ZincFive

Energy Storage Industry

BOUNDLESS
IMPACT RESEARCH & ANALYTICS

Climate Impact Profile
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Confidential

Executive Summary

Advanced energy storage solutions are increasingly needed to transition the electricity grid, transportation, building and industrial sectors towards renewable energy sources. ZincFive's nickel-zinc battery is a high-capacity battery with environmental and safety advantages. The materials comprising ZincFive's battery are non-flammable and environmentally benign compared to lithium-ion and lead acid batteries. ZincFive's ecological advantages and performance specifications drive its demand in a wide range of high-growth applications, such as data centers, intelligent (communicating) transportation, motive and start-stop applications.

Alignment with SDGs

7 AFFORDABLE AND CLEAN ENERGY — Affordable and Clean Energy

11 SUSTAINABLE CITIES AND COMMUNITIES — Industry, Innovation and Infrastructure

12 RESPONSIBLE CONSUMPTION AND PRODUCTION — Responsible Consumption and Production

13 CLIMATE ACTION — Climate Action

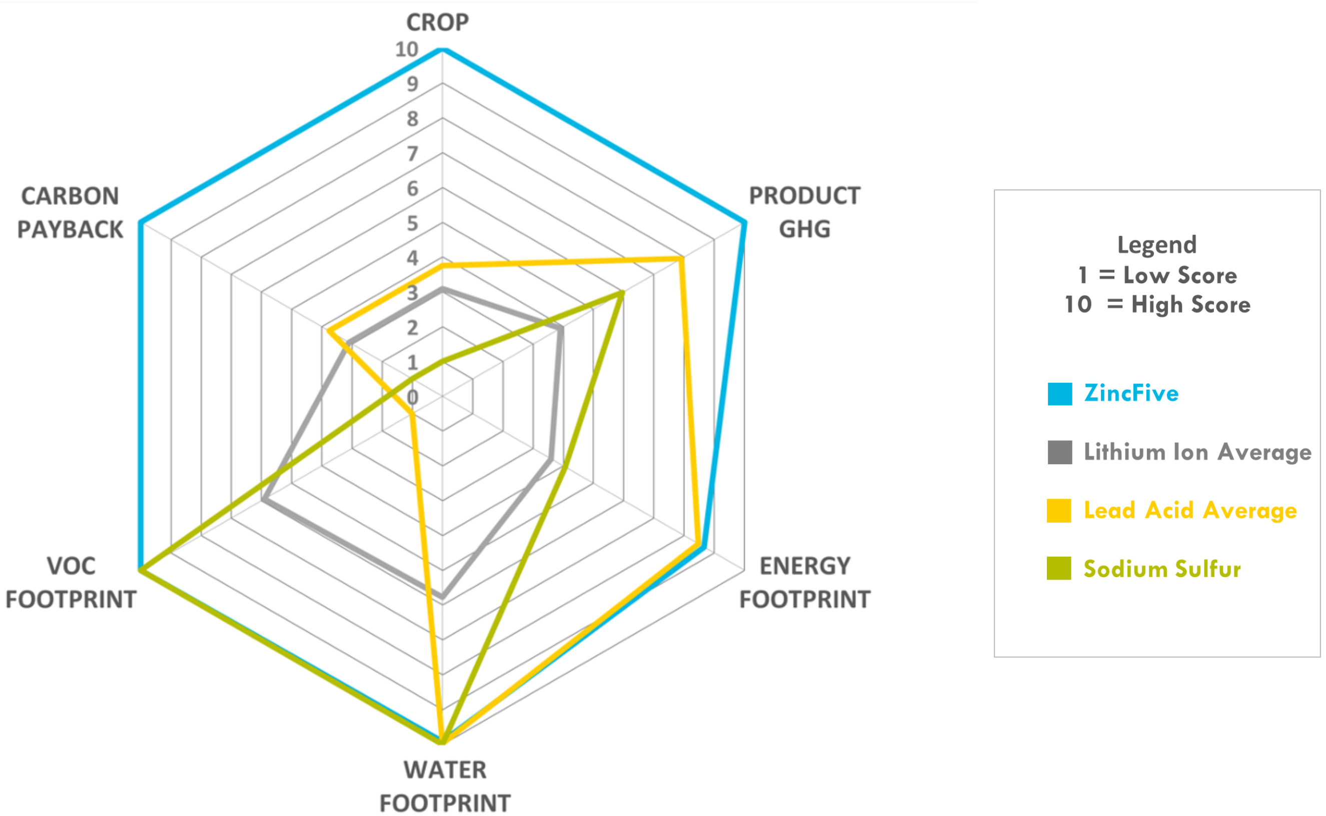
Climate Impact Score: 9.4/10

Boundless performed an environmental assessment of ZincFive's nickel-zinc battery, to quantitatively measure environmental outcomes and illustrate the relative benefits of its technology compared to traditional battery chemistries such as lithium-ion, lead-acid and sodium sulfur. Using its customized life cycle assessment (LCA) methodology, Boundless measured the impact and retained an independent battery industry expert to review the findings.

The assessment identified and analyzed the Carbon Return on Purchase (CROP), GHG Footprint, Energy Footprint, Water Footprint, Volatile Organic Compounds (VOC) Footprint, Carbon Payback Time (CPT) and the Levelized Cost of Storage (LCOS) of ZincFive's battery. The life-cycle inputs and impacts were evaluated considering raw material production, procurement and battery cell fabrication. Results were normalized relative to one kWh of stored energy and compared against lead-acid variants including pure lead (PbA Pure Lead), absorbent glass mat (PbA AGM), and acid–gel (PbA Gel), and lithium-ion variants including nickel-manganese-cobalt (Li-Ion NMC), nickel-cobalt-aluminum (Li-Ion NCA), and iron-phosphate (Li-Ion LFP), as well as sodium sulfur (NaS).

Using a formulaic comparison to measure relative performance across all metrics, ZincFive's technology scored a 9.4 out of 10 impact score on its overall performance. This Boundless Climate Impact Score is based on per kWh impact for above mentioned performance indicators and shows that ZincFive has significant environmental advantages over its competitors. The Climate Impact Score includes an analysis of the Levelized Cost of Storage of ZincFive's nickel-zinc battery. however this metric is excluded from this report for confidentiality reasons. Details to the score rationale can be found in appendix F.

Boundless assessed the Carbon Return on Purchase (CROP) metric using technology specific assumptions for energy storage and standardized depth of discharge rates to compare alternatives on an energy basis. The CROP metric measures the greenhouse gases avoided by ZincFive's customers per kWh of customer energy storage. Analysis showed that ZincFive's customers can realize significant GHG savings by investing in ZincFive's nickel-zinc battery, compared to lithium-ion, lead-acid and sodium sulfur batteries. Customers purchasing ZincFive's battery can save up to six times more GHG emissions compared to lithium-ion NMC and NCA batteries, and even higher compared to lithium-ion LFP batteries due to their relatively high GHG footprint. Analysis showed that up to four times more GHG emissions can be saved compared to lead-acid AGM and gel batteries. Per one-million dollar ZincFive batteries purchased, 148,255 tonnes of CO_2e savings can be realized by enabling renewable energy to enter the grid. The results of the complete analysis have been summarized in the spider-chart on the next page.



The ZincFive battery GHG Footprint was estimated to be 59 kgCO2e per kWh of stored energy, which is significantly lower than the GHG Footprint of lithium-ion (Li-Ion), lead-acid (PbA), and sodium sulfur (NaS) batteries. 38% of the GHG Footprint for the ZincFive battery is derived from the two main materials that compose the battery, zinc oxide (13%) and nickel(II) hydroxide (15%). ZincFive batteries only use safe and abundant materials that mitigate battery hazards, health risks and scarcity concerns. ZincFive's battery uses only a small amount of cobalt compared to lithium-ion batteries, so the sustainability concerns around this material are minimized. Both zinc and nickel are relatively abundant materials, four-times and five-times more abundant than lithium in the earth's crust, respectively.

In addition to the CROP and the GHG Footprint of ZincFive's battery, Boundless also analyzed the Carbon Payback Time (CPT), which measures the time it takes for a battery to offset its GHG Footprint by supporting more renewable resources to supply the electricity grid. The CPT was estimated to be between 0.16 and 0.21 years, four times faster than lithium-ion and lead-acid batteries and up to six times faster than sodium sulfur batteries. All other batteries reported a potential CPT exceeding one year.

The Energy, Water and VOC Footprint of ZincFive's battery were also analyzed. Volatile Organic Compounds (VOCs) are emitted as gases from solids and are known for creating short- and long-term adverse health effects. Unlike lithium-ion and lead-acid batteries, the ZincFive battery does not use VOCs in production. The Water Footprint of the ZincFive battery, including water requirements for raw material extraction, was estimated to be 96% lower than the average Water Footprint of lithium-ion batteries. For comparison, the Water Footprint of lead-acid batteries is 99% lower than the average lithium-ion battery, and roughly three times lower than ZincFive's battery. Lastly, the Energy Footprint of ZincFive's battery was estimated to be between 20 and 35 percent less than lithium-ion batteries, sodium sulfur batteries and lead-acid pure lead batteries. It was found to be slightly higher than lead-acid AGM and lead-acid gel batteries, mainly because these batteries are highly recyclable, and a strong recycling infrastructure is in place.

Boundless engaged Dr. Kent. J. Griffith, a battery chemistry expert and postdoctoral researcher at Northwestern University, to review the ZincFive assessment and validate the assumptions made in calculating the environmental metrics. Dr. Griffith concluded that the inputs to the study are detailed and correct, and that the ZincFive battery was compared to a diverse range of relevant energy storage technologies. A summary of Dr. Griffith's review is included in Appendix D.

Environmental Highlights

Summarized below are most relevant impact categories and codes that refer to the United Nation's Sustainable Development Goals (SDGs). The associated metrics highlight the most important factors that explain how this technology is impacting the environment.

Material Use

ZincFive batteries use safe and abundant materials that mitigate battery hazards, health risks and scarcity concerns. Nickel and zinc are four and five times more abundant in the earth's crust, respectively, than lithium and lead (1). They are also non-toxic substances that can be handled safely by production workers and customers alike. Whereas the ZincFive battery is nonflammable, lithium's reactivity with air and water creates an inherent fire hazard. The ZincFive battery composition requires minimal cobalt usage, mitigating human rights concerns with the procurement of cobalt in the Democratic Republic of Congo. It also completely avoids the global health concerns of lead exposure. ZincFive battery manufacturing also requires no solvents, unlike lithium-ion and lead-acid battery manufacturing. Relevant code: SDG 12.

Greenhouse Gas Emissions

The production of the ZincFive battery has lower GHG emissions per kWh of stored energy, compared to lithium-ion, lead-acid and sodium sulfur storage technologies. The GHG emissions of the production of ZincFive cells are 58.8 kgCO2e per kWh, or 5.3 kgCO2e per cell kilogram. On average, with ZincFive storage technology ~112 kg of CO2e can be saved per kWh of energy storage capacity compared to lithium-ion batteries, ~36 kg of CO2e per kWh compared to lead-acid batteries, and ~70 kg of CO2e per kWh compared to sodium sulfur batteries (please refer to Appendix A). GHG savings per kWh compared to lithium-ion batteries are equivalent to 278 miles driven by an average passenger car, and 89 miles when compared to lead-acid batteries. Savings are primarily driven by the materials that make up the batteries. Note that this analysis uses the 100-year GWP (Global Warming Potential). Using an alternative 20-year GWP assumption shows 23.5% higher emissions (72.7 kgCO2e per kWh). Relevant Code: SDG 13.

Clean Energy

Advanced energy storage is increasingly needed to transition the electricity grid, transportation, building and industrial sectors toward renewable energy resources. To accommodate intermittent supply, renewable electricity integration requires utility-scale storage, as well as demand-side energy storage to better manage loads. Data centers are a prime example of large electricity consumers that can deploy energy storage backup for operations and grid reliability to aid renewable power integration through the addition of advanced storage technologies like ZincFive's. A sustainable transportation sector also requires dramatic increases in battery use. As market share for electric vehicles increases, not only do tailpipe emissions decline, but grid-connected vehicles may further aid operational flexibility and renewable energy utilization. ZincFive's technology can help automakers meet growing EV charging demand with more environmentally benign materials. Relevant code: SDG 7.

Resiliency

ZincFive's systems are designed to provide reliable power to businesses and residences. The low maintenance, small footprint, and ability to operate at high temperatures enables ZincFive's batteries to be used in environments where the market increasingly demands green, sustainable power. Relevant Code: SDG 9.

(1) https://periodictable.com/Properties/A/CrustAbundance.v.html

APPENDIX A: Methodology

Key Goals

Key goals of this analysis were to:

1. Examine environmental performance in conjunction with financial data to arrive at environmental and hybrid environmental-financial metrics for ZincFive's storage technology versus existing technologies.

2. Provide equitable comparisons among relevant alternative technologies.

3. Incorporate a variety of methodological considerations that are relevant to the energy storage industry and which were expected to bear upon the results.

To ensure that these key goals were reached, an independent industry expert reviewed the study and assumptions to ensure that the methodology was coherent with industry standards. The expert review and commentary notes are provided in Appendix D.

Methodology

To address the first goal, Boundless researched the material, energy, and performance characteristics for ZincFive's energy storage technology, based on detailed information provided by ZincFive, describing the material components and energy inputs. At the core of the methodology is a life-cycle assessment (LCA) model for a kWh of stored energy on the ZincFive battery. The functional unit (FU) of this LCA was a kWh of stored energy, such that embodied energy and emissions are estimated for the battery production. We used SimaPro v9.0.0.41 and employed the IPCC 2013 methodology when calculating life-cycle impacts of material and energy systems not described elsewhere in the literature. The complete set of detailed calculations, impact assessment factors, assumptions, and references are available as Supporting Information (SI) upon request.

Each metric compares ZincFive's technology against alternative technologies. Metric construction for industry alternatives relies on comparisons, for which we relied on scientific literature, industry reports, white papers, as well as assumptions provided by the industry expert. The impact metrics are reported graphically using bar charts to illustrate a baseline result value, along with sensitivity bars reflecting a range of possible result values around deployment scenarios and key variables.

Research Approach

- Followed a life-cycle analysis approach and leveraged professional LCA software/data and scientific literature.
- Investigated non-GHG metrics, including water footprint and minerals use.
- Accounted for emissions offsets occurring from hypothetical marginal electricity system impact assuming energy storage facilitated renewable generation on a 1:1 basis.
- Identified sources of uncertainty and quantified their impact on results.
- Included important financial and operational variables to estimate the cost of production.

APPENDIX B: List of Metrics

EKPI	Unit of Measure	Description
Energy Intensity	MJ / kWh	A measure of the energy input per kWh of stored energy.
GHG Intensity	kgCO2e / kWh	A measure of the greenhouse gas impact per kWh of stored energy.
Water Footprint	Gallons / kWh	A measure of the water use per kWh of stored energy.
Solvent / VOC footprint	mg / kWh	A measure of the VOC avoided by using water-based manufacturing, measured per kWh of stored energy.
Carbon Payback Time	Years	A Measure of the time that it takes for a product's use to offset the GHG of its production.
Carbon Return on Purchase	kgCO2e / kWh Installed	Measures the greenhouse gases avoided by customers per kWh of customer energy storage.

APPENDIX D: Independent Expert Review

Independent Industry Expert

Kent J. Griffith holds a PhD in battery materials from the University of Cambridge, United Kingdom. He has ten years of experience in electrochemical and battery research and development. Kent is also the founder and CTO of a start-up company commercializing efficient, fast charging and high-power lithium-ion batteries based on new, patent-protected electrode materials. His experience in technical subfields includes cathode and anode chemistry, solid electrolytes for all solid-state batteries, nickel-rich NMC degradation and protection, fast charging battery applications, high power chemistries and electrode formulation, characterization and specification of batteries for individual applications (e.g. energy density, safety, power, variable temperature operation), mineralogy, materials synthesis and recycling.

Summary of Expert Review

Boundless Impact Investing analyzed the environmental impacts of the ZincFive nickel–zinc battery technology. The comprehensive life cycle analysis explicitly considered factors including air, water, carbon, levelized cost, and energy. The outputs of the report – e.g. environmental footprints and carbon payback time – are the result of evaluating individual cell components with data-supported environmental impact measures. The inputs are detailed and thus the assumptions are minimal. A diverse range of relevant energy storage technologies are included for comparison, including sub-categories of the major competing technologies: lithium-ion and lead-acid.

New battery technologies are emerging on the market now and in the next five years, and the trend is toward environmentally-friendly products. The strong trend toward high energy-density batteries is dependent on nickel-rich cathode chemistries, which have the simultaneous benefit of eliminating toxic cobalt. This report accounts for the trend toward nickel-rich LIBs as well as the variability in the nickel content of cells on the market. Water-based processing of cathodes is targeted but challenging, particularly for nickel-rich materials. For non-NMC/NCA chemistries, LFP is making movement for EVs in China, and lithium–sulfur will be coming online ca. 2023 from a large plant in Brazil. Silicon is partially-replacing graphite for lithium-ion anodes but the cost, energy, and environmental impacts are minimal at the present levels. Several other technologies one hears about, such as solid-state batteries and lithium metal batteries, are not mature and thus appropriately left out of this report. Cost may be driving the move away from cobalt and organic solvent processing/waste, but the environmental advantages will be there too. The analysis here focuses on the present state-of-the-art technologies with realistic considerations of materials, cost, and energy density.

The cost of energy storage depends strongly on the application. ZincFive batteries are suited for large-scale applications requiring a high degree of safety and reliability with a long shelf-life. Their energy density is intermediate between lead-acid and lithium-ion energy cells. However, the ZincFive stated power density is higher than conventional lithium-ion batteries, even when the latter are optimized in power cells. Thus the ZincFive technology may be well-suited for certain high-power applications. The Boundless report accounts for the variation in application of lithium-ion batteries with a range of energy densities that covers energy and power cells. For completeness, the metrics are evaluated on both a mass and energy density basis.

Battery collection and recycling practices are mature for lead-acid batteries but at a juvenile stage for lithium-ion batteries. The variation in lithium-ion battery chemistry, the minor contribution of each of many components, and the low resale value of most materials hinder lithium-ion battery recycling. The recyclability of the nickel–zinc battery is likely to be considerably better than lithium-ion because the electrodes are simpler composites than lithium-ion, and closer in a recyclability-sense to lead-acid, which has an excellent recycling record.

APPENDIX E: Global Warming Potentials

How Global Warming Potential Scenarios highlight the importance of investing in Emission Reduction Technologies

The methane impact from emissions depends on which Global Warming Potential (GWP) is used. GWP is a metric measuring how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide. The larger methane molecule provides a warming potential that is 28-36X that of CO_2 in a 100-year timeframe. (That is, over 100 years, methane traps 28 times more heat per mass unit than carbon dioxide). The lifespan of methane in the atmosphere was estimated at 9.6 years, and CO_2 is much longer (estimated from 20-200 years). In the shorter 20-year timeframe, methane's impact would, therefore, be 84-87X that of CO_2, and the GHG savings for all landfill technologies would be greater. Investment in methane reduction using this shorter timeframe increases the return for investment by a factor of 2.2-3X. The 20-year timeframe is especially important when considering critical climate change mitigation efforts needed over the next two decades.

APPENDIX F: Score Rationale

Climate Impact Score

The climate impact value is a number (1=worse to 10=best). This number represents an overall indicator of a company's climate impact performance against its most relevant industry competitors. The value is obtained by comparing the average of each resulting EKPIs for the company against its competitors. The score for each metric can be read from the summary Spider Chart of the profile for each product. The EKPIs are developed and displayed in the detailed graphs for both the target company and the competing companies.

ZincFive has a generally advantageous, performance when compared to its competitors. For example, ZincFive's technology has a lower GHG Footprint than its competitors, but a higher Energy Footprint than its lead-acid competitors. Using a formulaic comparison to measure relative performance across all EKPIs, ZincFive's technology scored a 9.4 out of 10 on its climate performance.

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About Boundless Impact Investing

Driven by the latest research by independent industry and academic experts, Boundless Impact Investing offers analysis, market trends, and evidence of best practices in a growing number of emerging sectors that address major social and environmental challenges. We are an advanced consulting firm that enables investors to connect with industry leaders and peers for expert analysis, diverse perspectives, and real-time collaboration. Our investor education and expert advisory services offer proprietary access to both subject-matter experts and other impact investors.

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