Electric Vehicle Revolution and Implications for the Nickel Market
“This presentation may include statements that present Vale’s expectations about future events or results. All statements, when based upon expectations about the future and not on historical facts, involve various risks and uncertainties. Vale cannot guarantee that such statements will prove correct. These risks and uncertainties include factors related to the following: (a) the countries where we operate, especially Brazil and Canada; (b) the global economy; (c) the capital markets; (d) the mining and metals prices and their dependence on global industrial production, which is cyclical by nature; and (e) global competition in the markets in which Vale operates. To obtain further information on factors that may lead to results different from those forecast by Vale, please consult the reports Vale files with the U.S. Securities and Exchange Commission (SEC), the Brazilian Comissão de Valores Mobiliários (CVM), the French Autorité des Marchés Financiers (AMF) and in particular the factors discussed under “Forward-Looking Statements” and “Risk Factors” in Vale’s annual report on Form 20-F.”

“Cautionary Note to U.S. Investors - The SEC permits mining companies, in their filings with the SEC, to disclose only those mineral deposits that a company can economically and legally extract or produce. We present certain information in this presentation, including ‘measured resources,’ ‘indicated resources,’ ‘inferred resources,’ ‘geologic resources’, which would not be permitted in an SEC filing. These materials are not proven or probable reserves, as defined by the SEC, and we cannot assure you that these materials will be converted into proven or probable reserves, as defined by the SEC. U.S. Investors should consider closely the disclosure in our Annual Report on Form 20-K, which may be obtained from us, from our website or at http://us.sec.gov/edgar.shtml.”
Government regulation is the key driver towards electrification

Planned emission standards in select regions, total fleet average for new sales

Current standards:
- China: China 5
- EU: Euro6
- Japan: JPN2009
- Canada/USA: Tier2
- South Korea: Kor 3

Source: McKinsey, EU Commission
Battery electric vehicles are becoming cheaper faster

Electric vehicles are simpler and faster to build compared to internal combustion engines.

**Benefits vs. ICE**

- 50% reduction in footprint
- 50% reduction in capital investment
- 30% reduction in hours per unit
- Flexible tooling / process fully scalable and reconfigurable to support increase in demand

Source: Ford Motor Company 'CEO Strategic Update', October 3, 2017
This enables electric vehicles to take a commanding share of the personal vehicle market

Market Share of Electric Passenger Vehicles (Battery Electric and Plug-in Hybrids only)

<table>
<thead>
<tr>
<th>Year</th>
<th>ICE</th>
<th>EV’s conservative</th>
<th>EV’s upside considering “market news”</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>99%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>80%</td>
<td>7%</td>
<td>+13%</td>
</tr>
<tr>
<td>2035</td>
<td>48%</td>
<td>25%</td>
<td>+27%</td>
</tr>
</tbody>
</table>

“Market News” refers to public commitments by various auto manufacturers as well as governments (such as UK/France committing to no ICE sales by 2040, California, China, etc.)

Source: Public Announcements, Media, Vale Analysis
Implications for the nickel market
Nickel and cobalt are key ingredients for the manufacture of lithium-ion batteries.

An example of a Nickel-Cobalt-Aluminum (NCA) battery:

- Nickel Sulphate: 8 parts
- Cobalt Sulphate: 1 part
- Aluminum Sulphate: 1 part
- Lithium Carbonate: 1 part

Source: Vale Analysis
Nickel based lithium-ion batteries offer the highest energy densities on the market today.

Comparing Energy Density for a range of Battery Technologies (Wh/kg)

- Lead Acid
- Nickel-Iron (NiFe)
- Nickel-Cadmium (NiCd)
- Lithium Titanate oxide (LTO)
- Nickel Hydride (NMH)
- Lithium Phosphate (LFP)
- Lithium Manganese Oxide (LMO)
- Lithium Nickel Cobalt Manganese (NCM)
- Lithium Cobalt Oxide (LCO)
- Lithium Nickel Cobalt Aluminum (NCA)

Increasing nickel content in NCM batteries increases energy density.

China approves NCM battery for use in 2016, abandoning LFP technology.

Source: batteryuniversity.com
The transition to higher nickel content batteries is accelerating due to cost benefits as well as concerns with securing cobalt.

Nickel and Cobalt costs for a 60kWh battery (USD at Q3 2017 average LME prices)

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Ni</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCM111</td>
<td>1,223</td>
<td>20kg Ni</td>
</tr>
<tr>
<td>NCM622</td>
<td>1,125</td>
<td>734</td>
</tr>
<tr>
<td>NCM811</td>
<td>883</td>
<td>363</td>
</tr>
</tbody>
</table>

-39% decrease in cost of NCM811 compared to NCM111.

Source: Vale Analysis
The size of the battery is increasing as well – another large impact on commodity demand.

<table>
<thead>
<tr>
<th>OLD Pure EV</th>
<th>NEW Pure EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Nissan Leaf</td>
<td>Nissan Leaf 2019</td>
</tr>
<tr>
<td>30 kWh</td>
<td>60 kWh</td>
</tr>
<tr>
<td>Hyundai Ioniq</td>
<td>Tesla Model 3</td>
</tr>
<tr>
<td>28 kWh</td>
<td>50-75 kWh</td>
</tr>
<tr>
<td>Ford Focus</td>
<td>Chevrolet Bolt</td>
</tr>
<tr>
<td>23 kWh</td>
<td>60 kWh</td>
</tr>
</tbody>
</table>

Drive Range (km) | 150-200 km | 350-400 km

Source: Public Announcements
As a result, the nickel demand for battery manufacturing is expected to increase.

"Market News" refers to public commitments by various auto manufacturers as well as governments (such as UK/France committing to no ICE sales by 2040, California, China, etc.).

Source: Public Announcements, Media, Vale Analysis
The nickel market is made up of two very different classes of product:

- **Class I** (48%): 99.98% nickel or higher (also chemicals such as nickel sulphate). Forms include powders, briquette, pellets, and cathode.

- **Class II** (52%): Nickel Oxide Sinters (>70% nickel), FeNi (15-30% nickel, balance iron), Nickel Pig Iron (2-12% nickel, balance iron).

Stainless steel does not need the high purity and if available prefers using Class II due to iron, while Class II due to iron and impurities can only be used in stainless steel (with few niche exceptions).
Roughly half of the global nickel production is suitable for use to make batteries.

- **Class I**: Not all Class I products are the same – dissolvability and impurities differentiate suitability for the battery market.
  - Shift existing production from nickel cathode to nickel sulphate.
  - Well suited although more costly than dissolving.

- **Class II**: Class II products are too expensive to purify and dissolve although non-ferrous Class II is a candidate.
  - Dissolving metal is required.

**Refining intermediates** (of acid leaching operations) and **refineries optimizing production** contribute to the process.

Source: Vale Analysis
The nickel industry needs to grow in suitable units

Battery Suitable Nickel Market Balance (kt Ni)

Source: Wood Mackenzie, CRU, Vale Analysis (takes into account Alloy, Plating, Foundry and minimum Stainless Steel Class I load against expected Class I supply with remainder less Battery demand shown as balance above)
There are no easy ways to grow in battery nickel

**suitability for battery market**

- **Class II**
  - Products are too expensive to purify and dissolve although non-ferrous Class II a candidate.

- **Class I**
  - Not all Class I products are the same – dissolvability and impurities differentiate.

**supply ability to respond**

- **All new nickel supply growth is in Nickel Pig Iron** – not suitable for battery use.

- Mines are closing, capital is being deferred. **Class I is too expensive to grow.**

- Very limited, cannibalizing nickel cathodes (not growth).

- Very limited today while this is the most likely candidate for future supply growth.

Source: Vale Analysis
The nickel industry is likely to turn to Limonite deposits in order to meet battery demand.

Source: SNL, Vale Analysis
However, it will be costly to increase production of suitable nickel units.

Recent capital cost to bring nickel into production – comparing Class I vs. Intermediate vs. Class II (USD/t Ni installed capacity)

Additional capital is required for refining the intermediate to remove impurities and make nickel sulphate.
Electric vehicles will usher in a new age for nickel.

A more balanced nickel consumption profile between stainless and non-stainless applications.

Batteries need high purity nickel sulphate, cannot readily use Class II such as nickel pig iron or ferronickel units – today, only ~50% of global production is suitable.

Nickel industry needs to grow significantly in suitable units to meet demand for battery manufacture.

Growing in suitable nickel units is expensive.
VALE

For a world with new values.