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<th><strong>Docket Number:</strong></th>
<th>17-IEPR-07</th>
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<tr>
<td><strong>Project Title:</strong></td>
<td>Integrated Resource Planning</td>
</tr>
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<tr>
<td><strong>Document Title:</strong></td>
<td>Global EV trends and forecast</td>
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<tr>
<td><strong>Description:</strong></td>
<td>4.18.17 Presentation by Alejandro Zamorano of Bloomberg</td>
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<td><strong>Filer:</strong></td>
<td>Raquel Kravitz</td>
</tr>
<tr>
<td><strong>Organization:</strong></td>
<td>Bloomberg</td>
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<td><strong>Submission Date:</strong></td>
<td>4/17/2017 4:45:58 PM</td>
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<td><strong>Docketed Date:</strong></td>
<td>4/17/2017</td>
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Global EV trends and forecast

IEPR workshop on Light Duty Vehicle Transportation Electrification

Alejandro Zamorano

April 18, 2017
Agenda

2017 forecast

Drivers of transport electrification: the role of mobility
### North America selected EV model sales, Q1-Q2 2015 – 2016 (thousand units, % change)

<table>
<thead>
<tr>
<th>Model</th>
<th>Chevrolet Volt</th>
<th>Tesla Model S</th>
<th>Tesla Model X</th>
<th>Nissan Leaf</th>
<th>Ford Fusion Energi</th>
<th>Ford C-max Energi</th>
<th>Toyota Prius Prime</th>
<th>BMW i3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q4 2016 (units)</strong></td>
<td>9,338</td>
<td>8,825</td>
<td>6,485</td>
<td>5,058</td>
<td>4,309</td>
<td>2,635</td>
<td>2,422</td>
<td>1,947</td>
</tr>
<tr>
<td><strong>Q3–Q4 2016 (%)</strong></td>
<td>20%</td>
<td>-10%</td>
<td>0%</td>
<td>29%</td>
<td>-3%</td>
<td>20%</td>
<td>-35%</td>
<td></td>
</tr>
<tr>
<td><strong>Q4 ’15 – Q4 ’16 (%)</strong></td>
<td>39%</td>
<td>-6%</td>
<td>26%</td>
<td>50%</td>
<td>36%</td>
<td>-40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2016 (units)</strong></td>
<td>28,208</td>
<td>32,037</td>
<td>20,148</td>
<td>15,381</td>
<td>16,055</td>
<td>8,140</td>
<td>2,422</td>
<td>8,081</td>
</tr>
<tr>
<td><strong>2015 – 16 (%)</strong></td>
<td>67%</td>
<td>11%</td>
<td>-17%</td>
<td>64%</td>
<td>5%</td>
<td>-30%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Bloomberg New Energy Finance, automakers, vehicles registration agencies
Global EV sales, 2012 – 2017e (thousand units)

Cumulative global EV sales hit one million in Q4 2015

We expect the next million to be hit by Q2 2017

Regional 2017 totals:
APAC - 426k units
AMER - 259k units
Europe - 275k units
RoW - 2k units

2012 2013 2014 2015 2016 2017
China Europe US Japan Canada Korea RoW
+135% +69% +40% +56% +55% +39%

27 29 32 23 21 25
30 66 96 116 122 206
2012 2013 2014 2015 2016 2017
240 275 378
## EV sales trends – Changing growth patterns

<table>
<thead>
<tr>
<th></th>
<th>North America</th>
<th>Europe</th>
<th>China</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3 – Q4 2016</td>
<td>8%</td>
<td>29%</td>
<td>18%</td>
<td>-12%</td>
</tr>
<tr>
<td>Q4 ’15 – Q4 ’16</td>
<td>47%</td>
<td>-6%</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>Q3 – Q4 2016</td>
<td>29%</td>
<td>48%</td>
<td>122%</td>
<td></td>
</tr>
<tr>
<td>Q4 ’15 – Q4 ’16</td>
<td>-6%</td>
<td>122%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Looking Up

**Europe: up 15% year-on-year** Driven by: Strong policy support in: Norway, UK, France. Germany recently introduced incentives. But growth is slowing from last 18 months.

**China EV sales up 148% year-on-year.** Driven by: strong domestic policy support, new models and strong growth in BEVs.

### Moving sideways

**Japanese EV sales dropped 12% year-on-year.** Driven by: shrinking market, restricted model availability.

**North America EV sales up 39% year-on-year.** Driven by: refreshed versions of current models. Welcomed change from 2015. Fuel prices and consumers awaiting longer range BEVs inhibiting broader uptake.

Source: Bloomberg New Energy Finance
Agenda

2016 end of year update

Drivers of transport electrification: the role of mobility
drivers

1. Technology development

2. Mobility
drivers

1 Technology development

2 Mobility
With incentives, the TCO of BEVs is lower than all but the cheapest ICE vehicles in the US...

<table>
<thead>
<tr>
<th>Car Model</th>
<th>Price, net</th>
<th>Running costs</th>
<th>Fuel</th>
<th>Total cost of ownership, thousand $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevrolet Cruze</td>
<td>15.2</td>
<td>5.6</td>
<td>3.2</td>
<td>23.0</td>
</tr>
<tr>
<td>Ford Fusion</td>
<td>19.4</td>
<td>5.8</td>
<td>3.2</td>
<td>28.4</td>
</tr>
<tr>
<td>Chevrolet Malibu</td>
<td>19.2</td>
<td>5.8</td>
<td>4.1</td>
<td>29.1</td>
</tr>
<tr>
<td>Toyota Camry</td>
<td>19.8</td>
<td>5.9</td>
<td>3.5</td>
<td>29.2</td>
</tr>
<tr>
<td>Honda Accord</td>
<td>20.3</td>
<td>5.9</td>
<td>3.1</td>
<td>29.3</td>
</tr>
<tr>
<td>Chevrolet Volt</td>
<td>19.2</td>
<td>5.5</td>
<td>1.4</td>
<td>26.1</td>
</tr>
<tr>
<td>Ford Fusion Energi</td>
<td>19.4</td>
<td>5.5</td>
<td>1.6</td>
<td>26.5</td>
</tr>
<tr>
<td>Ford C-MAX Energi</td>
<td>20.7</td>
<td>5.4</td>
<td>1.6</td>
<td>27.7</td>
</tr>
<tr>
<td>Toyota Prius PHEV</td>
<td>22.7</td>
<td>5.4</td>
<td>1.7</td>
<td>30.8</td>
</tr>
<tr>
<td>Chevrolet Spark EV</td>
<td>10.9</td>
<td>5.1</td>
<td>0.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Ford Focus EV</td>
<td>14.0</td>
<td>5.2</td>
<td>0.5</td>
<td>20.7</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>16.4</td>
<td>5.3</td>
<td>0.5</td>
<td>22.4</td>
</tr>
<tr>
<td>Kia Soul EV</td>
<td>18.6</td>
<td>5.4</td>
<td>1.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

With incentives:
The TCO of a BEV is up to 25% lower than an average midsize gasoline vehicles

PHEVs cost the same as midsize gasoline vehicles: higher purchase price, lower incentives

Labels in italics are $/mile; Price includes down payment, financing and sales tax and is net of incentives and resale value; running costs consist of road tax, insurance and maintenance. Based on $0.125/kWh electricity and $2.50/gal fuel prices. 10,100 miles driven per year, TCO is calculated over the first 5 years of ownership.
Without incentives:

Current BEV models are more expensive than midsize gasoline cars by ~13%, PHEVs by 15%

The Chevrolet Spark EV is still cheaper due to its low upfront price (~$25k)

Labels in italics are $/mile; Price includes down payment, financing and sales tax and is net of incentives and resale value; running costs consist of road tax, insurance and maintenance. Based on $0.125/kWh electricity and $2.50/gal fuel prices. 10,100 miles driven per year, TCO is calculated over the first 5 years of ownership

---

**US 2015 models**

<table>
<thead>
<tr>
<th>Model</th>
<th>Price, net</th>
<th>Running costs</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ICE</strong></td>
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<td></td>
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<td>Chevrolet Cruze</td>
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<td>5.6</td>
<td>3.2</td>
</tr>
<tr>
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<td>20.3</td>
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<tr>
<td><strong>PHEV</strong></td>
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<tr>
<td>Chevrolet Volt</td>
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<td>5.4</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>BEV</strong></td>
<td></td>
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</tr>
<tr>
<td>Chevrolet Spark EV</td>
<td>20.9</td>
<td>5.1</td>
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</tr>
</tbody>
</table>
Vehicle lithium-ion battery prices and monthly volumes of lithium-ion batteries sold in new EV sales, 2012-2015 ($/KWh and MWh)

The decline in price is partly due to technology improvements, increased plant utilization and aggressive pricing strategy by large players.

The five largest battery manufacturers control 64% of lithium-ion battery capacity for EVs
Panasonic supplies batteries to at least 18 models, LG Chem to 12, Samsung to 6

Note: Prices include both pack and cell costs
Source: Bloomberg New Energy Finance
Bloomberg New Energy Finance recorded learning rate of Si PV modules and Li-ion battery packs 2004 – 16 (multiple units)

Crystalline Si PV module prices have fallen 26.3% on average for every doubling of cumulative production capacity in 2004 – 15

Li-ion battery pack prices have fallen 19% on average for every doubling of cumulative production capacity in 2010 – 16
Observed and forecast EV lithium-ion battery prices 2010-30 ($/KWh)

The weighted average battery price in 2016 was $273/kWh. Based on a learning rate of 19%, we anticipate battery prices will reach $73/kWh by 2030.

The decline of battery pack prices has accelerated since 2014 due to improvements in energy density and pack design, and large contracts as mass market EVs such as the Bolt and the Model 3 are introduced.

Note: values shown are taken from BNEF’s annual EV lithium-ion battery price survey. Forecast is based on a learning rate of 14-20%. EV cost parity is calculated on an unsubsidised total cost of ownership (TCO) basis. The date range reflects cross over with different vehicle classes in the US.
1

$384/kWh: production costs of a 1GWh output plant, in the US, with a 12% WACC, 10 year lifetime

2

High volume US plants can produce batteries below the average market price ($273/kWh), despite high capital costs.

3

$223/kWh is our indicative 2016 battery pack price for a large (3GWh), US based plant that is optimized for high volume production.

Source: Bloomberg New Energy Finance, Note: 40 kWh NMC/graphite pack
BNEF battery price survey 2016 and experience curve forecast 2010-30, ($/KWh)

Source: Bloomberg New Energy Finance. Note: values shown are taken from BNEF’s annual EV lithium-ion battery price survey. Forecast is based on a learning rate of 19%. EV cost parity is calculated on an unsubsidised total cost of ownership (TCO) basis. The date range reflects cross over with different vehicle classes in the US.
Unsubsidized total cost of ownership of EVs will reach parity with ICE in the mid-2020’s

Between 2020 and 2030, EVs will become cheaper to own than ICE cars on an unsubsidized basis.

Note: 10,100 miles per year, 5-year ownership. Gasoline and electricity prices from EIA’s 2015 Annual Energy Outlook ‘Low Oil Price’ scenario (ranging from $50 to $65 between 2015 and 2025). The fuel economy of an internal combustion engine vehicle increases by 3.5% per year and its price increases by 1% per year. The purchase price of a battery electric vehicle is based on the battery pack price, using an adjustment factor of 3-to-4 between 2015 and 2030, plus a profit margin of 7%. All other costs remain constant in 2015 dollars.

Bloomberg New Energy Finance
Global LDV and EV yearly sales, 2015 – 2040 (million vehicles sold per year, %)

Global sales penetration forecast:
- 2020: 2%
- 2025: 8%
- 2030: 20%
- 2040: 35-47%

Bloomberg New Energy Finance Note: ICE+HEV = internal combustion engine and hybrid vehicles, BEV = battery electric vehicles, PHEV = plug-in hybrid electric vehicles.
drivers

1. Fuel efficiency
2. Technology development
3. Mobility
The rise of shared services and new mobility business models

Investments in ride-hailing companies, 2011-15 ($ billion)

- Other
- Ola
- Lyft
- Didi
- Uber

Operator car sharing
- zipcar
- CAR2GO
- KANDI

Peer-to-peer ride sharing
- BlaBlaCar
- scoop

Peer-to-peer car sharing
- easyCarClub
- FlightCar

On-demand ride-hailing
- Uber
- DiDi

Source: Bloomberg New Energy Finance
Sensitivity of the TCO of BEVS to changes in costs, using purchasing incentives

Running and fuel costs have a smaller impact on BEV’s total cost of ownership…
…but vehicle utilization rates important factors in determining competitiveness of EVs relative to gasoline cars…
…specially in a scenario where the global vehicle fleet is utilized around 5% of the time.
Global average unsubsidized total cost of ownership outlook of BEVs compared with internal combustion engine vehicles 2016 – 2036 ($/mile)

Any mass adoption of EVs – over 5% of new vehicle sales – needs to be supported by competitive TCO. Economics are not the only factor, but they are the leading indicator of future EV adoption.

Using EIA’s “low” reference crude oil price to 2040 ($50-$75/barrel) – and our battery cost forecast – BEVs will not be competitive on a TCO-basis with ICEs until 2022.

We project that a long-range 60kWh BEV can be competitively priced at $21,500 by 2040 (2015 dollars).

At that point, the total addressable market could exceed 50% of new sales for most markets.

Source: Bloomberg New Energy Finance
TCO scenario where EV utilization doubles relative to ICE vehicles
2016 – 2036 ($/mile)

Higher EV utilization relative to ICE may drive down TCO dramatically and push up adoption faster.

If ICE vehicle miles travelled are held constant in 2014 – 40, and BEV miles are doubled, TCO falls dramatically.

The effect on ownership economics is sharp and in 2025 the per-mile cost of owning and operating an EV falls by about 40%.

The additional electricity and maintenance costs are small and spread over a large number of miles driven.

Source: Bloomberg New Energy Finance
BNEF global NEW EV sales forecast by geography, 2015–2040 (million vehicles per year)

**EQUAL NUMBER OF MILES TRAVELLED**

- Under equal vehicle miles travelled the number of new EVs sold in 2030 globally is about 22m.
- The inclusion rate of EVs that year is 20% of new vehicles sold.

**DOUBLED THE EV MILES TRAVELLED**

- When doubling the utilization rate of plug-ins, the number of new EVs sold in 2030 increases to 25m.
- The penetration rate of new vehicle sales in 2030 increases to close to 24%.
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Storage
Electric Vehicles
Mobility and Autonomous Driving
Frontier Power
Emerging Technologies

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