Market Overview and Supporting Battery Technologies for Electric Vehicles

Introduction

Market Overview into Electric Vehicles

Supporting Battery Technologies

Consumers’ Attitudes & Perceptions

Conclusions and Questions
Our Global Presence Leading Consulting & Research Group, 2000 Staff in over 30 Offices. 40 Years of Global Partnerships With International Blue Chips
8 Key Business Sectors and Technical Insight

**Industrial Automation & Electronics**
- Power Transmission
- Test & Measurement, Sensors, Smartcards

**Technology**
- IT Security, Enterprise Software, Network Security, Telecom Service, Mobile,

**Aerospace & Defense**
- Battle Space IT, C4ISR, Satellites &Space, Military Aerospace, Training & Simulation

**Transportation**
- Automotive
- Transportation Systems, Logistics, Railway Systems

**Technical Insight**
- Emerging Technology Research, Cross Industries

**Energy**
- Power Generation
- Distributed Energy, Power supplies, Batteries, Renewable

**Healthcare**
- Medical Systems, Medical Devices, Drug Discovery, Diagnostic Technology, Pharmaceuticals

**Chemicals, Materials And Food**
- Agrochemicals, Specialty Chemicals, Fine Chemicals, Performance Materials

**Environment & Building Controls**
- Water & Wastewater, Waste, Air Treatment Building Mgt Technologies
# Automotive & Transportation Group

<table>
<thead>
<tr>
<th>Chassis</th>
<th>Powertrain</th>
<th>Safety &amp; Driving Assistance</th>
<th>Infotainment &amp; Telematics</th>
<th>Electric &amp; Electronic Systems</th>
<th>Aftermarket &amp; Garage Equipment</th>
</tr>
</thead>
</table>
| • Integrated Chassis Control Systems  
  • Advanced Steering Systems  
  • Chassis Modules and Systems  
  • Advanced Braking and Stability Control  
  • Drive Line Technologies  
  • Suspension Systems  
  • Mechatronics  
  • Tyre Technology | • Next Generation Diesel Engine Technologies  
  • Alternative Fuels/Vehicle Energy Systems inc Hybrids, Fuel Cells, 42 Volts  
  • Powert'n Modules/Systems  
  • Diesel Particulate Filters  
  • Next Gen Combustion Tech Tech - HCCI, laser  
  • Transmission Tech | • Driver Assistance Sys  
  • ADAS  
  • Active and Passive Safety  
  • Legislation / Regulations  
  • Commercial Vehicle Safety Sys  
  • Sensors  
  • Pedestrian Protection  
  • Obstacle Sensing  
  • ACC/Nightvision | • Intelligent Transportation Systems/Tolling/ Road User Charging / GPS  
  • Navigation Sys  
  • China Infotainment Market  
  • Interior Modules & Sys  
  • Wireless Communication / Bluetooth  
  • CV Telematics  
  • RVD | • Semiconductors  
  • In-Vehicle Network Architecture  
  • Automotive Software  
  • Wiring Harnesses  
  • Mechatronics  
  • Nanotechnology / SRP  
  • Interior / Exterior Modules  
  • Auto Lighting | • Engines & Transmissions  
  • Suspension & Brakes  
  • Starters & Alternators  
  • Accessories  
  • HVAC  
  • Tyres  
  • Handled Diagnostics  
  • Mechanical Testing |
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EV Market Entry Strategies of The Top OEMs is Expected by 2011 and is to Grow Post 2013.


Optimistic Scenario:
Early adaptation and high growth rate of electric vehicles owing to early market entrance and capacity expansion of Renault-Nissan, Mitsubishi, Daimler, PSA, BMW, VW, Toyota and Others. Leasing model achieving tremendous success across key regions.

Frost & Sullivan Scenario:
Not all the mentioned to make an early market entrance. OEMs opting for pilot regions to evaluate leasing and financial models. Good tax and insurance benefits offered in some regions.

Conservative Scenario:
Advancement of competitive technologies such as fuel cells. Legislation relaxed for competitive technologies and congestion charging not implemented in key cities.

Note: All figures are rounded. Source: Frost & Sullivan
At least 13 congestion charging cities to be in operation in Europe by 2013, all key cities have good EV potential.

- Future schemes at proposal stage, 2008-2015
- Schemes with future potential, beyond 2013
- Existing schemes

At least 13 congestion charging cities to be in operation in Europe by 2013, all key cities have good EV potential.

- Key Players: Government, EDF, Elektromotiv
- Key Players: VM's, Utilities
- Key Players: EDF, Govt, VM's
- Key Players: Daimler, ENEL
- Key Players: Govt
- Key Players: Govt, Nissan

Strong co-relation exists between regional markets adoption of congestion charging (and other green initiatives) and uptake of charging stations.

- E.g. London and Norway
- Pioneering efforts from relevant industries could facilitate faster expansion of infrastructure.
Number of Potential Customers* to Increase 5 Folds Post 2015 Across Prime W. European Markets as EV Range Extends to Reach Suburban and Adjacent Cities


- **Potential Customer = ~ 686K**
  - **Key Markets = 🇫🇷, 🇫🇮**
  - **Drivers:**
    - Competition will see EV manufacturers increase distance, speed and charging time configuration.
    - Consumers to increasingly use EVs to commute from home (suburban) to work (urban)

- **Potential Customer = ~876K**
  - **Key Markets = 🇫🇷, 🇫🇮, 🇪🇸, 🇳🇴, 🇳🇱**
  - **Scandinavian regions**
  - **Drivers:**
    - EV’s limiting range restrict application to cities
    - Competition will see EV manufacturers increase distance, speed and charging time configuration.

- **Potential Customer = ~ 3.42Mn**
  - **Key Markets = 🇫🇮, 🇫🇷, 🇳🇴, 🇳🇱**
  - **Drivers:**
    - EV’s limiting range restrict application to cities
    - Competition will see EV manufacturers increase distance, speed and charging time configuration.

*Potential Customer → Customers “Very likely” to purchase EV with present specifications.
Likely purchase to actual adoption rate would depend on individual market developments

Source: Frost & Sullivan
Innovative Business Opportunities Arise From Partnerships Formed Between Diverse Industries in Order to Expand Infrastructure to Support EV

New Business Models that will address additional Electric Vehicle (EV) energy requirements will be formed at the intersection of several diverse and cross functional industries.

Source: Frost & Sullivan
Leasing Business Model Provides Best Return: Future Leasing Models to Sell 75% of EVs; The Rest 25% Sold Traditionally

<table>
<thead>
<tr>
<th>TYPE</th>
<th>Business Scheme 1</th>
<th>Business Scheme 2</th>
<th>Business Scheme 3</th>
<th>Business Scheme 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVER</td>
<td>Energy Package</td>
<td>Maintenance Package</td>
<td>Part Subsidy</td>
<td>Full Subsidy</td>
</tr>
<tr>
<td>ENERGY</td>
<td>Monthly Bill</td>
<td>Flat: Max 2000km/month</td>
<td>Flat: 25,000km/year</td>
<td>Flat: 30,000km/year</td>
</tr>
<tr>
<td>CONTRACT</td>
<td>NA</td>
<td>NA</td>
<td>4 years</td>
<td>7 years</td>
</tr>
<tr>
<td>SUBSIDY</td>
<td>NA</td>
<td>NA</td>
<td>50% car price</td>
<td>Free car</td>
</tr>
</tbody>
</table>

**MONTHLY LEASE BREAKDOWN**

- **Business Scheme 1**: Up to €150
- **Business Scheme 2**: Up to €300
- **Business Scheme 3**: €500 - €800
- **Business Scheme 4**: ~ €900 - €1500

**Other Possible Leasing models**

- **Flexible Mileage**: Unlimited Miles, Max number of miles, Pay as you go
- **Flexible Contract**: The customer opts for the number of years and flexible mileage- customized lease

*Source: Better Place, Frost & Sullivan*
Number of Potential Customers* to Increase 5 Folds Post 2015 Across Prime W.

Environmental concerns to yield high adoption rate among potential customers.

2010

Drivers:

Competition will see EV manufacturers increase distance, speed and charging time configuration.

Scandinavia, Switzerland

Advancements in Lithium-ion Technology is Key for Electric Vehicle

Energy Density: 60WH/kg

Range: 70-80kms

NiMH

2010

Energy Density: 90WH/kg

- 2015

Li-Ion

Mild (NiMH)

Plug-in (Li-Ion)

Rural

9700 - 10200

5400 - 5800

2015

580 - 650

2000

25

15

Younger Consumers Are Less Resistant to Electric Vehicles

some likeliness to consider with A&B segment favouring them the most.

Electric Vehicle Segment

4%

6%

11%

16%

20%

26%

30%

18%

31%

32%

18%

31%

38%

Not likely

34%

39%

32%

26% 26%

25%

15%

SUV - Small

20

20

establishments with venture capitalist and investors.

the lobbying power of the local governments in favor of electric vehicles and are less resistant to them.
EV Technology and Product Roadmap- Charging Times to Drop from 6-8 hours to <15 minutes by 2015; But All Fast Recharging to be Made Off-Board

Battery Technologies

- Lead acid
- Nickel Metal Hydride
- Sodium Nickel Chloride
- Phosphate based
- Manganese based
- Titanate based
- Silica based
- Lithium Ion
- Zinc Air

Electric Motors

- Permanent Magnet
- Asynchronous
- Switch Reluctance
- In wheel motors

Performance

- Driving Distance/charge:
  - Up to 60 kms
  - Up to 200 kms
  - 300 + kms
- Charge Time:
  - 6 to 8 hrs
  - < 1 hour
  - < 15 minutes
- Battery Capacity:
  - up to 16kWh
  - Up to 50 kWh
  - 75 kWh +
- Motor Power:
  - Up to 70 kW
  - 70 kW – 250 kW

Infrastructure

- Slow charging - onboard
- Fast charging – mostly off board
- Battery Swapping

Source: Frost & Sullivan
Advancements in Lithium-ion Technology is Key for Electric Vehicle Penetration

- Lithium Ion Batteries have advantage of 50% reduction in size and over 35% reduction in weight compared to the present generation of Nickel Metal Hydride batteries.

Li-Ion
- Battery Capacity: >75kWh?
- Energy Density: 1600WH/kg
- Range: 300+ kms

...Increased production of the lithium-ion packs could see prices closer to cheaper but less effective nickel-based batteries.
Automotive Industries demand for Lithium is likely to increase with demand exceeding supply. Toyota and Mitsubishi have already approached the Bolivian government, but had been turned away.

Relations between Bolivia and America is weak and problematic if the big three are to be successful in their future EV strategies.

Partnerships to be forged between Mining Companies and battery manufacturers, ensuring supply of Lithium for the demand and to keep a check on pricing.
Market Overview and Supporting Battery Technologies for Electric Vehicles

Presentation Agenda

- Introduction
- Market Overview into Electric Vehicles
- Supporting Battery Technologies
- Consumers’ Attitudes & Perceptions
- Conclusions and Questions

Key Conclusions and Opportunities

- Younger Consumers Are Less Resistant to Electric Vehicles
- And are less resistant to them. While limited range, charge time and other factors need to be considered
- Some likeliness to consider with A&B segment favouring them the most.

Potential Customer =

• Potential Customers =

Drivers:

<table>
<thead>
<tr>
<th>Lithium Ion Batteries have advantage of 50% reduction in size and over 35% reduction in weight compared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Capacity: 10kWH</td>
</tr>
<tr>
<td>Range: 70-80kms</td>
</tr>
<tr>
<td>Energy Density: 110WH/kg</td>
</tr>
<tr>
<td>Range: 200-220kms</td>
</tr>
<tr>
<td>Li-Ion Energy Density: 90WH/kg</td>
</tr>
<tr>
<td>Range: 120-150kms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 Full (Li-Ion)</td>
</tr>
<tr>
<td>2020 Plug-in (Li-</td>
</tr>
<tr>
<td>Urban</td>
</tr>
<tr>
<td>2015</td>
</tr>
<tr>
<td>2020</td>
</tr>
</tbody>
</table>

Younger respondents are more likely to consider electric vehicles and are less resistant to them.
Multiple Sample Split with a Sample Size of 2,648 Respondents

To Evaluate “European Consumers’ Attitudes & Perceptions towards Sustainability, Environment and Alternate Powertrain”

Key objectives of this research study are:

- To determine consumers’ **perceptions and attitudes toward different environment and sustainability factors**
- To determine the importance, interest and influence of environment and sustainability factors in the **purchasing decision** of a new vehicle
  - Also their relative performance to other purchasing criteria including: price, safety, performance, driving dynamics, cost of ownership etc.
- **To recommend technology development and Product positioning**

Sample size by country and vehicle segment, in addition, samples had also been split by age and gender

<table>
<thead>
<tr>
<th></th>
<th>France</th>
<th>Germany</th>
<th>Italy</th>
<th>Spain</th>
<th>Sweden</th>
<th>UK</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;B</td>
<td>150</td>
<td>152</td>
<td>77</td>
<td>76</td>
<td>40</td>
<td>151</td>
<td>646</td>
</tr>
<tr>
<td>C</td>
<td>151</td>
<td>150</td>
<td>77</td>
<td>75</td>
<td>43</td>
<td>149</td>
<td>645</td>
</tr>
<tr>
<td>D&amp;E</td>
<td>149</td>
<td>150</td>
<td>77</td>
<td>76</td>
<td>45</td>
<td>150</td>
<td>647</td>
</tr>
<tr>
<td>MPV</td>
<td>81</td>
<td>75</td>
<td>48</td>
<td>38</td>
<td>43</td>
<td>79</td>
<td>364</td>
</tr>
<tr>
<td>SUV-Large</td>
<td>61</td>
<td>56</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>60</td>
<td>246</td>
</tr>
<tr>
<td>SUV-Small</td>
<td>15</td>
<td>26</td>
<td>16</td>
<td>12</td>
<td>16</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>607</td>
<td>609</td>
<td>317</td>
<td>300</td>
<td>211</td>
<td>604</td>
<td>2,648</td>
</tr>
</tbody>
</table>
Electric Vehicles Ranked Best Choice for Fuel Economy

Q32 Please rank the following vehicle engine types based on their fuel economy?

Mean

- Electric Vehicle: 5.0
- Diesel-Hybrid: 4.2
- Hydrogen: 4.1
- Plug-In Hybrid: 4.0
- LPG (Liquefied Petroleum Gas): 3.7
- CNG (Compressed Natural Gas): 3.5
- Bio fuels or Gasoline flex fuel vehicles: 3.4
- Petrol-Hybrid: 3.3
- Diesel: 2.7
- Petrol: 1.1

Q31 How likely are you to consider the following fuel/engine types for your next car purchase?

- France: 25.0%
- Germany: 8.0%
- Italy: 25.0%
- Spain: 25.0%
- Sweden: 12.0%
- UK: 11.0%

Base: 2008 n=2,648
Younger Consumers Are Less Resistant to Electric Vehicles

- Younger respondents are more likely to consider electric vehicles and are less resistant to them.
- Electric power has not been discounted across the segments, all show at least some likeliness to consider, with A&B and Small SUV owners favouring them the most.

Q31 How likely are you to consider the following fuel/engine types for your next car purchase? Electric

<table>
<thead>
<tr>
<th>Vehicle Segment</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18 to 25</td>
</tr>
<tr>
<td>A&amp;B</td>
<td>Very Likely</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
</tr>
<tr>
<td></td>
<td>Not likely</td>
</tr>
<tr>
<td></td>
<td>Not likely at all</td>
</tr>
<tr>
<td>C</td>
<td>Very Likely</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
</tr>
<tr>
<td></td>
<td>Not likely</td>
</tr>
<tr>
<td></td>
<td>Not likely at all</td>
</tr>
<tr>
<td>D&amp;E</td>
<td>Very Likely</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
</tr>
<tr>
<td></td>
<td>Not likely</td>
</tr>
<tr>
<td></td>
<td>Not likely at all</td>
</tr>
<tr>
<td>MPV</td>
<td>Very Likely</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
</tr>
<tr>
<td></td>
<td>Not likely</td>
</tr>
<tr>
<td></td>
<td>Not likely at all</td>
</tr>
<tr>
<td>SUV - Large</td>
<td>Very Likely</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
</tr>
<tr>
<td></td>
<td>Not likely</td>
</tr>
<tr>
<td></td>
<td>Not likely at all</td>
</tr>
<tr>
<td>SUV - Small</td>
<td>Very Likely</td>
</tr>
<tr>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td></td>
<td>Undecided</td>
</tr>
<tr>
<td></td>
<td>Not likely</td>
</tr>
<tr>
<td></td>
<td>Not likely at all</td>
</tr>
</tbody>
</table>

Base: 2008 n=2,657, A&B n=646, C n=650, D&E n=649, MPV n=364, SUV small n=101, SUV large n=247. Level of significance: 95% (right-tail: 2.5%)
Consumers See Use of Their Vehicles Greater for Commuting, Supermarket Shopping and Visiting Friends and Family

London, UK

- Commuting, supermarket shopping and visiting friends and family takes up 56% of vehicle use. While inner-city commute accounts for 6 in 10 consumers that live in London.

Q4 Thinking about the vehicle you purchased most recently, what would you say you use the vehicle for? Please break down your time by a percentage – note that should add up to 100% (Mean)

- Commuting to and from work: 26%
- To use while at work such as visiting clients: 7%
- Supermarket Shopping: 15%
- Retail Shopping: 8%
- Visiting friends or family: 15%
- Taking and picking kids up from school: 7%
- Weekend vacation/leisure driving: 11%
- Recreational activities: 5%
- Evening entertainment: 5%
- Others: 1%

Q5 What describes your pattern of commuting to and from work?

- Inner-city commute: 57%
- Outbound commute: 22%
- Incoming commute: 21%

Base: n=427

Base: Those that use their vehicle for driving to work n=254
While half of London consumers say they have easy access to electric sockets at home in the driveway, 16% also say they do not have easy access to sockets. Furthermore, only 8% say they have access in business car park.

Q20 Which of the following locations have easy access to accessible electric sockets? Please select all that apply
While distance and high price are seen as the biggest barriers to EV adoption, the length of time to charge and inconvenience of charging also rated as a leading barrier by 1 in 3 consumers.

<table>
<thead>
<tr>
<th>Q10 What do you dislike most about electric vehicles? please select all that apply</th>
<th>45.9%</th>
<th>44.3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited distance able to travel</td>
<td>High price</td>
<td>Length of time to charge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inconvenience of charging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited availability of models</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inconvenience of monitoring and/or maintaining battery charge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limitation in space (passenger/luggage compartment, because of bigger tank)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited performance (acceleration etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low reliability/durability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Less attractive vehicle designs and styles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low resale value (i.e. rapid vehicle depreciation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety concerns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Difficulties in recycling (scrapping high voltage hybrid systems)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Their fuel economy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
</tr>
</tbody>
</table>

Base: Those undecided, likely & very likely to consider buying an EV  n=318
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- Introduction
- Market Overview into Electric Vehicles
- Supporting Battery Technologies
- Consumers’ Attitudes & Perceptions
- Conclusions and Questions

Key Markets =

Potential Customers =

Drivers:

- Environmental concerns to yield high adoption rate among potential customers
- ~686K
- ~876K

Energy Density: 60WH/kg

2015

Plug-in (Li-

Energy Density: 1600WH/kg

Range: 330-350kms

Lithium Ion Batteries have advantage of 50% reduction in size and over 35% reduction in weight compared to the present generation of Nickel Metal Hydride batteries.

Source: Frost & Sullivan

Not likely

Not likely at all

2% 27%

12% 24%

14% 24%

13% 22%

16% 28%

16% 15%

12%

14%

13%

16%

26%

31%

38%

33%

24% 28%

24% 28%

22% 28%

Not likely

28%

15%

A&B C D&E MPV SUV -

SUV -

Base: 2008 n=2,657, A&B n=646, C n=650, D&E n=649, MPV n=364, SUV small n=101, SUV large n=247

Level of significance: 95% (right-tail: 2.5%)

Q31 How likely are you to consider the following fuel/engine types for your next car purchase?

- 2%
- 12%
- 14%
- 13%
- 16%
- 16%
- 26%
- 31%
- 33%
- 24% 28%
- Not likely
- 27%
- 24%
- 22%
- Not likely at all
- 28%
- 15%

A&B

C

D&E

MPV

SUV -

SUV -

Small

Base

20

2008

n=2,657

A&B

n=646

C

n=650

D&E

n=649

MPV

n=364

SUV small

n=101

SUV large

n=247

Level of significance: 95% (right-tail: 2.5%)

The EV growth depends on battery is the issue as it the local governments in favor Electric Vehicles

Strong potential solution, with Lithium younger respondents are more likely to consider electric vehicles and are less resistant to them
Urban Consumers are the Ideal Targets for EVs - Distance, Time to Charge, Style & Exterior, Speed and Charging Points as Areas of Interest

- Ideal hours to charge that will result in maximum uptake of potential EV customers in UK
- Ideal top speed characteristics that will result in maximum uptake of potential EV customers in UK
- Ideal price range that will result in maximum uptake of potential EV customers in UK
- Ideal distance characteristics that will result in maximum uptake of potential EV customers in UK

"My wish list for EV specification..." UK Consumer

Source: Frost & Sullivan
Key Conclusions and Opportunities

A new way of business, customer support and consumer attitudes

The EV growth depends on the lobbying power of advocates and the attitude of the local governments in favor of EVs. Optimistic almost 700,000 EV’s by 2015

Strong potential solution, with Lithium Phosphate and Lithium Manganese technologies would be effective and safe by 2010

Investments required for battery leasing, infrastructure and other services. Ownership of the battery is the issue as it requires 4-6 years to make profits.

High reliance on access to Lithium-ion reserves to ensure a sustainable solution beyond the next decade
Your Questions?

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Sylvain Filippi
Account Manager
Automotive & Transportation
Direct: +44 (0) 207 343 83 77
Email: sylvain.filippi@frost.com

Many Thanks for Your Attention