Supply Chains for Vehicle Power Packs: Li-Ion Batteries and Hydrogen Fuel Cells

Challenges & Opportunities

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Supply Chains for Vehicle Power Packs: Li-Ion Batteries and Hydrogen Fuel Cells is part of a series of discussion papers produced by Foresion that aim to holistically explore contemporary supply chain issues and future directions, focusing on logistics, emerging technologies, and environmental sustainability. These papers are aimed at business practitioners, policymakers and governments as a vehicle for improving integration and visibility along key supply chains.

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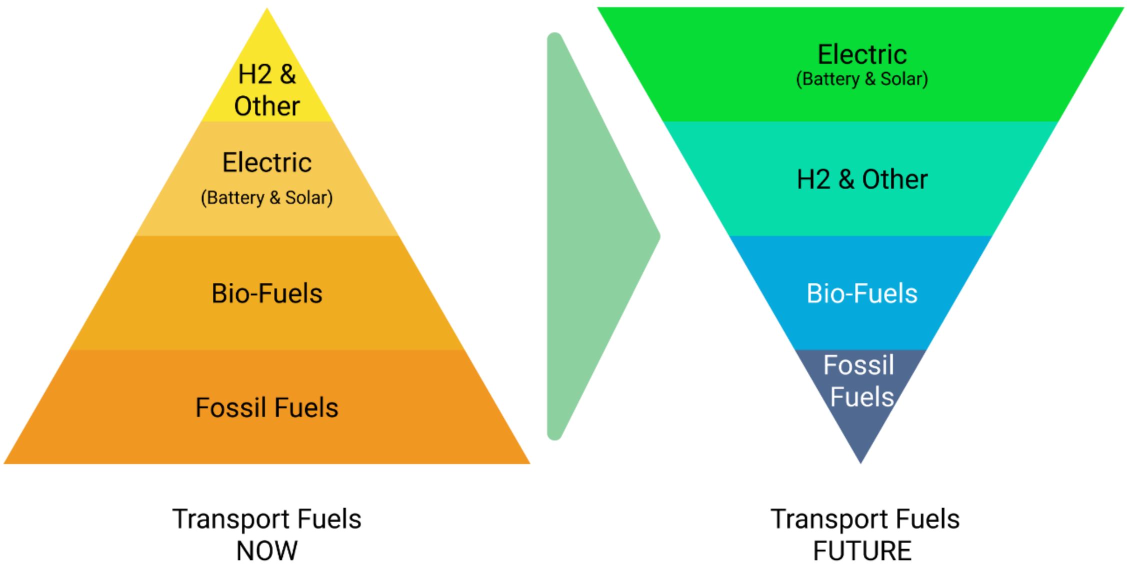


Figure 1 Transport Fuels Now and Into the Future (Foresion, 2021)

Context

The environmental impact of human activity is evident in almost every aspect of our lives as are the implications for future sustainability and prosperity. Transport emissions totalled 8 billion tonnes of CO2 in 2018 [1] and represent close to a quarter of global energy-related emissions. Tackling transport emissions is one of the pathways to addressing man-made environmental impacts.

Contemporary debates around what actions to take to address production, power and sustainability in Western societies is increasingly focused on responses to climate change through electrification of transport and increasing use of renewables. This future vision entails diminishing the role of fossil fuels in favour of batteries, hydrogen, and other renewable fuel sources.

While these actions are certainly a step forward towards a more sustainable future, most initiatives lack integrated perspectives on the supply chains that will enable these visions to be realised. In looking at these supply issues, this paper aims to highlight the **problems** and to suggest potential **solutions** that could ensure sustainability goals are achieved without sacrificing global supply chains' integrity and risking dramatic reductions in citizens' physical and social mobility.

In this context, this paper examines existing supply chains for battery electric vehicles (BEV) and hydrogen fuel cell electric vehicles (FCEV) that have emerged as strong contenders to traditional internal combustion engine vehicles (ICE).

Executive Summary

The push towards transport decarbonisation has led to the emergence of Li-Ion battery (BEV) and hydrogen fuel cell (FCEV) powered vehicles as key contenders to traditional fossil fuel vehicles. With an increasing number of countries proposing bans or restrictions to fossil fuel vehicles within the next 10-20 years. In this context it is critical to understand the key challenges and opportunities in the battery and hydrogen fuel cell manufacturing supply chains for road vehicles.

These supply chain challenges in vehicle Li-Ion batteries and hydrogen fuel cells are:

1. **The limited reserves of Cobalt** cannot support the replacement of more than half of the world vehicle fleet
2. **The extraction capacity** for Lithium, Cobalt – for Li-Ion batteries – and Platinum – for hydrogen fuel cells – **is close to 10 times less** than what would be required to supply power pack manufacturing to replace old vehicles.
3. **The Li-Ion battery and hydrogen fuel cells manufacturing capacity** may be insufficient to cater for demand in countries where the sale of fossil fuel vehicle sales will be banned.

It is critical to consider and address the raw material supply, extraction capacity and energy pack manufacturing capacity challenges. Failure to do so risks poorer mobility outcomes and, more importantly, worsening environmental outcomes. If bottlenecks in the battery or fuel cell supply chains limit the number of vehicles sold to less than the sales required to replace the stock of old vehicles, older, more polluting cars may well be left on the roads for longer. Limiting new car sales may also mean a reduction in the population's mobility. Indeed, many of the world's urban centres suffer from congestion, lack of parking or sufficient road infrastructure. However, reducing mobility without providing alternative means of transport, both for personal vehicles and commercial goods delivery, may result in significant negative socio-economic impacts.

It seems unlikely that either Li-Ion batteries or hydrogen fuel cells alone will become the uncontested replacement for fossil fuels powered road vehicles. It is more likely that the three energy sources will co-exist and evolve in parallel, each energy source building on its strengths for a particular application. This probable future, raises some interesting policy and business innovation opportunities around:

1. **Power pack modularisation,** especially for Li-Ion batteries. This approach can reduce waste by only replacing faulty components rather than an entire power pack.
2. **Power pack interoperability** among vehicles. This approach could increase the potential for reusing power packs without the need for remanufacturing.
3. **Exchangeable power packs.** Exchanging discharged power packs with charged ones would circumvent charging time limitations, especially for Li-Ion batteries, and could significantly reduce the infrastructure requirements and expenditure required to transition away from fossil fuels.
4. **Converting fossil fuel vehicles** to batteries or hydrogen fuel cells to avoid expending resources and avoid a significant waste management problem would circumvent the need to dispose of all fossil fuel vehicles.

The supply chains for BEV and FCEV power packs are still maturing. Policymakers and governments have the opportunity to direct and coordinate industry to achieve the most sustainable outcomes and ensure supply chain integrity and social mobility. There is also ample opportunity for business-led innovation to use resources more efficiently.

Introduction

The push towards transport decarbonisation has led to the emergence of Li-Ion battery (BEV) and hydrogen fuel cell (FCEV) powered vehicles as key contenders to traditional fossil fuel vehicles. With an increasing number of countries proposing bans or restrictions to fossil fuel vehicles, it is critical to understand the key challenges and opportunities in the battery and hydrogen fuel cell manufacturing supply chains for road vehicles.

Given that batteries and hydrogen fuel cells are the most likely candidates to replace the existing vehicle fleet it is important to answer these three questions:

- Are there enough raw materials reserves to replace the existing vehicle stock?
- What raw material extraction and production rates are required to, at least, support the replacement of old vehicles?
- What battery or hydrogen fuel cell manufacturing capacity are required to meet expected demand for new vehicles in the countries where the sale of fossil fuel vehicles is restricted?

Approach & Structure

This report adopts a worldwide perspective towards battery and hydrogen fuel cell manufacturing supply chains. First, global vehicle sales, replacement and stock figures are analysed to better understand the potential demand for batteries and fuel cells. Considering the demand figures, challenges and opportunities in battery and hydrogen fuel cell manufacturing supply chains are explored in three key areas: raw material reserves, raw material extraction and production and power pack manufacturing capacity. This report takes a projections-based approach to uncover opportunities and challenges. This means that extraction, production, and consumption trends are extrapolated into the future to identify potential '*deal-breakers*' but also to identify potential opportunities that can lead to more efficient and sustainable supply chains.

Photo Credit: Brainstudy

Global Vehicle Stock & Yearly Sales

The global motor vehicle stock is estimated at 1.3 billion vehicles[2] of which 75% cars, and 25% commercial vehicles. In 2020, more than 77 million vehicles were sold[3], including just over 56 million cars[4]. The 2020 sales figures are significantly smaller when compared to previous years. Between 2016 and 2019, more than 90 million vehicles were sold each year[3], including more than 65 million cars[4]. However, only some of the new vehicles sold add to the global vehicle stock, while others replace older vehicles. In previous years (2011-to 2015) about two thirds of the yearly car sales added to the world vehicle fleet, while one third of sales replaced older cars. About 30% of yearly commercial vehicle sales added to the commercial vehicle fleet, while 70% of sales replaced older commercial vehicles[3,5]. In 2015, this translated to replacing 21 million cars and 19 million commercial vehicles.

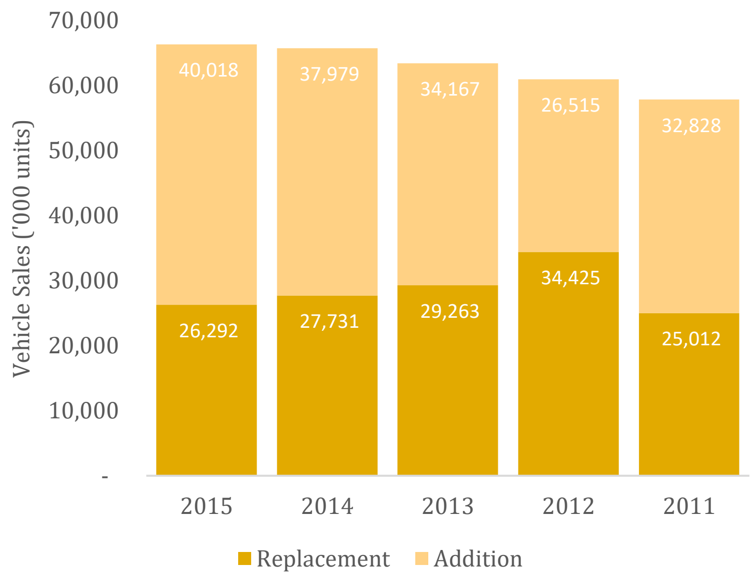


Figure 2 New Light Vehicle Sales by Contribution to World Fleet (2011-2015)

* Elaborated based on Statista, Best Selling Cars figures [3,4,5]

Figure 3 New Commercial Vehicle Sales by Contribution to World Fleet (2011-2015)

Elaborated based on Statista, Best Selling Cars figures [3,4,5]

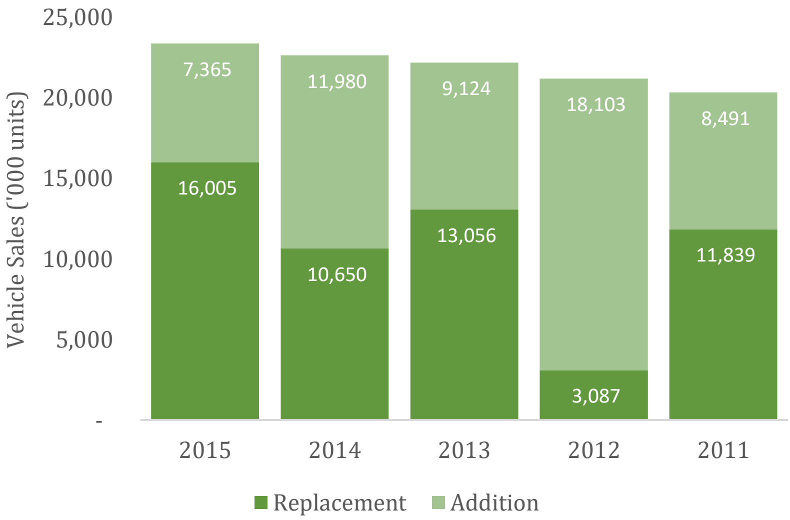



Photo Credit: Border Now

Raw Material Reserves

Lithium & Cobalt Reserves for Li-Ion Batteries

Li-Ion batteries for BEV require several raw materials, with Lithium and Cobalt being the rarest. While Lithium reserves, currently estimated at 86 million tonnes[6], would be enough to manufacture around 5.3 billion vehicles – without considering other material inputs - the same cannot be said for Cobalt. Currently known terrestrial Cobalt reserves are estimated at 25 million tonnes[7]. This would only be sufficient to manufacture around 600 million vehicles if all Cobalt is used for this purpose.

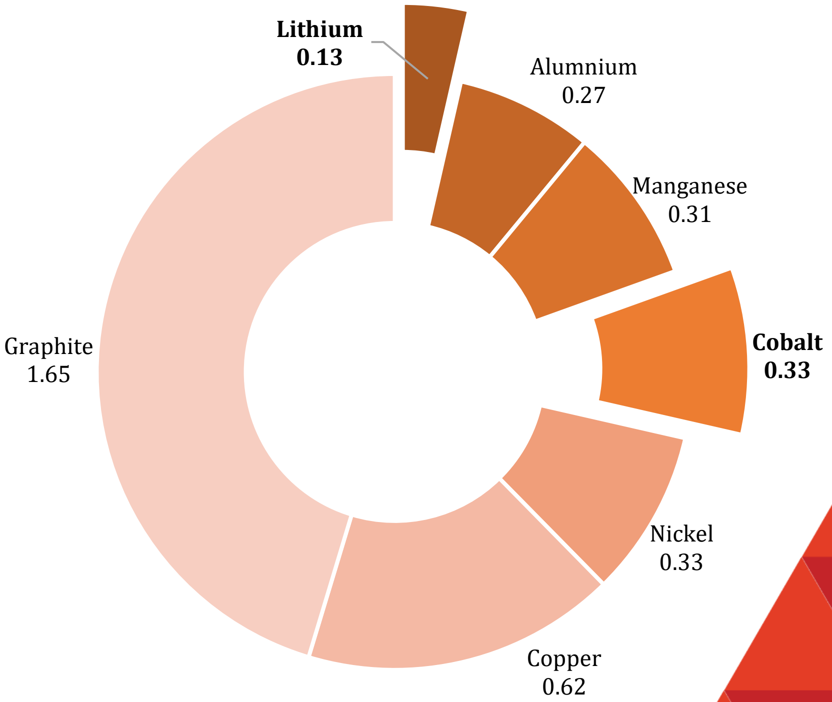
The potential challenges posed by limited Cobalt reserves have been recognised by some researchers who have begun exploring alternative cathode formulations for Cobalt-free power packs[8]. However, Cobalt-free power packs are still in a research stage. Most substitutes for Cobalt result either in decreased power pack performance or increased production costs[7]. Lithium seems unlikely to be replaced in batteries given that it is the third lightest element and has the lowest reduction potential[6].

Platinum Reserves for Hydrogen Fuel Cells

Hydrogen fuel cells for FCEV require small amounts of Platinum (roughly 0.4 grammes/kWh[9]), an extremely rare material. Known Platinum reserves are estimated at 100 million kilograms or 100,000 tonnes. If all Platinum reserves were used to manufacture fuel cells, these would be enough to power just over 2 billion vehicles.

Platinum can be replaced in certain application with moderate amounts of Palladium, another rare raw material.

Figure 4 Key Raw Materials Used for Li-Ion Batteries (Kg/KWH)



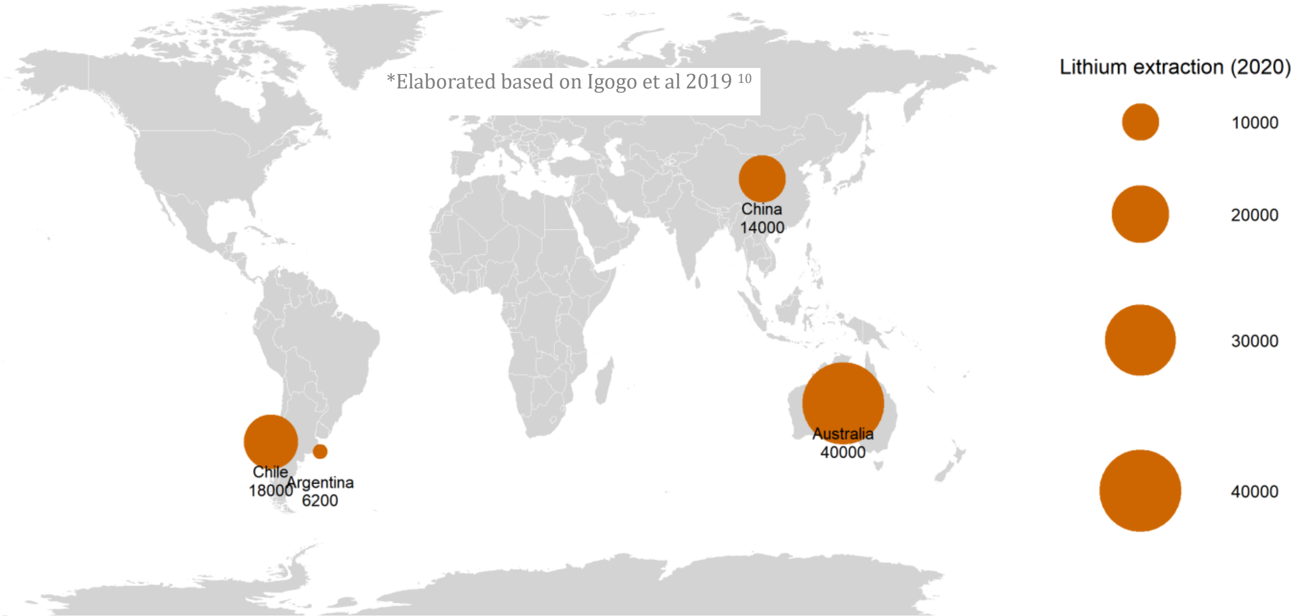


Figure 5 Worldwide Lithium Extraction in 2020 (based on Statista figures [4])

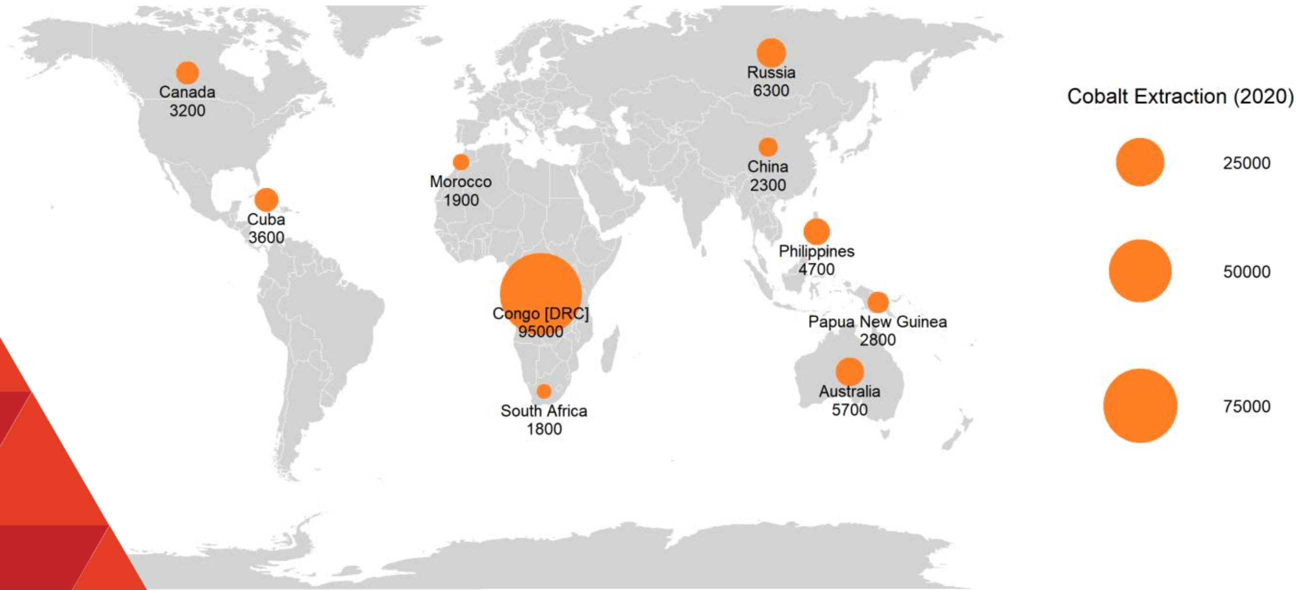
Raw Material Extraction

Lithium & Cobalt Extraction for Li-Ion Batteries

Raw material extraction and production rates can also impact the battery or fuel cell production capacities. In 2020, 82,000 tonnes of Lithium[6] and 140,000 tonnes of Cobalt were produced[7]. These extraction rates support a yearly production of 3.5 million Li-Ion batteries for BEV.

To provide enough raw materials for replacing (about 40 million) older vehicles, would require an annual production of 880,000 tonnes of Lithium and 2.2 million tonnes of Cobalt. Increasing Cobalt extraction is a complex endeavour, given that most Cobalt is mined in the Democratic Republic of Congo (DRC), often as a by-product of Copper or Nickel mining and is rarely extracted in dedicated mines [10].

Figure 6 Worldwide Cobalt Extraction in 2020 (based on Statista figures [7])



Platinum Extraction for Hydrogen Fuel Cells

On the hydrogen fuel cell side, in 2019, 180,000 kilograms of Platinum were produced[11]. This production would support a yearly production of about 3.6 million vehicles. To manufacture enough hydrogen fuel cells to power replaced fossil fuel vehicles, Platinum extraction and production would need to increase 15-fold to 2.7 million kilograms.

Figure 7 Worldwide Platinum Extraction in 2020 (based on Statista [9])

Power Pack Manufacturing Capacity

The battery and fuel cells manufacturing capacities also impact on the volume and availability of power packs. In 2020, the worldwide Li-Ion battery manufacturing capacity was approximately 450 GWh[12,13]. By 2030, this figure is expected to quadruple to 1.3 TWh[12]. The existing Li-Ion battery manufacturing capacity can support producing batteries for 3.6 million vehicles. The anticipated production capacity in 2030 can support production of batteries for more than 10 million vehicles. There are few reliable figures of worldwide fuel cell manufacturing capacity, however this is estimated at several hundred thousand units per year and will likely increase in the coming decade. So, are the increases in battery and fuel cell manufacturing capacities sufficient to meet expected demand for new vehicles in the countries where the sale of fossil fuel vehicles is restricted? The answer is 'maybe!'.

Several countries including Austria, Belgium, Denmark, Germany, Iceland, India, Ireland, Israel, Japan, the Netherlands, Norway, Slovenia, Sweden and the United Kingdom have set or plan to set a 2030 or earlier deadline for banning new fossil fuel vehicle sales. New vehicle sales in 2020 in these 14 countries totalled 15 million vehicles including 12.5 million cars and 2.5 million commercial vehicles. It is possible that by 2030 the battery and fuel cell production capacities together may be sufficient to sustain new vehicle sales in the 12 countries, provided that similar bans of fossil fuel sales are not announced in other major vehicle markets such as China or the United States.

Supply Chain Opportunities

Consideration of raw material supply, extraction capacity and energy pack manufacturing capacity challenges are critical supply chain issues that have not so far received sufficient attention and are almost entirely absent from contemporary public debates and policy-making approaches. Failure to address these issues may well lead to poorer mobility outcomes and, more importantly, worse environmental outcomes. If bottlenecks in the battery or fuel cell supply chains limit the number of vehicles sold to less than the sales required to replace the stock of old vehicles, older, more polluting cars could be left on the roads for longer.

Limiting new car sales may also mean a reduction in the population's mobility. Indeed, many of the world's urban centres suffer from congestion, lack of parking and insufficient road infrastructure. However, reducing mobility without providing alternative means of transport, both for personal vehicles and commercial goods delivery, may also result in significant negative socio-economic impacts.

It seems unlikely that either Li-Ion batteries or hydrogen fuel cells alone will become the uncontested replacements to fossil fuels for road vehicles. It is more likely that the three energy sources will co-exist and evolve in parallel alongside additional new entrants into the transportation power market. Each energy source will leverage its strengths for particular applications. This situation raises some interesting opportunities.

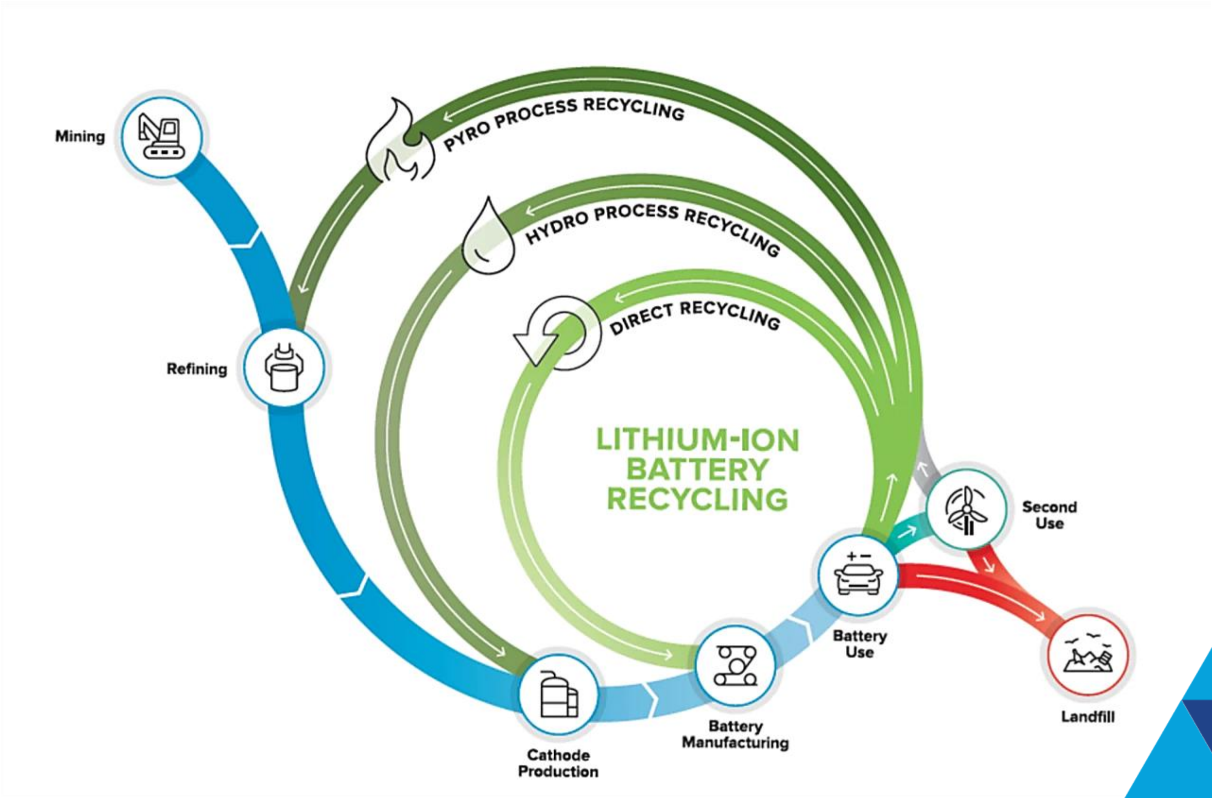


Figure 8 Circular Use of Li-Ion Batteries (Source: ReCell [14])

Opportunities for battery and fuel cell manufacturing capacity have implications for policy and business innovation initiatives. Promoting power pack modularisation, especially for batteries, interoperability, and to fossil fuel vehicles conversions to batteries or hydrogen fuel cells are key opportunities.

1. Power Pack Modularisation

Modular and interoperable power packs can reduce waste and raw material extraction requirements. Batteries are already constructed in modules.

2. Power Pack Interoperability

Power packs are generally built to the vehicle manufacturers' specifications. The potential for reusing power packs is considerably reduced if each vehicle requires a specific power pack configuration. Modular and interoperable power pack designs can be used to overcome this issue.

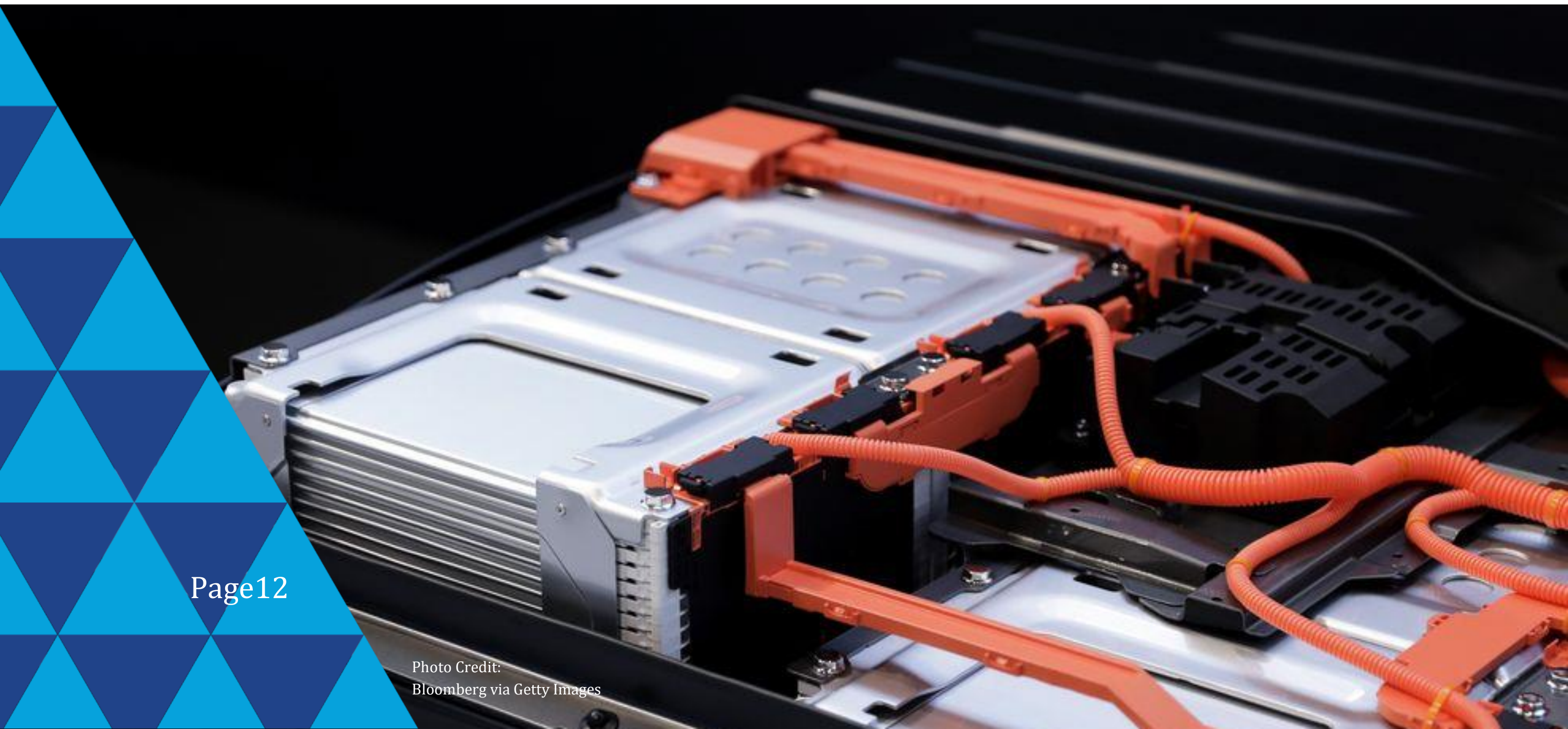
3. Exchangeable Power Packs

Exchanging discharged power packs with charged ones can circumvent charging time limitations (especially for Li-Ion batteries) and can reduce the infrastructure requirements and expenditure required to transition away from fossil fuels.

4. Fossil Fuel Vehicles Conversion

The existing vehicle fleet, or parts of it, can be converted to run on batteries or fuel cells. This would avoid expending resources to replace vehicles and would avoid a significant waste management problem after fossil fuel vehicles are disposed of.

The supply chains for BEV and FCEV power packs are still maturing. Policymakers and governments have the opportunity to direct and coordinate industry to achieve the most sustainable outcomes and ensure supply chain integrity and social mobility. There is also ample opportunity for business-led innovation to use resources most efficiently.



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Bloomberg via Getty Images

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