Renaissance and Global EV Development

Professor C.C. Chan, FIEEE, FIET, FHKIE
Academician, Chinese Academy of Engineering
Fellow, Royal Academy of Engineering, U.K.,
Founding President, World Electric Vehicles Association

Fuel Choices Global Summit

December 3-4, 2014
Tel-Aviv, Israel
Civilization & Open Mind
Civilization / Technology
Migration of Center of Gravity

Think Globally
Act Globally
Yi-jing basic principles:
Change, Periodic, Balance, Unity of Opposites

Straight Forward Approach

Holistic, Dialectic Approach

“‘Yes’ is ‘Yes’
‘No’ is ‘No’”

“‘Yes’ can be turned into ‘No’
‘No’ can also be turned into ‘Yes’”
The beginning of the cultural movement of the Renaissance

David, by Michelangelo, an example of high renaissance art

Leonardo da Vinci’s Vitruvian Man, an example of the blend of art and science during the renaissance
Open Mind

• A closed Mind Can Not Change!

• Saw Beyond What Was, to See What is!
Renaissance Scientists & Engineers are those not only understand WHY and HOW THINGS work but also on WHY and HOW the WORLD works!
Characters of Renaissance Scientists & Engineers
Think the World and not just the THINGS

• Global thinking instead of local thinking;
• Harmony thinking between human and nature;
• Circle thinking instead of linear thinking;
• Closed loop thinking instead of open loop thinking;
• Life cycle thinking instead of partial life thinking;
• 3R thinking (Reduce, Re-use, Recycle).
EV Development
Mobility is Freedom.
Mobility is the most apt expression for our quest for happiness.
Historical Document Signed at EVS.9
Committing Support to Formation of World Electric Vehicle Association

Memorandum of Understanding

1. The undersigned, conservatives and people who are, in their respective countries, committed to the development of electric vehicles in an economic, rational, and practical manner, hereby establish the Memorandum of Understanding, the terms and conditions of which are as follows:

2. The aim of the worldwide co-operation is to:

- extend the exchange of information which encourages the development of electric vehicles,
- consolidate the efforts of EVS co-operation to build a network in the world, in the form of conferences, seminars, and meetings, and
- stimulate the establishment of organizations in individual countries and regions.

3. To achieve the objectives set forth above, the undersigned countries agree to:

- facilitate the development of electric vehicles in each country, and
- establish a network of organizations in individual countries and regions.

The undersigned countries commit to:

- fostering the development of electric vehicles in their respective countries,
- promoting the exchange of information among the countries,
- and establishing a network of organizations in individual countries.

Participants from Top left: B. Fijalkowski (Poland), R. Atanassov (Bulgaria), H. Payot (France), C. Hayden (U.S.), Z. Feng (China), W.A. Adams (Canada), Bottom left: M. Chiogioji (US), R. Leembruggen (Australia), J. Lea (Korea), L. Secord (Canada), C.C. Chan (Hong Kong), F. Dierkens (A.V.E.R.E.), A. Ananthakrishna (India), T. Matsuo (Japan). The above gentlemen signed the memorandum of agreement for the formation of a World Electric Vehicle Association during EVS.9 last November. Cliff Hayden (US), Ferdinand Dierkens (Europe) and D.C. Chan (Asia) have been appointed a steering committee.
Government, Industry and Market
Key Issues

Three Goodness Factor:
Good Products; Good Infrastructure; Good Business Model
Good Products: High Performance @ Reasonable Cost

I: Integration of Automotive Technology and Electrical Technology
A: Alliance among Auto Makers and Key Component Suppliers
Executive Summary

• The train of EV commercialization has taken off. We are seeing the dawn. Key challenges of success: Cost; Usage Convenience; Energy Saving and Emission Reduction. The market will not do it by self. Government incentives are essential at the beginning.

• Innovative Regulatory Leadership is essential. Technical solutions are available. The shake hand and compromise between auto industry and electric power industry is crucial.
The success of commercialization of electric vehicles depends on the satisfactory tackling of four factors:

Initial cost; 成本;
Convenience of use; 方便;
Energy consumption and exhaust emission. 节能减排。

Therefore, we need three goodness factors:

• 1. Availability of **Good Products** at affordable cost; 好产品
• 2. Availability of **Good Infrastructures** that is efficient and friendly to use; 好的基础设施
• 3. Availability of **Good Business Model** to leverage the cost of batteries. 好的商业模式
Changes in Automotive Industry

Assemble Unification

- Internal Combustion Engine Car
  - Engine, Gasoline
  - Engine Car
  - Assemble
  - Parts
  - Materials

- Electric Car
  - Battery, Motor
  - Design
  - Traditional Art & Craft
  - IT Services
  - Venture Capital
  - Trading Company
  - Retail
  - Body Chassis
  - Material
  - Energy
  - Electronics
  - Electric

Closed (inhouse)
Long Span R&D
About 30,000 Parts

Order like Customizable PC

Open ( facto Standard)
Venture, Speed
About 5,000 Parts
History of Electric Vehicles: Rise & Fall 1828 -1932

Early Inventions—Horseless Age
- Thomas Parker EV, 1884, England
- Morris & Salom Electrobat, 1895, U.S.A

Early Commercialization & Infra.
- City Taxi, 1901, New York, U.S.A
- Charging Station, 1900’s, GE, U.S.A

Lessons to Learn: Key Issues:
- Cost,
- Convenient Use
- Fuel Consumption,
- Environment Impact.

Philosophy of Engineering: System Integration and Optimization
Key Points: Open mind; Courage; Yes, It Can Do!
Electric Key Components Play Vital Role in EV/HEV
EV Key Technologies

• Three Big Electricity :
  Motor
  Battery
  Controller

• Three Small Electricity :
  Electric Steering
  Electric Air-conditioning
  Electric Braking
Global EV Development Status
Global EV Population

- In 2014: Total 500,000
  - USA No.1; Japan No. 2; China No. 3
  - Norway per capita No.1, 4EVs/1000 persons, Nation wide charging stations, quick charge along highway per 30-60 km.

- In 2012: Total 380,000
  - Japan No.1; USA No.2; China No.3
<table>
<thead>
<tr>
<th>Country</th>
<th>PEV fleet (Cum sales or registrations)</th>
<th>Population as of December 2013</th>
<th>PEV market penetration per 1,000 people (Dec 2013)</th>
<th>PEV market share of total new car sales in 2013</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>172,000</td>
<td>320,050,716</td>
<td>0.53</td>
<td>0.62%</td>
<td>(a)</td>
</tr>
<tr>
<td>Japan</td>
<td>74,124</td>
<td>127,143,577</td>
<td>0.58</td>
<td>0.85%</td>
<td>(b)</td>
</tr>
<tr>
<td>China</td>
<td>38,592</td>
<td>1,385,566,537</td>
<td>0.03</td>
<td>0.08%</td>
<td>(c)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>28,673</td>
<td>16,759,229</td>
<td>1.71</td>
<td>5.37%</td>
<td>(d)</td>
</tr>
<tr>
<td>France</td>
<td>28,560</td>
<td>64,291,280</td>
<td>0.44</td>
<td>0.65%</td>
<td>(e)</td>
</tr>
<tr>
<td>Norway</td>
<td>20,486</td>
<td>5,042,671</td>
<td>4.04</td>
<td>5.60%</td>
<td>(f)</td>
</tr>
</tbody>
</table>

Note: Plug-in electric vehicle fleets include only highway-capable vehicles except where noted in comments. French and Norwegian registrations do not include plug-in hybrids.

Comments: (a) Sales between 2008 and December 2013. Includes only plug-in electric passenger cars. (b) Sales since July 2009 through December 2013. Kei cars not included for market share estimate. Includes plug-in electric cars and all-electric utility vans. (c) New energy vehicle sales between 2011 and 2013. Includes a significant number of all-electric buses. (d) Registrations between 2009 and December 2013. Includes plug-in cars and all-electric commercial vans. (e) Registrations between 2010 and December 2013. Includes only all-electric cars and 11,304 utility vans. Market share is 0.49% if only all-electric cars are considered. (f) Registrations between 2003 and December 2013. Includes only all-electric cars, vans and over 1,500 heavy quadricycles.
## EV Market Share

### Top 10 countries by market share of new car sales in 2013 by electric-drive segment\(^{(a)}\)

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Country</th>
<th>PEV market share (%)</th>
<th>Ranking</th>
<th>Country</th>
<th>BEV market share (%)</th>
<th>Ranking</th>
<th>Country</th>
<th>PHEV market share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Norway</td>
<td>6.10%</td>
<td>1</td>
<td>Norway</td>
<td>5.75%</td>
<td>1</td>
<td>Netherlands</td>
<td>4.72%</td>
</tr>
<tr>
<td>2</td>
<td>Netherlands</td>
<td>5.55%</td>
<td>2</td>
<td>Netherlands</td>
<td>0.83%</td>
<td>2</td>
<td>Sweden</td>
<td>0.41%</td>
</tr>
<tr>
<td>3</td>
<td>Iceland</td>
<td>0.94%</td>
<td>3</td>
<td>France</td>
<td>0.79%</td>
<td>3</td>
<td>Japan</td>
<td>0.40%</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>0.91%</td>
<td>4</td>
<td>Estonia</td>
<td>0.73%</td>
<td>4</td>
<td>Norway</td>
<td>0.34%</td>
</tr>
<tr>
<td>5</td>
<td>France</td>
<td>0.83%</td>
<td>5</td>
<td>Iceland</td>
<td>0.69%</td>
<td>5</td>
<td>United States</td>
<td>0.31%</td>
</tr>
<tr>
<td>6</td>
<td>Estonia</td>
<td>0.73%</td>
<td>6</td>
<td>Japan</td>
<td>0.51%</td>
<td>6</td>
<td>Iceland</td>
<td>0.25%</td>
</tr>
<tr>
<td>7</td>
<td>Sweden</td>
<td>0.71%</td>
<td>7</td>
<td>Switzerland</td>
<td>0.39%</td>
<td>7</td>
<td>Finland</td>
<td>0.13%</td>
</tr>
<tr>
<td>8</td>
<td>United States</td>
<td>0.60%</td>
<td>8</td>
<td>Sweden</td>
<td>0.30%</td>
<td>8</td>
<td>United Kingdom</td>
<td>0.05%</td>
</tr>
<tr>
<td>9</td>
<td>Switzerland</td>
<td>0.44%</td>
<td>9</td>
<td>Denmark</td>
<td>0.28%</td>
<td>9</td>
<td>France</td>
<td>0.05%</td>
</tr>
<tr>
<td>10</td>
<td>Denmark</td>
<td>0.29%</td>
<td>10</td>
<td>United States</td>
<td>0.28%</td>
<td>10</td>
<td>Switzerland</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Note: \(^{(a)}\) Market share of highway-capable electric-drive vehicles in the corresponding segment as percentage of total new car sales in the country in 2013.

### Sales of highway-capable new electric cars in China by model between 2011 and March 2014

<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Chery QQ3 EV</td>
<td>11,528</td>
<td>25.4%</td>
<td>2,016</td>
<td>4,207[b]</td>
<td>5,305</td>
<td></td>
</tr>
<tr>
<td>JAC J3 EV</td>
<td>6,731</td>
<td>14.8%</td>
<td>163</td>
<td>2,500</td>
<td>2,485</td>
<td>1,585[c]</td>
</tr>
<tr>
<td>BYD e6</td>
<td>4,287[d]</td>
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<td>2,091</td>
<td>613</td>
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<td></td>
<td>1,201</td>
<td>613</td>
</tr>
<tr>
<td>BYD Qin</td>
<td>2,526</td>
<td>5.6%</td>
<td>2,384</td>
<td></td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>BAIC E150 EV</td>
<td>1,354</td>
<td>3.0%</td>
<td>710</td>
<td>644</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zotye TD100 EV</td>
<td>845</td>
<td>1.9%</td>
<td></td>
<td>845</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAIC Roewe E50</td>
<td>648</td>
<td>1.4%</td>
<td>4</td>
<td>406</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>Zotye M300 EV</td>
<td>354</td>
<td>0.8%</td>
<td>220</td>
<td>134</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venucia e30</td>
<td>246</td>
<td>0.6%</td>
<td>30</td>
<td>216</td>
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<td></td>
</tr>
<tr>
<td>Zotye Zhidou E20</td>
<td>142</td>
<td>0.3%</td>
<td></td>
<td>142</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chang'an CX30 EV</td>
<td>100</td>
<td>0.2%</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAIC Senova EV</td>
<td>52</td>
<td>0.1%</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai-GM Springo</td>
<td>11</td>
<td>0.02%</td>
<td></td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zotye T200 EV</td>
<td>8</td>
<td>0.02%</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesla Model S</td>
<td>2</td>
<td>0.004%</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chevrolet Volt</td>
<td>2</td>
<td>0.004%</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total sales[e][7][8][9][1]</strong></td>
<td><strong>45,445</strong></td>
<td><strong>71.5%</strong></td>
<td><strong>6,853</strong></td>
<td><strong>17,642</strong></td>
<td><strong>12,791</strong></td>
<td><strong>8,159</strong></td>
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</table>

Notes: (a) Market share as percentage of the 45,445 new electric vehicles sold between 2011 and March 2014. (b) Only includes sales between January and October 2013[e] (c) Includes units sold during 2010 and 2011[e] (d) BYD e6 total includes 33 units sold in 2010. F3DM total includes 417 units sold in 2010 and 48 in 2009[e][8][9] (e) Total annual sales figures include all-electric bus sales.

Sources:
China EV Development Strategy
Pressure on Energy & Environment

Beijing Tian An Men Square
1950                             2014

London Bridge
1950                             2014

Oil Consumption & Energy Saving

2014/12/17
# China Road Map of New Energy Vehicles

<table>
<thead>
<tr>
<th>Period</th>
<th>Now~2020年</th>
<th>2020年~2030年</th>
<th>2030年~2050年</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Force</td>
<td>PM2.5为主</td>
<td>Mainly Energy Conservation</td>
<td>Mainly CO2 Reduction</td>
</tr>
<tr>
<td></td>
<td>Mainly PM2.5 Reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Mark</td>
<td></td>
<td>Gas production exceed oil</td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
<td>Focus on Bus, Taxi, Logistic, Small EV,</td>
<td>EVs in various applications</td>
<td>Large scale hydrogen fuels and fuel cells; Increase in biofuels</td>
</tr>
<tr>
<td>Penetration %</td>
<td>2%</td>
<td>10% - 15%</td>
<td>50%</td>
</tr>
</tbody>
</table>

By 2020 focus on emission; By 2030 on fossil fuel consumption.
Chinese Electric Mobility Achievement

Chinese Transportation System Structure
“Points-lines-Areas” model

Points—larger city
- New energy bus
- 25000 vehicles
- Number 1 in the world

Areas—town
- E-bike
- 200 millions units
- Number 1 in the world

Lines—city-city
- High-speed train
- 9356km electric railway
- Number 1 in the world
China Vehicle Fuel Consumption reach max in 2030

来源：《中国车用能源展望2012》清华大学中国车用能源研究中心
In 2017 if New Energy Vehicles penetration will be 3%, it will contribute 13% of total vehicles emission.
Under the constrain of CO₂ emission, considering various fuels, sedan annual production maintain at 300 million. If EV popular, than China can afford 100 million more vehicles.
# Sales of highway-capable new electric cars in China by model between 2011 and March 2014

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**Total sales[5][6][8][9][10] 45,445 71.5% 6,853 17,642 12,791 8,159**

Notes: (a) Market share as percentage of the 45,445 new electric vehicles sold between 2011 and March 2014. (b) Only includes sales between January and October 2013. (c) Includes units sold during 2010 and 2011. (d) BYD e6 total includes 33 units sold in 2010. F3DM total includes 417 units sold in 2010 and 48 in 2009. (e) Total annual sales figures include all electric bus sales.

Sources:
Huapu: Mini EV, used as mini public transport in Hangzhou.

Jianghuai: Same price as corresponding ICE

Beijing Auto: Series E. Optimized performance & cost

BYD: E6 Crossover

2013 Sales in sequence: Huapu, Jianghui, Beijing Auto, BYD, Chang An, Cherry
HEV/EV Architecture
Typical Hybrid Powertrain

✓ Planetary Gear Power Split

Power-split is Toyota and Ford's mainstream configuration scheme, with multiple HEV models produced and promoted to PHEV.
Typical PHEV Powertrain

- Four wheel drive

Volvo V60 PHEV

| Gross Weight | 1724kg |
| Engine       | 160kW/440Nm |
| Real Axis Motor | 52kW/200Nm |
| Battery      | 12Wh |
| Electric Range | 50km |

PSA 3008 PHEV

- PSA 3008 PHEV
- BMW i8 PHEV

- 四驱电桥方案也被多家公司采用，典型的为PSA公司，该构型易于PHEV化；
- 在原有混动技术基础上加入电驱动桥实现PHEV，也是国内值得重点研究的技术方案。
Honda Accord Plug-in

**Typical Sedan PHEV Powertrain**

- Two Electric Machines Drive

**i-MMD Structure**

<table>
<thead>
<tr>
<th>Features:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Integration of Transmission &amp; Motor/Gen;</td>
</tr>
<tr>
<td>2) Motor &amp; Generator different gear ratio;</td>
</tr>
</tbody>
</table>

**Honda Accord Plug-in**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Weight</td>
<td>1724kg</td>
</tr>
<tr>
<td>Engine</td>
<td>105kW/165Nm</td>
</tr>
<tr>
<td>Motor</td>
<td>124kW/307Nm</td>
</tr>
<tr>
<td>Generator</td>
<td>105kW</td>
</tr>
<tr>
<td>Generator Gear Ratio</td>
<td>8.38</td>
</tr>
<tr>
<td>Motor Gear Ratio</td>
<td>2.74</td>
</tr>
<tr>
<td>Battery</td>
<td>6.7kWh/41kW</td>
</tr>
<tr>
<td>Electric Range</td>
<td>20km</td>
</tr>
<tr>
<td>Fuel Consumption (FTP75)</td>
<td>CD阶段 2.03L/100km</td>
</tr>
<tr>
<td></td>
<td>CS阶段 5.06L/100km</td>
</tr>
</tbody>
</table>

**i-MMD技术应用于本田雅阁PHEV车型，是本田全新开发的高效混动系统；**

**通过创新高效的构型方案，是国内OEM取得技术优势的可选之路。**
Typical Chinese Hybrid Bus Powertrain

Without AMT

Diesel / Gas Engine

High torque motor direct drive

12 m Bus Oil Consumption 20L/100 km, oil saving over 40%
Range Extender Bus

Range Extender Configuration

Pure Electric Mode
SOC: 100% ~ 60%

APU Assisted Mode
SOC: 60% ~ 30%

APU Mode
SOC: 30%
Improving battery technology and light-weighting has enabled EVs to emerge from Niche to potential mainstream vehicles

<table>
<thead>
<tr>
<th>Model</th>
<th>Year</th>
<th>Price</th>
<th>Battery Type</th>
<th>Motor Power</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>REVA G-Wiz</td>
<td>2008</td>
<td>~ $16,000</td>
<td>270 kg PbA battery</td>
<td>13 kW</td>
<td>50 miles range</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitsubishi i-MiEV</td>
<td>2010</td>
<td>~ $50,000</td>
<td>200 kg Li-ion battery</td>
<td>80 kW</td>
<td>80 miles range</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>2011</td>
<td>$33,000</td>
<td>272 kg Li-ion battery</td>
<td>80 kW</td>
<td>100 miles range</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM EV1</td>
<td>1996-2002</td>
<td>$34,000 (lease)</td>
<td>300 kg NiMH (Gen-2) battery</td>
<td>102 kW</td>
<td>140 miles range</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesla Roadster</td>
<td>2008</td>
<td>$109,000</td>
<td>450 kg Li-ion battery</td>
<td>185 kW</td>
<td>221 miles range</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesla Model S</td>
<td>2012</td>
<td>$57,000 – 77,000</td>
<td>540 kg Li-ion battery</td>
<td>~ 200 kW</td>
<td>160 to 300 miles range</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tesla

**Tesla-Roadster**

**Tesla-Model S**

**Tesla-Model X**

**60 kWh Battery**

- 208 miles range (EPA)
- 302 hp
- 5.9 seconds 0-60 mph
- 120 mph top speed
- 8 year, 125,000 mile battery warranty
- Supercharging and 19" tire upgrade optional

**Dashboard**

- 17” Touchscreen

**Induction Motor**

**Battery Package**
### Development Platform & Modularization

<table>
<thead>
<tr>
<th>Toyota Hybrid System</th>
<th>Lexus</th>
<th>Ford</th>
<th>Nissan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota</td>
<td>Yaris</td>
<td>CT200h</td>
<td>Fusion</td>
</tr>
<tr>
<td></td>
<td>Prius</td>
<td>ES300h</td>
<td>Altima</td>
</tr>
<tr>
<td></td>
<td>Camry</td>
<td>GS300h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Avalon</td>
<td>RX400h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highlander</td>
<td>LS400hL</td>
<td></td>
</tr>
</tbody>
</table>

#### VW电动汽车方案

- **HEV**
  - TSI/TDI+P2+DQ400+HV电池

- **短里程PHEV**
  - TSI/TDI+P2+DQ400+PHEV电池

- **长里程PHEV+4WD**
  - TSI/TDI+P2+DQ400+PHEV电池 + 纯电驱动桥

- **BEV**
  - 纯电驱动桥+EV电池
Spectrum of New Energy Vehicles

From TOYOTA

Cruising Speed

ICE · HV · PHV Area

FCHV Area

Heavy duty

FCHV-BUS

Rote bus

Delivery truck

Driving distance

Fuel

Electricity

Gasoline/Diesel/Bio-fuel/CNG/GTL/CTL etc.

Hydrogen

EV Area

Short commuter

Motor cycle

TOYOTA PHV

Passenger car

TOYOTA FCHV-adv

Small delivery

Winglet

i series

Express train

Railway

LRT

From TOYOTA
Battery Technology
新能源汽车发展的技术支撑

动力电池技术 Road Map of Battery Technology

持续提升磷酸铁锂、锰酸锂、三元等正极材料和硬碳、硅基等负极材料的先进制备技术和工艺，攻关功能电解液、高安全性隔膜等高性能动力电池的关键技术，支持锂离子电池材料行业的技术进步；

组织国内的优势研发机构，跨领域联合开展新一代高容量锂离子正负极材料和以锂聚合物电池锂硫、锂空气、钠空气为代表的新型体系电池深度的基础研究和制造技术工艺研究开发，在下一代电池和材料发展过程中形成我国的高价值专利。
Li / Li-Ion: “New” Anode and Cathode Materials: Larger Capacities and/or Higher Voltage

Cathode materials: Lithium/Li-ion

- $x\text{Li}_2\text{MnO}_3/(1-x)\text{LiMO}_2$ ($M = \text{Mn, Ni, Co,}$…)
- LiCoPO$_4$
- LiNi$_{0.5}$Mn$_{1.5}$O$_2$
- LiMnPO$_4$
- Li$_2$FeSiO$_4$, organic cathodes

Anode materials: Lithium/Li-ion

- Li$_4$Ti$_5$O$_{12}$
- Graphite
- Sn/C composites
- Si/C composites
- Sn metal
- Li metal
- Si

Capacity / Ah kg$^{-1}$

Battery Anode Research in MEET | Pengfei Gao | November 2013
Waste Management System Reduc
Research on Battery Safety

- Composite Separator & Short Circuit Protection
- Voltage Sensitive Separator & Over Charge Protection
- Safety Electrode Materials & Self Temperature Protection
- Ionic Liquids & Safety Composite Electrolyte
- Battery Safety Design
Motor Drives Technology
Typical Torque-Speed Characteristics
Motor Design /新能源汽车电机设计流程

Electromagnetic Design
电机电磁设计

Rotor Stress Analysis
转子应力分析

Structure Analysis
部件结构分析

Fluid Analysis/ 流体动态分析

Thermal Analysis/热分析

Mobility Analysis
车辆动态机壳变形校核
EV Infrastructure
### Features of EV Charging

**Complex Systems**: Involved science, technology, engineering, industry, finance and business model.

**Connected**: The charging plug is connected to the grid, affect the grid at various levels. Unlike the gas station is decoupled with oil pipeline.

**Dynamics**: The charging has instant impact to the grid, unlike the gas station has no impact to the pipeline.

**Interactive**: The mode of charging, the status of the grid and the status of the batteries are mutually interactive.

**Integration**: V2G, Active Distributed Power Systems, Smart City.....

**Key issues**: Integration of energy and information, win-win situation to grid, battery and user.
### Good Infrastructure: Efficient & Convenience

<table>
<thead>
<tr>
<th></th>
<th>AT HOME</th>
<th>PUBLIC AREA</th>
<th>WORK PLACE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parking Durations</strong></td>
<td>14 hrs per day</td>
<td>2 hrs per day</td>
<td>7 hrs per day</td>
</tr>
<tr>
<td><strong>Charging Points</strong></td>
<td>1 charging point per vehicle</td>
<td>&lt; 0.5 charging point per vehicle</td>
<td>1 charging point per vehicle</td>
</tr>
<tr>
<td><strong>Power &amp; Charging Time Requirements</strong></td>
<td>Low power and normal charging (e.g. 3kW, 10 hrs)</td>
<td>High power and quick charging (e.g. 22 kW, 2 hrs)</td>
<td>Low power and normal charging (e.g. 3kW, 7 hrs)</td>
</tr>
</tbody>
</table>
EV Charging Infrastructure Solution
Comparison of Gas Station & Storage Quick Charging

- Traditional Petroleum Underground Storage Tanks
- Advanced Battery Pack Electric Storage Banks
  Available for Peak Load Demand Using Renewable and/or Off Peak Power
AC charger (100V/200V) for daily use
DC charger (rapid charging) for emergency use
Battery Swapping
Smart Battery Charging, Swapping, Delivery Network

- **AC charging**
  - Long charging time

- **DC charging**
  - Battery technology does not support fast charging
  - Grid cannot sustain fast charging

- **Battery swapping**
  - Immediate replenishment of electricity
  - Easy battery maintenance and longer life
Inductive Charging for Passenger Cars

• Operation in Cherry eQ Evs,
• Range 250 km.

• Operation in Chang An EVs,
• Max power 107 kW.
Inductive Charging for Commercial Vehicles

- Operation in mid size commercial vehicles
- Operation in Chengdu;
- Operation in short distance van;
Inductive Charging for Buses. Unit Power 30kW, Max 300kW

- Power：30kW
- Gap：20cm
- Efficiency：90%
- Space：1 square meter

Operation in Deng Feng Bus in Xiangyang
Intelligent EV Integration
Motivation

**Smart charging**
Charging is delayed or advanced in time based on e.g. energy cost or renewable contents.

**Energy backup**
Advance or postpone charging in time and to deliver the energy back to the grid at a later time.

**Ancillary services**
Continues short-duration charging and discharging operations to balance the grid.
Two Integrations

• Integrate EV with Smart Grid

• Integrate EV with Telemetic / ICT
Smart House:

- Increasing low carbon electricity and reduce peak electricity consumed
- Management of electricity storage by EV and/or Lithium ion battery
Intelligent Electric Vehicles

智能电动汽车
## Human being versus intelligent EVs

<table>
<thead>
<tr>
<th></th>
<th>Human being (intelligent life)</th>
<th>Future intelligent EVs</th>
<th>Note on intelligent EVs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System architecture</strong></td>
<td>Essentially identical but evolving</td>
<td>Diverse at current development stage</td>
<td>Potentially to be optimized for given applications</td>
</tr>
<tr>
<td><strong>Brain (controller)</strong></td>
<td>One</td>
<td>Three: driver; vehicle-oriented; ITS/IV-oriented</td>
<td>Emerging demands in coordinating the 3 ‘brains’</td>
</tr>
<tr>
<td><strong>Energy management</strong></td>
<td>Internal (control management, regen) + external (food, drink, etc)</td>
<td>Internal (control management, regen) + external (charging)</td>
<td>Preliminary stage &amp; potential to optimize</td>
</tr>
<tr>
<td><strong>Thermal management</strong></td>
<td>Internal control + external (clothes, air conditioning, etc)</td>
<td>Internal (control management for different subsystems requirements)</td>
<td>Highly challenging</td>
</tr>
<tr>
<td><strong>Health management</strong></td>
<td>Evolution: millions of years (physical &amp; mental)</td>
<td>Very new topic; hardware &amp; software (control systems)</td>
<td>Emerging &amp; critical</td>
</tr>
<tr>
<td><strong>Performance envelope</strong></td>
<td>Clear performance envelope &amp; limitations while in slow evolution</td>
<td>Clear performance envelope &amp; limitations while in rapid development</td>
<td>Advances in key components &amp; system integration</td>
</tr>
<tr>
<td><strong>Status of system synergy</strong></td>
<td>Optimal &amp; evolving</td>
<td>Very preliminary at current development stage</td>
<td>Significant potential &amp; benefit to be synergised</td>
</tr>
</tbody>
</table>
Unmanned Ground Vehicles (UGVs) in DARPA (Defense Advanced Research Projects Agency) Grand/Urban Challenge

- Grand Challenge 2005
- Stanford Stanley

- Urban Challenge 2007
- CMU, Tartan
Intelligent Vehicle
Smart Mini EV
SUCCESS
SUCCESS
SUCCESS
Thank you!