Renaissance and Global EV Development

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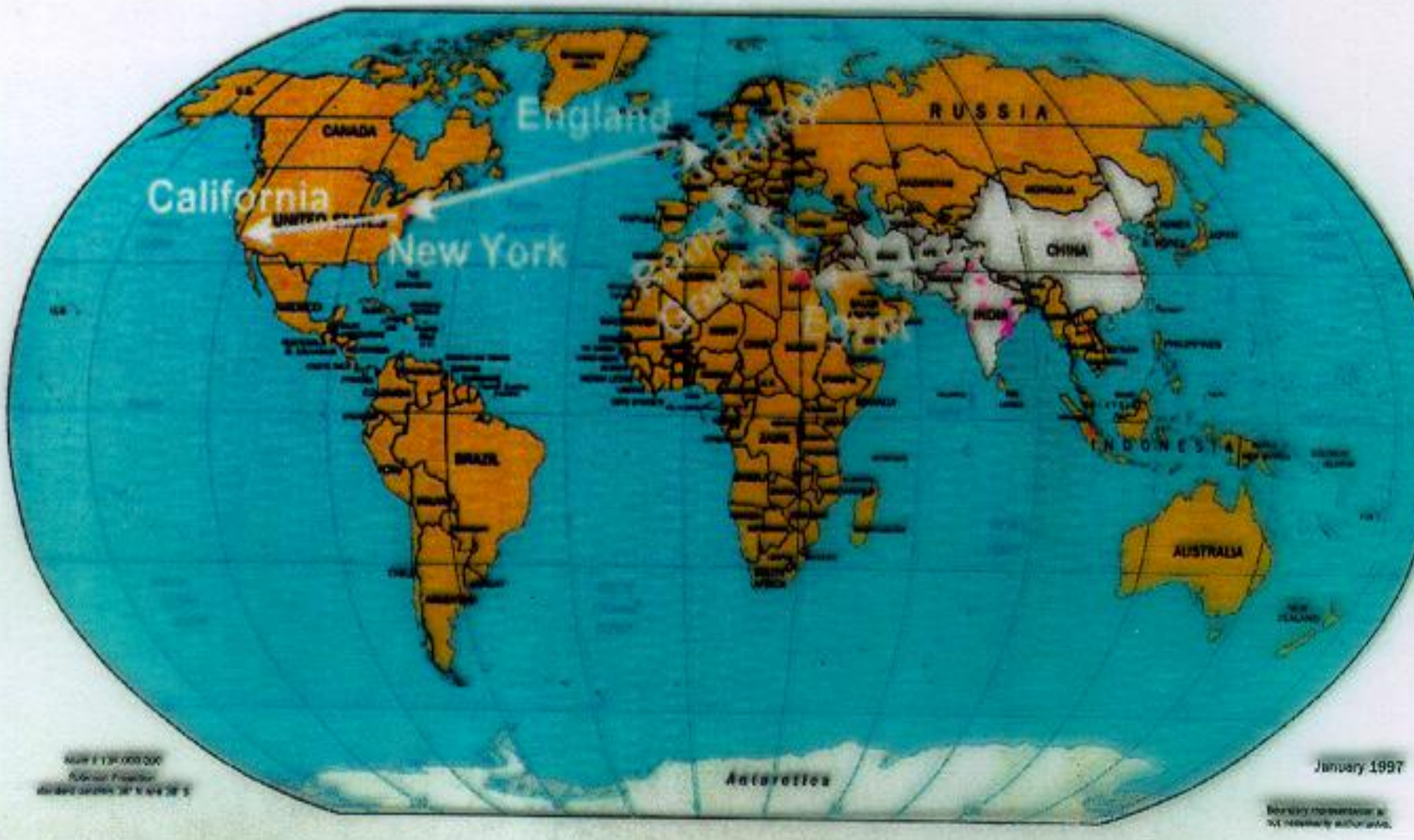
Founding President, World Electric Vehicles Association

Fuel Choices Global Summit

December 3-4, 2014
Tel-Aviv, Israel

Civilization & Open Mind

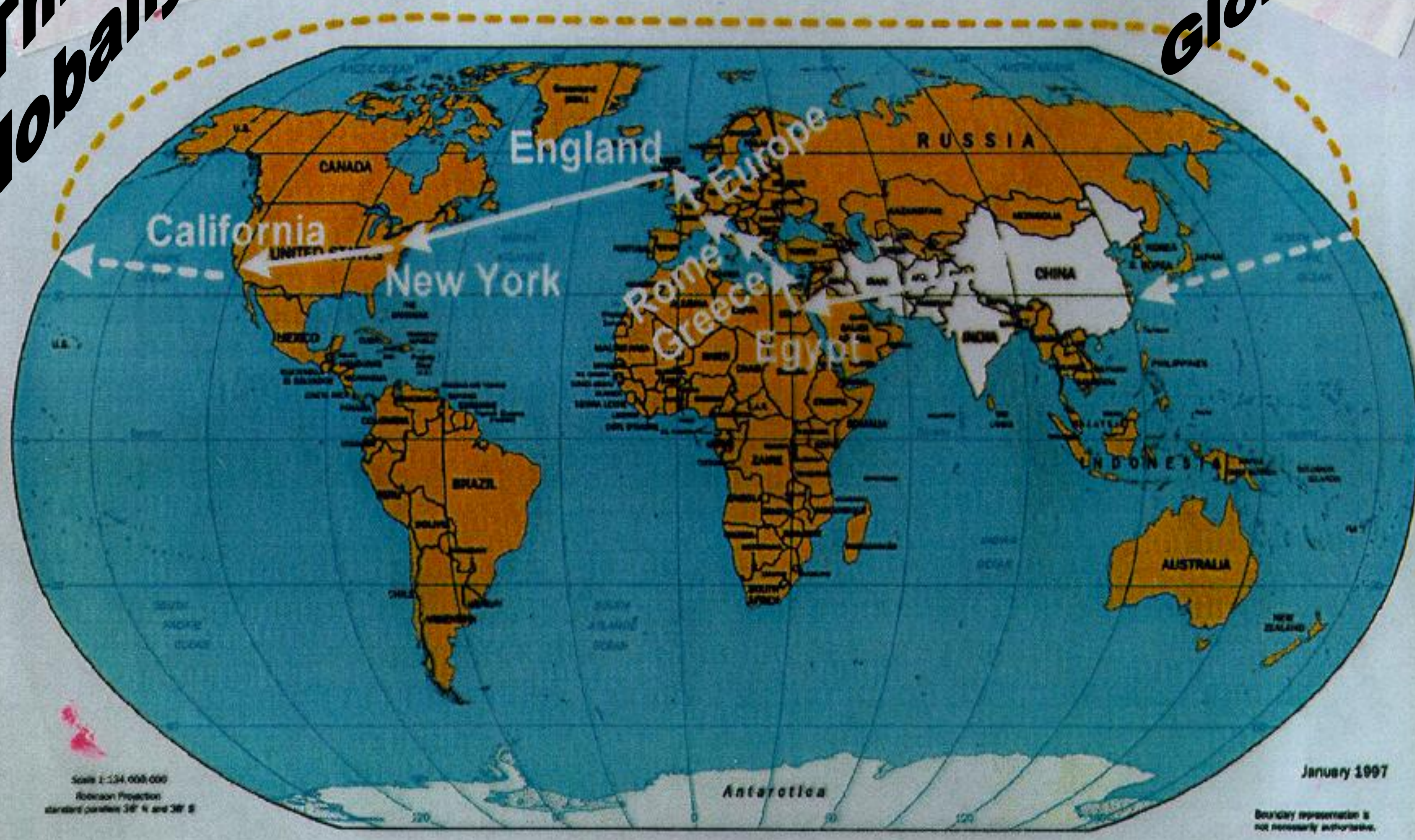
Civilization / Technology
Migration of Center of Gravity



Think Globally

Civilization / Technology
Migration of Center of Gravity

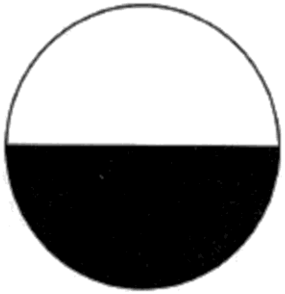
Act Globally

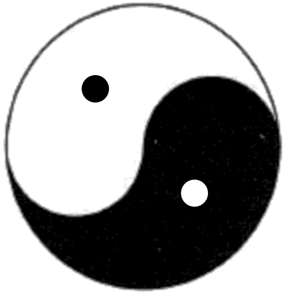


Yi-jing basic principles:
Change, Periodic, Balance, Unity of Opposites

Straight Forward Approach

Holistic, Dialectic Approach



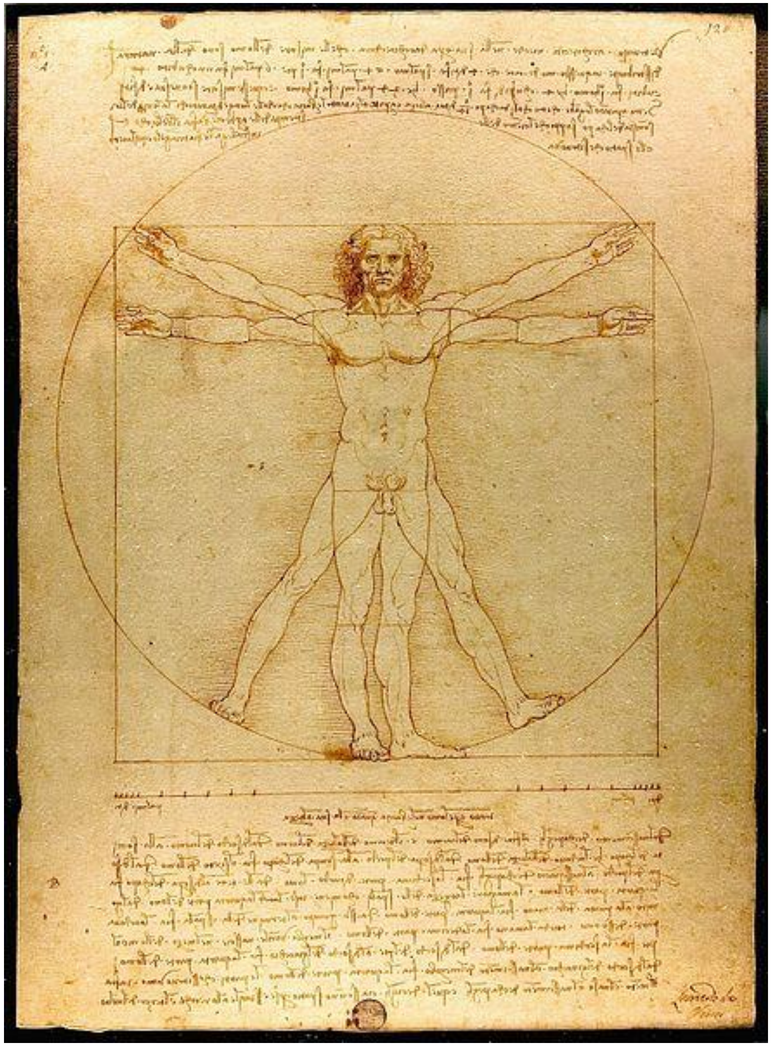


” “Yes” is “Yes”
“No” is “No”

“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

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

16th November 1988

Memorandum of Understanding

1 The undersigned, representing throughout the world a large majority of the organizations and people who, in their respective countries, undertake the development of electric road vehicles or, more generally, electric propulsion, indicate by this memorandum their desire to join forces and share their experiences.
Therefore they resolve to convene within the framework of a worldwide organization, the aims and structure of which are described hereunder.

2 The aims of the worldwide organization are:
- to facilitate the exchange of information which encourages the development of electric vehicles;
- to coordinate the schedule of "EVS" symposia to be held once every two years and, by rotation, in the three geographical zones: American continent, Asia and Pacific, Europe and Africa
Using this principle, EVS 10 will be held in the Asia-Pacific zone and EVS 11 in the Europe-Africa zone, following EVS 9 in Canada
This world organization has strictly no authority over national or regional meetings but specifically reserves all rights for future "EVS" worldwide symposia, avoiding, by appropriate contacts, duplication and fruitless competition

3 To establish this world organization and achieve the above aims, avoiding costly administration, Canada has been asked to help for an initial period and has graciously agreed to provide a centralised Secretariat, under the direction of a Steering Committee composed of a limited number of representatives of the three geographical zones nominated by the organization active in electric vehicle development within these zones

This Steering Committee is entrusted to propose as soon as possible general working rules for the world organization, to the success of which the undersigned are committed and for which they pledge to devote benevolently their utmost efforts.

Toronto, Canada
November 15, 1988.

16 novembre 1988

DÉCLARATION

1 Les personnalités soussignées, représentant sur le plan mondial une large majorité des organismes et personnes participant dans leur pays respectif ou zone d'influence au développement du véhicule électrique routier ou de façon plus générale des engins de propulsion électrique, marquent par le présent mémorandum leur volonté de joindre leurs efforts et de partager leur expériences..

C'est pourquoi ils conviennent de se rencontrer au sein d'un organisme à l'échelle mondiale dont les buts et la structure sont définis ci-après.

2 Les buts de cet organisme sont :

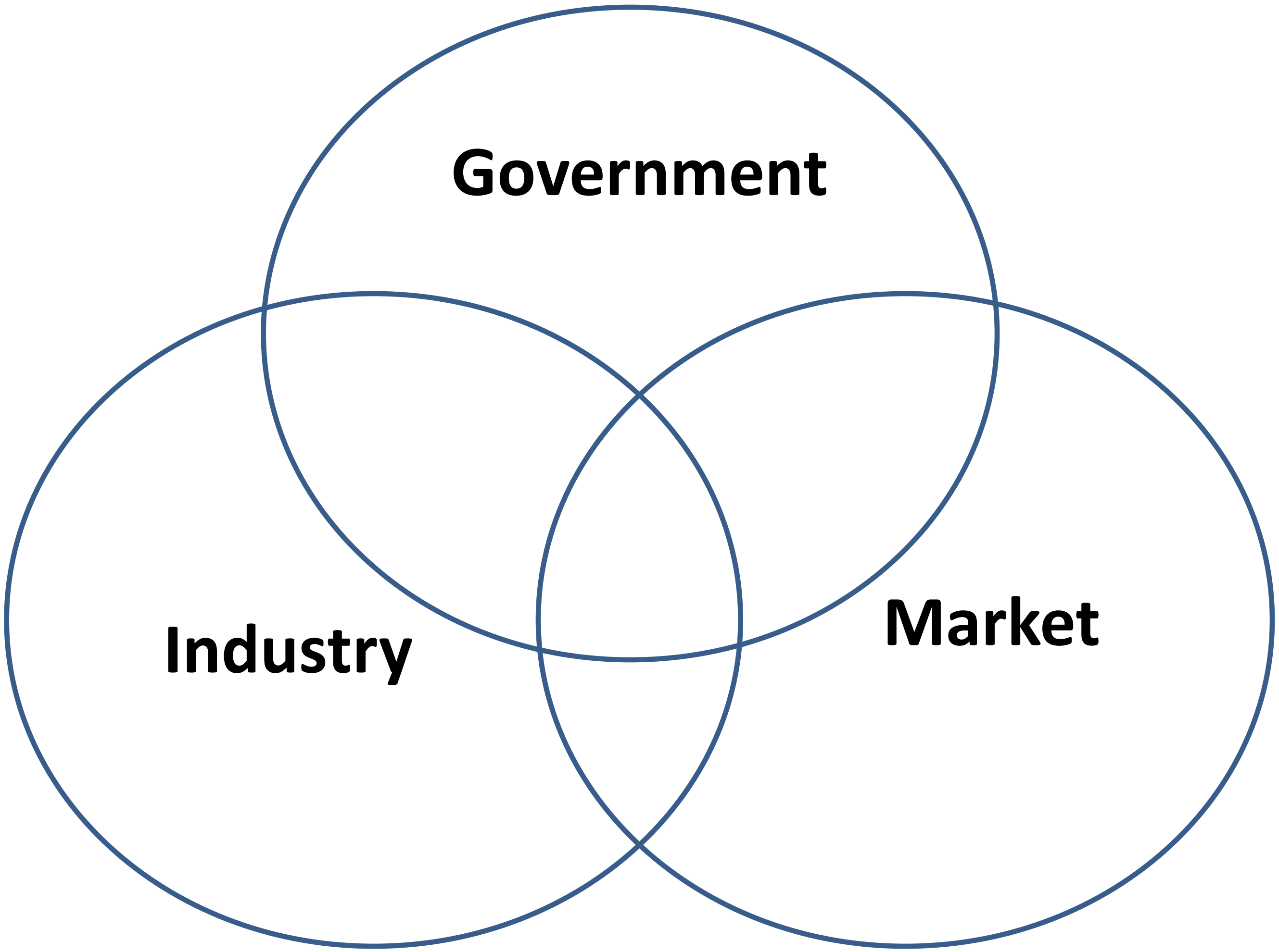
- de faciliter l'échange de toutes informations susceptibles de favoriser le développement du véhicule électrique;

- de coordonner l'organisation des symposium "E.V.S." au rythme d'un tous les deux ans, par rotation entre les trois zones géographiques : continent américain, Asie-Pacifique, Europe-Afrique. Ce principe de rotation entraînera l'organisation d'E.V.S. 10 dans la zone Asie-Pacifique et d'E.V.S. 11 dans la zone Europe-Afrique, après EVS 9 tenu au Canada.

MEMORANDUM SIGNED FOR WORLD ELECTRIC VEHICLE ASSOCIATION

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 Dr. C. Chan (Asia) have been appointed a steering committee.

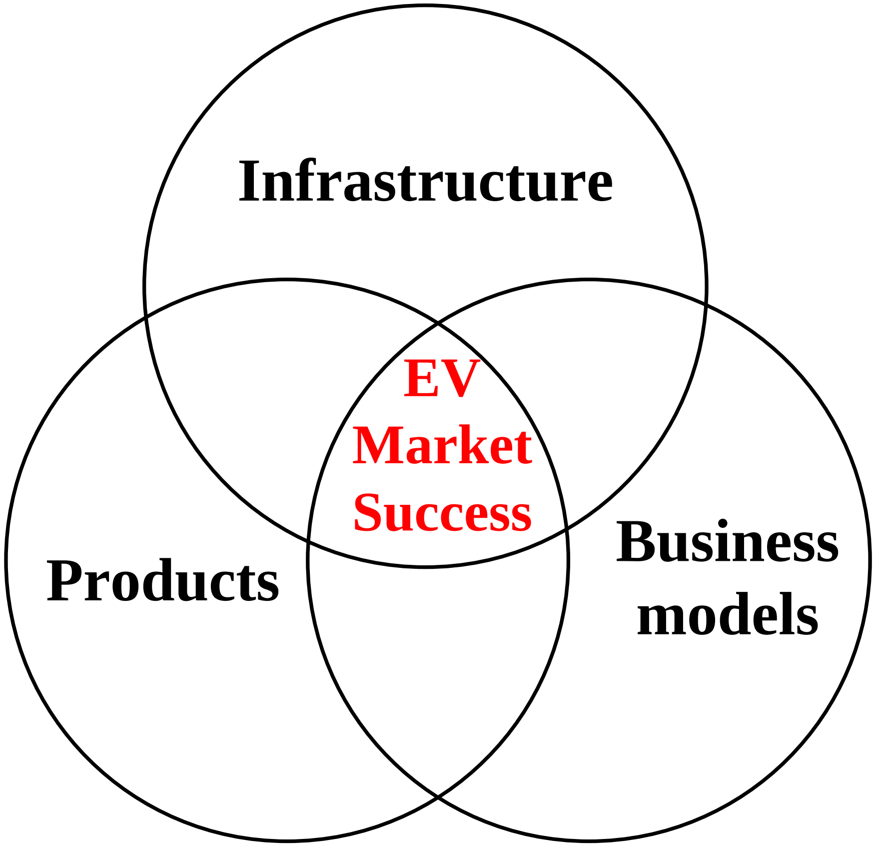
Government, Industry and Market



Key Issues

Three Goodness Factor :

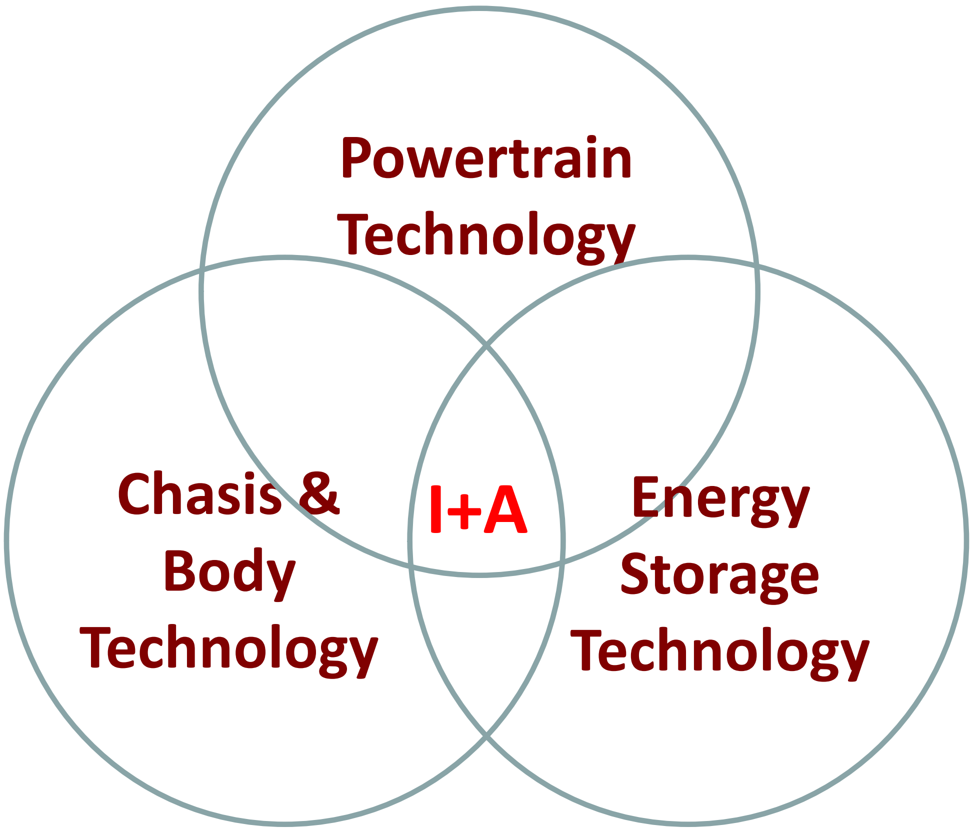
Good Products; Good Infrastructure; Good Business Model



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.**

Key Issues – Three Goodness

关键因素 – 三好因素

The success of commercialization of electric vehicles depends on the satisfactory tackling of four factors:

Initial cost; 成本；

Convenience of use; 方便；

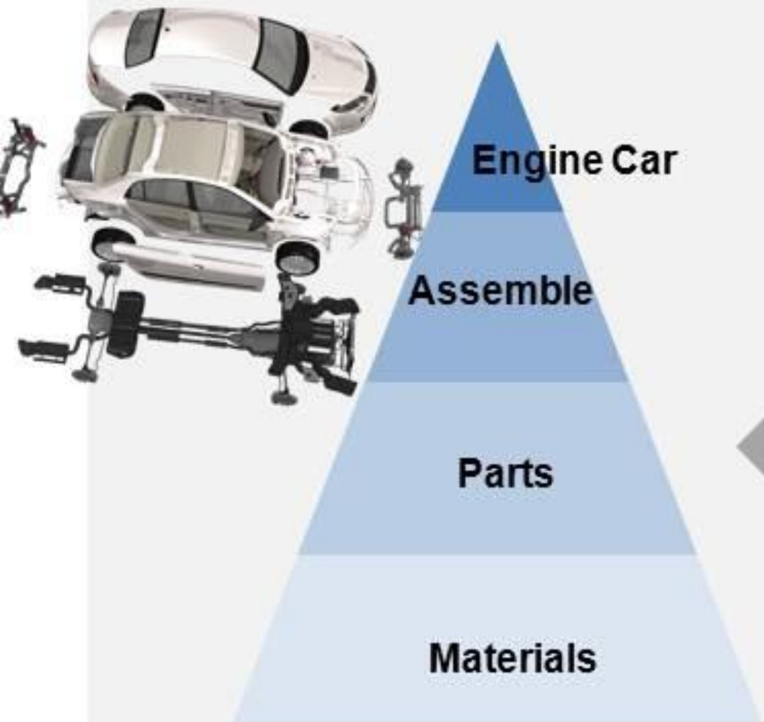
Energy consumption and exhaust emission. 节能减排。

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**

Internal Combustion Engine Car

Engine, Gasoline

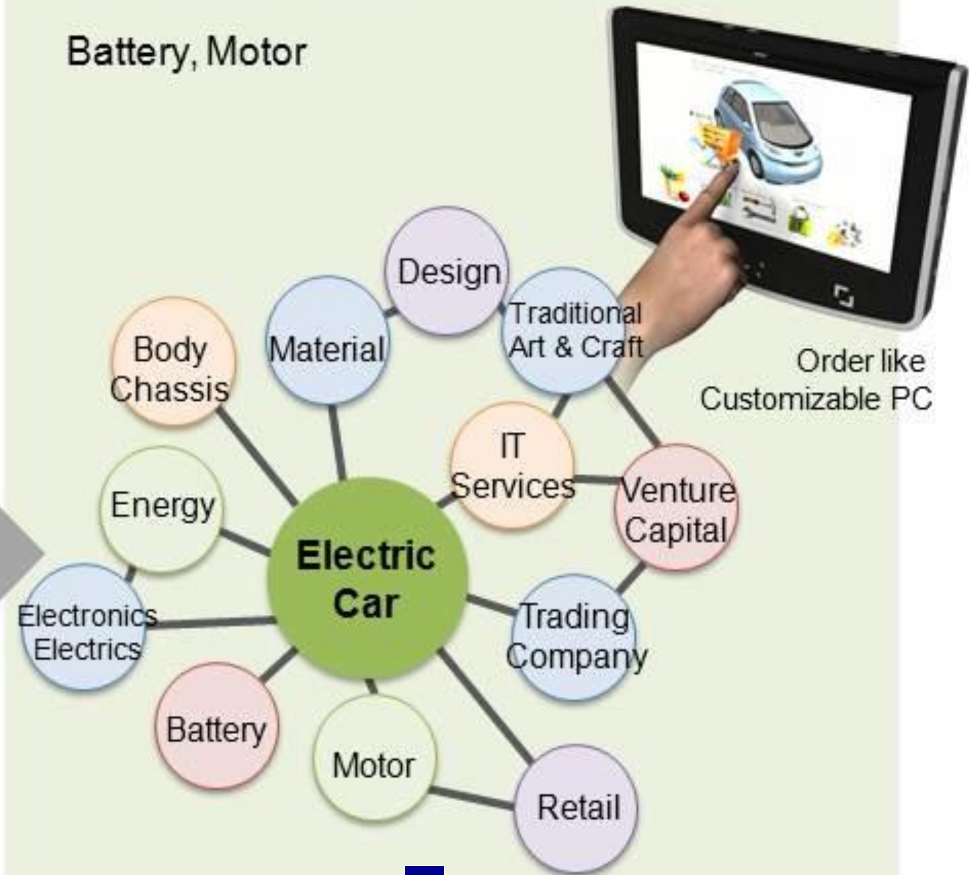


Unification

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

Electric Car

Battery, Motor



Assemble

facto Standard)
Venture, Speed
About 5,000 Parts

History of Electric Vehicles: Rise & Fall 1828 -1932

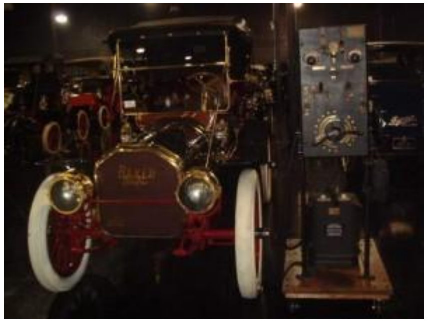
- Early Inventions–Horseless Age

Thomas Parker EV, 1884, England

Morris & Salom Electrobat 1895, U.S.A

- Early Commercialization & Infra.

City Taxi, 1901, New York, U.S.A

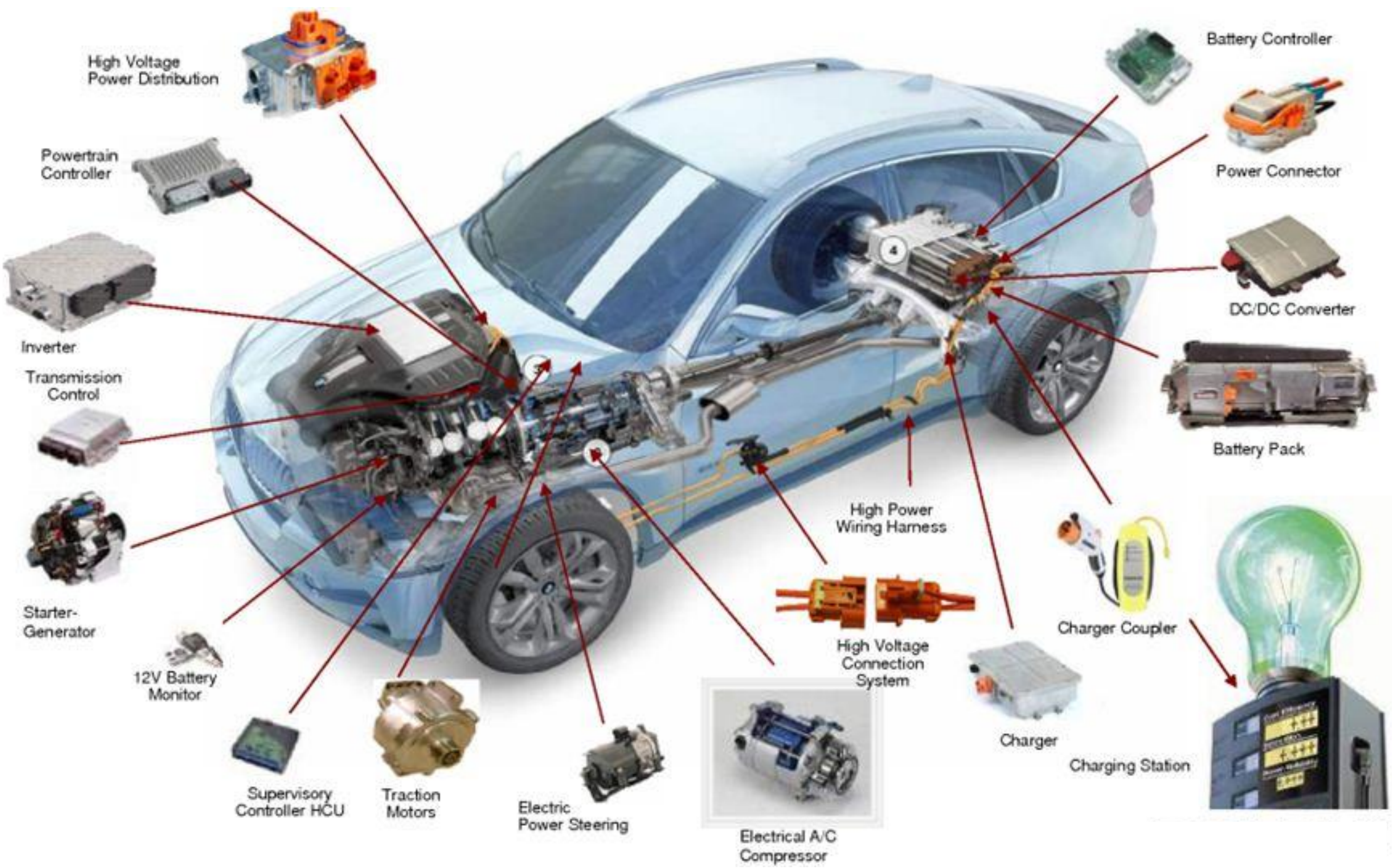


Charging Station, 1900's GE, U.S.A

- 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

Global Electric Vehicles Population

Country	PEV fleet (Cum sales or registrations)	Population as of December 2013	PEV market penetration per 1,000 people (Dec 2013)	PEV market share of total new car sales in 2013	Comments
United States	172,000	320,050,716	0.53	0.62%	(a)
Japan	74,124	127,143,577	0.58	0.85%	(b)
China	38,592	1,385,566,537	0.03	0.08%	(c)
Netherlands	28,673	16,759,229	1.71	5.37%	(d)
France	28,560	64,291,280	0.44	0.65%	(e)
Norway	20,486	5,042,671	4.04	5.60%	(f)

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

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.
Source: Zachary Shahan (2013-03-07). "Electric vehicle market share in 19 countries". ABB Conversations.

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

Model	Total sales 2011-1Q 2014	Market share(a)	Total Sales 1Q 2014[1]	Total Sales 2013[2][3]	Total Sales 2012[4]	Total Sales 2011[5][6]
Chery QQ3 EV	11,528	25.4%	2,016	4,207(b)	5,305	
JAC J3 EV	6,731	14.8%	163	2,500	2,485	1,585(c)
BYD e6	4,287(d)	9.4%	619	1,544	2,091	401
BYD F3DM	3,284(d)	7.2%		1,005	1,201	613
BYD Qin	2,526	5.6%	2,384	142		
BAIC E150 EV	1,354	3.0%		710	644	
Zotye TD100 EV	845	1.9%			845	
SAIC Roewe E50	648	1.4%	4	406	238	
Zotye M300 EV	354	0.8%		220	134	
Venucia e30	246	0.6%	30	216		
Chery Riich M1 EV	197	0.4%	107		90	
Zotye 5008 EV	142	0.3%			142	
Zoyte Zhidou E20	142	0.3%	142			
Chang'an CX30 EV	100	0.2%			100	
BAIC Senova EV	52	0.1%		52		
Shanghai-GM Springo EV	11	0.02%			11	
Zoyte T200 EV	8	0.02%	8			
Tesla Model S	2	0.004%	2			
Chevrolet Volt	2	0.004%	2			
Total sales(e)[7][8][9][1]	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[3] (c) Includes units sold during 2010 and 2011[6] (d) BYD e6 total includes 33 units sold in 2010. F3DM total includes 417 units sold in 2010 and 48 in 2009[10,11] (e) Total annual sales figures include all-electric bus sales.

Sources:

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[7] Jiang Xueqing (2014-01-11). "New-energy vehicles 'turning the corner'". China Daily. Retrieved 2014-01-12.
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[9] Cars21.com (2013-02-13). "EV sales increase 103.9% in China in 2012- Electric China Weekly No 17". Cars21.com. Retrieved 2014-01-12.
[10] "BYD Delivered Only 33 Units of e6, 417 F3DM in 2010". ChinaAutoWeb. 2011-02-23. Retrieved 2014-05-31.
[11] "BYD Plans to Start European Car Sales Next Year (Update 2)". Bloomberg News. 2010-03-08. Retrieved 2014-05-31. 48 F3DMs were sold in 2009.

China EV Development Strategy

Pressure on Energy & Environment

Oil Consumption & Energy Saving

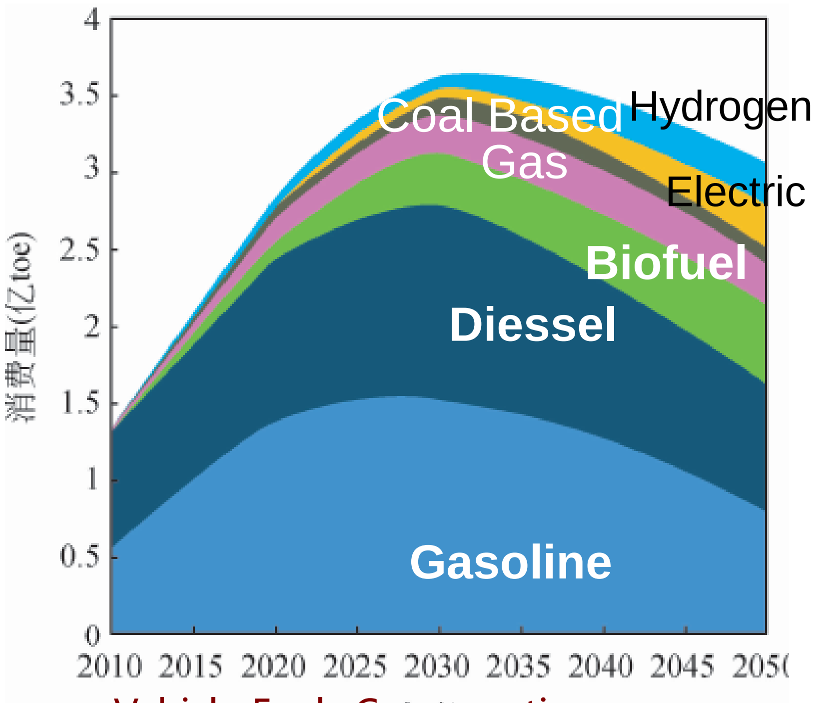
China Road Map of New Energy Vehicles

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

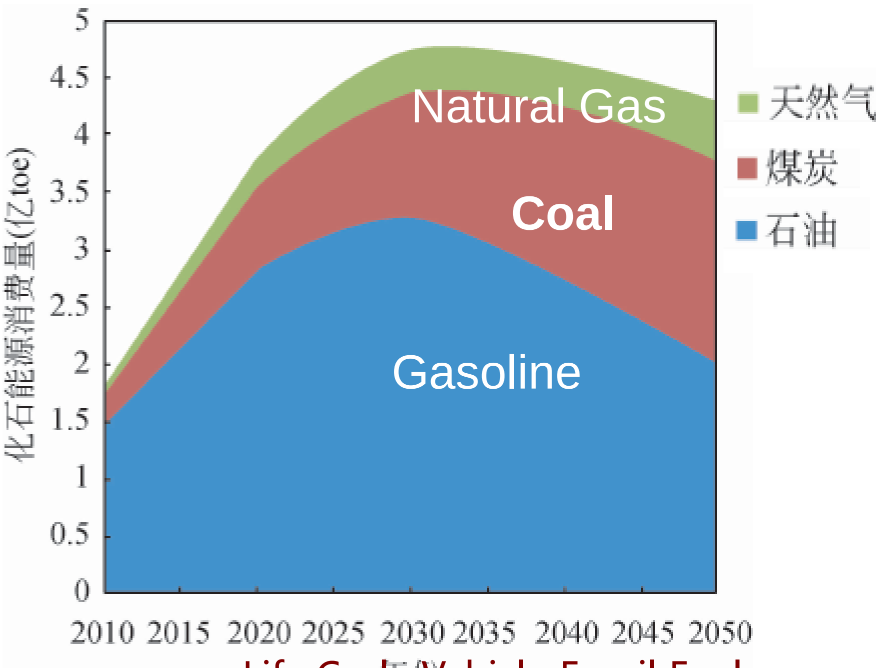
By 2020 focus on emission; By2030 on fossil fuel consumption.

Chinese Electric Mobility Achievement

◆ Contribution of New Energy Vehicles to Energy Consumption



Vehicle Fuels Consumption



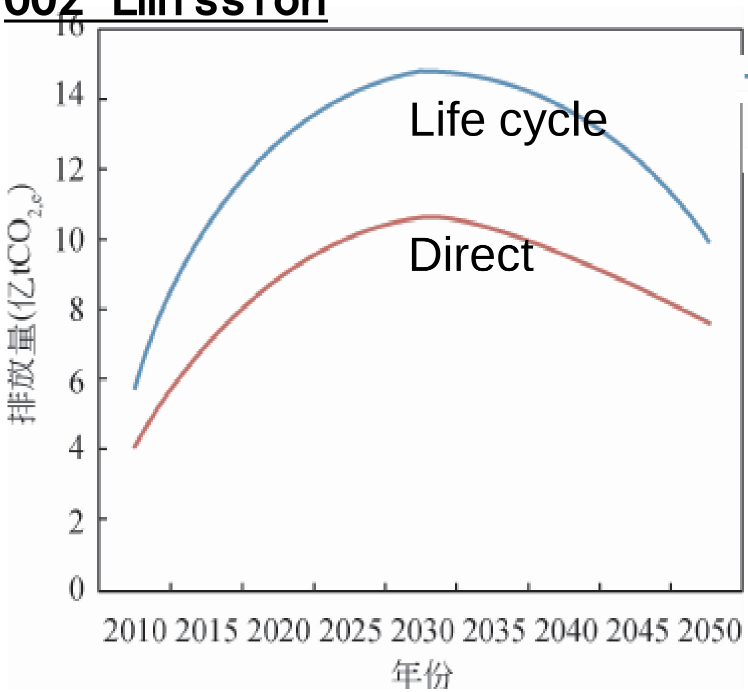
Life Cycle Vehicle Fossil Fuels

China Vehicle Fuel Consumption reach max in 2030年

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

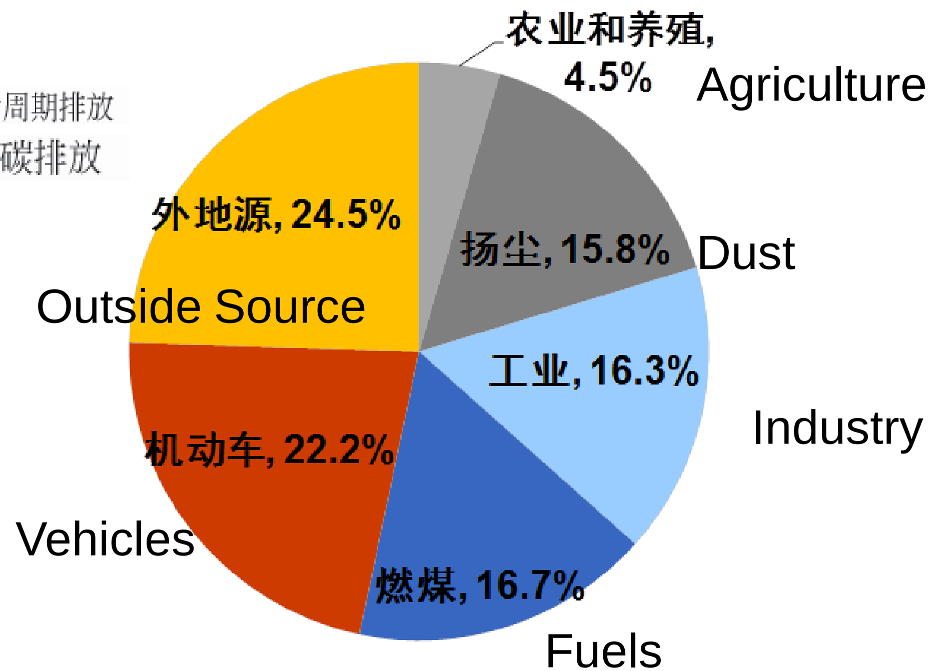
◆ Contribution of New Energy Vehicles to Environment

CO2 Emission



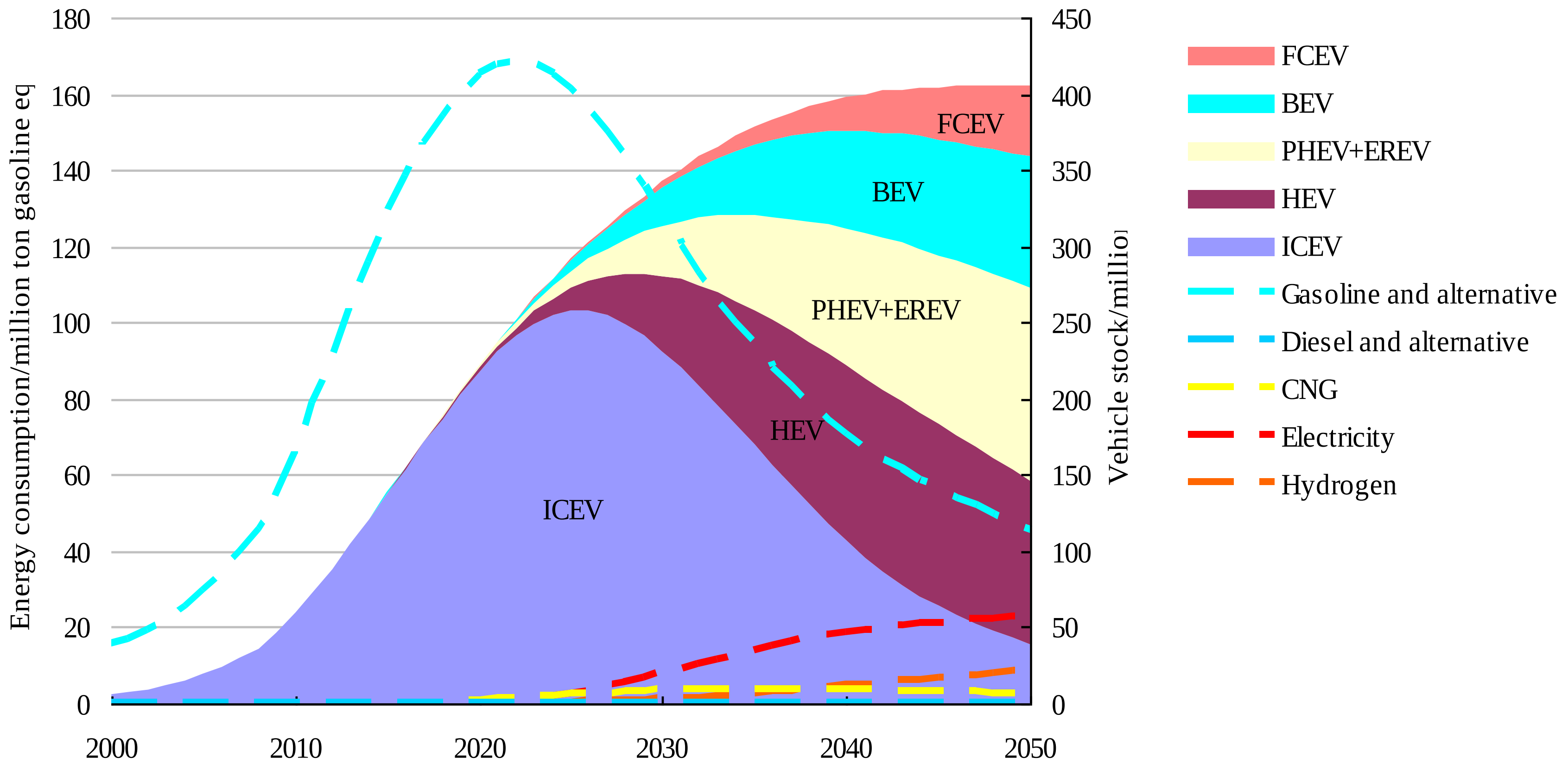
Year 2050WTW CO2 Emission reduces 53.5%左右，per capital vehicle CO2 Emission WTW 0.68 Ton；

Beijing PM2.5 Sopurces



In 2017 if New Energy Vehicles penetration will be 3 %，it will contribute 13% of total vehicles emission

Outlook of China Various Vehicle Types



Vehicle Population and Fuel Consuption

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.

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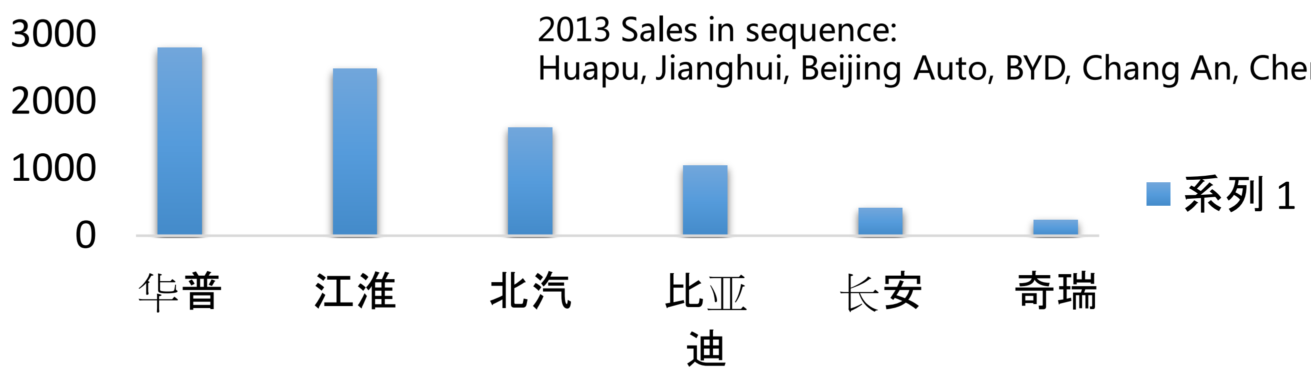
Huapu：
Mini EV, used as mini public transport in Hangzhou.

Jianghuai：
Same price as corresponding ICE

Beijing Auto：
Series E. Optimized performance & cost

BYD：
E6 Crossover

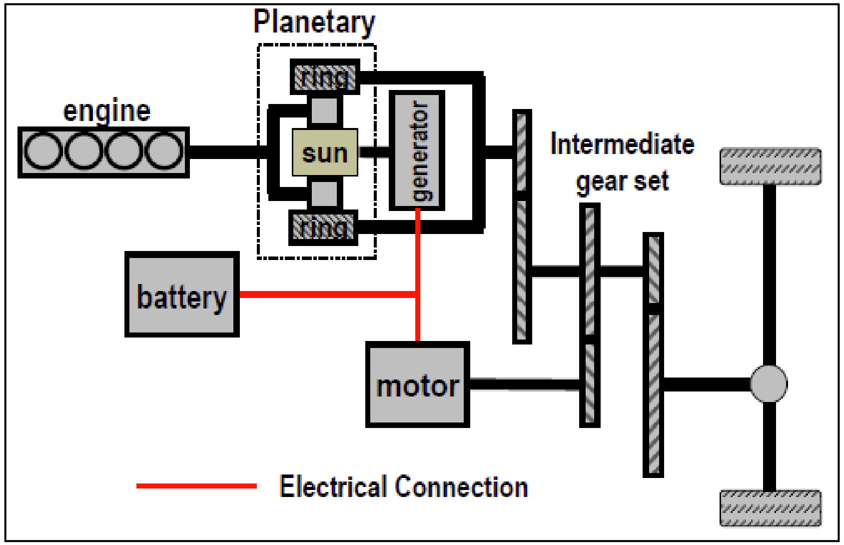
2013 Sales in sequence:
Huapu, Jianghui, Beijing Auto, BYD, Chang An, Cherry



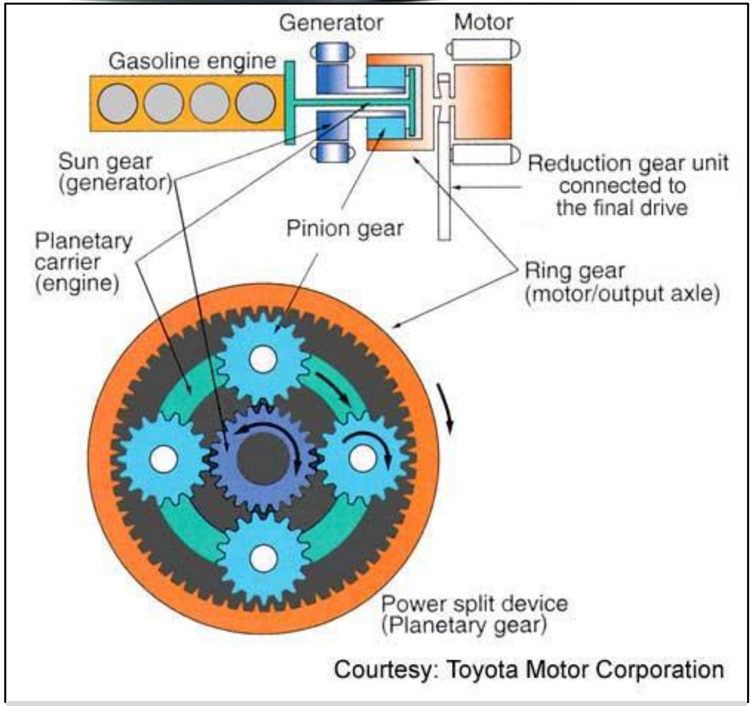
HEV/EV Architecture

Typical Hybrid Powertrain

✓ Planetary Gear Power Split



Ford FHS

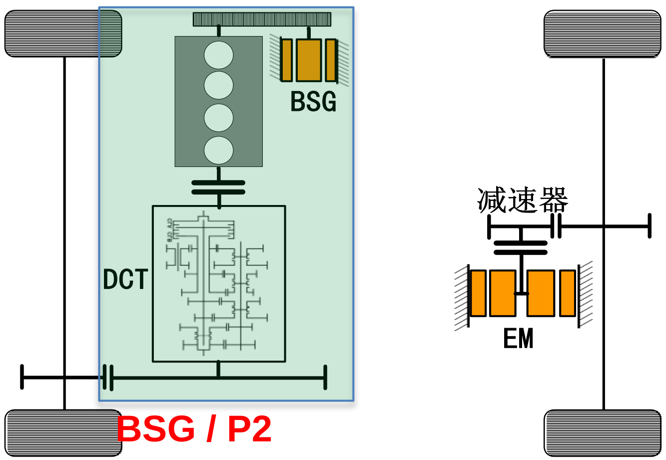


Toyota THS

Power-split是丰田、福特的主流构型方案，已有多款HEV车型量产，并推广到PHEV。

Typical PHEV Powertrain

✓ Four wheel drive



Volvo V60 PHEV

	Volvle V60 PHEV
Gross Weight	1724kg
Engine	160kW/440Nm
Real Axis Motor	52kW/200Nm
Battery	12Wh
Electric Range	50km

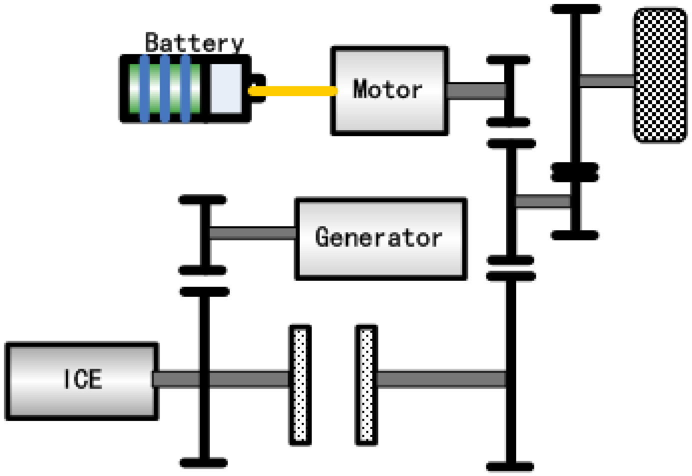
PSA 3008 PHEV

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。

Typical Sedan PHEV Powertrain

✓ Two Electric Machines Drive



i-MMD Structure

		Honda Acxcord Plug-in
Gross Weight		1724kg
Engine		105kW/165Nm
Motor		124kW/307Nm
Generator		105kW
Generator Gear Ratio		8.38
Motor Gear Ratio		2.74
Battery		6.7kWh/41kW
Electric Range		20km
Fuel Consumpion （FTP75）	CD阶段	2.03L/100km
	CS阶段	5.06L/100km

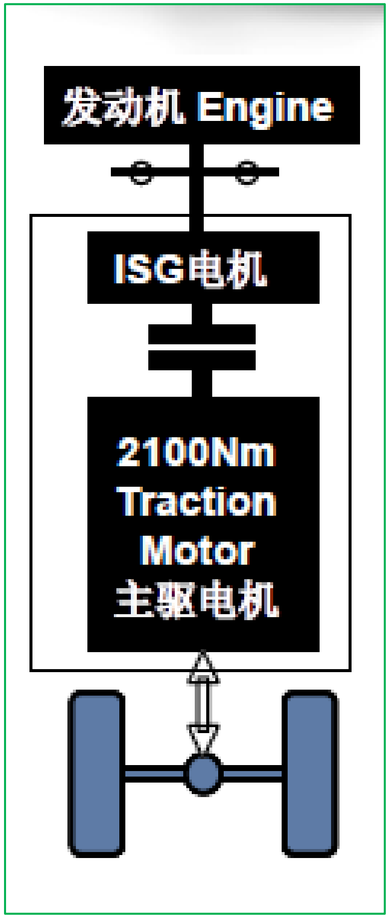
Features:
1） Integration of Transmission & Motor/Gen;
2） Motor & Generator different gear ratio;

- 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。

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

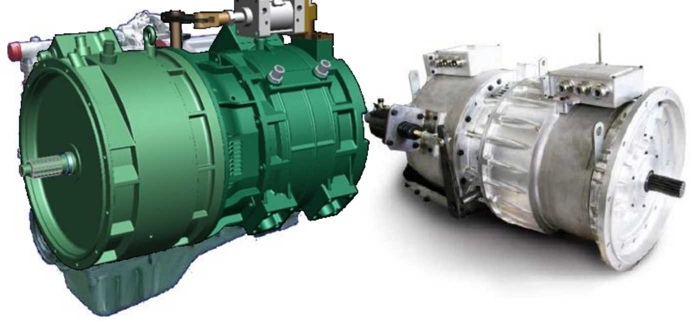
Without AMT



发挥我国永磁同步电机技术优势，取消变速器，用高转矩高效率电机直驱技术打破跨国公司电驱动变速器的垄断

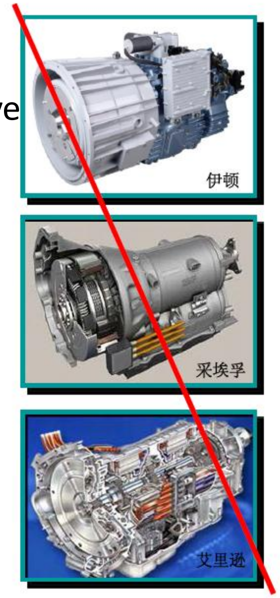
Diesel / Gas Engine

High torque motor direct drive



柴油机或气体燃料发动机

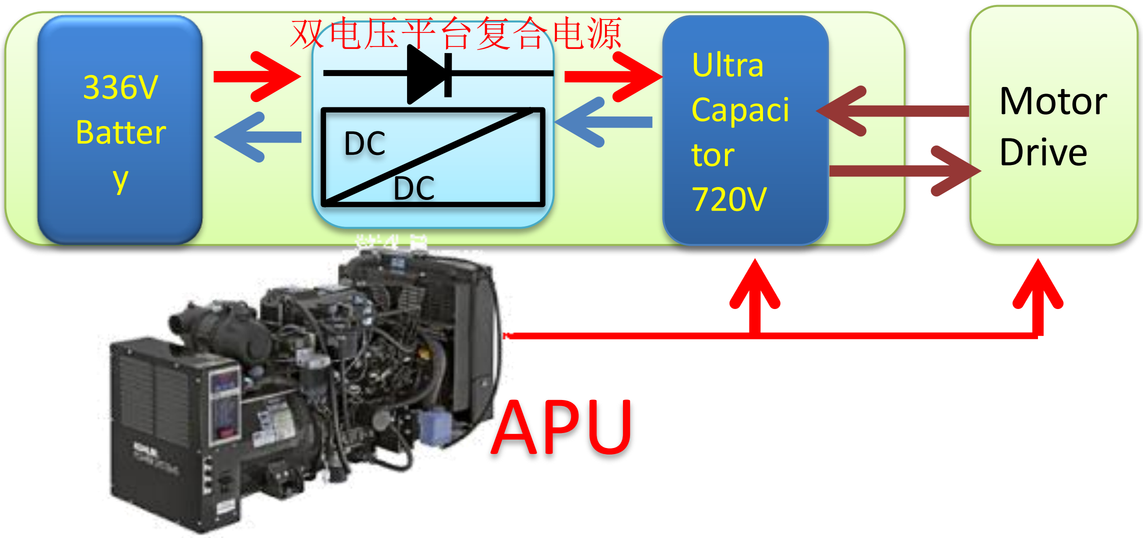
双电机直驱混合动力单元（无变速箱）



12 m Bus Oil Consumtion 20L/100 km, oil saving over40%

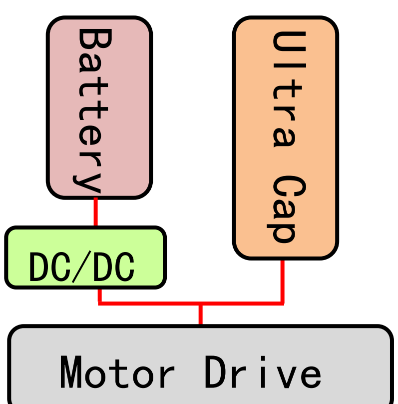
Range Extender Bus

Range Extender Configuration



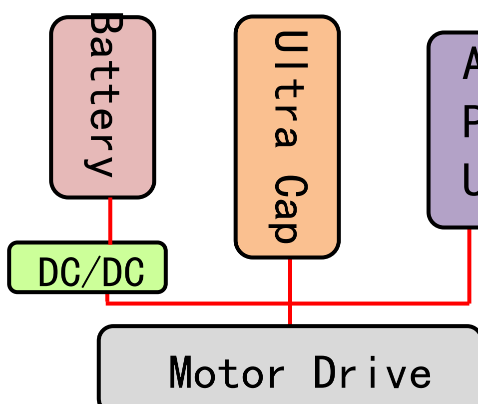
Pure Electric Mode

SOC：100%～60%



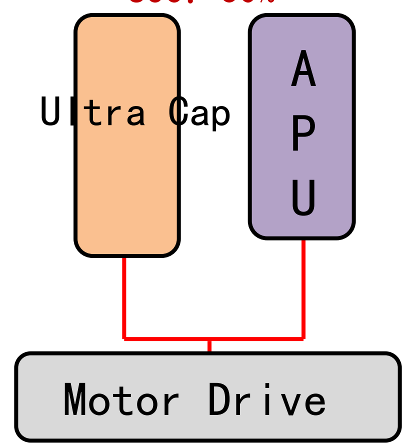
APU Assisted Mode

SOC：60%～30%



APU Mode

SOC：30%



Improving battery technology and light-weighting has enabled EVs to emerge from Niche to potential mainstream vehicles

RICARDO

REVA G-Wiz
(2008)
~ $16,000

- 270 kg PbA battery
- 13 kW motor – 50 miles range

GM EV1
(1996 - 2002)
$34,000 (lease)

- 300 kg NiMH (Gen-2) battery
- 102 kW motor – 140 miles range

Mitsubishi i-MiEV
(2010)
~ $50,000

- 200 kg Li-ion battery
- 80 kW motor – 80 miles range

Tesla Roadster
(2008)
$109,000

- 450 kg Li-ion battery
- 185 kW motor – 221 miles range

Nissan Leaf
(2011)
$33,000

- 272 kg Li-ion battery
- 80 kW motor – 100 miles range

Tesla Model S
(2012)
$57,000 – 77,000

- 540 kg Li-ion battery
- ~ 200 kW motor – 160 to 300 miles range

Tesla

Tesla-Roadster

Tesla-Model S

Tesla-Model X

60 kWh Battery

208 miles range (EPA)

302 hp

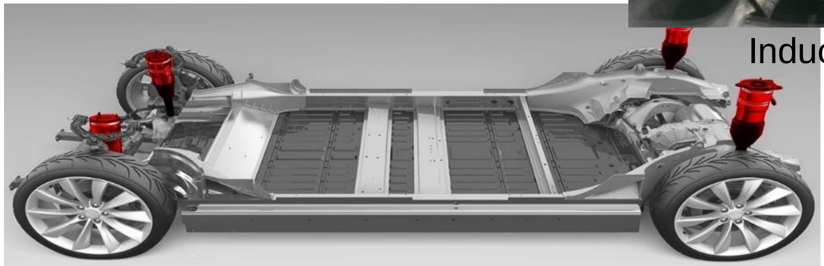
5.9 seconds 0-60 mph

120 mph top speed

8 year, 125,000 mile battery warranty

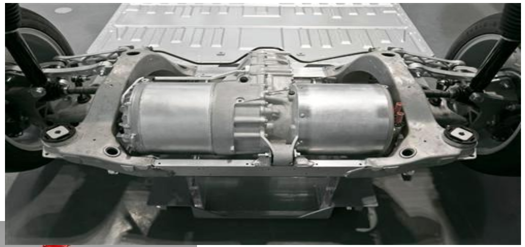
Supercharging and 19" tire upgrade optional

Spec. Tesla-Model S



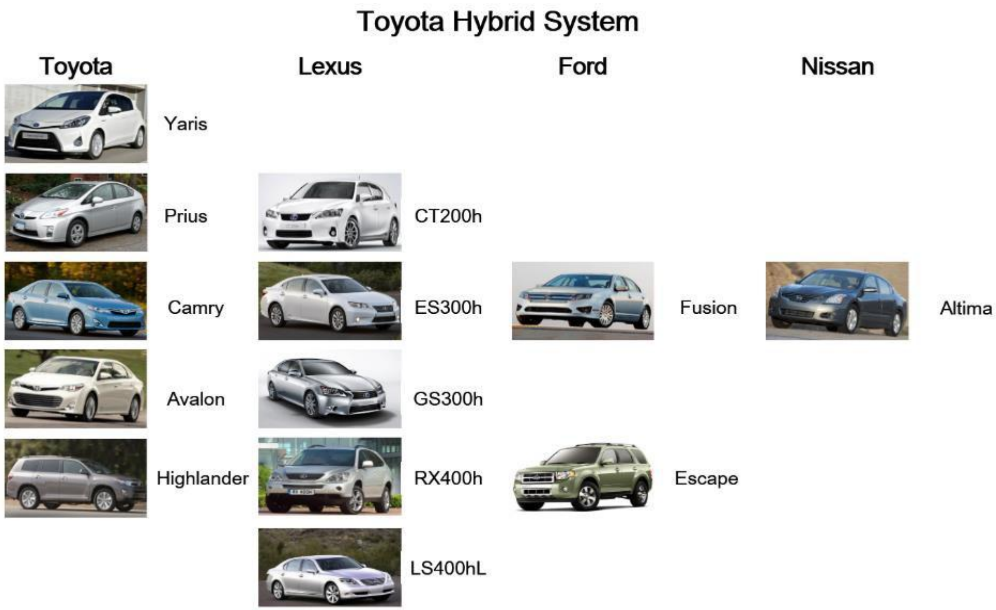
Battery Package

Dashboard-17” Touchscreen

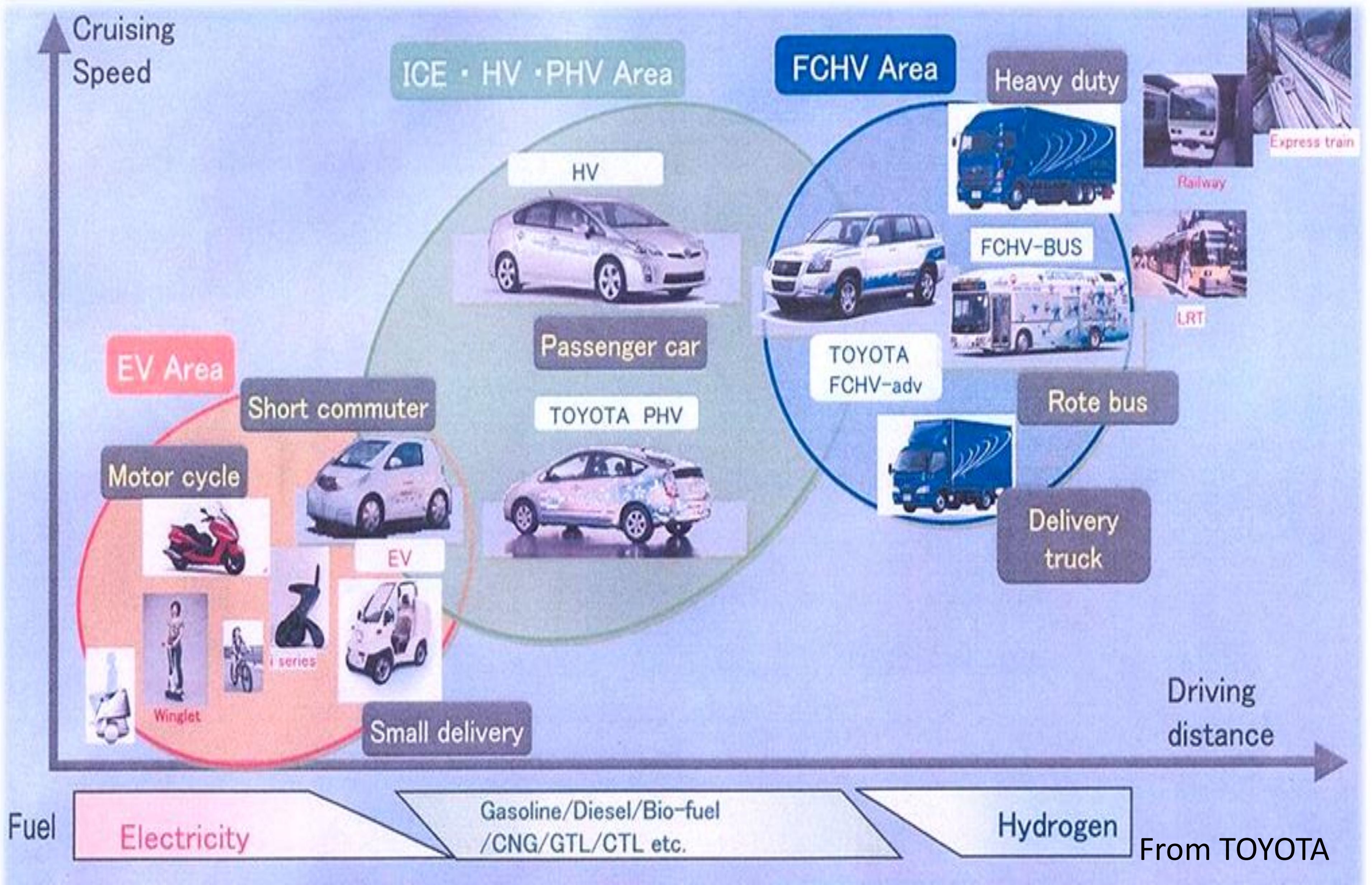


Induction Motor

Development Platform & Modularization



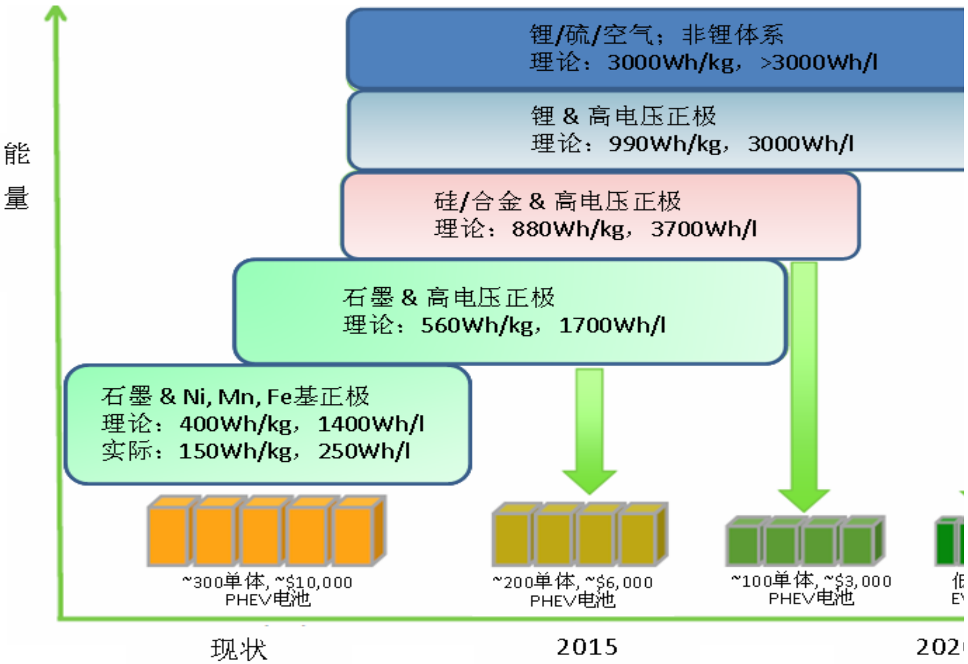
Spectrum of New Energy Vehicles



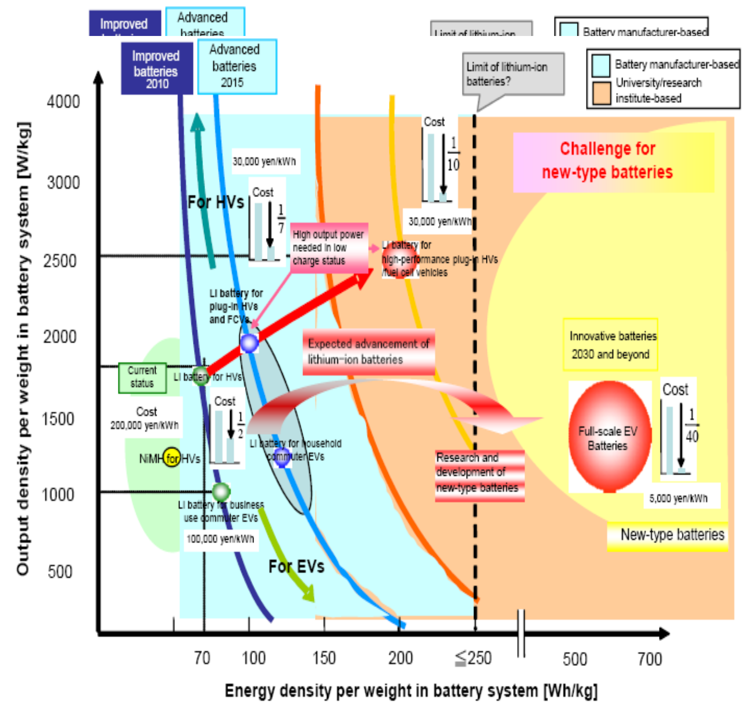
From TOYOTA

Battery Technology

动力电池技术 Road Map of Battery Technology



USA 美国动力蓄电池研发路线图

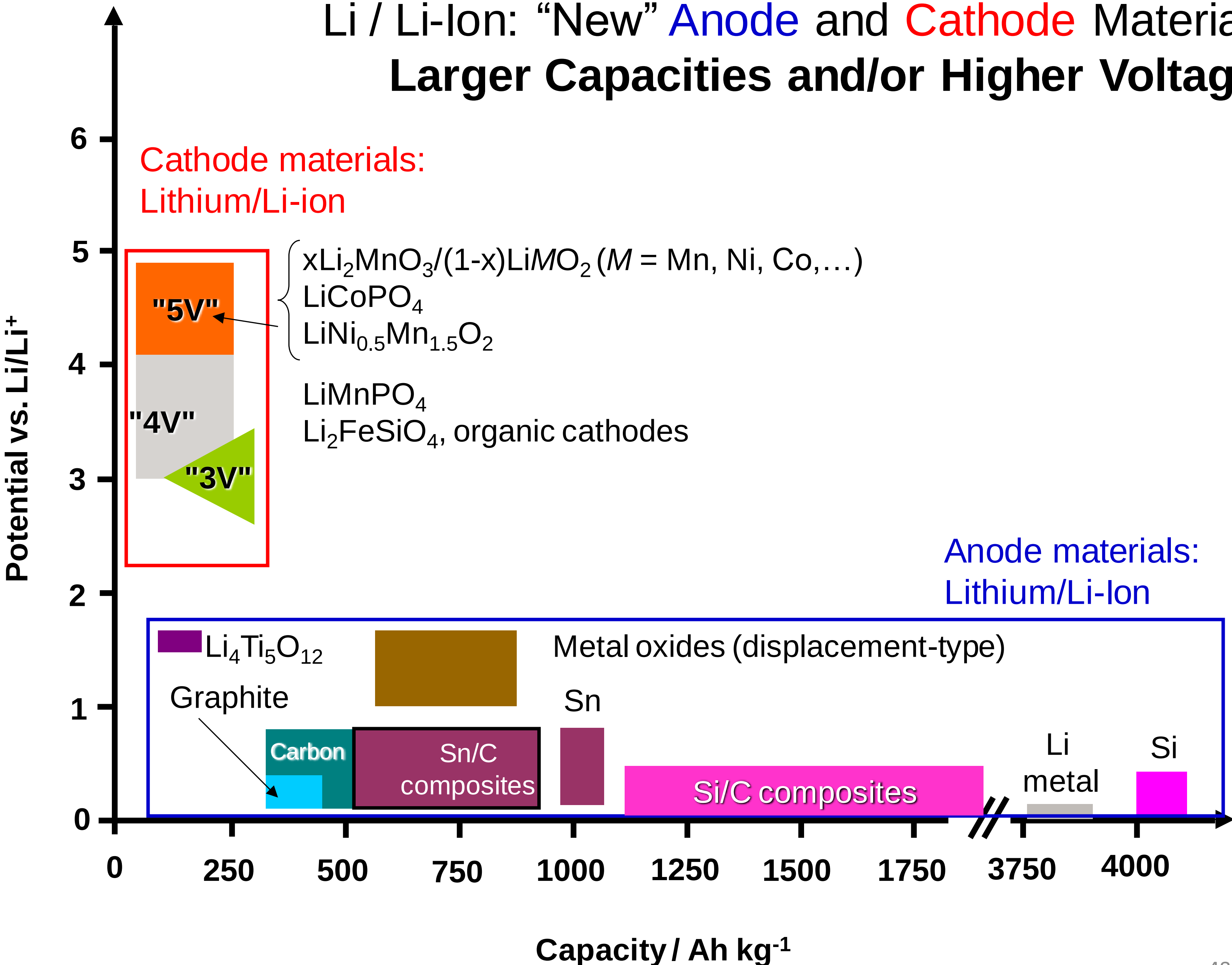


Japan 日本动力蓄电池研发路线图

我国动力电池发展建议：

- 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**



EV Battery System Research

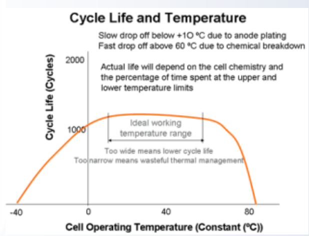
Safetey

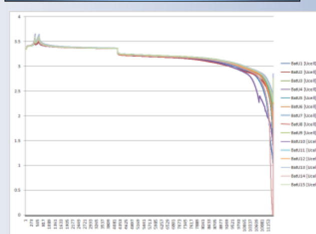
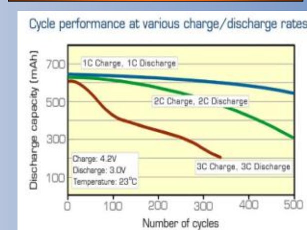
Over heat | Leakage | Contact | Abuse

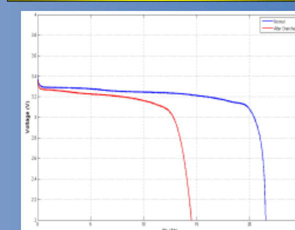



Enduran
ce

High Low Temp | Over Charge | Over Discharge | Others

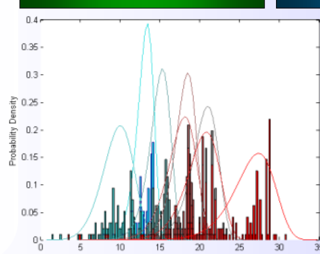


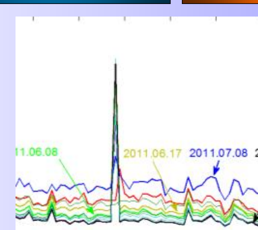



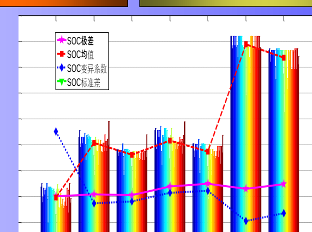
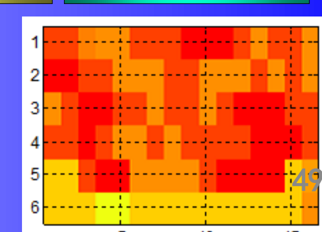


Consist
ency

Capacity | Resistance | Self Discharge | Thermal | Others





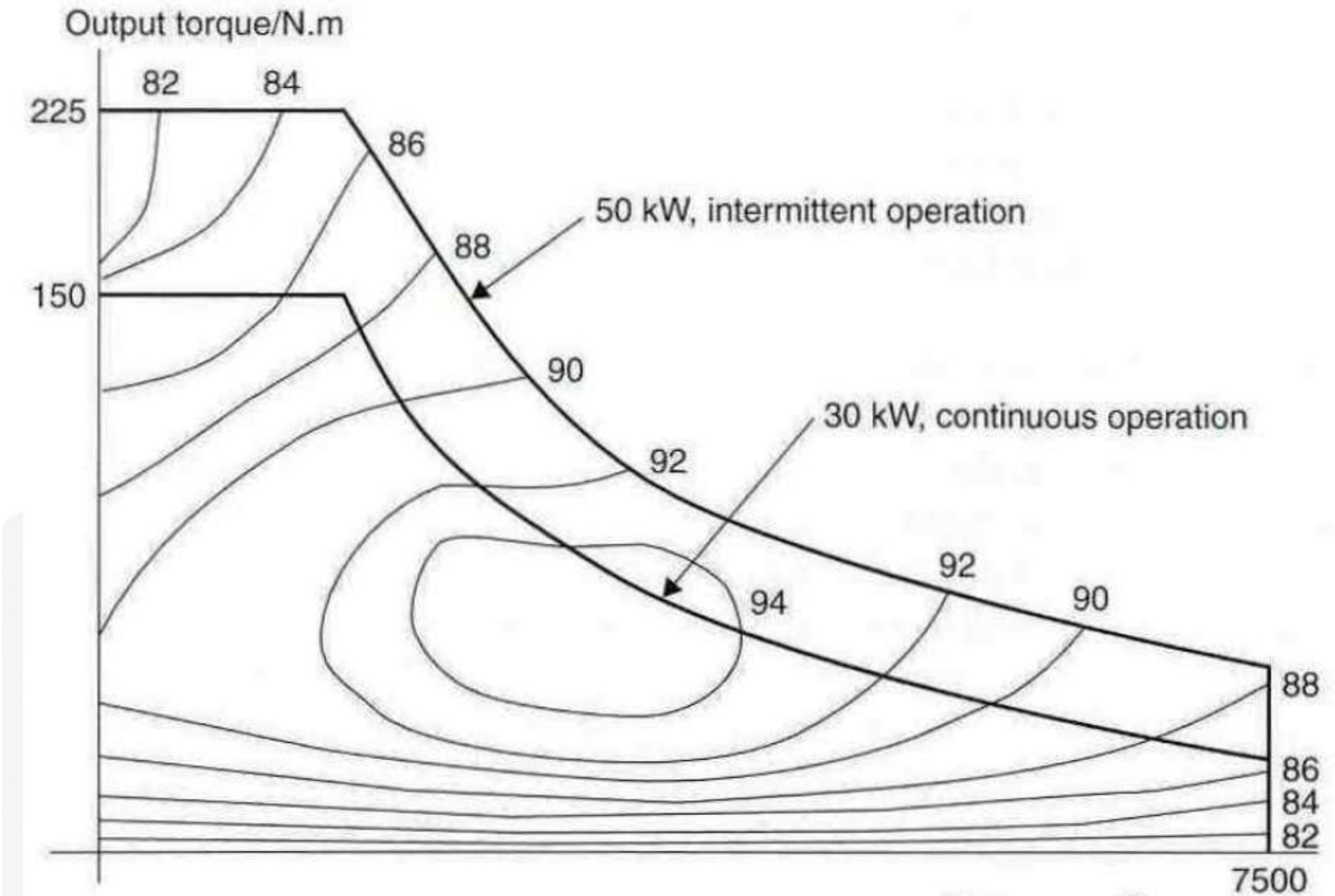



Research on Battery Safety

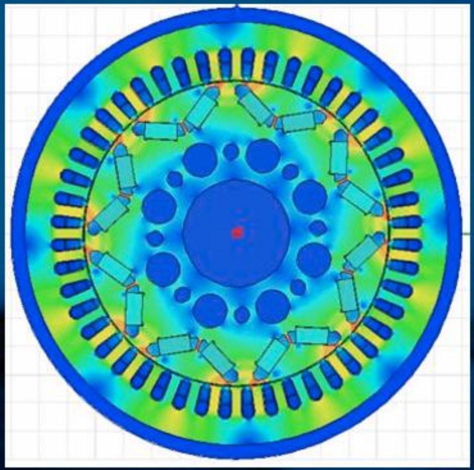
- Composite Separator & Short Circuit Protection
- Voltage Sensitive Separator & Over Charge Protection
- Safety Electrode Materials & Self Temperature Protection
- Ionic Liquids & Safety Composite Electrolyte
- Battery Safety Design

Motor Drives Technology

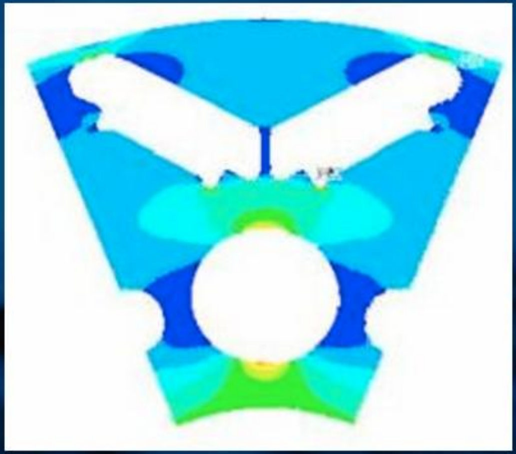
Typical Torque-Speed Characteristics



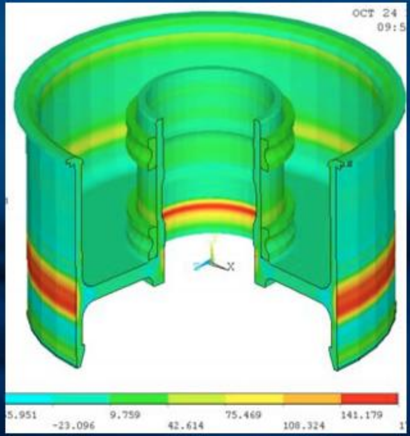
Motor Design /新能源汽车电机设计流程



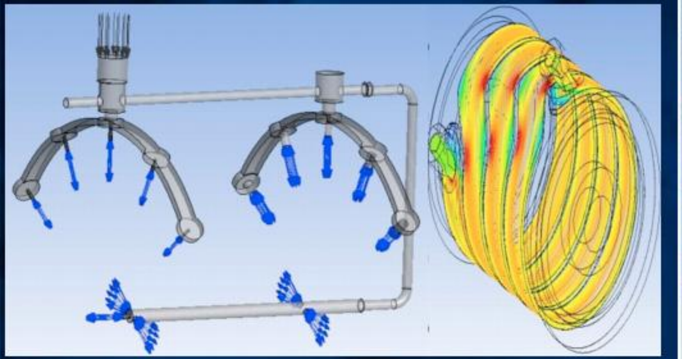
Electromagnetic Design
电机电磁设计



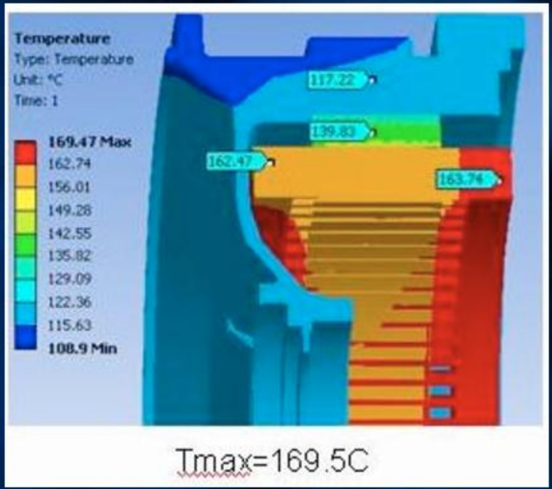
Rotor Stress Analysis
转子应力分析



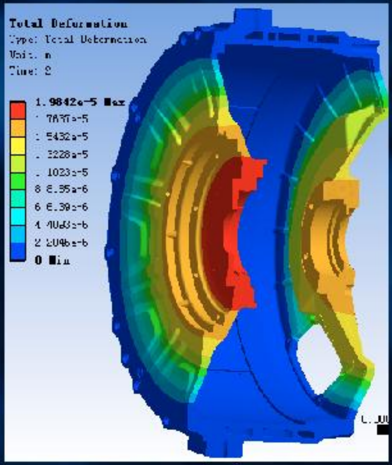
Structure Analysis
部件结构分析



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.

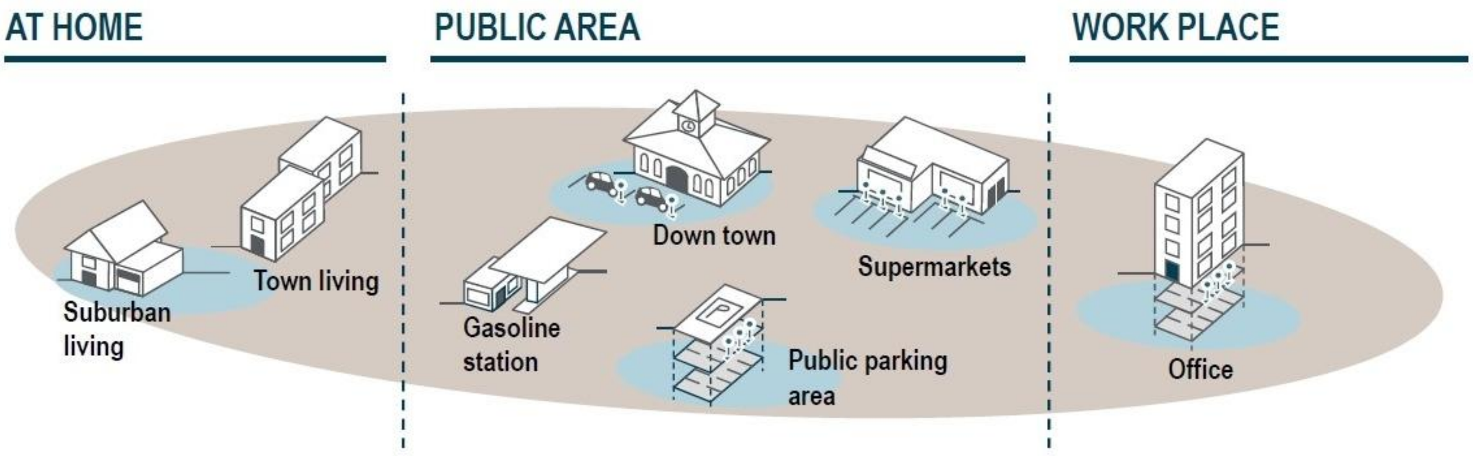
Dynamics: The charging has instant impact to the grid, unlike the gas station has no impact to the pipeline.

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

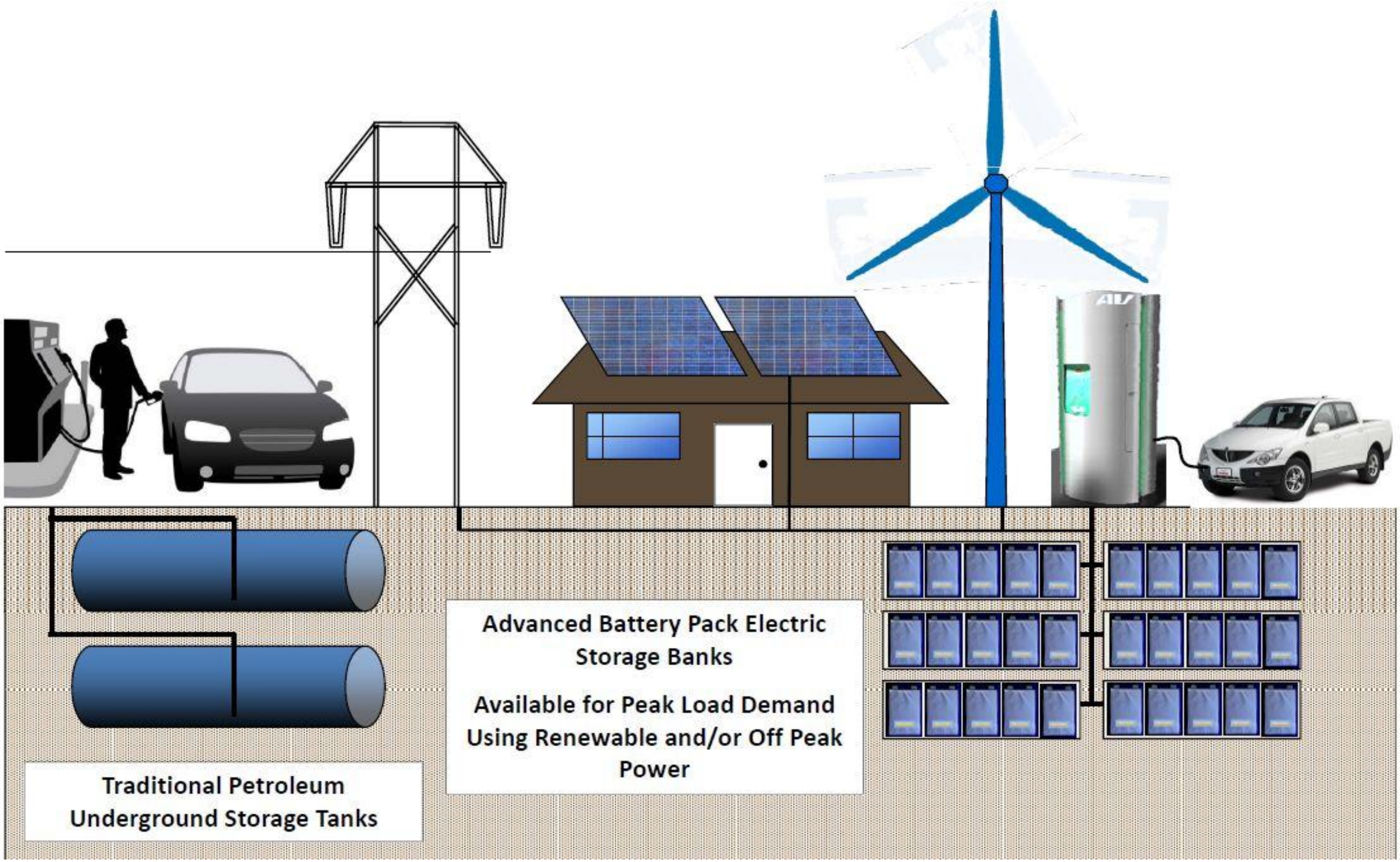


Parking Durations	14 hrs per day	2 hrs per day	7 hrs per day
Charging Points	1 charging point per vehicle	< 0.5 charging point per vehicle	1 charging point per vehicle
Power & Charing time Requirements	Low power and normal charging (e.g. 3kW, 10 hrs)	High power and quick charging (e.g. 22 kW, 2 hrs)	Low power and normal charging (e.g. 3kW, 7 hrs)

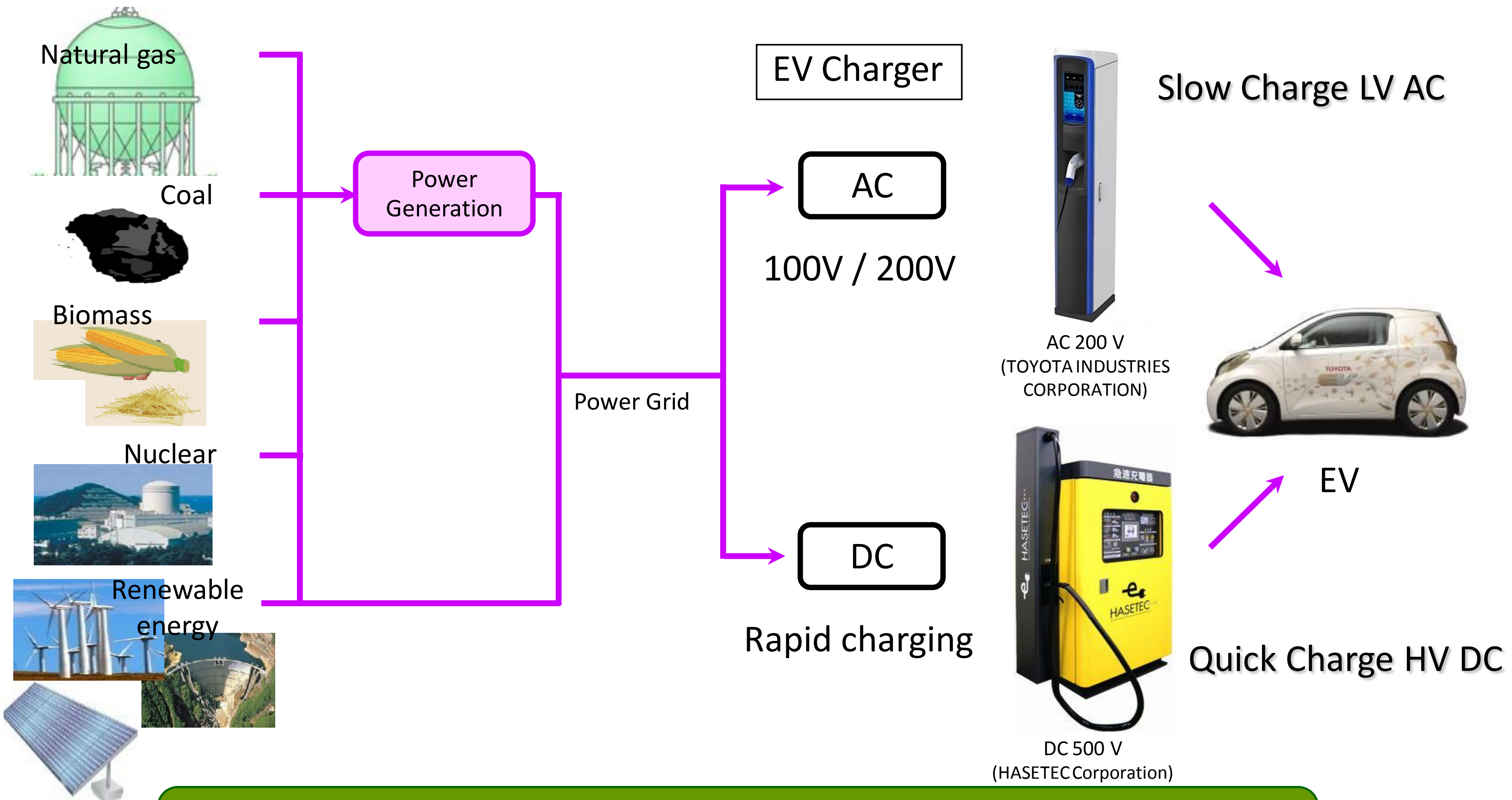
EV Charging Infrastructure Solution

CHAdeMO	AC	Combo2

Comparison of Gas Station & Storage Quick Charging

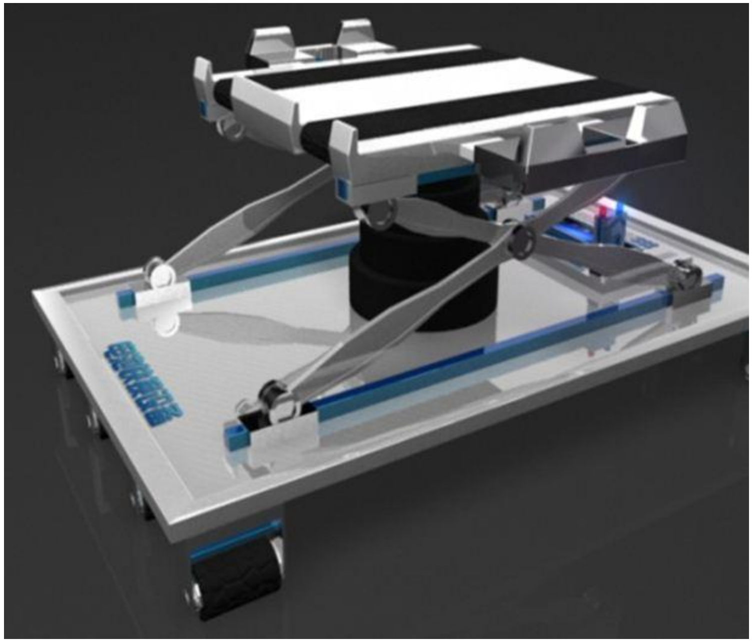


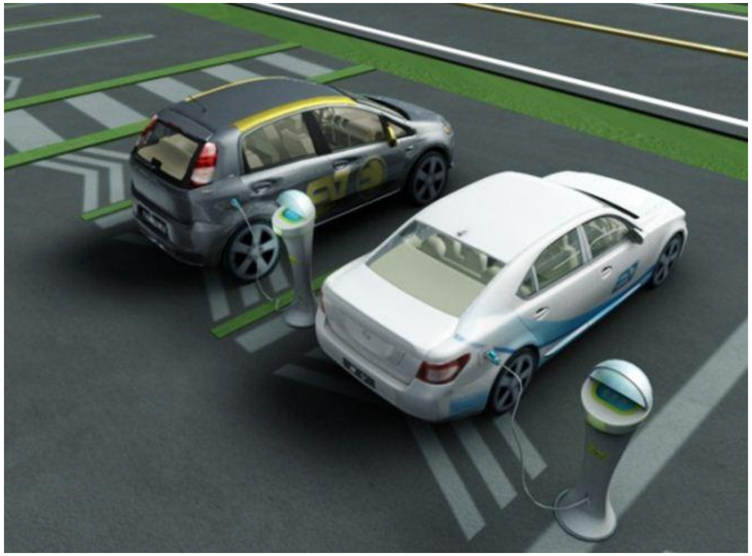
EV Charger



AC charger (100V/200V) for daily use
DC charger (rapid charging) for emergency use

Battery Swapping



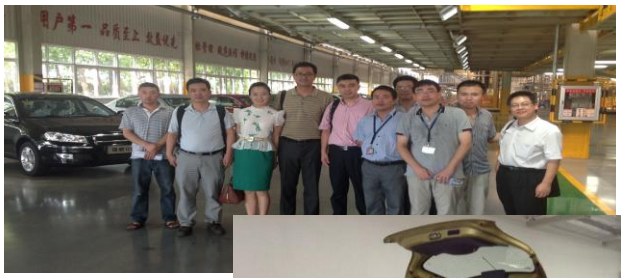


Smart Battery Charging, Swapping, Delivery Network

- 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

奇瑞汽车 ZTE中兴

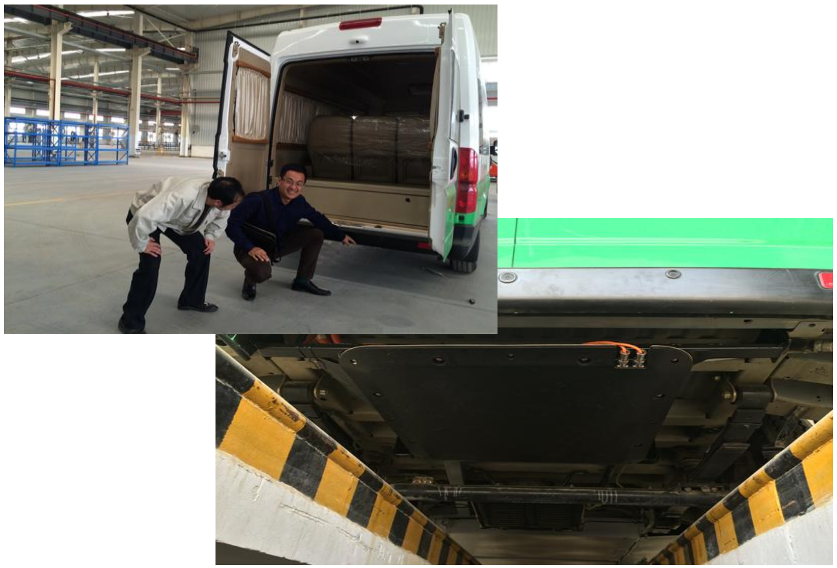


- Operation in Cherry eQ Evs,
- Range 250 km.

- Operation in Chang An EVs,
- Max power 107 kW.

长安汽车 ZTE中兴

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

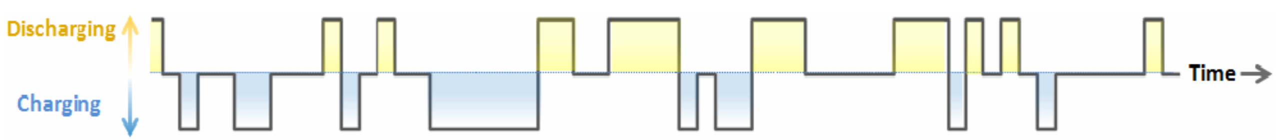
Operation in Deng Feng Bus in Xiangyang

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.



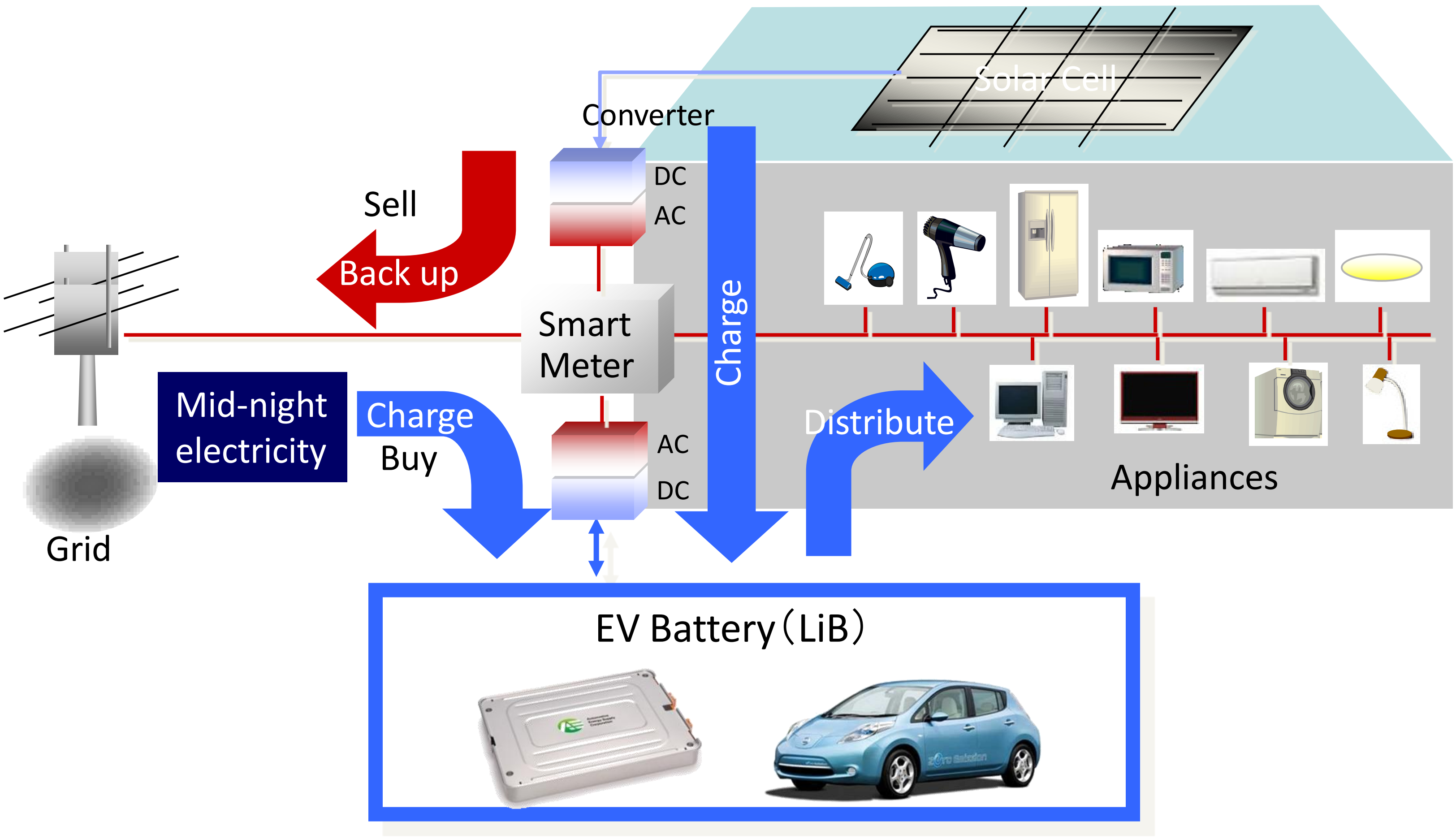
Two Integrations

- 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

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

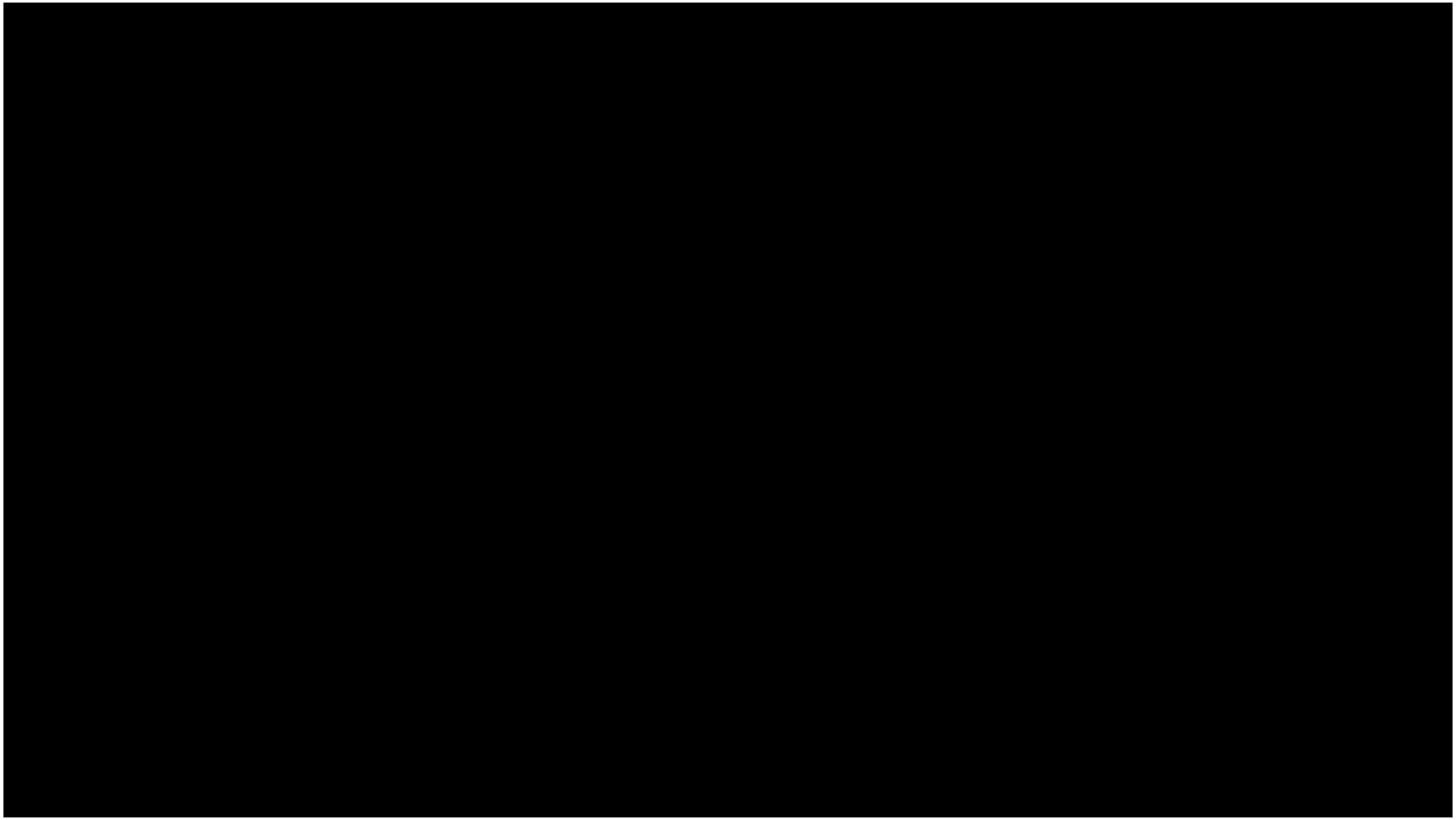
Unmanned Ground Vehicles (UGVs) in DARPA (Defense Advanced Research Projects Agency) Grand/Urban Challenge

- *Grand Challenge 2005*
- *Stanford Stanley*

- *Urban Challenge 2007*
- *CMU, Tartan*

Intelligent Vehicle

Smart Mini EV



Thanks

未来汽车社会

SUCCESS

SUCCESS

Inspiration	激情
Imagination	想像力
Innovation	創新
Integration	集成
Implementation	實現
Investment	投資

Thank you!