WHITEPAPER:

BATTERY ENERGY STORAGE SYSTEMS OVERVIEW & OPPORTUNITIES

PHOENIX MERCHANT PARTNERS

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Abstract

Building upon Phoenix's **Inflation Reduction Act** whitepaper released in June 2023, the objective of this report is to present an overview of the latest advancements and opportunities in **Battery Energy Storage Systems** (BESS), a pivotal element of an energy grid undergoing decarbonization. This paper covers:

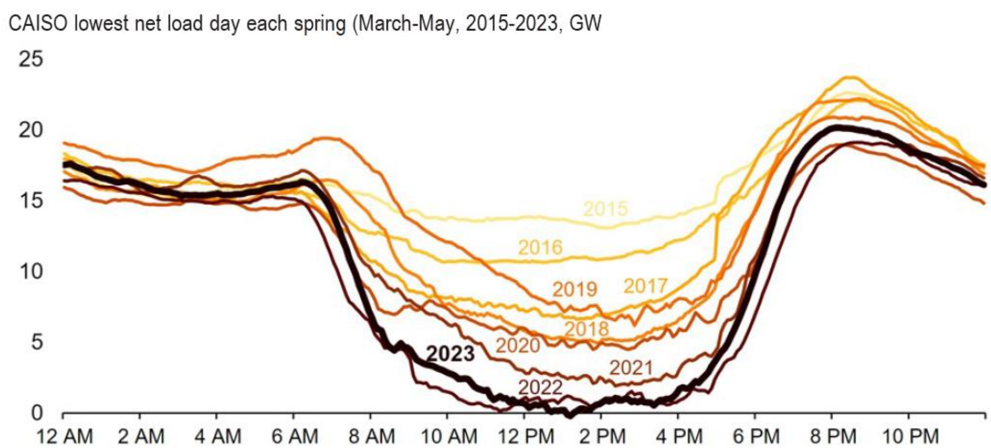
- An overview of grid level energy storage systems, focusing on the growth of the BESS sector.
- A short summary of the prevailing battery technology landscape for storage systems
- A description of the battery energy storage value chain, focusing on clean-tech manufacturing
- An initial assessment of the IRA's impact on the sector.

Our review confirms the multitude of investment opportunities within the BESS space, characterized by a broad value chain experiencing significant growth and innovation. Specifically, we find the system integration phase, with its emphasis on technology, software, and service elements, to be of interest.

Grid Level Energy Storage Systems

Electrification and the rapid deployment of renewable energy are both critical for a low-carbon energy transition. However, the intermittency of critical renewable energy technologies, wind and solar, combined with increasing electrification present a challenge to grid stability and security of supply.

Figure 1 – For Illustrative Purposes Only



Source: U.S. Energy Information Administration

The "Duck Curve" – showing net electricity load during the day in California - illustrates the increasing impact of intermittency. During mid-day hours, solar electricity floods the grid, sometimes reaching points of oversupply. But during the evening, as demand increases, solar generation falls off, forcing utilities to ramp up generation from other sources. As more solar is added, the load ramp from afternoon to evening becomes steeper and the opportunity cost from curtailment rises[1].

Energy storage represents a solution to the intermittency challenge of renewable energy. Utility scale storage systems are designed to meet the needs of the electric grid, with large systems (10-500 MWh) often packaged into multiple shipping containers. Large scale "renewables & storage" projects are

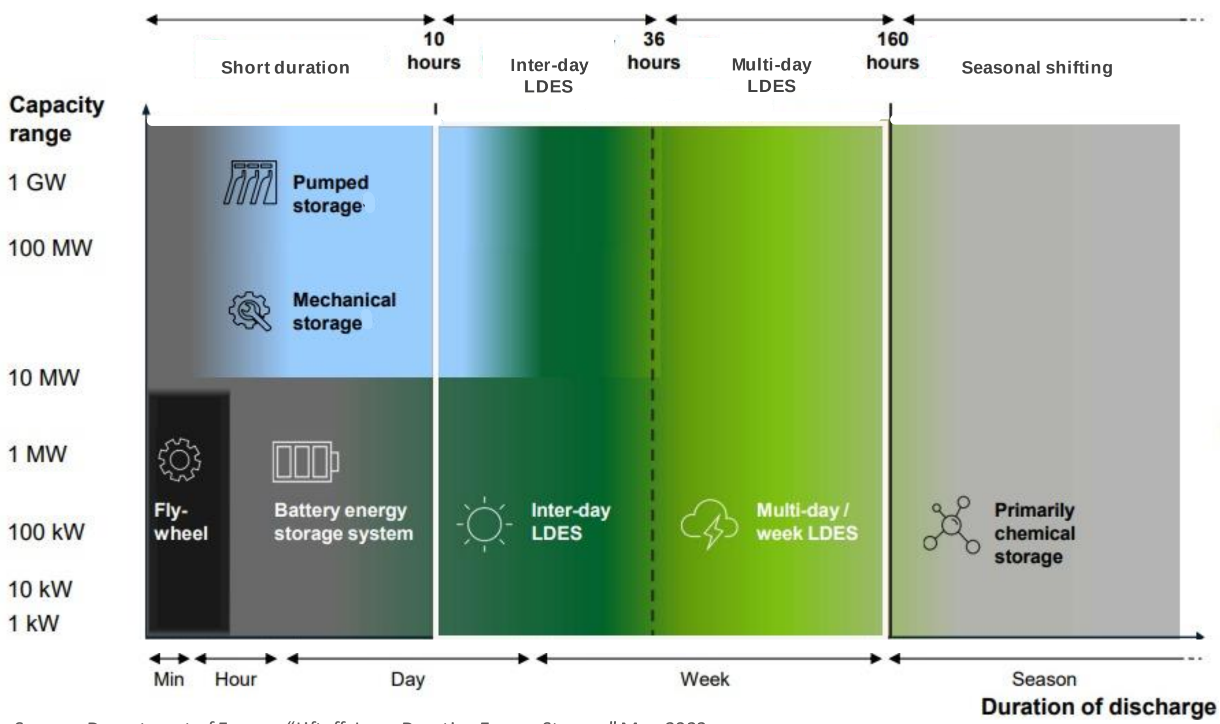
[1] J.P. Morgan: "A Beginner's Guide to the Decarbonization, Decentralization and Digitization of Energy", 16-Sep-2023

becoming commonplace across the globe, helping reduce renewable energy curtailment and adding grid stability.

Different energy storage types are generally defined by their duration of dispatch, considering the following broad categories,

- **Short Duration Storage**, defined as shifting power by less than 10 hours, primarily through Lithium-ion battery storage. Pumped storage hydropower and mechanical storage can also be used for short durations.
- **Long Duration Storage**, includes,
  - (i) Inter-day periods (10-36 hours), shifting excess power produced at one point in a day to another point the same or next day. Includes all mechanical and some electrochemical technologies (e.g. flow batteries).
  - (ii) Multi-day periods (36-160 hours), covering for extended power shortfalls (e.g. multiple days of low wind and solar). Includes many thermal and electrochemical technologies.
- **Sesonal Storage**, moving energy over an extended time period, mostly over several months (e.g., summer to winter), and likely to be filled by hydrogen or fossil fuels with carbon capture.

Figure 2 – For Illustrative Purposes Only



Source: Department of Energy; "Liftoff: Long Duration Energy Storage" Mar-2023

There are multiple initiatives focusing on Seasonal Energy Storage, including e.g. the DOE's Hydrogen Shot[2] and multiple clean hydrogen tax credits under the IRA. However, the relevant technologies and infrastructure are still in their infancy and industrial scaling is not expected before the end of the decade.

[2] U.S. DOE: "Pathways to Commercial Liftoff: Clean Hydrogen", Mar-2023

Equally, there is significant activity and support for Long Duration Energy Storage, however, no solution has yet gone beyond proof-of-concept and achieving commercial liftoff[3] requires improvements in technology, cost declines, regulatory support, and supply chain development.

Pumped Storage Hydropower is a mature short duration storage technology that competes for the 4-10 hours dispatch period. However, the scale-up potential of traditional PSH is limited by the planning process to get a project approved and built; a typical cycle spans 8–10 years.

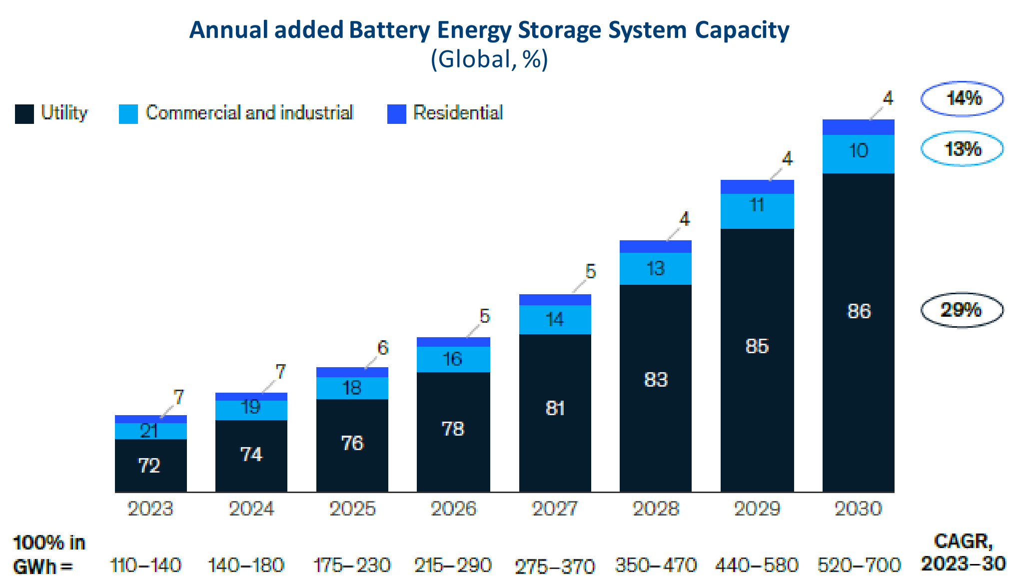
The growth in energy storage anticipated through the end of the decade is expected to be driven by **short duration Battery Energy Storage Systems**.

Energy Storage – Sector Volume and Growth

Technological advancements, particularly in Lithium-ion batteries, are paving the way for substantial growth in global deployments of short-duration energy storage. The resulting large-scale BESS capacity will enable widespread integration of renewable energy sources, allowing for typically high cycling grid services, such as energy shifting, and frequency/voltage regulation.

Global battery capacity additions - for utility scale applications - are expected to **grow at ~29% annual rate in 2023-2030**, with annual additions reaching 450-620GWh[4]. This represents a ~5.5x increase of the ~90 GWh installed in 2023.

Figure 3 – For Illustrative Purposes Only



Source: McKinsey Energy Storage Insights BESS market model, Aug-2023

Industry growth, driven by declining costs and ramping supply chains, is anticipated to exceed even the fast pace of growth within renewable energy generation.

[3] U.S. DOE: "Pathways to Commercial Liftoff: Long Duration Energy Storage", Mar-2023

[4] McKinsey: "Enabling renewable energy with battery energy storage systems", Aug-2023

The **U.S. market installed ~22GWh in 2023**[5] and seeks to deploy ~15-20% of global annual energy storage capacity additions, reaching ~90GWh installations by 2030. Development is driven by large-scale projects in California, the Southwest and Texas. Market growth has already been catalyzed by the Inflation Reduction Act, starting to narrow the gap to China.

Addressable Market

Globally, energy storage investment reached $36 bn in 2023 with a YoY growth of 76%[6]. To stay in line with the Paris NZS target, annual spending on energy storage must exceed its current rate by more than 2x from 2024 to 2030.

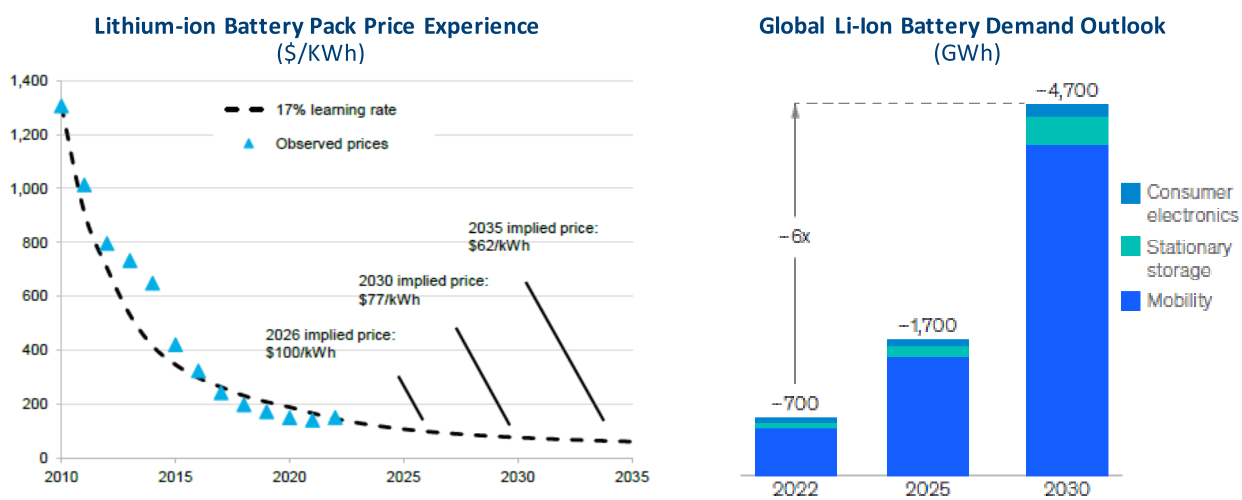
In the **United States, grid-scale investments** totaled **~$13 billion in 2023** and are anticipated to reach $**25-30bn by 2030**.

Battery Energy Storage Systems

With its demonstrated performance, consistent learning rate and established supply-chain, Lithium-ion is expected to remain the preferred energy storage technology for the foreseeable future.

The development of a global manufacturing base, of established supply chains and economies-of-scale for Lithium-ion have largely been driven by the growth of the electric vehicle industry. From 2010 to 2022, the cost of lithium-ion battery packs has declined over 88%, as shown in Figure 5.

Figure 5 – For Illustrative Purposes Only



Source: BloombergNEF

Source: McKinsey Battery Insights Demand Model

During that period, **Lithium-ion** represented over **90% of utility-scale stationary battery storage** additions in the US[4], primarily as short-duration storage, with most commercial applications ranging from 2- to 4-hours of discharge time.

[5] Wood Mackenzie: "US Energy Storage Monitor", Dec-2023

[6] BloombergNEF: "Energy Transition Investment Trends 2024", 30-Jan-2024

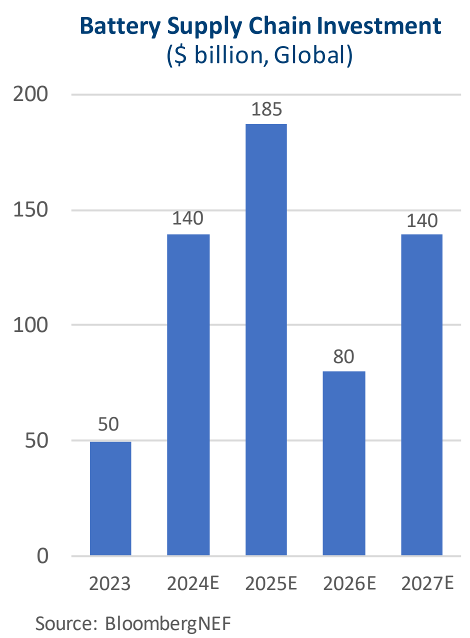
Global **demand for Lithium-ion batteries** is expected to **rise by ~6x over the next decade**, from ~700 GWh in 2022 to ~4.7 TWh by 2030[7], with mobility applications, such as EVs, accounting for a significant majority of demand.

Stationary battery energy storage system (BESS) installations are anticipated to grow by ~30% annually. Projections indicate that by 2030, annual deployments could surpass 500 GWh. Based on this rapid expansion, it may be foreseen that stationary **energy storage** will surpass **10% of the global Lithium-ion battery demand** within this decade.

Battery Production

Growth of the BESS sector (i.e. short duration energy storage) is closely linked to the electrification of mobility. Investments in production capacity over the coming years will be driven by **Lithium-ion battery manufacturing** facilities.

Figure 4 – For Illustrative Purposes Only



Investments in the global battery supply chain -, excluding metal mines and refineries - totaled ~$50bn in2023[6].

Current **investment plans** show a **280% increase from 2023 to 2024,** driven by a pipeline of battery gigafactories. Following completion of announced facilities by 2025, a temporary drop off in investments is expected.

Facilities and supply chains for new, lower-cost chemistries (e.g. Sodium-ion) will start taking a larger share of investments after 2027.

Global investments in battery metals production reached ~$14bn in 2023 and are expected to double by 2026[6]. U.S. domestic facilities stand to gain from IRA incentives in §48C (production or recycling of renewable energy property) and §30D (domestic critical mineral requirement).

Battery Technology

Lithium-ion encompasses several different cell chemistries, including Lithium Iron Phosphate (LFP), Lithium Nickel Manganese Cobalt (L-NMC), and Nickel Cobalt Aluminum (NCA).

L-NMC batteries offer higher energy density, making them suitable for applications where space and weight are at a premium, such as electric vehicles. However, LFP batteries offer stronger cycle life and safety, making them more suitable for applications where durability and safety are critical, such as energy storage systems. Lithium NCA is generally viewed as a higher cost chemistry and represents a relatively small and shrinking portion of the global mix.

In recent years, alternatives to Lithium-ion batteries have emerged, notably Sodium-ion. This battery chemistry has the advantages of relying on lower cost materials, and of completely avoiding the need for

[7] McKinsey: "Battery 2030: Resilient, sustainable, and circular", 2023

rare minerals. Sodium-ion technology developed in China is estimated to cost 30% less than an LFP battery. With a somewhat lower energy density than Lithium-ion, Sodium cells are primarily relevant for urban vehicles, and stationary storage. There are nearly 30 Sodium-ion battery manufacturing plants currently operating, or under construction, for a combined annual production capacity of ~100 GWh, almost all in China.

Though unlikely to become commercially viable at scale before 2030, other promising alternative technologies include Sulfur, Flow and Iron-air batteries.

Iron-air batteries use a reversible rusting process. This technology can provide long-duration energy storage of ~100 hours, while Iron is abundant and cheap compared to metals needed for Lithium-ion technologies. The batteries are large and slow to charge and discharge, making them less suited for quick response, high-cycling, and mobile applications. In 2023, two pilot systems have been approved for construction (Minnesota, California), providing 10MW/ 1,000MWh and 5MW/ 500MWh of energy storage respectively[8]

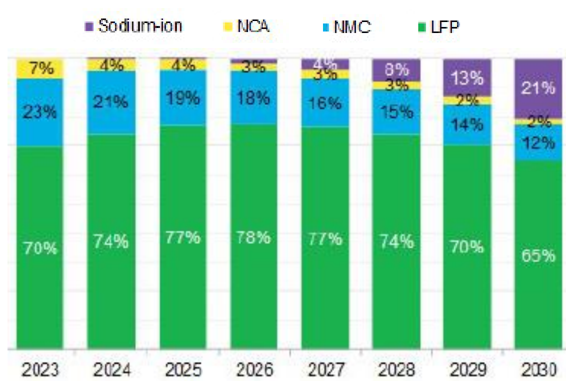
Figure 6 – For Illustrative Purposes Only

Battery Pack Characteristics by Chemistry

Feature	L-NMC	L-FP	Sodium
Spec. Energy (Wh/kg)	150-250	90-160	70-160
Cycle Life (# cycles)	1,000-2,000	2,000-5,000	2,000-5,000
Price per kWh ($)	130-180	120-150	90-120
2023 Market Share Energy Storage EV Mobility	 23% 60%	 70% 30%	 N/A N/A
Safety	Moderate	High	High

Sources:
International Energy Agency, Wood Mackenzie, Nature Communications

Battery Storage Chemistry Mix Outlook
(% based on GWh)



Source: Bloomberg NEF

Battery Energy Storage Value Chain

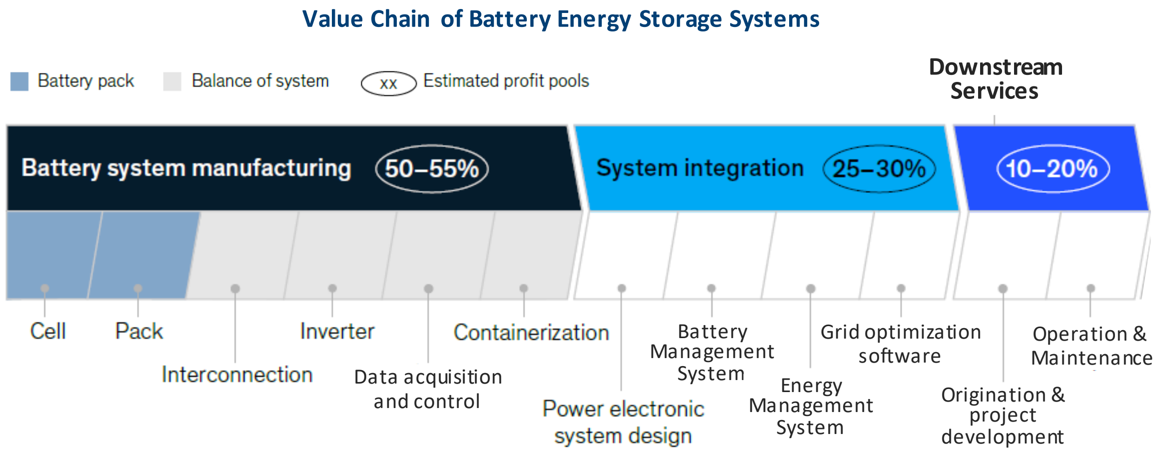
The U.S. market for BESS is estimated at **~$13 billion in 2023**[4]. Its value chain can be split into three stages, (i) Hardware Manufacturing, (ii) System Integration and (iii) Downstream Services.

Battery system manufacturing covers roughly 50% of the BESS market revenue pool, while **system integration activities** capture additional **25 – 30% of available revenues**. Finally, between 10 – 20% of the revenue pool is associated with downstream services, such as project development, commissioning, operation and maintenance.

The level of integration varies across the industry. Some participants cover only cell manufacturing and see the BESS business as ancillary to their EV product line, others are specialized system integrators that offer turnkey energy storage solutions to utilities, inclusive of software solutions and O&M services.

[8] Form Energy: Press releases Jan-2023 and Dec-2023

Figure 7 – For Illustrative Purposes Only



Source: McKinsey "Enabling renewable energy with battery energy storage systems"

	BESS Value Chain Components
Hardware	Most BESS-Providers do not build cells but work with major battery manufacturers due to the high capital intensity and large advantages of economies of scale. These cells are combined in a metal frame to make up the battery racks and equipped with inverters, monitoring sensors and grid connections. By developing their own rack technology/production, companies can streamline costs and keep ownership of the storage system's design.
Software	Software is a key differentiator for BESS-Providers, main components include: – Battery Management System (BMS), that regulates the safe charging process, monitoring all battery cell metrics (e.g. cell voltage, temperature). – Energy Management System (EMS), the main operating software integrating the BESS with grid operators and controlling its activities. – Energy Trading Software, offering forecast algorithms for energy prices and optimized wholesale energy market bids. The software automates discharge timing and pricing. In-house BMS, EMS and Energy Trading software allows providers to differentiate their platform from competitors, as well as increasing the safety and performance of the entire storage systems.
Services	The main service offered is system integration. This entails setting up the respective hard- and software components -sourced from one or several producers- and ensuring functionality of the units. The physical deployment at the project site, however, is generally outsourced to local partners (EPC's). After project completion most BESS-Providers offer long-term O&M services including performance guarantees (10 – 20 yrs), warranties and technical maintenance

Inflation Reduction Act

The Inflation Reduction Act (IRA) replicates China's approach of the past decade, by using demand- and supply-side subsidies to build a supply chain. Historically, U.S. federal policy has focused on incentivizing renewable and energy storage **deployment**. The IRA, however, broadens incentive programs to include **domestic manufacturing** through new tax credits, grants, and low-cost loans.

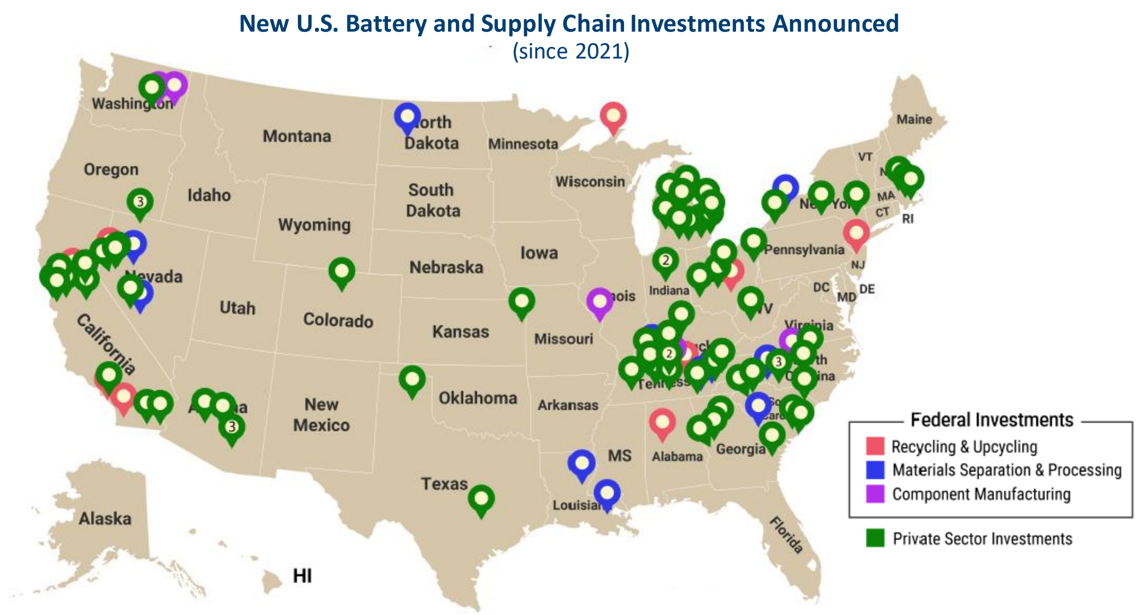
Note: The IRA eliminated the need for a BESS to attach to a qualified renewable energy generation facility. This allows standalone storage systems to qualify for ITC, including retrofits to operational assets.

Tax Incentives available for Battery Energy Storage Manufacturing[9]

Program	Description/ Status	Domestic Bonus
§48C Advanced Energy Project Credit Total Volume: $6.0bn	Extended to include manufacturing facilities for energy storage systems and components. Initial allocation round for 48C closed August 3, 2023. The IRS will make all Round 1 allocation decisions by March 31, 2024	Product components that contribute to domestic content for BESS technology include – Battery pack (i.e. cells, packaging, thermal management system and battery management system – Battery container/ housing – Inverter
§45X Advanced Manufacturing Production Credit Total Volume: $31bn	New production tax credit for clean energy (incl. battery storage) technology components Treasury/IRS released proposed regulation on December 14, 2023. Requested comments by February 13, 2024	

Manufacturing tax credits in §48C and §45X support the "Hardware" stage of the BESS value chain and represent a major step in establishing domestic production. For a facility to qualify for the domestic content bonus, >40% of the direct costs of manufactured products must be U.S.-made (increases to 55% after 2026).

Figure 8 – For Illustrative Purposes Only



Source: U.S. Department of Energy, Feb-2023

The IRA's has already altered the US battery cost curve, helping bridge the capex gap with China. For LFP cells, the cost averaged around $125/kWh, with investment tax credits reaching 30% [10].

[9] Congressional Research Service: "Tax Provisions in the Inflation Reduction Act of 2022 (H.R. 5376)", Aug-2022

[10] Columbia SIPA: "The IRA and the US Battery Supply Chain: One Year On", Sep-2023

Government support has accelerated new battery manufacturing announcements. US gigafactory capacity projected through 2030 increased from around 700 GWh in July 2022 (prior to IRA) to over 1.2 terawatt-hours (TWh) as of July 2023[11], while 14 new production facilities have been announced to serve the energy storage market.

Considering the entire battery supply chain, including material processing and recycling, **96 new and expanded manufacturing plants** were announced, representing **~$80bn in investments**.[12]

Electric Mobility Considerations

While electric mobility and grid-level BESS represent distinct use cases, both depend on advancements in battery technology for their expansion. The widespread adoption and large-scale production of Electric Vehicles (EVs) are important drivers for the transition towards a low-carbon economy.

- **Light Electric Vehicles:** Sales of EVs in the U.S. have grown strongly in 2023 to reach 1.2m units (~7.6% of total vehicle sales). For 2024 growth is expected to continue, but at a slower rate, reaching ~10% of total sales[13]. While established automakers are cutting EV production targets, pure-play manufacturers continue expanding. Market growth, beyond early adopters, will depend on price reduction (at average $50k EVs are still expensive), battery technology advances and rollout of a reliable charger infrastructure.
- **Commercial Electric Vehicles:** Overall, in 2022 there were 1.85m new commercial registrations (GVW 1-8) in the U.S., of which ~2% were EVs. The speed of adoption is driven by segment-specific dynamics. On a TCO basis, LCVs are already breakeven with ICE alternatives, and medium-duty trucks (MDT) are expected to reach TCO parity 2025. HDTs may not achieve parity before the end of the decade[14].

  Adoption of e-LCVs is accelerating with the continuous expansion of e-commerce and e-groceries, which focus on last-mile delivery; as well as the introduction of low-emission zones. Between H1-2022 and H1-2023, sales of Class 2 e-LCVs (i.e. cargo vans and small box trucks) have risen by ~300% to 10,000 registrations[15].
- **Challenges to the Grid:** While generating the power for electric mobility from renewable sources will present few challenges, delivering that power at the times and speeds needed will put pressure on the grid, requiring significant investment into distribution infrastructure.

  Integrating the battery capacity of EVs into energy storage systems could assist in balancing the load curve and alleviating strain on the grid. This two-way vehicle-to-everything (V2X) technology is currently undergoing early-stage development[16] (e.g. pilot programs with school bus fleets). By 2030, it holds the promise of meeting a significant portion of short-term grid storage demands[17]. This scenario presents an opportunity for system integration providers throughout the BESS value chain.

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[11] Benchmark Mineral Intelligence: "Gigafactory Assessment", Aug-2023

[12] U.S Department of Energy: "American Made Batteries", Feb-2023

[13] Cox Automotive: "A record 1.2 million EVs were sold in the U.S. in 2023", Jan-2024

[14] McKinsey: "Why the economics of electrification make this decarbonization transition different", Jan-2023

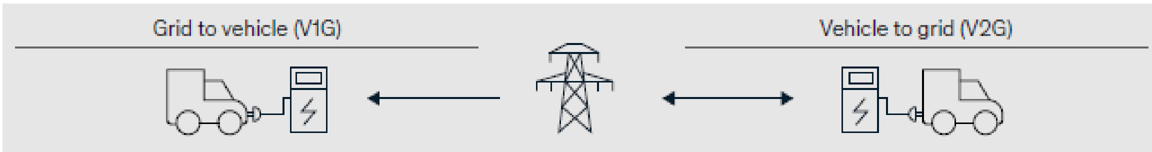
[15] S&P Global: "US commercial vehicle fleet registrations roaring back from pandemic lows", Sep-2023

[16] McKinsey: "What promise does V2X hold for fleets?", Aug-2023

[17] Nature Communications: "Electric vehicle batteries alone could satisfy short-term grid storage demand by as early as 2030", 17-Jan-2023

Figure 9 – For Illustrative Purposes Only

Vehicle Battery to Electricity Grid Technology



Grid to vehicle (V1G):

- Energy flows from the grid into the vehicle battery
- All electric vehicles (EVs) can do this
- Vehicle owners choose when battery charges from the grid and how quickly (based on charger power, measured in kW) the electricity is drawn

Vehicle to grid (V2G):

- Energy can flow from the battery to the grid
- To enable V2G, both the EV and charger require bidirectional hardware and software
- Vehicle owners can sell electricity back to the grid during times of high demand, reducing peak demand of buildings and providing services to balance the grid

Source: McKinsey & Company

Conclusion

Energy storage systems have a crucial role in achieving clean and reliable energy grids. The sector's growth, projected through this decade, will be driven by short duration battery energy storage systems (BESS). The United States, grid-scale investments totaled ~$13 billion in 2023 and are anticipated to reach $25-30bn by 2030.

Supply chain investment in the coming years will be driven by lithium-ion battery manufacturing, while sodium-ion batteries are expected to take market share, and promising alternative technologies are in advanced stages of development.

The BESS value chain consists of three stages, (i) hardware manufacturing, (ii) system integration and (iii) downstream services. On-shoring of battery production is a U.S. policy priority, with large incentive programs for domestic manufacturing contained in the IRA.

Phoenix believes the energy storage sector offers multiple opportunities for lenders throughout a diverse value chain marked by substantial growth and innovation. Specifically, we find the system integration phase, with its emphasis on technology, software, and service elements, to be of interest.

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