Rapid Vehicle Electrification - What are the challenges?

Report for Transport & Environment,
By Christian Berggren and Per Kågeson, Sept. 2017

Highlights and update Oct. 10, 2018
How to electrify half of new car sales by 2030?

1. **Trends**: Strong sales growth, increasing model variety, rapid cost decline

2. **Challenges**: Satisfy rapidly growing demand, Battery production, Materials supply & recycling

3. **Policy needs**: Mandates, standards, incentives
1. Trends: Strong EV Sales growth

Global Sales of Electric Vehicles and Plug-in Hybrids

- Other
- Canada
- Sweden
- Netherlands
- Japan
- Germany
- France
- UK
- Norway
- USA
- China
- Pure EVs

EV VOLUMES.COM

Knowledge Integration and Innovation in Transnational Enterprise
Strong growth: Key data!

2016 - 2018:
+ **Global EV sales** (BEVs and plug-ins)
  
  From 774 000 to 1900 000 (est) !
+ **European** EV sales.
  
  From 222 000 to 430 000 (est).
+ **EV fleet in Europe** > 1 million vehicles
+ **Market share** EU (Q2): 2,4%
  
  Sweden (Q2-Q3): 7,3% and increasing
Increasing model variety: Two EV models on sale in EU in 2010, 34 in 2016.

...and customer interest:
“In 2015, Jaguar expressed zero interest in electrics. In Nov. 2016, they presented the electric I-pace, on sale in 2018. What changed?
It’s driven by the customers, Speth said. They see this type of vehicle as cool and sexy, especially young customers who ... are not interested in the sound of the engine and things like that.”
Rapidly falling battery costs

From:
$1000/kWh in 2010

To:
On average $200/kWh today.

A further decline
to $108-144/kWh in 2020 is expected.
Much faster than previously assumed
EVs still expensive, but cost parity is approaching

Impressive development…
In 2010, Mitsubishi iMIEV, the cheapest EV with a 16 kWh battery, had a sticker price of €36,000
In 2017 GM Bolt with a 60 kWh battery and a 380 km range cost only slightly more.
But: Still too expensive for main markets

Cost parity (TCO) with standard cars requires:
1. Cheaper batteries
2. Much higher volumes per EV model!
Motors, contacts, HV cables and inverters are technically mature.
But to make them price competitive, volumes must increase from a ten thousand scale to a multi-million scale.

This volume leap is now happening in China!
What a difference in six months

In Jan., we predicted 25% growth – and were criticized.
-Real growth 2017 and H1 2018: + 40%

Six months ago, the question was: Where are the customers
Now the question is: Where are the cars?
Key issue now: Supply the market

**EU:** An average of only 4 days of stock
Many models have > 10 000 unfulfilled orders.

**Sweden:** Impossible to get EVs this year
+ Nissan Leaf: 6 months waiting time,
+ Passat GTE – ”probably next year”
+ Golf GTE – not possible to order
+ Volvo – ”start delivery next year…”

Hyundai & Kia. Only Evs with normal delivery times

Bottleneck: Batteries!
2. Three challenges!

+ Ramp up EU battery production,
+ Secure critical materials
+ Invest in power supply: Generation, grid capacity, charging systems
Global battery demand


BATTERY DEMAND - XEV
2025 FORECASTS

Li-ion for EV, HEV & P-HEV Battery needs (MWh)
CAGR 2017-2025: +24%

Li-ion for EV, HEV & P-HEV Battery needs (M$)
CAGR 2017-2025: +17%
The Challenge Battery production: Only 1% in the EU!

LITHIUM ION CELL PRODUCTION
Korean companies start to move in Malaysia
New production capacity in Europe and US

Source: AVICENNE 2017

* OTHERS: Malaysia mostly
(1) Government subsidies only

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Batteries — a strategic EU weakness

Today 97% of all Li-ion batteries, including the main components, are manufactured and developed in Asia.

EU produces < 1%. This needs to change — and change fast!

If half of new EU cars in 2030 are electric, Li-ion batteries will be needed in eight million vehicles.

If half are BEVs (50 kWh) and half plug-ins (10 kWh), **240 Giga Wh production capacity is needed** = eight Tesla size factories.
LIB Cell mfg in the EU: Plans and actors

In operation: Nissan/GSR, UK. 2 GWh.

Under construction:
+ LG Chem, Poland Plans for 6 GWh/y
+ Samsung/Hungary Approx 3 GWh/y.
+ SK Innovation/H. 7,5 GWh (2020)
+ NorthVolt, Sweden. 32 GWh 2023.

Announced:
+ TerraE, Germany. Plans for 34 GWh by 2028.
+ CAGL/China, plant in Erfurt/G. Capacity & timing unknown.

Maybe: BYD and more?
The NorthVolt initiative

Started by former Tesla executive; first module of four to produce 8 GWh in 2020

Full-scale production in 2023.

Partners: Siemens, ABB, Scania

Capital needs. €3.5 – 4 billion!

Key competence from Japan

Ambition: Produce the world’s greenest battery cells
+ Tailor design to customer specs
+ Powered by 100% renewable energy
+ Supply from regional mineral sources (Nickel, Copper..)
+ Design for recycling
Six reasons for EU battery production

1. Safe supply and efficient logistics

2. Interaction with R&D: Batteries are still in an intensive technology phase

3. Protect jobs: Electrification without battery production = drastic employment decline

3. Safeguard low carbon mfg. Battery production is energy intensive and Asian plants highly coal-dependent. EU power emits 276 g CO2/kWh; Korean power 540 g CO2/kWh.

5. Drive sustainable mining, in particular in Africa

6. Combine design, labeling, manufacture and recycling
Challenge 2.

Supply of critical materials, recycling of scarce minerals
EVs are materials-intensive!

<table>
<thead>
<tr>
<th>GLOBAL SUPPLY</th>
<th>Copper</th>
<th>Nickel</th>
<th>Lithium (ton)</th>
<th>Cobalt (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual prod.</td>
<td>20 million</td>
<td>2 million</td>
<td>35 000</td>
<td>100 000</td>
</tr>
<tr>
<td>% to EVs today</td>
<td>&lt; 1%</td>
<td>2%</td>
<td>12.5%</td>
<td>7-8%</td>
</tr>
<tr>
<td>% to EVs 2030</td>
<td>15 % (2,5 -3 million)</td>
<td>20 - 30% (0,4-0,6 million) Increase in production needed</td>
<td>80 % (130 000) Major increase in production needed.</td>
<td>70 % (240 000) Content reduction will limit demand surge.</td>
</tr>
<tr>
<td>Cost/kWh NMC battery, 2016</td>
<td>$3.8 per kWh</td>
<td>$5.5 per kWh</td>
<td>$20 per kWh (mid ’17)</td>
<td></td>
</tr>
<tr>
<td>Sources</td>
<td>Several, reliable</td>
<td>Several, reliable</td>
<td>Australia, Chile, Argentina</td>
<td>“Democratic Rep. of Congo” 50%</td>
</tr>
</tbody>
</table>

Materials cost:
Appr 20% of battery cost, and increasing

Key issue: Mid-term supply
Rapidly increasing demand

METAL NEEDS FOR RECHARGEABLE BATTERY WILL INCREASE RAPIDLY

Sources: AVICENNE ENERGY 2018
Uneven 5-year price trends – Co and Li up, Ni down

<table>
<thead>
<tr>
<th>Year</th>
<th>Cobalt</th>
<th>Nickel</th>
<th>Lithium</th>
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<tbody>
<tr>
<td>2018</td>
<td>$80,490</td>
<td>$8,932</td>
<td>$16,500</td>
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<tr>
<td>2017</td>
<td>$38,243</td>
<td>$11,236</td>
<td>$9,318</td>
</tr>
<tr>
<td>2016</td>
<td>$24,996</td>
<td>$10,051</td>
<td>$7,830</td>
</tr>
<tr>
<td>2015</td>
<td>$36,290</td>
<td>$12,712</td>
<td>$6,966</td>
</tr>
<tr>
<td>2014</td>
<td>$29,072</td>
<td>$18,122</td>
<td>$5,417</td>
</tr>
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</table>
Cobalt – a byproduct of copper mining

+ Strong price increase & robust growth

+ European refineries in Finland, Norway, Belgium.

+ Raw mtrl supply dominated by DR Congo - with strategic Chinese presence.

+ Opening of new mines require high prices, leadtimes 5-8 y.

+ Transition to low-cobalt NMC-chemistries expected.
Cobalt supply and sustainable mining

>50% of Co from DRC with a history of human rights abuse.

The industry & EU need to:

+ Implement protocols for sustainable mining, e.g. *The Responsible Raw Materials Initiative*.
+ Diversify supply & support mining projects outside DRC, pay a temporary premium, or co-invest in mine expansion
+ Reduced Co content in battery cells under way
+ Recycling? Only a minor source for the next 15 years
Lithium: No worry
Nickel: Shortage of Class 1 looming

Lithium. Price growth only temporary
Massive demand growth is matched by investment plans in mining industry

Nickel. Overcapacity & rock-bottom prices today.
Transition to Low-Co batteries drives demand surge: from 30 kton 2016 to 500 kton in 2025
+ Many mining sources,
+ Eur. refineries in Finland & Norway.
- Key problem: Will the mining industry react in time to the demand surge, given today’s poor prices?
Lithium recycling: A long-term issue

In the growth phase, the industry needs virgin minerals. When demand stabilizes, recycling will be critical.

The Battery Directive requires producers to collect 95% of used batteries and recycle 50% of the weight, without specifying critical metals. Market value drive recycling of Cu, Ni and Co in melting furnaces.

For Lithium: only lab-scale processes; Industry needs R&DD support to develop advanced processes.
3. Power supply: A four per cent increase in average demand

If half of new EU vehicles are EVs in 2030, the total number on the roads will be c. 40 million.

This will increase the average electricity demand with 4% (50% BEVs, 50% plug-ins)

At the same time: Ageing nuclear plants and dirty coal plants will be decommissioned.

Supplying power to a rapidly growing EV fleet requires careful planning and investments in long-distance grids
Home-charging is key

Rapid charging systems will remain marginal
Norwegian studies suggest that 95% of EV power will be provided by slow, and inexpensive, charging at home or at work.

Grid investments needed.
Connecting hundreds of cars in the same area at about the same evening time could stress local grids.
Investments in grid capacity and smart metering are necessary.

Building standards important for rental houses
Early EV buyers own their homes and install their own chargers.
Charging stations are also important in apartment blocks.
Ambitious EU building standards directives are needed.
Challenge 3: Policy! ZEV-mandate, standards & LIB mfg support

Today Local EV incentives, plus an EU-wide “super credit”, which firms use to sell PHEVs with higher CO2-emissions than 130 g/km.

The report suggests: A union-wide ZEV mandate.
A ZEV-mandate forces manufacturers to produce and sell increasing proportions of zero-emission cars.
A fully electric car could be awarded 1,0 credit; a plug-in with a 50 km electric range - 0,5 credit.
To reach 50% EV market share (half BEVs and half PHEVs) the target for 2030 would be 37.5 ZEV-credits per 100 new cars.

Scrap the “super-credits”
The “super credit” should be scrapped. All combustion engines, in standard cars and in plug-in hybrids, should be subject to the same rule.
Standards and incentives also needed.

**EU efficiency directives** for EVs are important.

**Local taxes** can further support efficient EVs and penalize models with batteries >60 or 80 kWh.

**Urban zero-emission zones** will speed up EV diffusion.

EU initiatives are needed to **encourage large-scale investments in battery plants**. To rely on Asian shipments will seriously impact jobs, supply security, R&D and overall sustainability.

A package of policies are needed!
Taking stock: When are EVs really really sustainable?

*EVs are good for the urban environment. But how to make them really sustainable?*

**Requirement 1.** The power used for charging the car has a low and declining fossil share.

**Requirement 2.** The power used for battery production has a low and declining fossil share.

**Requirement 3.** The battery size is modest. Life cycle emissions and battery size have a linear relation: a 100 kWh battery consumes twice the resources of a 50 kWh battery.

**Requirement 4.** The major part of the metals used in battery cell production are recycled and re-used when demand has matured.
Europe has a chance to develop a genuinely sustainable electro-mobility!