Electric Vehicle Revolution and Implications for New Energy Metals

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How we got here...
5\textsuperscript{th} Avenue, NYC, Easter 1900
5th Avenue, NYC, Easter 1913
Shanghai, 2015
There are many drivers contributing to the shift towards electric vehicles (EVs)

- Tightening of emissions regulations across the globe
- Restrictions on internal combustion engines (ICEs)
- Monetary and other incentives
- China is the main driver

Movement towards renewable energy
## Large sums of capital committed

<table>
<thead>
<tr>
<th>Company</th>
<th>Investment Details</th>
<th>Source</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volkswagen</strong></td>
<td>Volkswagen invests <strong>US$ 40 billion</strong> on electric cars. “With the planning round now approved, we are laying the foundation for making Volkswagen the world’s No. 1 player in electric mobility by 2025,” Chief Executive Matthias Mueller. Nov 24, 2017</td>
<td>Nov 24, 2017</td>
<td></td>
</tr>
<tr>
<td><strong>JAC</strong></td>
<td>Volkswagen &amp; JAC Put <strong>$12 Billion</strong> Into Chinese EV Boom. JAC has had a range of electric cars under the iEV name and has an established production base in China. It will […] help the introduction of 40 locally produced vehicles. Nov 25, 2017</td>
<td>Nov 25, 2017</td>
<td></td>
</tr>
<tr>
<td><strong>Daimler</strong></td>
<td>“We want to shape the profound transformation of the automotive industry.” […] <strong>$11.7 billion</strong> to introduce 10 pure electric and 40 hybrid models, […] electrify its full range of vehicles, from minicompact commuters to heavy-duty trucks. Reuters - Jan 15, 2018</td>
<td>Reuters - Jan 15, 2018</td>
<td>Jan 15, 2018</td>
</tr>
<tr>
<td><strong>Ford</strong></td>
<td>Ford Motor Executive Chairman Bill Ford Jr said of the company’s <strong>$11 billion</strong> investment, announced on Sunday at the North American International Auto Show in Detroit. Reuters - Jan 15, 2018</td>
<td>Reuters - Jan 15, 2018</td>
<td>Jan 15, 2018</td>
</tr>
<tr>
<td><strong>Other ex-China</strong></td>
<td>Over <strong>US$ 20 billion</strong> of investments announced: Porsche (US$ 8 billion), Tesla (US$ 5 billion), BMW (US$ 2.7 billion), Dyson (US$ 2.6 billion), Toyota (US$ 1.6 billion), Mercedes (US$ 1 billion).</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>Estimates of over <strong>US$ 100 billion</strong> in committed capital for investments related to electric vehicles.</td>
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</tbody>
</table>
There is a growing consensus that EV production will grow exponentially.

**Number of electric vehicles**

1. **Millions of EVs**

- **8%-20% of market share by 2025**
- **17%-38% of market share by 2030**

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1 Including Plug-in Hybrid Electric Vehicle (PHEV) and Battery Electric Vehicle (BEV)

Source: Public Announcements, Media, Vale Analysis
The key ingredients in the batteries of Electric Cars are the New Energy Metals

Typical BEV battery composition
Using NCM 622 chemistry

Cost  Energy density

Chemistry favors more nickel and less cobalt
Battery types

Cost  Energy density

Nickel rich

LCM 811  NCA
LOWER COST  HIGHER DENSITY

NCM 622  LCO
HIGHER COST  LOWER DENSITY

NCM 111  LFP
2 Implications for
New Energy Metals
Demand for nickel from the battery market will reshape the nickel industry

**Nickel demand for NEV batteries**

<table>
<thead>
<tr>
<th>Year</th>
<th>Conservative</th>
<th>Upside</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018E</td>
<td>38</td>
<td>260</td>
</tr>
<tr>
<td>2025E</td>
<td>590</td>
<td>890</td>
</tr>
<tr>
<td>2030E</td>
<td>1,700</td>
<td></td>
</tr>
</tbody>
</table>

Class I market today

**Breakdown of Ni demand 2017 vs. 2030**

<table>
<thead>
<tr>
<th>Year</th>
<th>Alloy steels</th>
<th>Non-ferrous alloys</th>
<th>Stainless steel</th>
<th>Foundry</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>4%</td>
<td>10%</td>
<td>7%</td>
<td>7%</td>
<td>37%</td>
</tr>
<tr>
<td>2030E</td>
<td>3%</td>
<td>7%</td>
<td>3%</td>
<td>5%</td>
<td>37%</td>
</tr>
</tbody>
</table>

1 Considers Vale’s expected demand growth from battery market by 2030 (50% Upside Case and 50% Conservative Case).
As a result, the nickel production will need to grow to supply the EV battery market

- There is availability of nickel and technologies to extract it are well known
- Capital costs are high and development cycles are long
- The nickel industry will need to invest up to US$ 70 billion by 2030
- Currently, prices are not reflecting the need to grow nickel mining to such an extent

**Class I (non-stainless) market balance**

<table>
<thead>
<tr>
<th>Year</th>
<th>Class I surplus Kt Ni</th>
<th>Class I inventory Kt Ni</th>
<th>Class I deficit Kt Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>100</td>
<td>0</td>
<td>-100</td>
</tr>
<tr>
<td>2018E</td>
<td>80</td>
<td>0</td>
<td>-80</td>
</tr>
<tr>
<td>2019E</td>
<td>60</td>
<td>0</td>
<td>-60</td>
</tr>
<tr>
<td>2020E</td>
<td>40</td>
<td>0</td>
<td>-40</td>
</tr>
<tr>
<td>2021E</td>
<td>20</td>
<td>0</td>
<td>-20</td>
</tr>
<tr>
<td>2022E</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2023E</td>
<td>0</td>
<td>0</td>
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<td>2024E</td>
<td>0</td>
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<td>2025E</td>
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<td>2026E</td>
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<td>2027E</td>
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<tr>
<td>2028E</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2029E</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2030E</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- Including only highly probable projects

Note: Considers the amount of capital expenditures needed to provide sufficient supply based on third-party sources estimates (CRU and Wood Mackenzie) and Vale’s expected deficit by 2030 (50% Upside Case and 50% Conservative Case).
Other New Energy Metals will have their own challenges to meet the growing demand of EVs

Copper

Although not directly used in battery chemicals, copper is critical for motors and infrastructure

- Demand from electrification adds but does not transform the copper market
- The copper industry will need to **invest up to US$ 40 billion** by 2030 to support electrification
- Challenged with **declining ore grades**
- Next wave of **projects needed**
Other New Energy Metals will have their own challenges to meet the growing demand of EVs

**Cobalt**

Cobalt is needed to help stabilize nickel within the battery, efforts are being made to minimize its content but it is difficult to completely eliminate it

- Cobalt supply is inelastic and heavily dependent on DRC source
- DRC copper mining could support cobalt, as a by-product, in the near term
- Increased expected nickel production can also support higher cobalt supplies as a by-product
- However, timing of supply growth versus demand growth may result in continued deficits that may lead to persistent high prices
- High prices are likely to de-incentivize use of cobalt in batteries vs. other metals such as nickel
The nickel mining industry is lagging behind in investments due to the lack of incentive price.

The **downstream industry** has committed **over US$ 150 billion**

- **Over US$ 70 billion** needed in investments for nickel
- **Over US$ 40 billion** needed in investments for copper
- **Cobalt is constrained inasmuch as Ni and Cu are under invested**
- Meanwhile, over **US$ 150 billion** committed by the downstream industry

The **nickel industry needs better prices**
Sources

Number of electric vehicles graph (slide #9)

CRU – Nickel Market Outlook (January 2018)

BMO - The Lithium Ion Battery and the EV Market: The Science Behind What You Can’t See (February, 2018) – Bull scenario


Barclays - Global Autos & Auto Parts: Industrie 4.0 vs. Tesla's 'lights out'? (April 17, 2018)


World bank – The Growing Role of Minerals and Metals for a Low Carbon Future (June 2017)

Morgan Stanley – Global Investment Implications of Auto 2.0 (April 19, 2016)

Wood Mackenzie – The rise of the electric car: how will it impact oil, power and metals? (November 2017)

Bernstein - Electric Revolution 2018: The Resistance, Part 3 - Raw material bottlenecks in the EV supply chain (February 23, 2018) Govt targets