April 6, 2025
Director General Christina Paradiso,
National Resources Canada, Energy Policy Branch
580 Booth Street
Ottawa, ON, K1A 0E4

Subject: Feasibility Report on the Future of Lithium-ion Batteries.

Director General Paradiso:

We are writing to formally transmit to you a brief report on the feasibility of the use of lithium-ion batteries as the metal of choice for clean energy projects. We understand that Canada is amidst a delicate transition towards zero-emissions electric vehicles and propose that sodium-ion batteries may, in fact, be a suitable alternative for the long-term future of energy storage.

This document aims to compare the strengths and weaknesses of the two battery chemistries across the following: resource extraction & material quantity concerns, environmental and safety concerns, modern manufacturing constraints, and performance concerns for long-term projects at scale.

We hope that this report will provide valuable insights and assist in upcoming policy decisions regarding a sustainable battery supply chain for the electric vehicle. If you have questions regarding anything at all in the attached material, please do not hesitate to contact us.

Thank you for your attention to this important matter,

Sincerely,

Cael Coulson
Gordon McGinn, B. Sc

Encl. Feasibility of Lithium-Ion vs. Sodium-Ion Battery Cells in EVs: Manufacturing & Sustainability

Feasibility of Lithium-Ion vs. Sodium-Ion Battery Cells in EVs:

Manufacturing & Sustainability

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Table of Contents

Executive Summary

As the world moves towards cleaner forms of transportation, the fundamental material of the battery electric vehicle, lithium, is being challenged. While lithium-ion batteries have been historically attractive to manufacturers for their high energy density, their unsustainable mining practices, increasingly scarce resources, and underdeveloped recycling processes have become difficult to ignore.

This paper examines the feasibility of sodium-ion batteries as a primary alternative. In comparison, sodium is much more abundant and easier to find than lithium, is easier to recycle due to its unique composition, and is cheaper to manufacture on a cell-to-cell basis. Sodium batteries also largely able to be built in existing lithium battery infrastructure thanks to similarities in their chemical structures.

However, sodium ion batteries are not ready for the spotlight just yet. Their energy density and charging efficiency fall short of the lithium standard. Still, with the battery sector rapidly advancing, these performance gaps may close within the next two decades.

Lithium-ion batteries will dominate the market for the next decade, but sodium is projected to soon surpass the giant and establish itself as the sustainable solution to the affordable and environmentally friendly future of green transportation.

Feasibility of Lithium-Ion vs. Sodium-Ion Battery Cells in EVs: Manufacturing & Sustainability

As the world moves toward cleaner energy, battery technology has become a major focus for making electric vehicles (EVs) more sustainable. Lithium-ion batteries (LIBs), while currently the dominant metals for EV battery cells due to their favorable energy storage properties (Nekahi *et al.,* 2024, p. 4), are neither a sustainable nor abundant resource (Ankathi *et al.*, 2024, p. 14). As supply struggles to keep up with demand (Nekahi *et al.,* 2024, p. 11), and while political pressures push a zero-emissions market (Axsen & Bhardwaj, 2022, p. 28; Transport Canada, 2021), the automotive industry is desperate for a more sustainable way forwards.

The concerns about the lithium-ion battery's (LIBs) long-term dominance are well justified. The power sources of major refineries and the scarcity of raw materials, mixed with overmining, and undeveloped recycling technologies (Vega-Muratalla *et al.* 2024, p. 9; Nekahi *et al.,* 2024, p. 11) work against the goal of a sustainable market all while driving costs up for manufacturers and consumers alike.

Meanwhile sodium-ion batteries (SIBs) present a promising, more sustainable alternative by leveraging the abundance and accessibility of their key metals (Nekahi *et al.,* 2024, p. 4); energy-cost advantages during processing (Zhao *et al.,* 2021, p. 176); and increased recyclability factor (Ankathi *et al.,* 2024, p. 11) to name but a handful of their many benefits.

This paper explores the feasibility of transitioning from lithium to sodium-ion batteries in EVs, questioning if current manufacturing practices can adopt SIB production at scale, and if a new battery cell composition is adopted, how sustainable is it as a long-term solution? While consumer demand for lithium-based energy storage is at its greatest, so is the need for a more sustainable alternative – is sodium the answer?

Discussion of Findings

The Lithium-Ion Battery Supply Chain

Consider for a moment global effort of the lithium-ion battery (LIB) supply chain. Composed of nickel, cobalt, manganese, graphite, and lithium, its materials suffer geographical constraints (Overland *et al.,* 2024, p. 7). Natural Resources Canada's 2023 (a, b) statistics for cobalt and lithium production – the two most critical materials for renewable energy (Overland *et al.*, 2024, p. 29). The Democratic republic of Congo mined 78% of the global supply of cobalt, (170,000 tonnes), while Australia (51.0%), Chile (25.9%), and China (15.4%) were leaders in lithium supply (146, 450 tonnes global total respectively). These raw materials are sent to refineries in Europe or China, with the latter producing 75% of the world's lithium-ion batteries, compared to Europe's 10% (Orozco *et al.,* 2023). China still derives power from coal-dependent sources, ironically exacerbating the emissions problem EVs seek to solve. According to Orozco *et al.,* "The mining and refining of materials, cell manufacturing, and battery assembly processes together account for 10–30% of the total life cycle emissions of a BEV" (2023). Considering that China's emissions for battery manufacturing may be three times higher than the same batteries if made in the United States (US) (Ankathi *et al.,* 2024, p. 11), a global dependency on raw materials may in fact be a weak point for the LIB.

Peiseler *et al's* 2024 article further investigates the carbon emissions profile of LIBs. They conclude that the cathode and anode materials used in LIBs, specifically the common lithium-iron-phosphate (LFP) chemistries, are responsible for 56.1% and 19.1% respectively of the battery cell's overall carbon footprint. The cathode material plays the most important role in determining the cost and overall energy performance of the battery (Zhao *et al.,* 2021, p. 177). As BEV production is expected to trend upwards over the next few decades (Ankathi *et al*., 2024, p. 2), lithium being a costly material from both a raw material and manufacturing emissions perspective has motivated large scale manufacturers to look to alternative chemistries for their battery needs.

The Case for Sodium-Ion Batteries

Sodium-ion batteries (SIBs) offer a promising alternative to lithium-cathode batteries, leveraging sodium's similar electrochemical properties while addressing supply chain limitations. Sodium, consisting 2.3% of the Earth's crust by weight (Nekahi *et al*., 2024, p. 9), can be sourced through mineral deposits such as halite and soda ash, or extracted from seawater, making it significantly more accessible as a raw material (Nekahi *et al*. 2024, p. 9). The composition of SIBs is much less dependent on the scarce, and geographically constrained rare earth metals used in LIBs (namely cobalt, manganese and lithium), and is projected to offer a predicted cost reduction of ~30% (Nekahi et al, 2024, p. 11). The SIB thus offers developing countries the opportunity to contribute to affordable energy research while also improving on the sustainability of the battery cell supply chain.

It is worthwhile to mention the commonly assumed consequence of the SIB alternative. Historically, it has been assumed that due to the larger size of the sodium-ion, its electrons—responsible for carrying an electric charge—do not flow as freely as those of the lithium-ion. However, others like Zhao *et al*, believe that this is a misconception that neglects the cathode-anode interaction, and suggest "there is no reason to believe that SIBs will be inferior to LIBs with respect to energy density" (Zhao *et al*., 2024, p. 177). While no SIB exists to date that can outcompete the energy storage capacity of a lithium-ion battery cell, as research and innovation continues to grow this field, it is projected that sodium-based energy storage will be very attractive to the BEV manufacturer by as soon as 2030 (Nekahi *et al.,* 2024, p. 3).

Manufacturing Feasibility and Trade-offs

Existing infrastructure for manufacturing of LIBs, "can be directly employed with minor modifications to make SIBs," (Zhao *et al.,* 2021, p. 176). However there is obvious bias towards lithium manufacturing despite its manufacturing inefficiencies: LIB cathodes undergo calcination for several hours at temperatures above those of SIBs (Gutsch & Leker, 2024, p. 2), increasing their energy costs, and since the dissolution of the LIB's copper current collector at low voltages poses safety risks, costly transport regulations require a standard state of ~30% charge be maintained (Zhao *et al*., 2021, p. 177). In contrast, SIBs may substitute copper current collectors with aluminum, lessening both weight and cost, with the added benefit of zero-voltage storage and transportation – a key safety, energy, and cost advantage (Zhao *et al*., 2021, p. 177). SIBs remain limited, however, as they experience greater initial charge losses during cell formation, take longer to fully charge, and have a shorter cycle life on average than their LIB rival (Nekahi *et al.,* 2024, p. 10).

Comparing battery pack assembly emissions between battery types, SIBs perform poorly as they require more cells per pack to compensate for their – currently – weaker electrochemistry (Nekahi *et al.,* 2024, p.12). It is important to note that most research into SIB applications has been theoretical and does not fully represent their entire lifecycle within a battery electric vehicle (BEV) setting, as this remains a recent development. As a result, SIBs are unlikely to replace LIBs in BEVs beyond short-range applications until their advantages are better established, allowing for a transition away from LIBs without significant drawbacks.

Environmental Impact

Resource extraction acts on behalf of a single driver: demand. Environmentally harmful lithium mining operations often releases harmful arsenic, boron, and magnesium, each of which severely impacts the quality of life of local communities and ecosystems (Vega-Muratalla *et al.,* p.8). Developing recycling techniques for batteries means providing a secondary supply stream to satiate demand, which is "essential to reduce the environmental impact and mitigate uncertainty about lithium availability" (Vega-Muratalla *et al.,* p.8). Between 2010 and 2100, the lithium battery recycling sector could supply 50-63% of global demand, significantly easing the reliance on material extraction processes – though it will nonetheless remain necessary (Vega-Muratalla *et al.*, p.8).

Regardless of the EV battery's primary minerals, the environmental impact of the BEV industry is projected to decline through 2050, partly because related industries such as energy and steel are also working to reduce their environmental impact (Zhang *et al.*, p.1). Despite these projections, a sustainable alternative to the current technologies is still required. According to Zhang *et al.* (p.4), SIBs currently only outperform one type of LIB when considering the common metal variations across both supply chains – excluding their end-of-life phase – suggesting that an immediate transition to SIBs would resolve the environmental concerns the industry faces.

However, the environmental impact of SIBs is projected to decrease by 43-57% over the next 40 years (Zhang *et al.,* p.1). With more global interest in further investing and researching sodium technologies, coupled with improving environmental policies across tangent industries, a cleaner and more sustainable path exists as electric vehicle demand grows. In the meantime, LIBs and SIBs must coexist as the industry continues shifting into the coming decade.

Conclusion

Despite the challenges of transitioning from lithium-ion to sodium-ion batteries, the potential benefits of SIBs – greater abundance of raw materials, compatibility with existing production methods, and improved safety and recyclability – make them an appealing alternative as the power system of the future's BEV. While their lower energy density and manufacturing inefficiencies suggest LIBs will continue to dominate for some years, rising interest in the sustainability of the sector is rapidly propelling alternative energy technologies forwards. The physical constraints and limitations on technological innovation will ultimately be what guides the BEV to a more sustainable future.

Recommendations

To ensure the gap between sodium and lithium battery performance closes with ample time for market adoption before the Canadian market's zero emissions deadlines, all nations should increase funding to their local SIB research programs, diversifying the research field.

Furthermore, Canada should re-evaluate the carbon emissions within tangential industries by the same deadline, as their effects ripple downstream. It would be counterproductive to better the carbon footprint of battery cell production if the cost to the overall market was worse off.

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