Research (NCAR), Truckee Meadows Community College (TMCC) Jump Start, and University of Nevada, Las Vegas (UNLV), Applied Research Collaborative (ARC), production and assembly facilities, and finally several battery recycling startups. These assets all happen in one form or another in Nevada, putting our state front and center in a world that is ever increasing its demand for electricity generation and storage to power everything from homes to cars to cell phones and even hotels, restaurants, and large industrial operations.

Due to rising demand, the total global lithium-ion battery market is forecasted to go from $21.95 billion to $115 billion by 2030, driven primarily by the EV market and electricity grid storage.[9] A report by Bloomberg projects that total global deployment of energy storage will grow by 122-fold: from 9 gigawatts (GW) in 2018 to 1,095 GW in 2040.[10]

> **To keep pace with demand, the global lithium supply will need to quadruple in the next ten years to keep pace.**[11]

According to Mckinsey, the U.S. will need to invest $65 billion annually by 2030 just in new battery manufacturing plants to keep up with rising demand.[12] Yet, the U.S. is strategically behind in the domestic manufacturing of lithium-ion batteries and supply chain security from the beginning to end of battery life cycle according to a report by the U.S. Energy Department's Consortium for Advanced Batteries.[13] For example, 90 percent of the lithium that arrives in the United States comes from two countries: Argentina and Chile.[14]

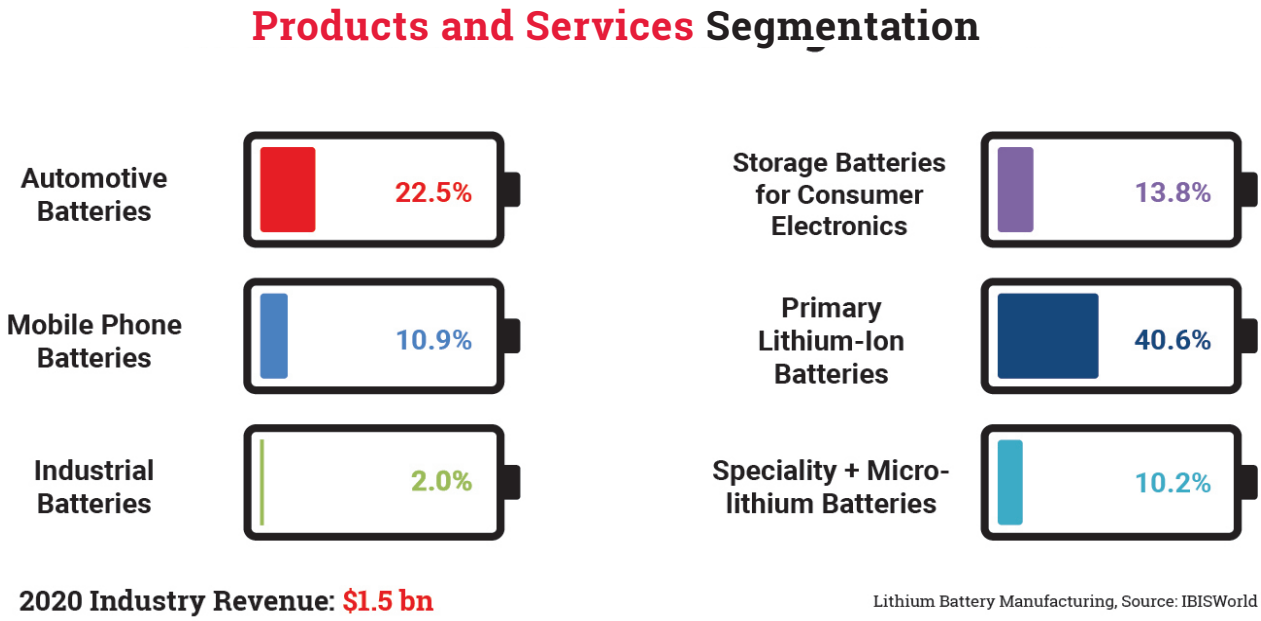


9 FinancialNewsMedia; **10** Bloomberg; **11** Fastmarkets2030; **12** McKinsey & Company, 2021; **13** Department of Energy202; **14** The Conversation 2022

Many of the companies in those countries involved in the extraction of lithium as well as other key metals, such as cobalt, are owned or partially owned by Chinese companies. 80 percent of the world's refinement of raw materials for use in advanced batteries, like lithium-ion batteries, is done by Chinese chemical companies according to the Institute for Energy Research.[15] Several U.S. administrations have mentioned the need to invest in research and development in domestic production of the Lithium-ion Economy as a way to achieve economic, environmental, and geopolitical goals of not only transitioning but being a leader in the clean energy economy.

III. Application of Lithium Battery:

In 2020, industry revenues from battery manufacturing alone totaled $1.5 billion according to IBIS World.[16] There are two types of batteries produced in the lithium battery industry: storage batteries, which are rechargeable and reusable, and primary batteries, which are one-time use. Storage batteries are used most heavily in consumer electronics, such as cell phones, automotive batteries, and increasingly industrial batteries. Automotive batteries are the single biggest and most recognizable most used storage product, accounting for 22.5 percent of revenue in 2020. This is followed by mobile phone batteries, accounting for 10.9 percent revenue, and industrial batteries accounting for 2.0 percent of revenue.[17] Another 40.6% of revenues come from primary lithium batteries (single use) that are used in consumer products, though that share is rapidly falling.



Used and recycled lithium-ion batteries are used by consumer product manufacturers as inputs in other consumer products including phones, tablets, toys, and electronic cigarettes. Furthermore, advances in lithium-ion battery technology, combined with lower lithium prices, have caused increasing dominance in a range of new applications, such as home-energy storage and power-grid distribution. Recent geopolitical events will likely push prices for lithium-ion

15 et. al. Institute for Energy Research 2020; **16** IBISWorld, Page 17; **17** IBISWorld, Page 17

batteries higher for the time being after a long downward trend over the past decade.[18] For example, a typical lithium-ion battery pack for an EV costs around $6,300, but is forecasted to increase by $1,000 per unit as a result of recent sanctions on Russian commodities. In particular, nickel is a necessary raw material in modern lithium-ion batteries and 20 percent of the world's nickel comes from Russia.[19]

Lithium-ion is the preferred storage battery in many applications, since it can charge faster and hold more energy than other types of batteries. The use of lithium-ion batteries in new applications will continue to be a major development driver, especially as the United States and the world work to reduce their carbon footprint from the use of fossil fuels, especially in transportation and energy generation economic sectors.[20][21] One limitation to further advancement in the lithium-ion battery economy occurs in the research and development phase.

> **While lithium-ion batteries have achieved cost-competitiveness with other batteries and forms of energy storage and delivery, studies document that advancement in the industry increases at a very steady, but not necessarily stunning pace of 7-8 percent per year.[22]**

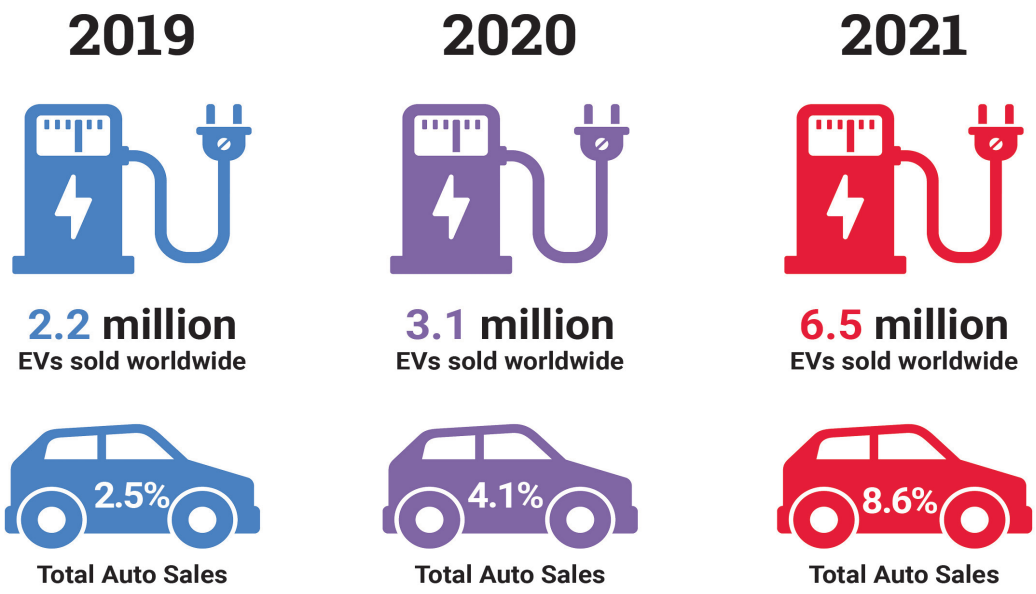
Even when innovations occur in battery storage or efficiency, the time lag until a commercial application emerges can be extensive, thus preventing any immediate acceleration in the technological application as we have seen in some other industries, notably computing.

IV. Demand:

Lithium-ion based batteries are expected to be the leading technology in the market. The main demand for lithium-ion batteries comes from the automotive industry and not just from automotive tech startups such as Tesla, Rivian, and Lucid, but now from legacy automotive producers such as Ford, GM, Volkswagen, and Stellantis. Bloomberg estimates that by 2025, there will be 54 million passenger EVs on the road globally, up from 12 million today.[23] The vast majority of that growth will come from China and certain European countries such as Germany, though U.S. sales of electric vehicles are on the rise. For example, in 2021, 801,550 hybrids and 434,879 electric vehicles were sold in the United States, representing an 83-percent increase for the EV market from 2020.[24]

The demand for electric vehicles globally has been increasing in a very short time period. In 2019, 2.2 million EVs were sold worldwide, accounting for only 2.5 percent of total automobile sales. In 2020, it jumped to 3.1 million units, accounting for 4.1 percent of total vehicle sales despite the pandemic. In 2021, global EV sales doubled to 6.5 million units in 2021.[25] The International Energy Agency reports that the share of EVs in the global automotive sales market increased from 4.11 percent of the total market in 2020 to 8.57 percent in 2021.[26] In the United States just 4 percent of passenger automobiles sold in 2021 were electric.[27]

18 Bloomberg; **19** Bloomberg; **20** IBISWorld, Page 17and16; **21** Environmental protection Agency; **22** WSJ 2022; **23** BloombergNEF Electric Vehicle Outlook ; **24** Kierstein "Motor Trend"; **25** Saur Energy (2022); **26** Fred Lambert; **27** Bloomberg NEF Electric Vehicle Outlook



By 2025, the global figure will double again as 16 percent of passenger vehicle sales around the world will be an electric vehicle according to Bloomberg.[28]

Home-energy storage batteries have been on the market for a long time, and there are now many different types and sizes to choose from. Modern lithium battery systems swiftly surpassed traditional lead-acid batteries as manufacturers developed clever, flexible systems to fit many energy storage applications, thanks to significant advancements in lithium technology.[29] Another use is the ever increasing need for on demand electricity storage for the electrical grid. The demand for electrical grid storage as measured by GW is forecasted to increase 122-fold as more utilities move to sustainable power. This will require large scale industrial sized batteries and new technology to handle demand.

Other uses include zero-emissions air trips, using aircraft (drones) for urban package delivery. By 2025, the global eVTOL aircraft market is predicted to be worth between $162 million and $1 billion. This doesn't include other lithium-ion battery uses in the consumer product market such as cell phone batteries, power packs for recharging devices, wheel-cahirs, scooters, stair lifts, emergency backup power for medical equipment, etc…[30]

V. Economic Impact:

In 2021, the global lithium-ion battery market was valued at $21.95 billion and is expected to grow to $115 billion by 2030.[31] Despite supply-chain bottlenecks and the expiration of EV subsidies in China, EVs, as a percentage of vehicles on the road, continue to grow, especially as uncertainty surrounding oil production and supply chains continues.

According to IBIS World, as of 2022, the lithium battery manufacturing industry alone employs 4,860 people in the United States.

28 CNBC 2022; **29** Best Solar Battery Systems; **30** eVTOL "Aircraft Market"; **31** Financial-NewsMedia

Between 2017 and 2022, the number of persons employed in the Lithium battery manufacturing industry in the United States decreased by - 0.6 percent on average, most likely due to technological advances, dependence on international battery manufacturers, and prioritization of areas in the battery life cycle such as research and development, end of life cycle processing, and EV production and assembly.[32] In the 3rd quarter of 2021, Nevada employed about 2,913 workers in lithium battery manufacturing, accounting for 59.9 percent of the jobs nationwide.[33]

The average wage in Nevada in the battery manufacturing industry is $55,383.47 per year, higher than the average wage in the whole battery industry.[34] The average wage in the battery industry as a whole in Nevada is $48,991, slightly below the national average of $49,521.

The salaries in the United States battery industry presently vary from $27,000 (25th percentile) to $58,500 (75th percentile), with top earners (90th percentile) earning $104,000 annually.[35] In Las Vegas, the average hourly rate salary is $36,618 $(18 an hour), while hourly work in the battery industry starts at $18 an hour and goes up to $30.41 an hour, higher than the Las Vegas average.[36] [37] For comparison, the median household income in Las Vegas is $60,365 according to the U.S. Census Bureau.[38] [39]

A Sample of Jobs, Salary, and Education Required in the Lithium-Ion Battery Industry

Job Title	Annual Salary	Education
Operations	$115,872	Bachelor's Degree Plus Experience
Software Engineer	$102,604	Bachelor's Degree, Programing Language Proficiency
Battery TEST Engineer	$101,789	Bachelor's Degree
Lithium-Ion Battery Engineer	$89,556	Masters Degree
Battery Engineer	$86,117	Masters Degree
Energy Storage Technician	$71,116	Bachelor's Degree
Machine Operator	$37,752 - $63,252.80	Highschool Diploma Plus Certification
Lithium mining	$56,000	GED Plus Some Certifications
Production Manager	$79,071	Master's Degree
Technical Support + Product Specialist	$37,440 - $63,252.80	Highschool Diploma Plus Certification

Source: ZipRecruiter

32 IBIS World, 2022; **33** Walburg, Chelsea 2022; **34** EMSI, 2022; **35** ZipRecruiter; **36** EMSI, 2022; **37** ZipRecruiter; **38** U.S. Census Bureau; **39** IBISWorld, Page 15 and 9

VI. Workforce Impact:

From 2015 to 2020, the number of lithium battery industry operators expanded at a 3.0-percent yearly pace to 36 enterprises globally. At the same time, however, lithium battery manufacturing employment decreased by 1.3 percent to 4,631 employees on an annualized basis. This decrease largely reflects increased degrees of automation in cutting-edge industrial facilities and dependence on international manufacturers. Employment in battery manufacturing is predicted to grow at a 2.3 percent yearly pace to 5,193 workers with the number of industry firms rising at an annualized rate of 2.6 percent to 41 companies globally by 2025. Those figures are likely on the low end as in the last year there have been a flood of announcements of new battery manufacturing facilities just in the United States (at least 15) under construction or set to be up and operating within the next 5 years (see section VII). According to McKinsey & Company, each large battery factory, aka gigafactories, employ 2,000 or more workers.[40]

> **Simple math would dictate that at least 30,000 or more workers will be needed to staff all 15 proposed or planned gigafactories in the United States by 2025.**

Over the next four years to 2025, the number of facilities in the overall Lithium-ion battery manufacturing space are forecasted to grow at an annualized pace of 2.6 percent, to 50. In 2020, wage expenditures are expected to account for 18.8 percent of total industry sales, up from 14.4 percent in 2015. Wages increased throughout time as employment increased in line with industry revenue. The tremendous demand for qualified workers, in particular engineers

US Battery Manufacturing Employment Outlook[41]

Year	Employment (Units)	Revenue ($m)	Wage ($m)	Average Wage
2020	4,631	$1,545	$291	$62,837
2021	4,720	$1,581	$297	$62,924
2022	4,860	$1,647	$306	$62,963
2023	4,991	$1,706	$315	$63,114
2024	5,102	$1,756	$323	$62,119
2025	5,193	$1,796	$329	$63,355
2026	5,294	$1,835	$335	$63,279

40 McKinsey & Company, 2021; **41** IBISWorld, Page 15

and technicians, to develop new products and outperform competitors has kept wages high.[42] Positions such as chemical, electrical, and mechanical engineers, all jobs that require at least a bachelor's degree or an equivalent amount of experience, are required for both upstream and downstream of the production process. Many of the floor technicians in manufacturing only require a high school diploma but require certifications and specialty training through either their employer or local education facilities. For example, Tesla offers an eight week "START' program for its floor technicians, which teaches the basics of EV manufacturing.[43] Jobs in the Lithium mining process require a GED as minimum education and pay wages of $56,000 in Humboldt County, Nevada.[44] Workers on energy storage projects, such as the Nevada utility, NV Energy, earn an average annual salary of $71,116, or $34.19 per hour, on a national scale. While the average employee salary at NV Energy is $71,116, pay varies greatly depending on the role.[45]

VII. Conclusion : The Future of The Lithium-ion Battery in Nevada

The United States lags behind much of the world in key points of the Lithium-ion Battery supply chain. Australia, China, and Chile produce 88 percent of the world's raw Lithium.[46] The rest of the supply chain is dominated by China, which produces 66 percent of the world's cathodes and anodes, 73 percent of the Lithium-ion cells, and 80 percent of the world's refined battery chemicals.[47] Nevada's Lithium deposits in Thatcher Pass and Clayton Valley, totaling 593.3 million tonnes of ore graded at 1,073ppm lithium,[48] could supply the raw materials necessary for the United States to be a much larger domestic producer of raw lithium. The Department of Energy has stressed the need for the United States to play a bigger role in every step of the lifecycle of battery deployment to ensure energy independence and to reduce greenhouse gas emissions.[49]

Nevada is home to at least 16 companies in the Lithium battery economy, including battery recycling companies such as Redwood Materials. Firms like Redwood, Tesla, and Panasonic are all located in northern Nevada and have given rise to an innovation cluster. Continuing to harbor this cluster with increased investment at all supply-chain levels, as well as statewide investment in complementary institutions like education and research and development, would boost growth in the Lithium battery industry while strengthening our economic diversification efforts.[50]

To be clear, battery manufacturing is no longer contained just in the north. Southern Nevada has three battery companies in Henderson, Nevada: K2 Energy and Lithion Battery Inc., which employ between 163 and 312 individuals. Legislative help at the state and federal level could increase Southern Nevada's commercial capacity by opening more land for commercial facilities such as for research and development, assembly, production, and recycling. Northern Nevada is unable to do so at this time, but has a critical role in the processing of materials as well as contributing to research and development, and the development of new companies.

42 IBISWorld, Page 12; **43** "Tesla Start"; **44** Borden, Buddy, & Tom Harris. "Economic and Fiscal Impacts from New Lithium Mine and Lithium Processing Operations in Humboldt County, Nevada.", Page 35; **45** Zippia Score, Feb 2022; **46,47** "Visualizing the Global Demand for Lithium."; **48** "Clayton Valley Lithium Project, Esmeralda County, Nevada, US."; **49** "Department of Energy, Page 7."; **50** Bailey, "Clusters and Innovation Districts: Lessons from the United States Experience."

This would follow a similar path to the gaming industry, which initially took off in the north and later came to dominate southern Nevada with legacy gaming companies in Reno supporting the Las Vegas Strip.

This would also incentivize Northern and Southern Nevada stakeholders to strengthen their ties along the I-95 corridors such as among academic and private facilities, knowledge bases, and raw material producers.

On November 15, 2021 Congress passed and U.S. President Joe Biden signed into law the Infrastructure Investment and Jobs Act (IJJA) which dedicates $3.1 billion for domestic manufacturing of batteries. The funding in the form of grants by the Department of Energy aims to build, retool, and expand the manufacturing of batteries and battery components. This is part of $7 billion in the $1 trillion bipartisan law dedicated to strengthening the U.S.'s battery supply chain.[51]

Other legislation before Congress, the BBB Act, has proposed an expansion of EV tax credits originally introduced in the Energy Policy Act of 1992. Individual buyers would receive a $4,000 guaranteed credit, with additional credits for battery capacity, nationally built cells, and union manufacturing. All combined, consumers would receive $12,500 per EV.[52] Global leaders in this EV space, such as Elon Musk, have commented that once EVs are mass-produced in large numbers, the globe will require several dozen large battery manufacturing facilities.[53] As of 2022, there were 7 operational EV battery manufacturing plants of various sizes and 15 in various stages of completion in the United States.[54] Not since Tesla and Panasonic has another large electric vehicle battery facility been built in Nevada.

It is worth mentioning that lithium-ion is not the only battery material in existence. Other sources include sodium-sulfur batteries, which are currently being used in Abu Dhabi for energy storage.[55] Hydrogen fuel cells have also been mentioned as an alternative, with Toyota having spent significant sums investing in hydrogen automobile technology, including getting the Japanese government to encourage the production of hydrogen refueling stations. One of the stumbling blocks has been an efficient way to produce hydrogen in large and safe quantities to power the hundreds of millions of vehicles on the roadway. [56]

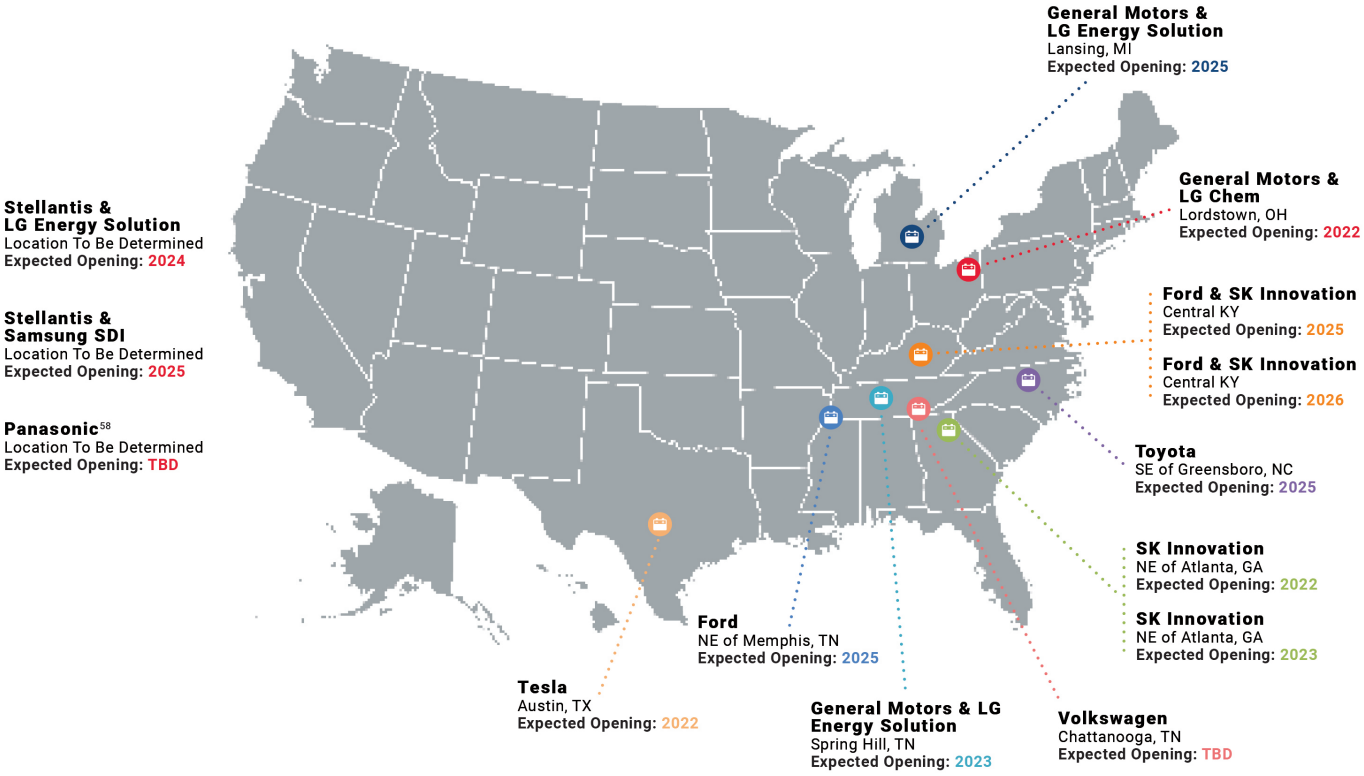
VIII. Further Research

Further questions worth researching on this topic:

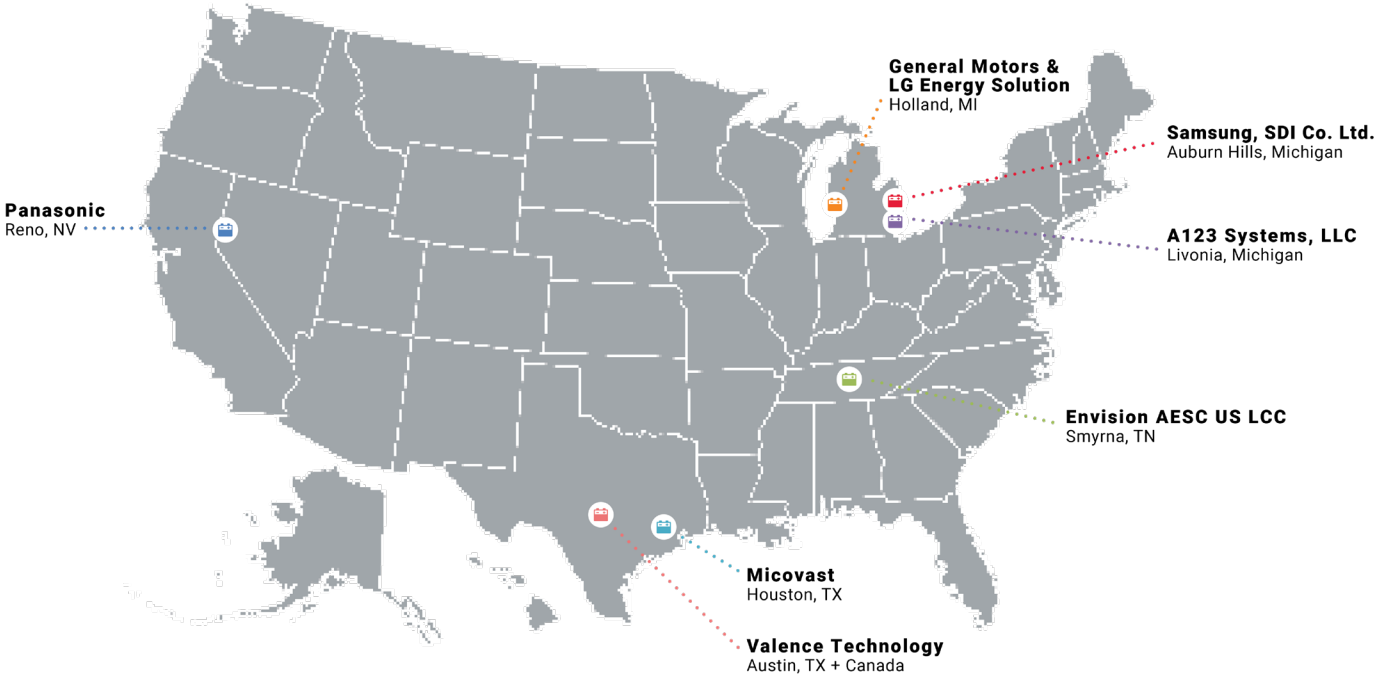
- What are further impendents to industry expansion in Nevada?
- Are there areas of the battery manufacturing ecosystem that Nevada should focus on or should it be all of them and all types of batteries?
- Can the industry be fully onshore or will the supply chain always be dependent on facilities in other countries?
- What are the spin-off industries that come from specializing in battery production?
- Is there enough lithium to meet demand in the coming decades?

51 CNBC, 2021; **52** Tsafos, "The United States' Industrial Strategy for the Battery Supply Chain."; **53** "We Are over Elon Musk's 100 Gigafactory Target for Sustainable Energy: Do We Need a Terafactory?" **54** Moores, "The Global Battery Arms Race: Lithium-Ion Battery Gigafactories and Their Supply Chain."; **55** Power-Technology, 2022; **56** Green Authority, 2021

Appendix I: Planned Electric Vehicle Battery Factories in the United States as of January 2022 [57]

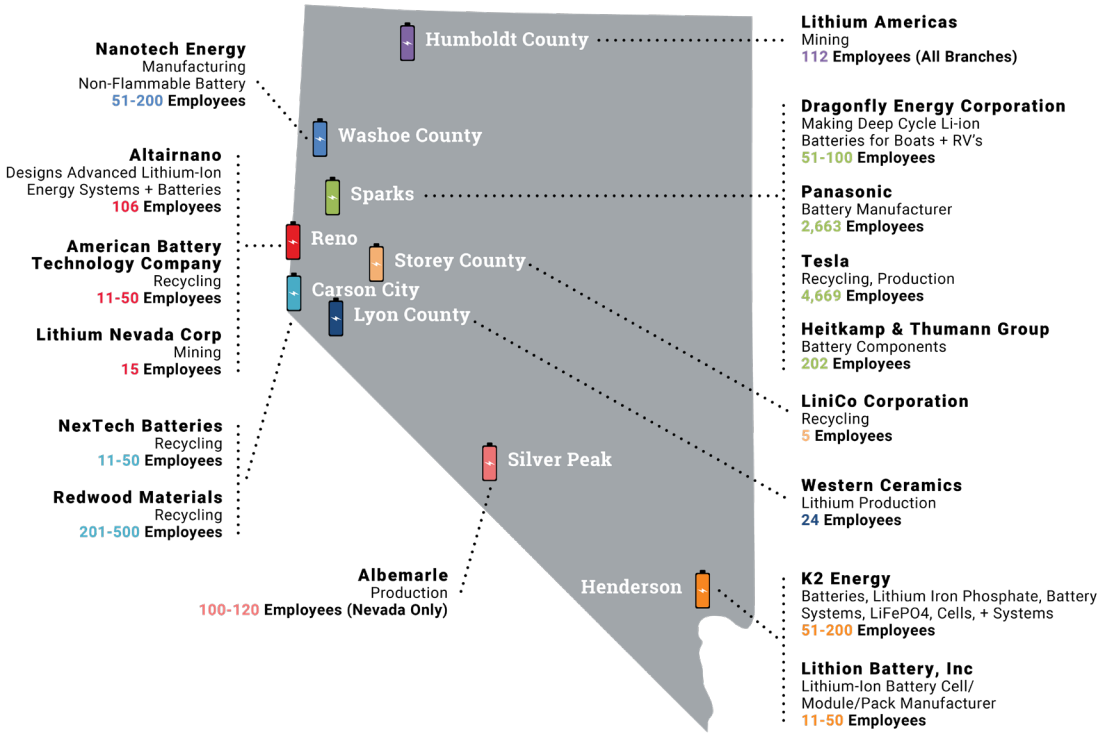


Appendix II: Electric Vehicle Battery Manufacturers Already Operating in the United States [59]



57 Energy.Gov; **58** Fred Lambert, 2022; **59** Coffin and Horowitz, 2018

Appendix III: The Lithium-Ion Battery Economy in Nevada



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