Electric & Hybrid Vehicles Roadmaps and Their Developments in China

Professor C.C. Chan, FIEEE, FIET, FHKIE

Academician, Chinese Academy of Engineering
Fellow, Royal Academy of Engineering, U.K.,
President, World Electric Vehicles Association

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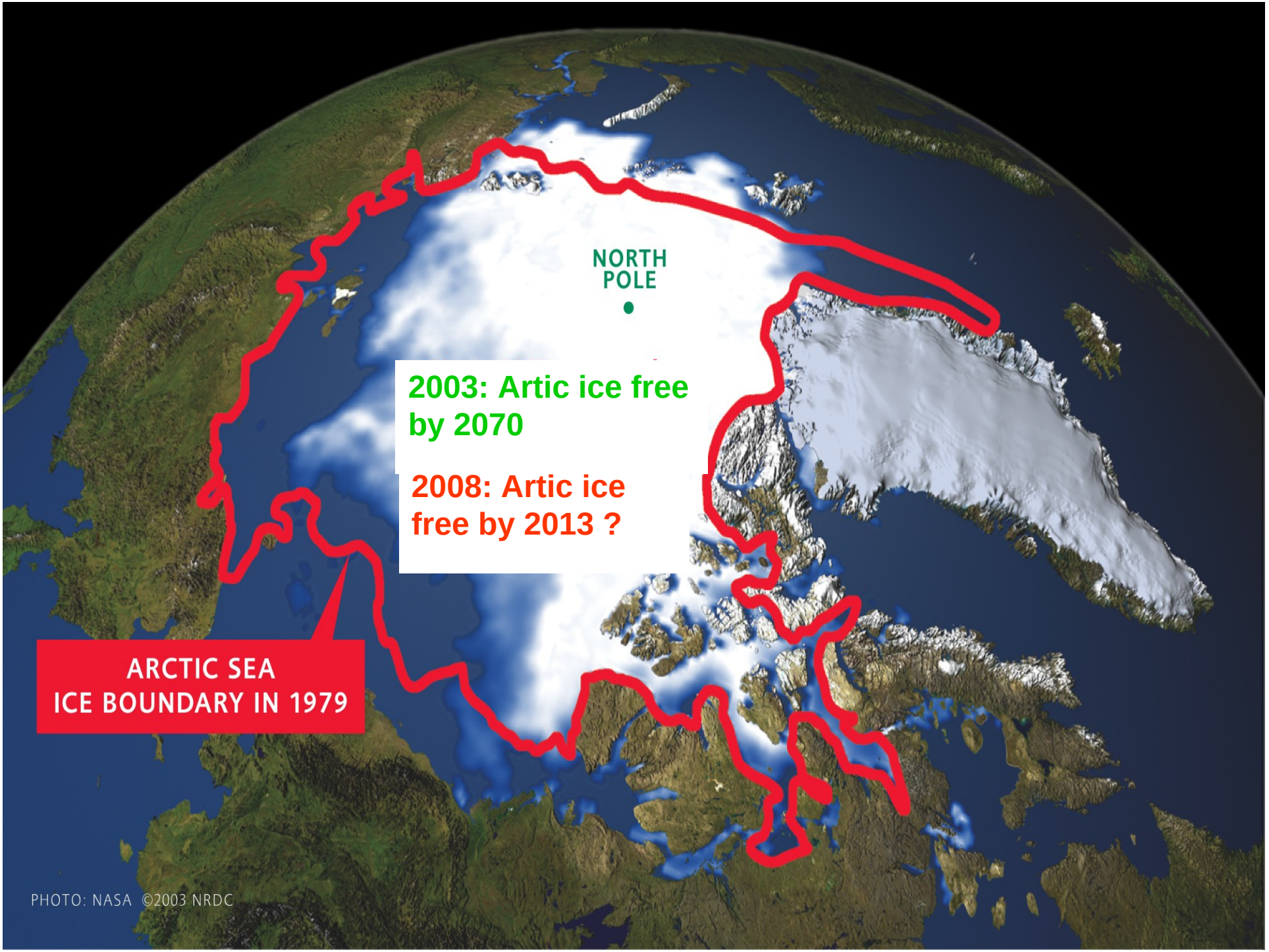
Detroit September 9, 2009

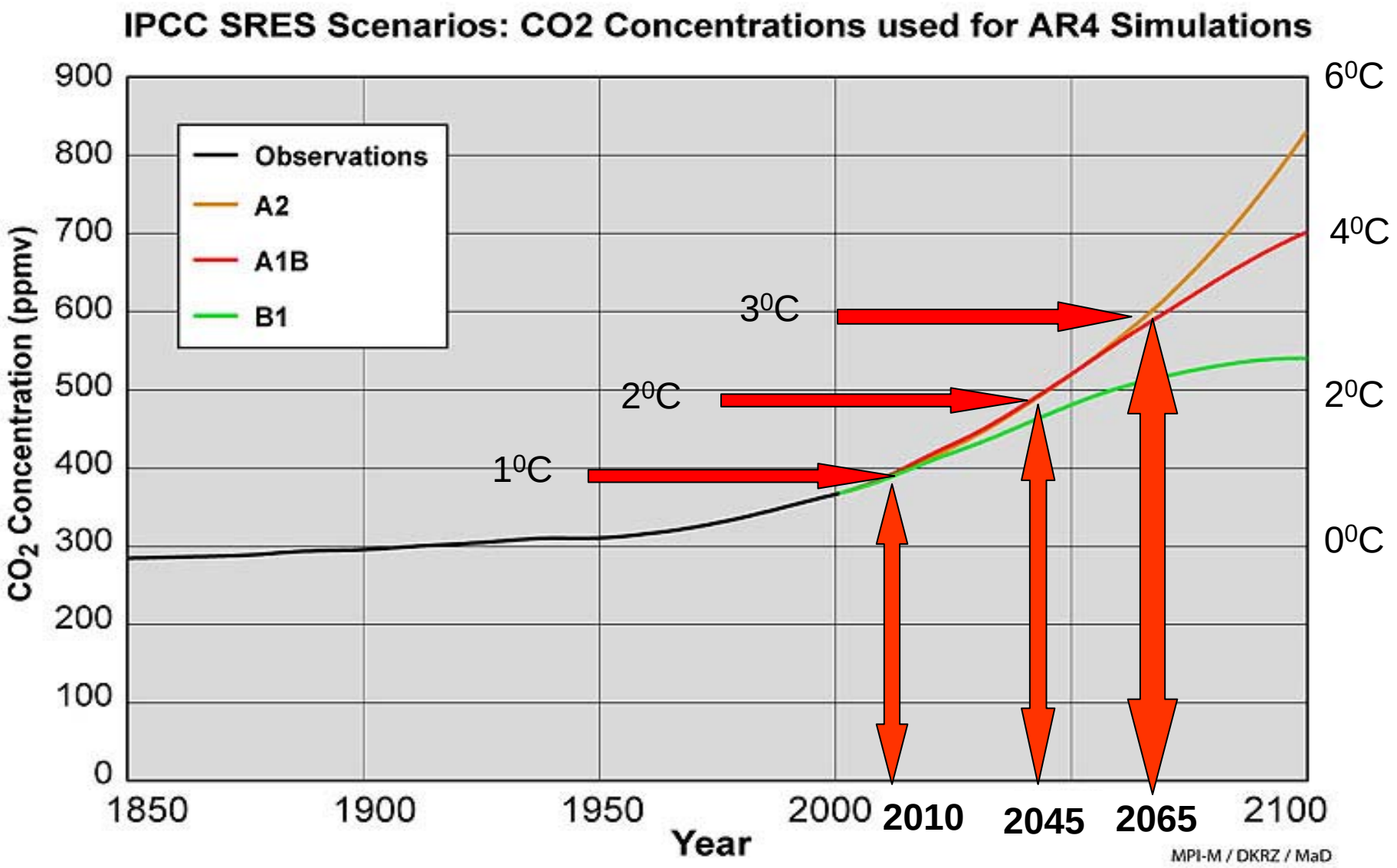
Content

- **Global Sustainable Development**
- **Electric & Hybrid Vehicles Roadmaps**
- **Development of Electric, Hybrid & Fue Cell Vehicles in China**


starting with a
problem

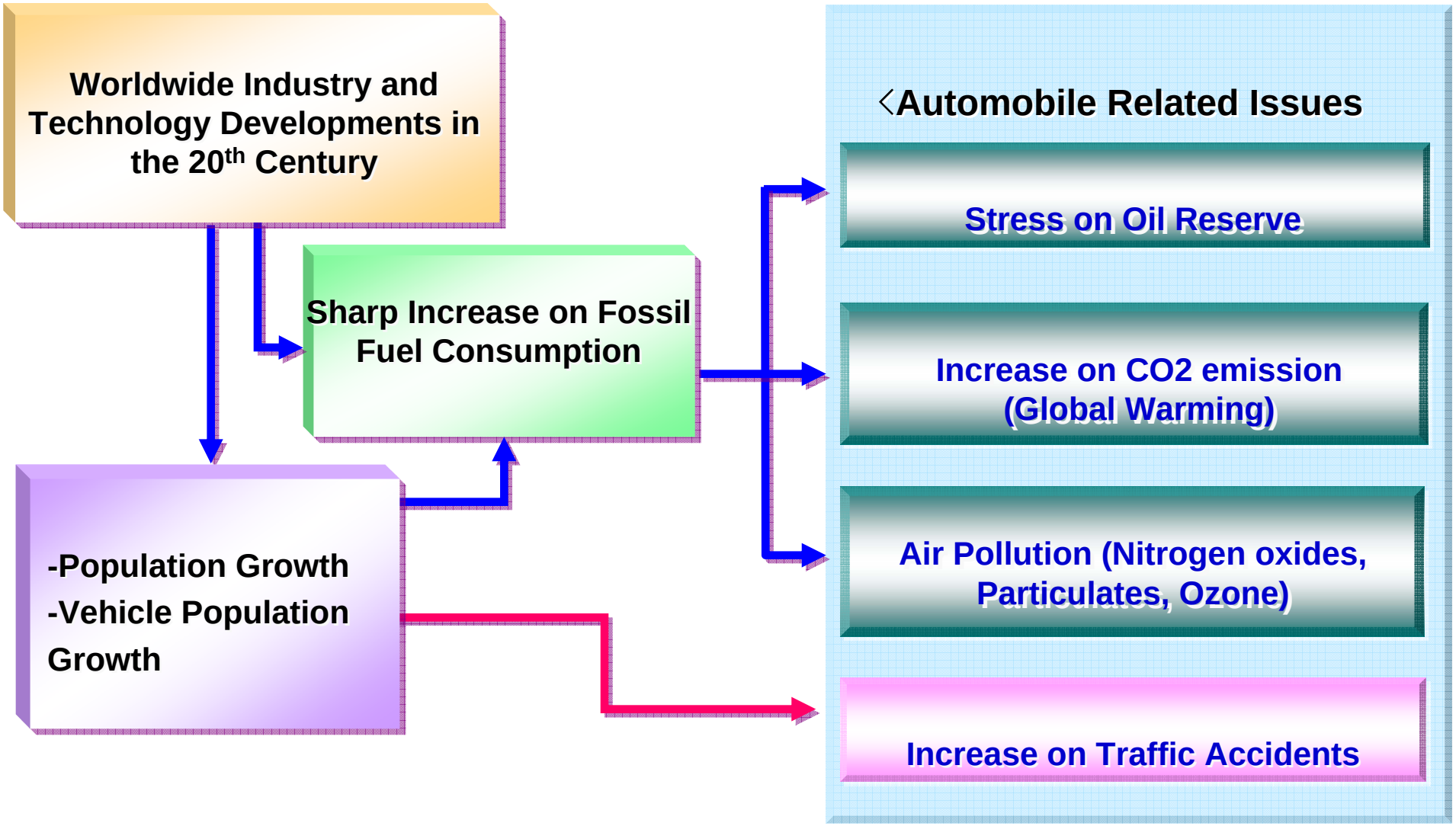

NORTH
POLE
2003: Artic ice free
by 2070
2008: Artic ice
free by 2013 ?
ARCTIC SEA
ICE BOUNDARY IN 1979
PHOTO: NASA ©2003 NRDC

THE RATE OF CHANGE IS NOT

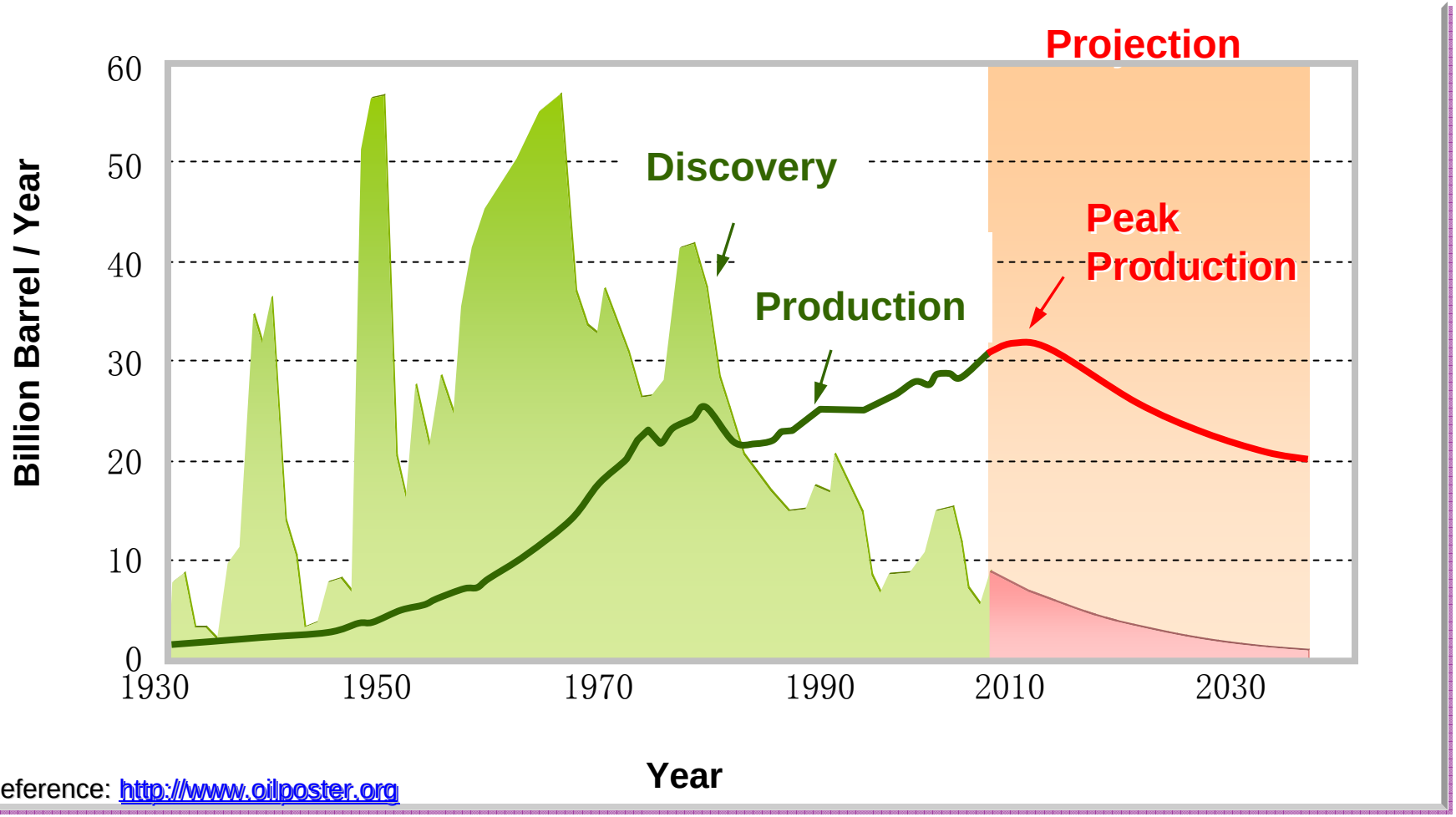


www.**ipcc**.ch/SPM6avr07.pdf

Problems from Automobiles

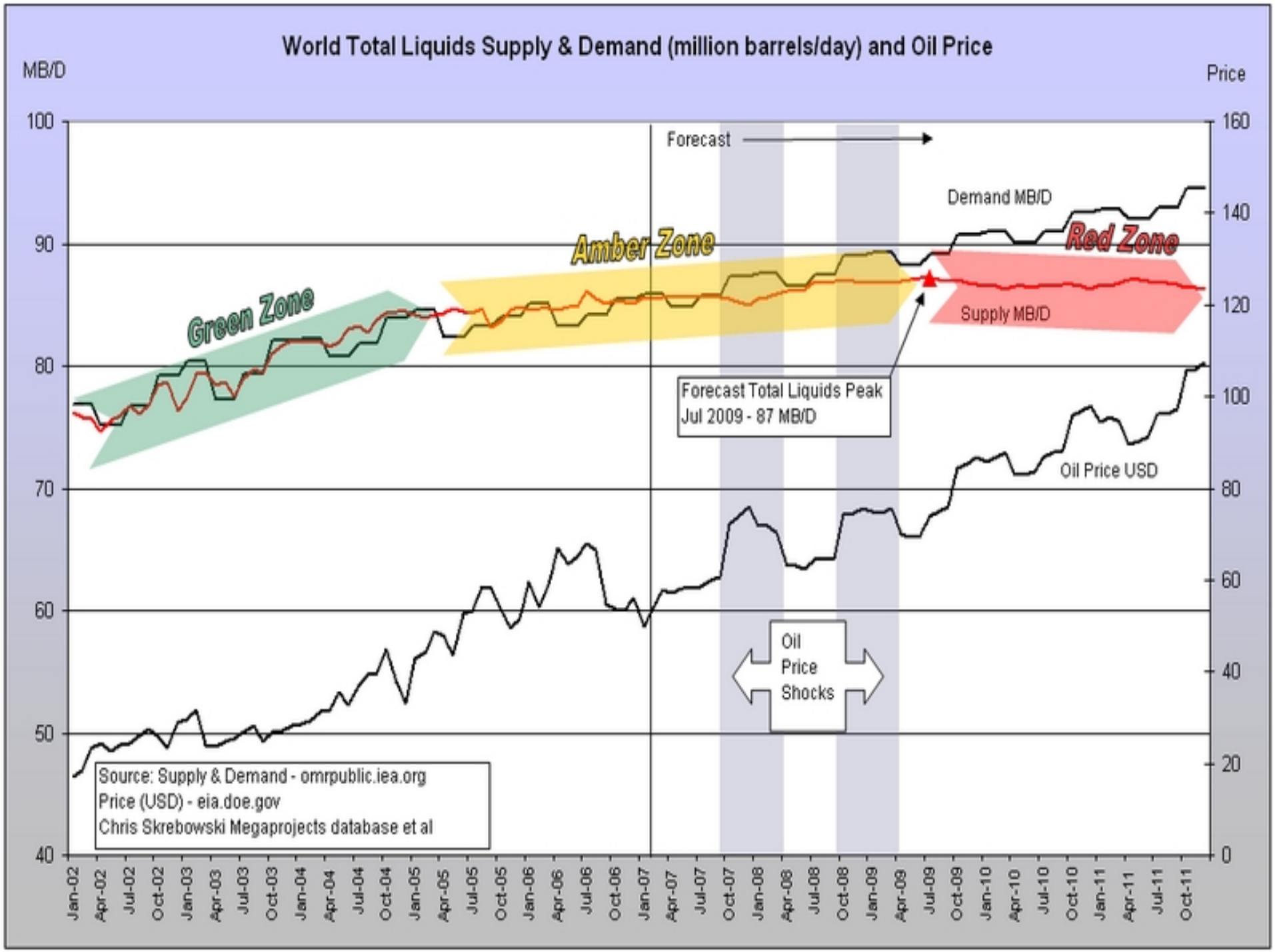


Growing Gap between Oil Discovery and Production



Reference: http://www.oilposter.org

Oil production will reach the peak in the near future


World Total Liquids Supply & Demand (million barrels/day) and Oil Price
MB/D
Price
Forecast
Demand MB/D
Amber Zone
Red Zone
Green Zone
Supply MB/D
Forecast Total Liquids Peak
Jul 2009 - 87 MB/D
Oil Price USD
Oil
Price
Shocks
Source: Supply & Demand - omrpublic.iea.org
Price (USD) - eia.doe.gov
Chris Skrebowski Megaprojects database et al
100
90
80
70
60
50
40
160
140
120
100
80
60
40
20
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Apr-11
Jul-11
Oct-11


developing a
solution

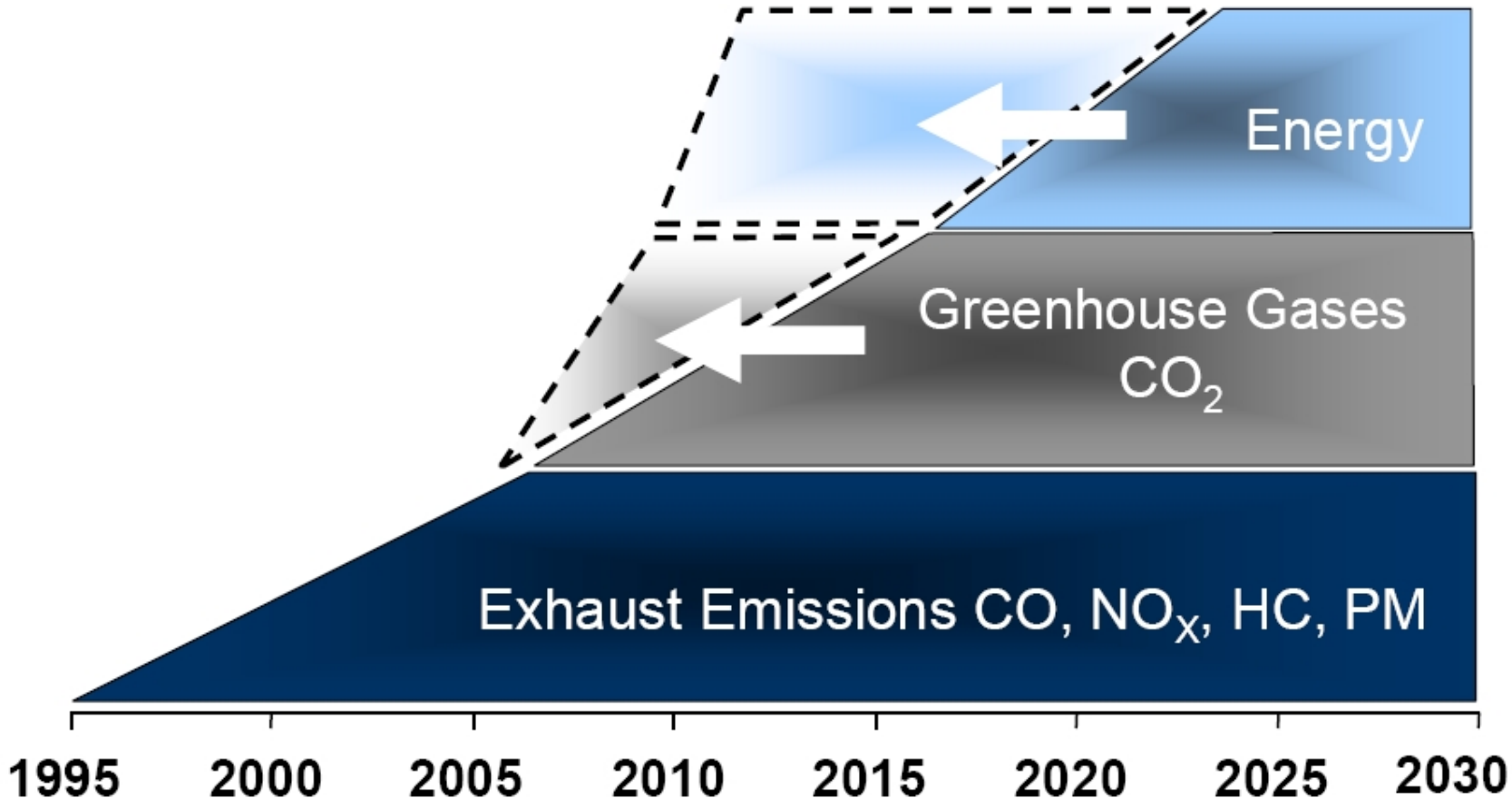
Automobile Revolution in New Century

- **Energy: Efficient, Alternative Fuels.**
- **Environment: Minimal Emissions.**
- **Safety and Intelligent.**

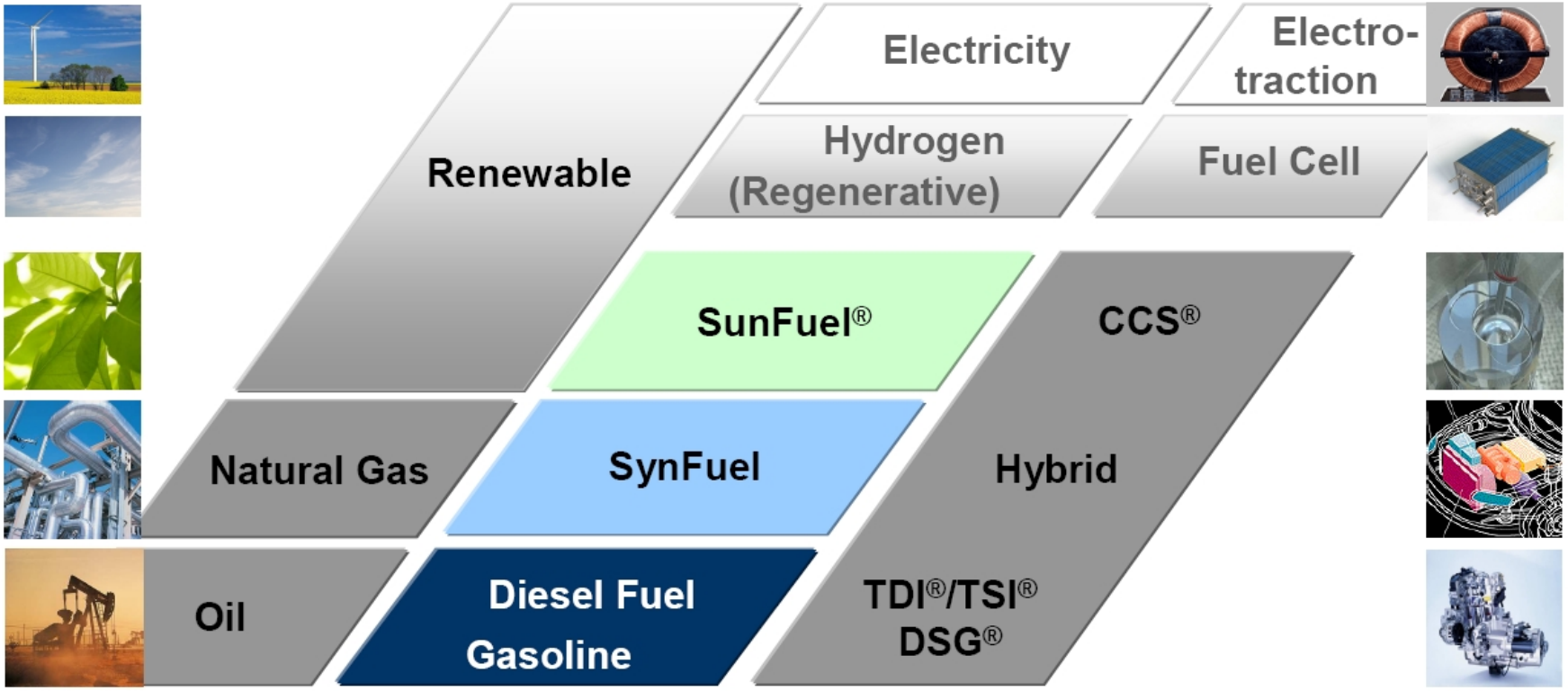
- **Powertrain: Electrification and hybridization**
- **Control: New Control Theory and Algorithm, Computerization and Digitalization**

- **Future Vehicle: 4 wheels +computer**

Sustainable Mobility Challenges



Fuel-and Powertrain Strategy

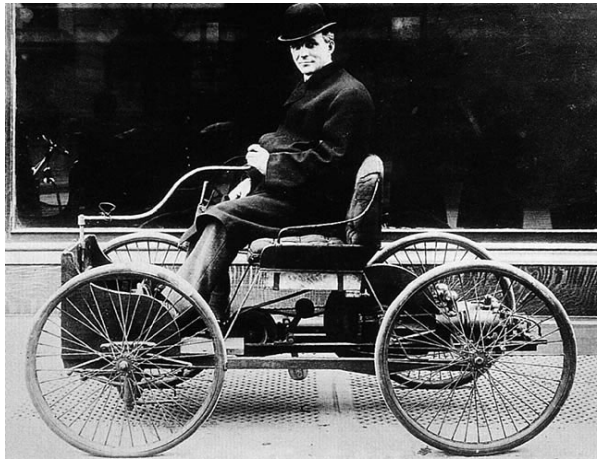


The First Electric Cars

1910

1893

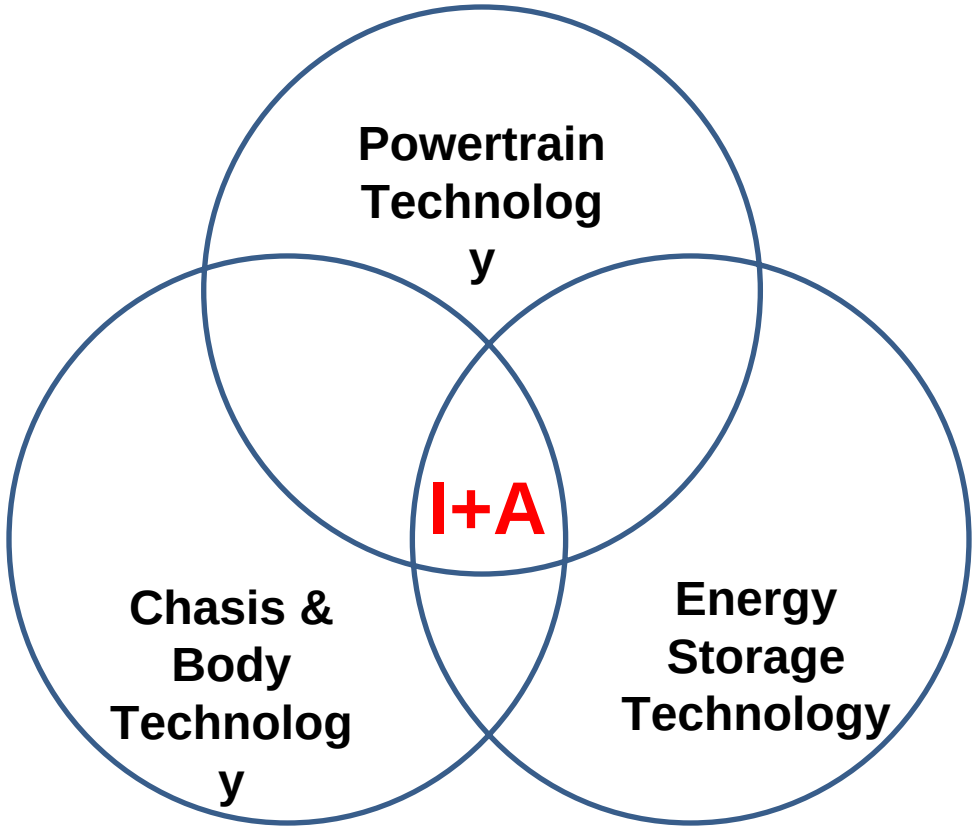
1899



Success of EV/HEV/PHEV Products: High Performance @ Reasonable Cost

I: Integration & Optimization of Automotive & Electrical Technologies

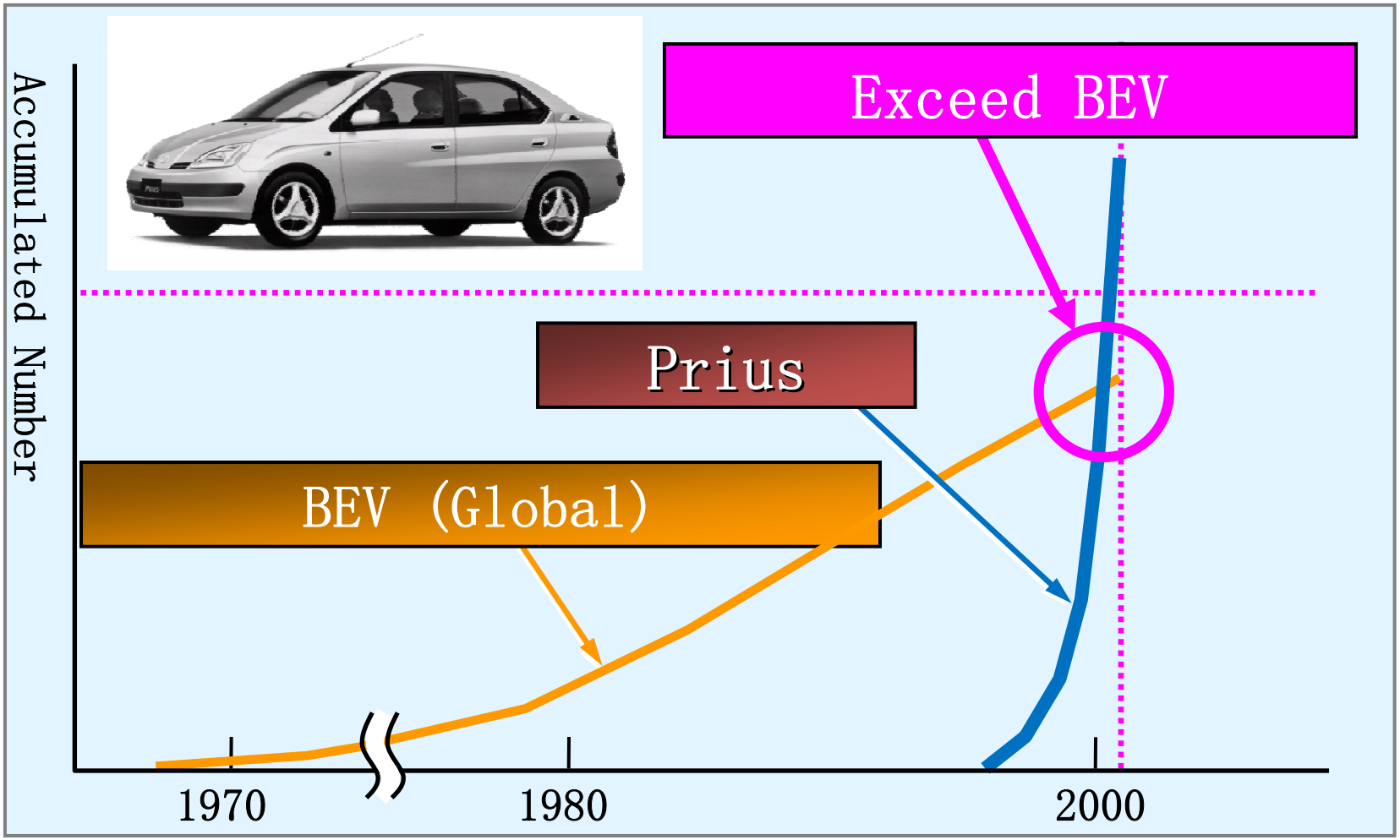
A: Alliance of OEM & Key Components Suppliers



Characteristics of BEV, HEV and FCV

Types of vehicles	BEV	HEV	FCV
Propulsion	• Electric motor drives	• Electric motor drives • Internal combustion engines	• Electric motor drives
Energy storage subsystem (ESS)	• Battery • Supercapacitor	• Battery • Supercapacitor	• Need battery / supercapacitor to enhance power density.
Energy source & infrastructure	• Electric grid charging facilities	• Gasoline stations • Electric grid charging facilities (for Plug In Hybrid)	• Hydrogen • Hydrogen production and transportation infrastructure
Characteristics	• Zero local emission • High energy efficiency • on crude oils • Relatively short range • High initial cost • Commercially available	• Low local emission • High fuel economy • Long driving range • Dependence on crude oil • Higher cost than ICE vehicles • Commercially available	• Zero low local emission • High energy efficiency • from crude oil (if not using gasoline to produce H_2) • High cost • Under development
Major issues	• sizing and management • Charging facilities • Cost	• sizing and management • Control, optimization and management of multiple energy sources.	• Fuel cell cost, life cycle and reliability • Hydrogen infrastructure • Cost

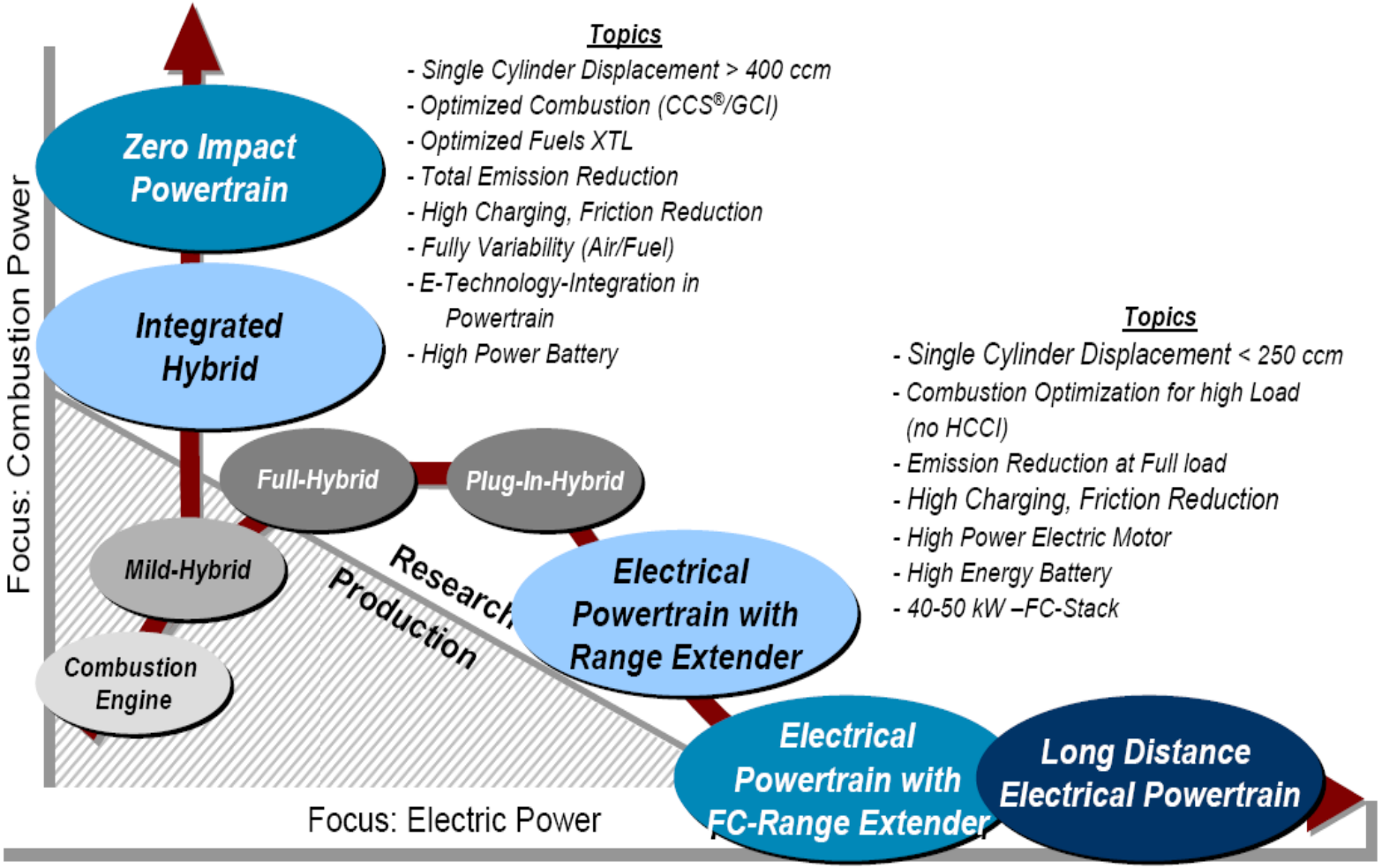
BEV & HEV Production



Two Pathways for HEV Technology Development

Two Way Powertrain Roadmap

Technical Road Map



Philosophy of Engineering: Six Principles of Integrated System Design

1. Debate, define, revise and pursue the purpose/objective

   The system exists to deliver capability, the end justifies the means.

   The statement of a requirement must define how it is to be tested.

   Requirements reflect the constraints of technology & budgets.

2. Think holistic

   The whole is more than the sum of the parts – and each part is more than a fraction of the whole

3. Be creative

   See the wood before the trees

4. Follow a disciplined procedure

   Divide and conquer, combine and rule

5. Take account of the people

   To err is human ; Ergonomics; Ethics & Trust

6. Manage the project and the relationships

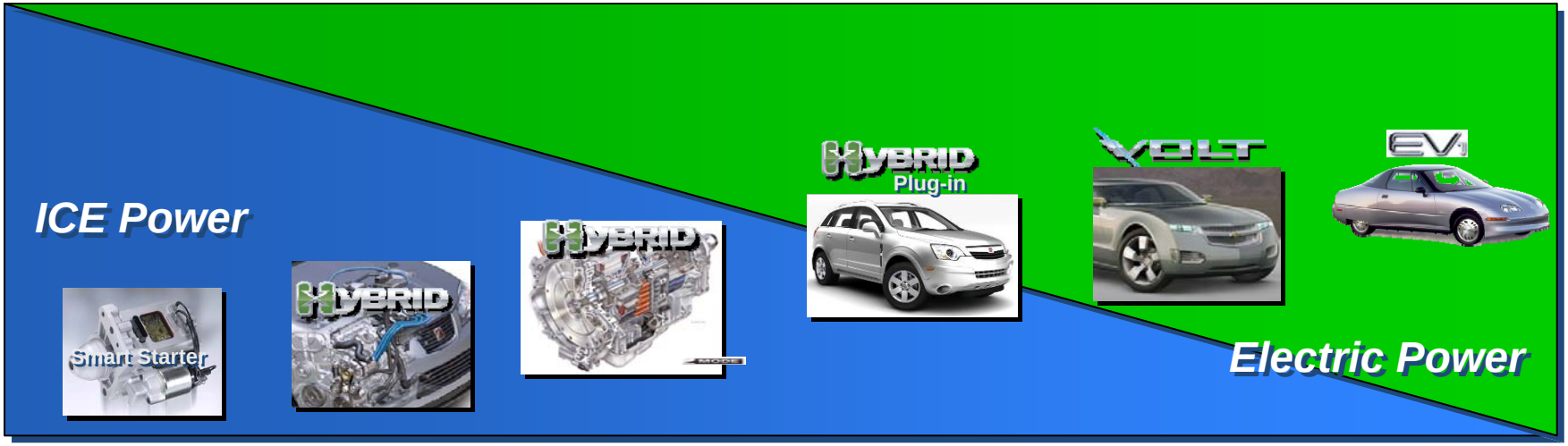
   All for one, one for all

Hybrid Engineering Philosophy: 1+1>2

Hybrid Mule 骡 = Horse 马 (Mother) + Moke 驴 (Father)

Mule is the hybrid of horse and moke, mule takes the best DNA of horse and moke, hence more powerful and endurance.

HEV should have added value gained from the integration of engine propulsion and motor propulsion, fully sizes the intelligent electrical, electronic and control technologies



	Start-Stop	Mild Hybrid	Full Hybrid	Plug-in Hybrid	Plug-in Range Extender EV/	Electric Vehicle/
Functionality/	• Engine start-stop at idle	• Engine off on deceleration • Mild regenerative braking • Electric power assist	• Full regenerative braking • Engine cycle optimization • Electric launch • Limited pure electric drive • Engine downsize	• Plug-in rechargeable • More electric drive during charge-depletion • Reduced refueling	• Full-function electric drive • Initial pure electric range • Significantly reduced refueling	• Plug-in recharge only • 100% pure electric range/100% • No refueling
FUEL ECONOMY	• +2-4%	• +10-20%	• +30-50% Cars • +20-40% Trucks	• +100% in charge depletion/100% • same as full hybrid afterward	• Electricity only in EV range/在EV • same as full hybrid afterward	• Electricity only

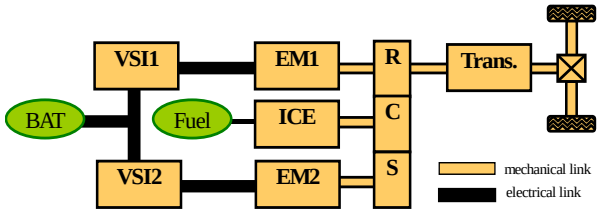


Fig. 1; Series-parallel hybrid Vehicle using a planetary gear unit

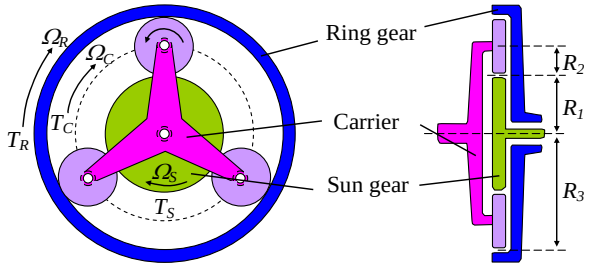


Fig. 1a; Planetary gear unit

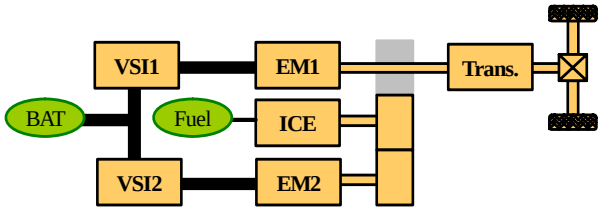


Fig. 2; Series hybrid Vehicle

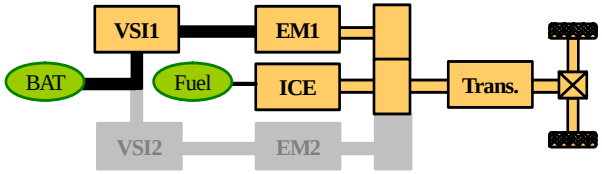


Fig. 3; Parallel hybrid Vehicle

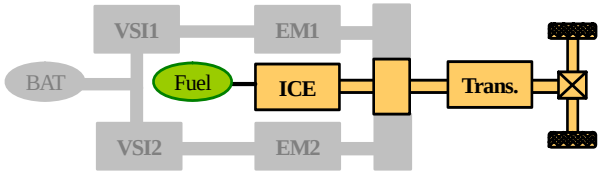


Fig. 4; ICE Vehicle

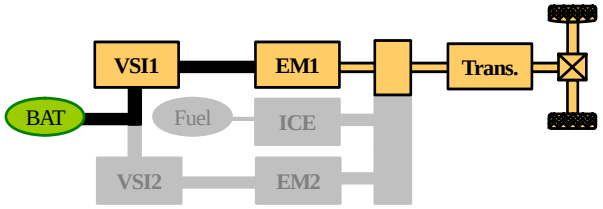
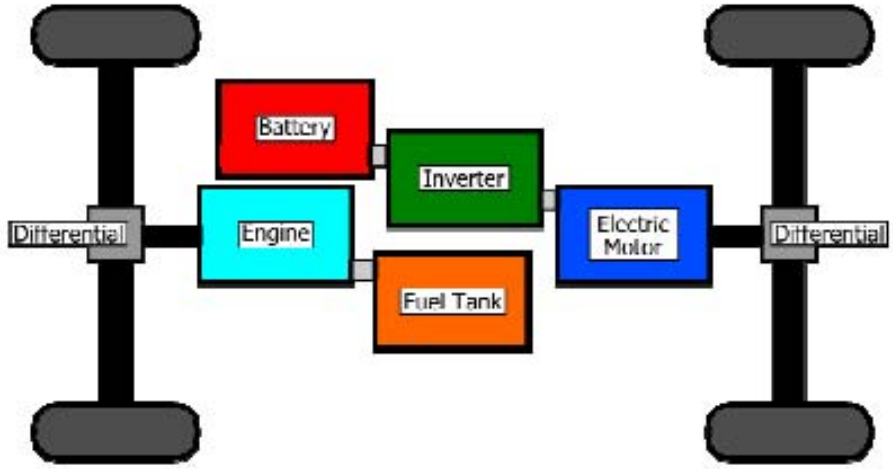


Fig. 5; Battery powered Electric Vehicle

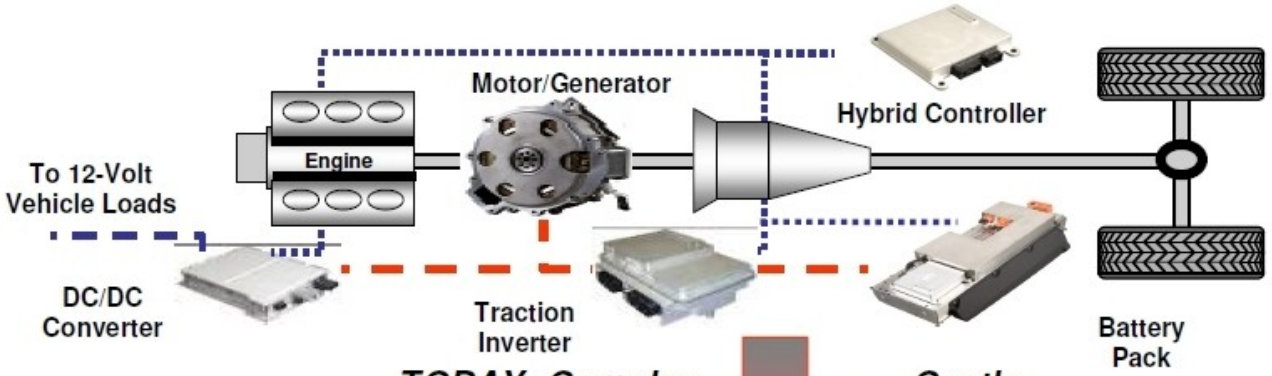
Parallel Through-the-Road Configuration

- Same as Parallel Configuration, except Internal Combustion Engine and Electric Motor operate independently of one another, and act on separate axles.
- All four wheels are powered.
- Propulsion System mass is evenly distributed.



Hybrid and Electric Vehicle Popwertrain Solutions Approach

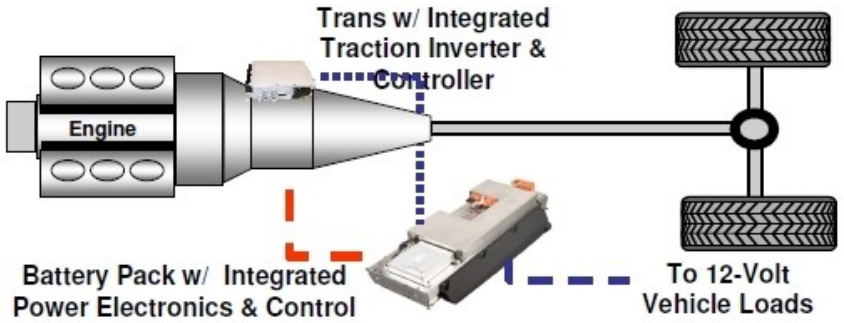
Today's hybrids use distributed components, creating vehicle performance, cost & packaging challenges



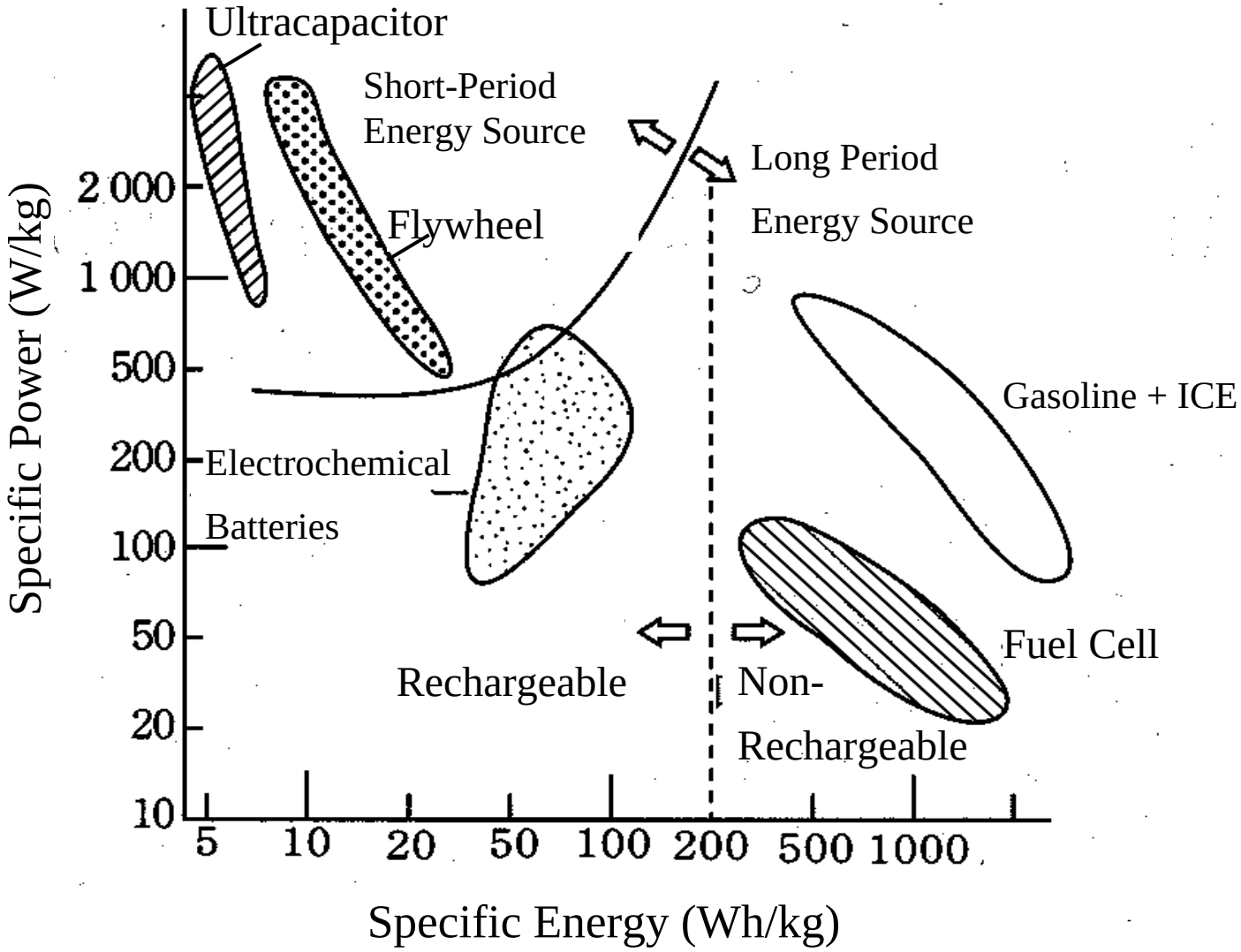
TODAY: Complex.....Costly

FUTURE: Simplified.....Lower Cost, Compact, Robust

Delphi's power electronics building blocks enable up-integration for lower cost, improved packaging, robustness & fuel economy



Energy Sources



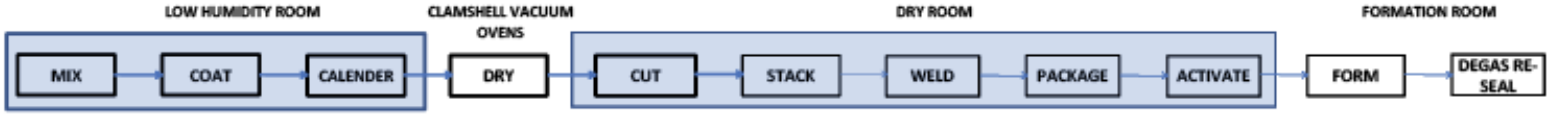
Best Battery Technology

Chemistry		Features for EV, PHEV					
	Stage	Power	Energy	Life	Safety / Environmental	Cost	Comments
Pb-Acid	Long Established Commercially	Good	Very Low	Cycle: Low Calendar: Low	Good safety with extensive recycling in place	Very low	Well understood, but limited to no value for EV / PHEV due to weight and life
Ni-Cd	Long Established Commercially	Low	Low	Cycle: Medium Calendar: High	Good safety. Cadmium metal highly toxic.	Medium	Memory effect, toxicity and low performance make for no value in EV / PHEV
NiMH	Long Established Commercially	Medium	Medium	Cycle: Medium Calendar: Low	Good safety. Recyclable	Medium	Very mature technology but low life and self discharge limit EV / PHEV utility
Lithium: $LiCoO_2$/Graphite	Commercialized	Good	High	Cycle: Low Calendar: High	Prone to Thermal runaway	High	Too dangerous for EV / PHEV
Lithium: $Li(Ni_{0.85}Co_{0.1}Al_{0.05})O_2$ / Graphite (NCA)	Commercialized	Good	High	Cycle: Low Calendar: High	Prone to thermal runaway	Medium high	Too dangerous for EV / PHEV
Lithium: $LiFePO_4$/Graphite (LFP)	Commercialized	Good	Medium High	Cycle: High Calendar: High	Good, but SEI can lend to runaway	Medium high	Lowest overall risk of current Li technologies for EV and PHEV
Lithium: $Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$ / Graphite (NCM)	Commercialized	Medium	High	Cycle: Low Calendar: High	Prone to thermal runaway	Medium high	Too dangerous for EV / PHEV
Lithium: $LiMn_2O_4$/Graphite (LMO)	Pre Commercial	Medium	High	Cycle: Very Low Calendar: Medium	Good. But SEI can lent to runaway	Medium	Good candidate for EV / PHEV if life issues can be overcome
Lithium: $LiMn_2O_4/Li_4Ti_5O_{12}$ (LTO)	Pre Commercial	Very High	Medium	Cycle: Extremely High Calendar: High	Very good. Organic electrolyte can ignite	Medium high	Good candidate for EV / PHEV but energy density limits utility. Can be Rapid charged (>10 min)
Zink-Air	Commercialized	Low	High	Cycle: High Calendar: High	Very good. Highly recyclable	Low	Rechargeable only by mechanical means.
NaNiCl (ZEBRA)	Commercialized	Low	High	Cycle: Low Calendar: Medium	Safe in cold state	Medium	High temperature battery

Cell Manufacturing

Cell model used to detail manufacturing plan

- Processes
- Equipment
- Materials
- Man-power

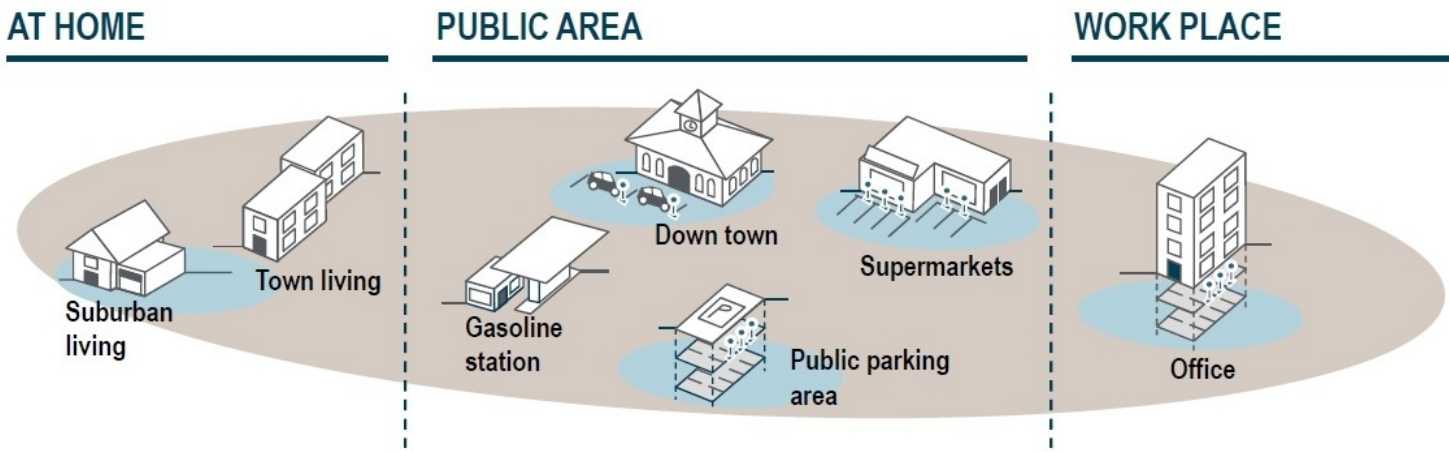


EQUIPMENT											
MATERIALS											
EQUIP CAP											
TOTALS											
PERSONEL											
ENGINEERS	1	1			0.5	0.5	0.5	0.5		0.5	0.5
TECHS	2	2	2	2	1	1	1	1	1	6	6

TOTAL HEADCOUNT

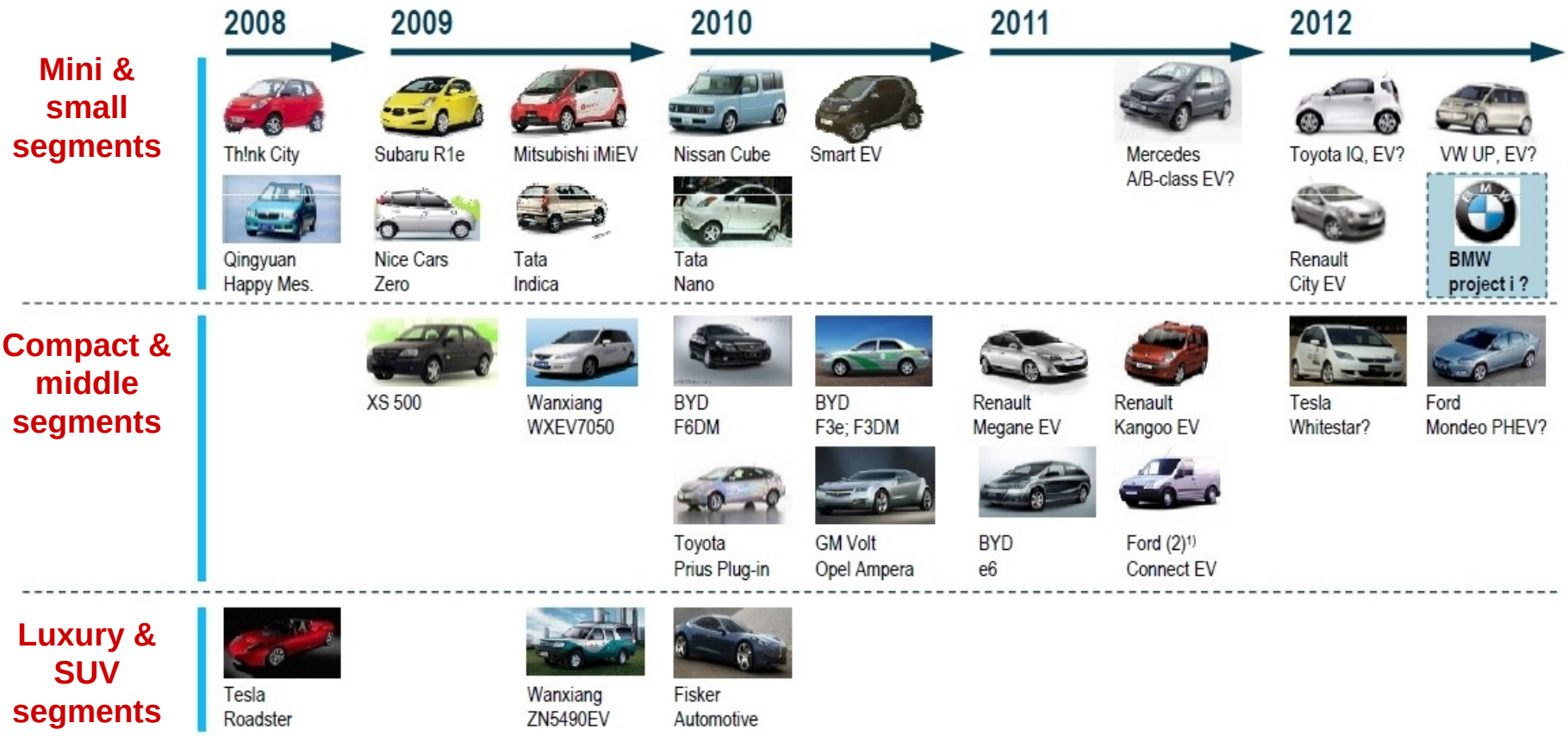
Cell manufacturing is 90% experience, skill, & know-how, 10% buildings and machinery

Infrastructure and Power Requirements

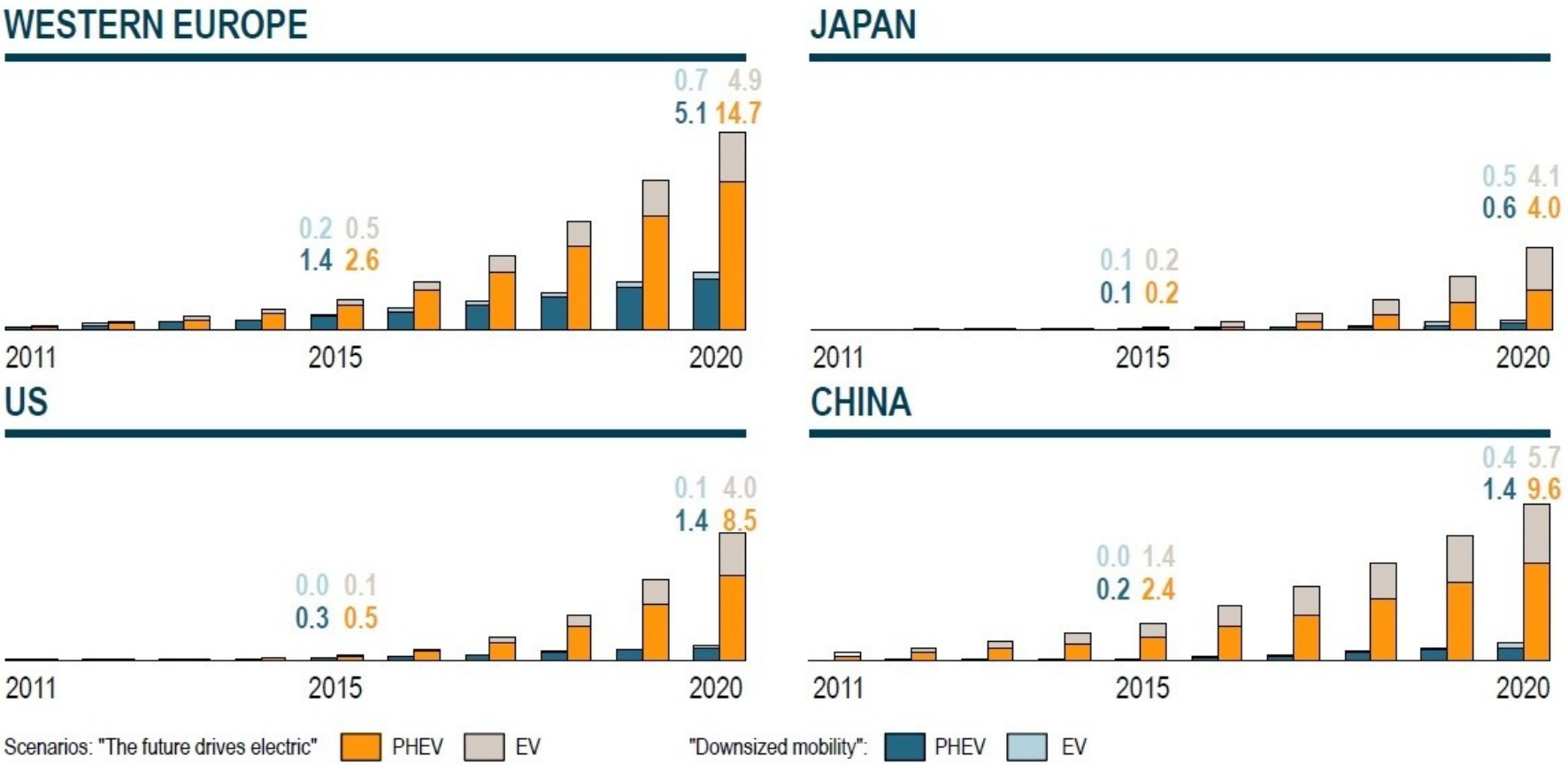


Parking Durations	14 hrs per day	2 hrs per day	7 hrs per day
Charging Points	1 charging point per vehicle	< 0.5 charging point per vehicle	1 charging point per vehicle
Power & Charing time Requirements	Low power and normal charging (e.g. 3kW, 10 hrs)	High power and quick charging (e.g. 22 kW, 2 hrs)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

Productions of EVs and PHEVs until 2012



Forecasts of EV and PHEV Sales

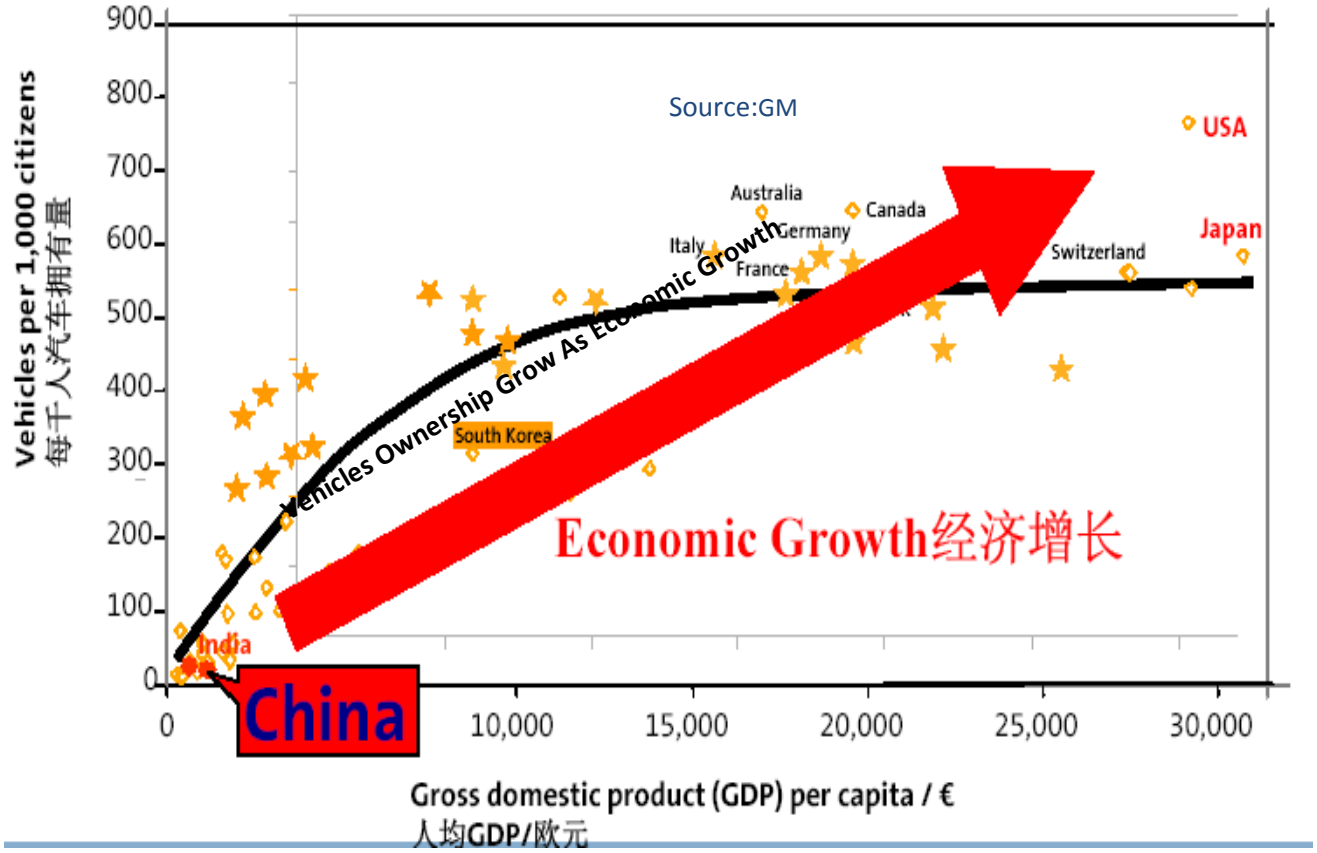


Sales forecast, 2011-2020 [% of new car sales]

Development of EV/HEV/FCV in China

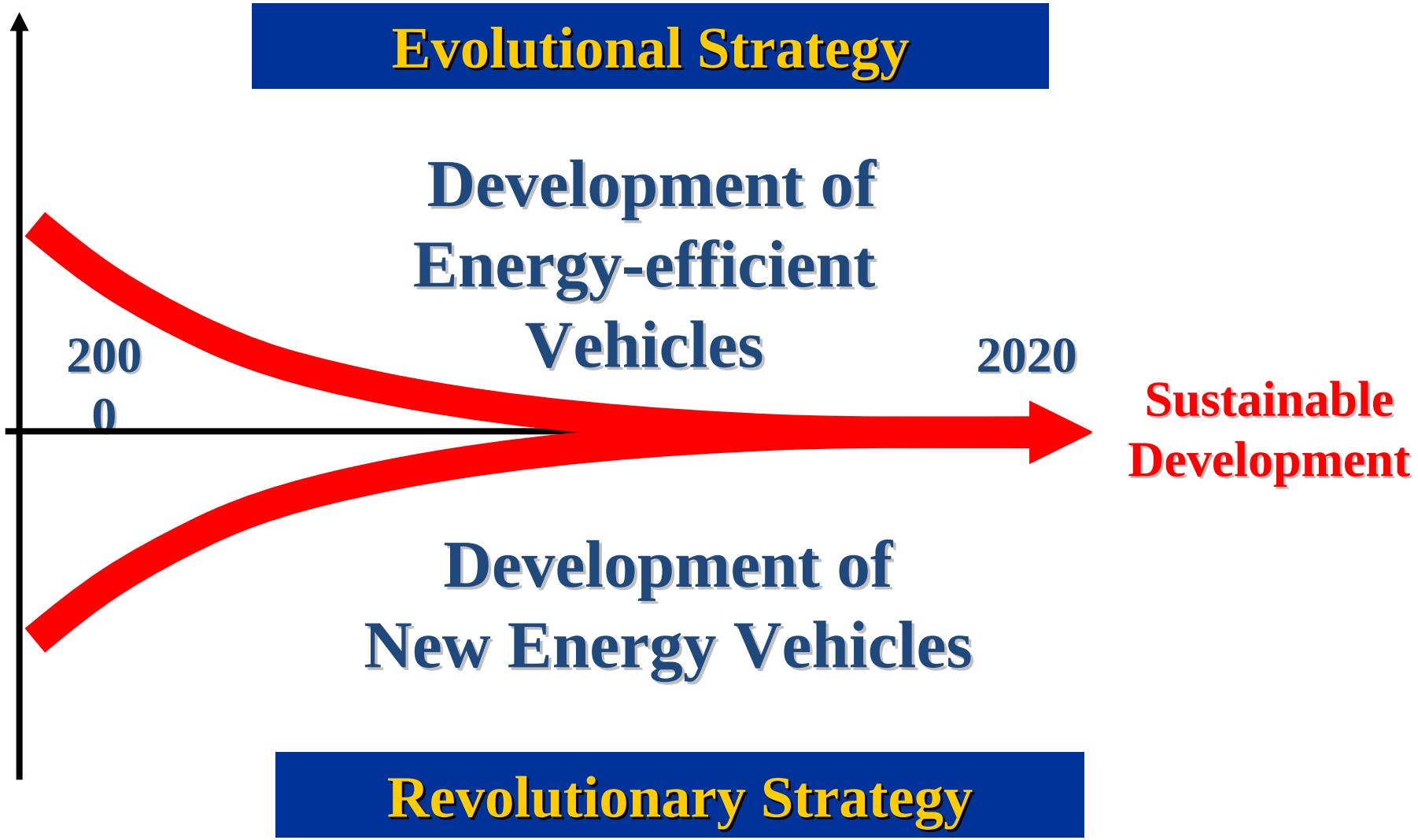
- Policy
- Technologies
- Demonstration & Commercialization

China's automobile industry has great potential



The total auto production was 10 millions in 2008, the second largest country of automobile production,and it will be the largest in 2010. Chinese Automobile quantity is 40 millions,and it will reach 150 millions in 2020.

Strategy for Chinese Transportation Energy



Three-Dimensional Automotive Energy and Power system routines

Liquid fuel（gasoline, diesel and bio-mass substituted fuel ）	+	Advanced IC engine (Esp. CIDI)	+	Fuel Auto and HEV to Plug-in HEV

→ **Highway Transportation**

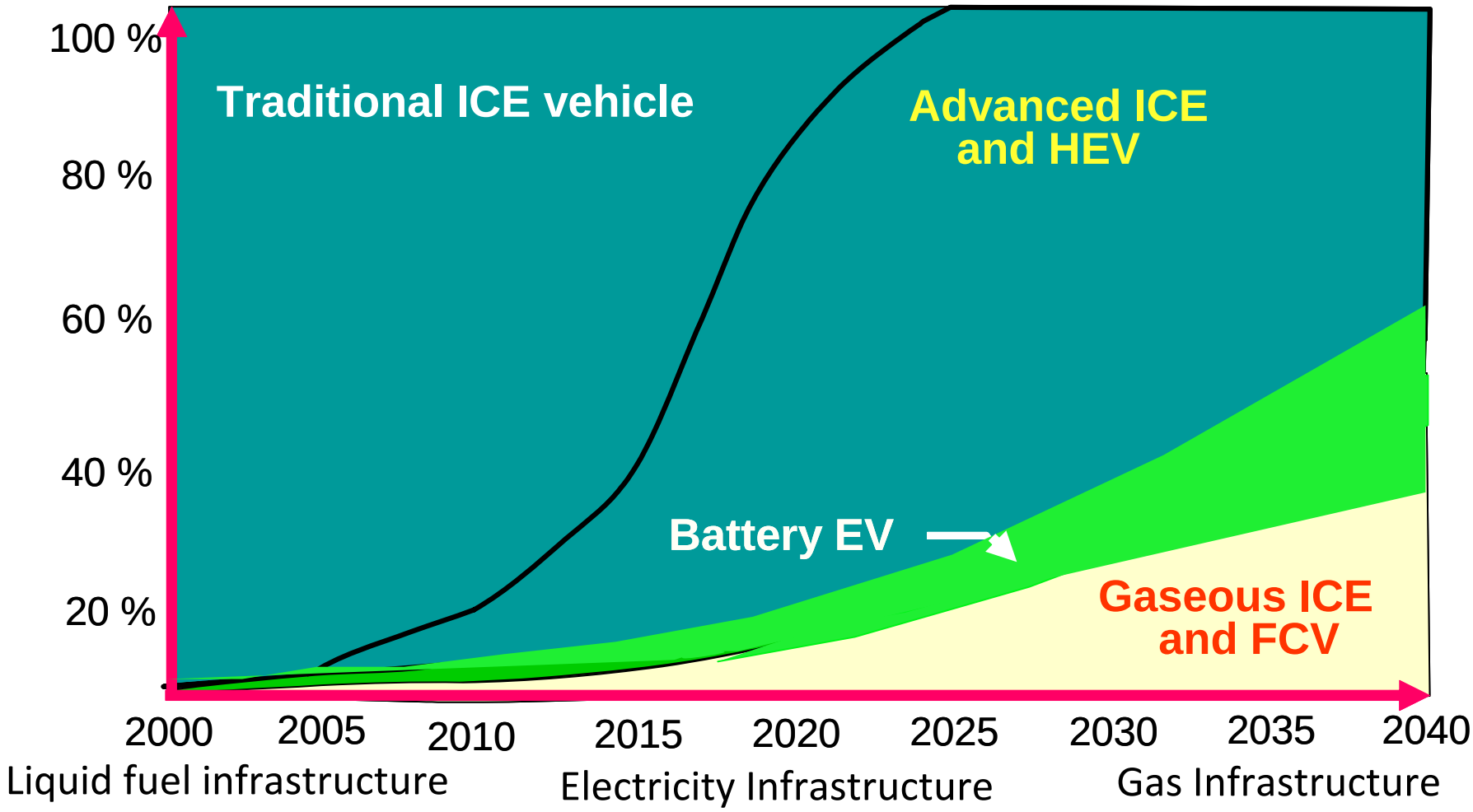
Gaseous fuel (NG、Syn-gas、H2）	+	Internal combustion engine to Fuel Cell Engine	+	Gaseous Auto and HEV to Fuel Cell Vehicle

→ **City Public Transportation**

Electric fuel (Coal-based electricity)	+	Battery/Motor energy motivation system	+	Micro-EV to Electric Vehicle

→ **Personal Transportation**

Development Trend of Automotive Energy and Powertrain in China Based on Three Different Fuel Infrastructure



National Electric Vehicle Program (2001-2005)

Battery Electric Vehicle

Develop EV product， establish commercialization running mode

Product authentication,demonstration in 2005.

R&D | DEMO | Production

Hybrid Vehicle

Develop the Product of Hybrid Vehicle and fit for the Market

Product authentication in 2005， release market in 2006.

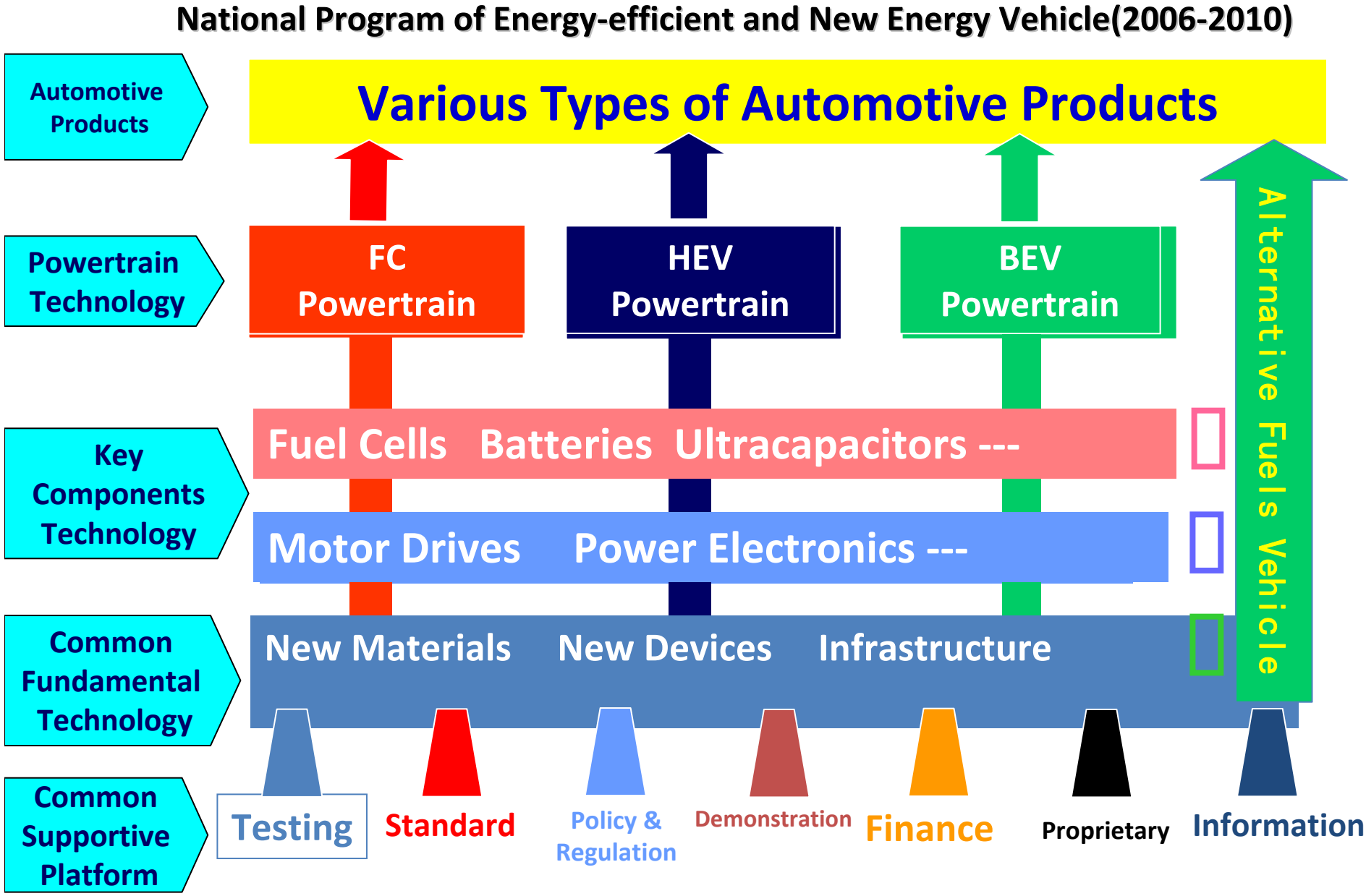
R&D | DEMO | Production

Fuel Cell Vehicle

Research and developing fuel cell Power Trains & vehicle technology platform . Test run in Olympic Games in 2008.

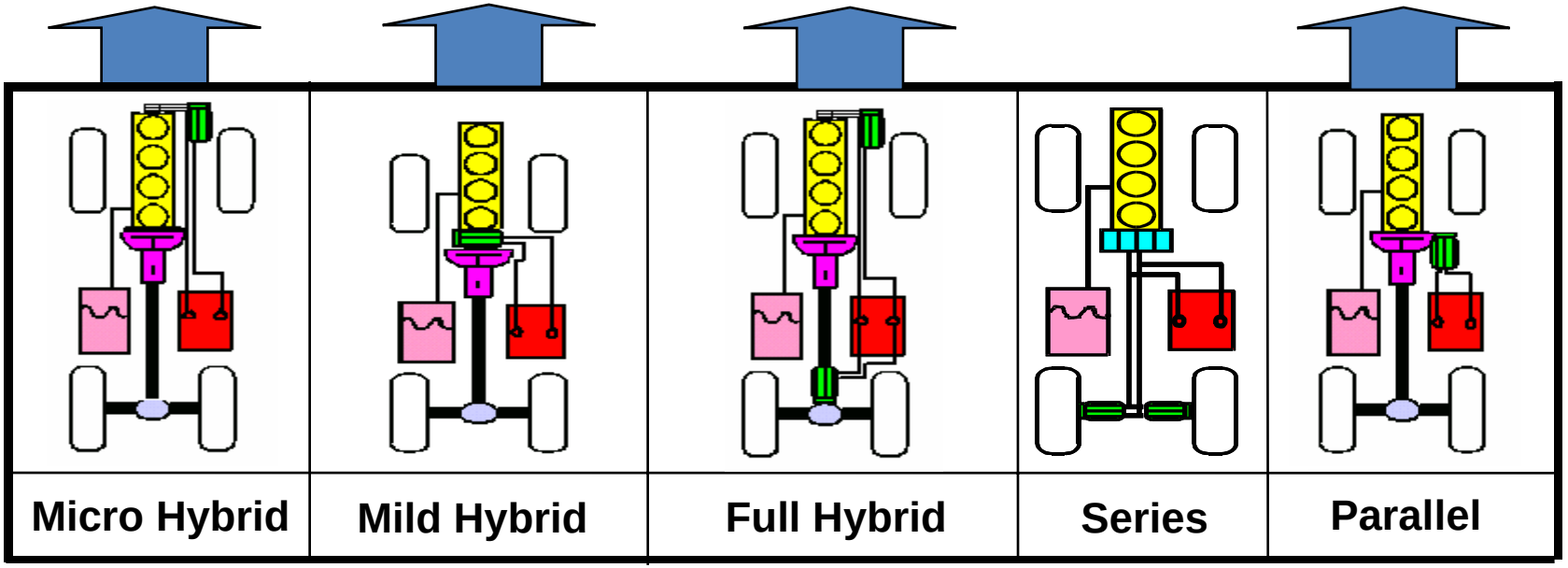
R&D | DEMO

2002.1 — 2005.3


National Program of Energy-efficient and New Energy Vehicle(2006-2010)
Automotive Products
Various Types of Automotive Products
Powertrain Technology
FC Powertrain
HEV Powertrain
BEV Powertrain
Alternative Fuels Vehicle
Key Components Technology
Fuel Cells Batteries Ultracapacitors ---
Motor Drives Power Electronics ---
Common Fundamental Technology
New Materials New Devices Infrastructure
Common Supportive Platform
Testing
Standard
Policy & Regulation
Demonstration
Finance
Proprietary
Information

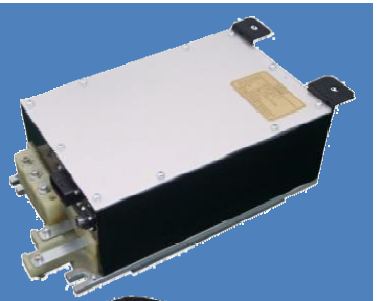
Hybrid Vehicles Development

Micro Sedan	Compact Sedan	Medium Sedan	City Bus
			

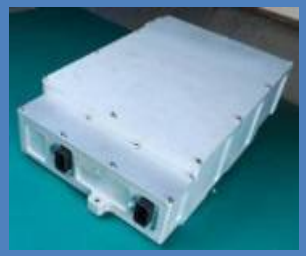


Development of Motor Drives

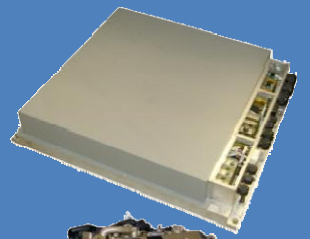
Motor Drive for BEV

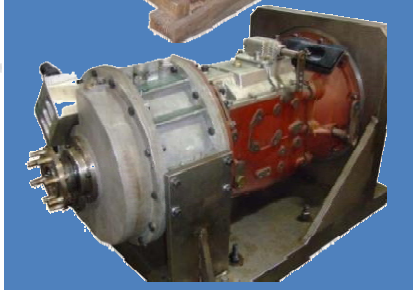


ISG for Sedan



Dual Motor Drive for Sedan





Duel Motor Drive for Buses

Development of Battery

NiMH (Chun Lan)

NiMH (Seng Lai)

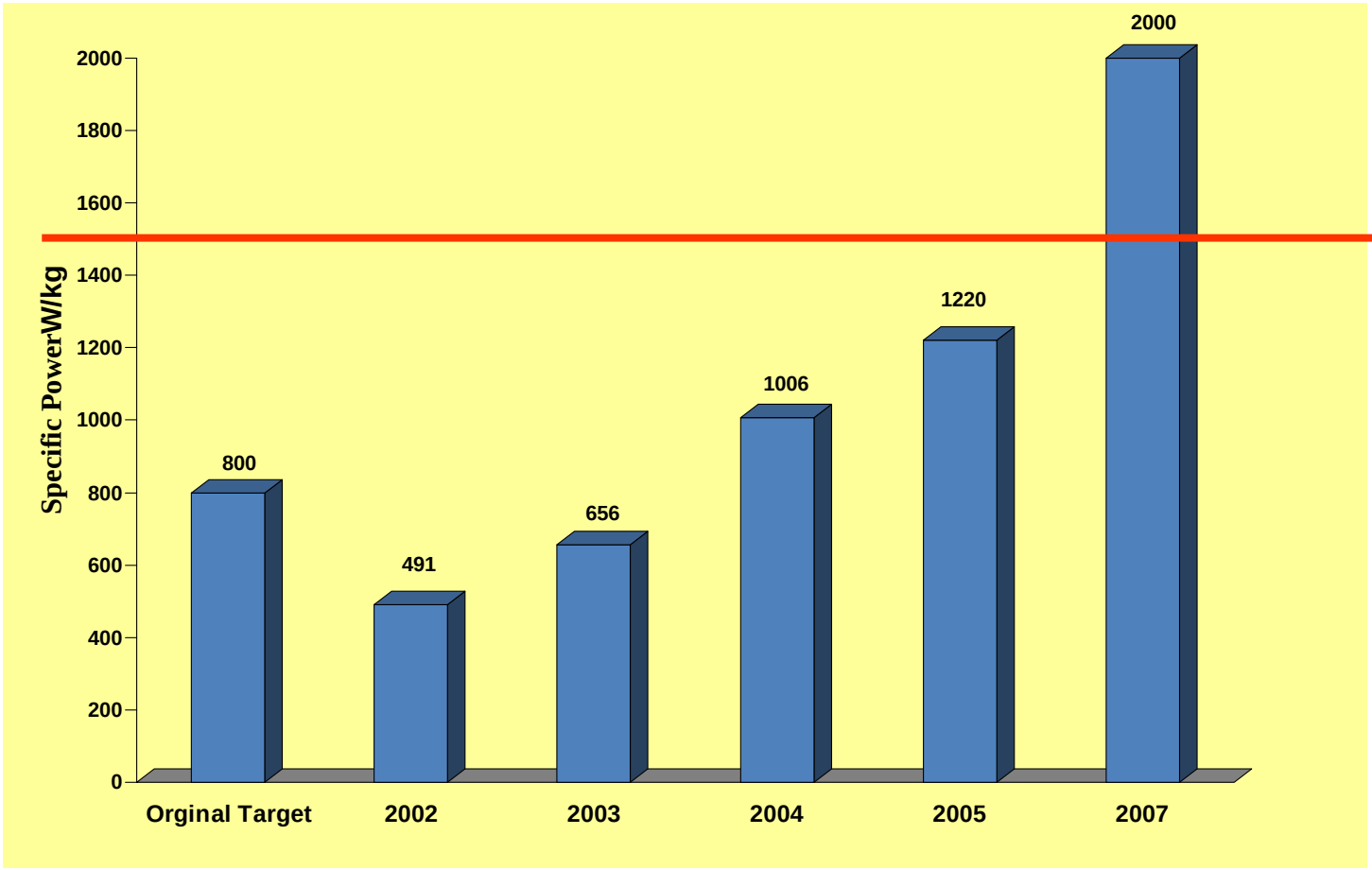
NiMH (Shen Zhou)

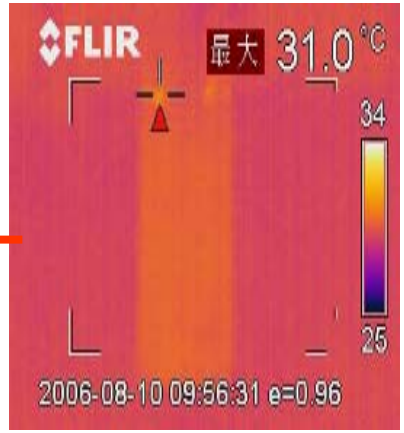
Li Ion (Li Shen)

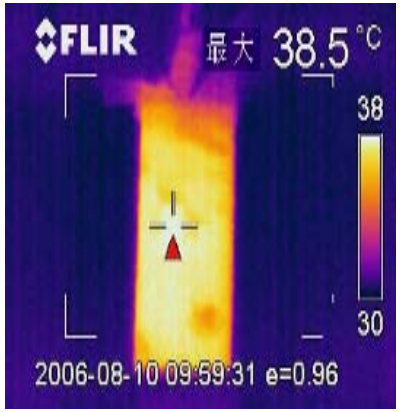
Li Ion (Phylia)

Li Ion (Meng Gu Li)

Improvement of Li Ion Batteries: Specific Power

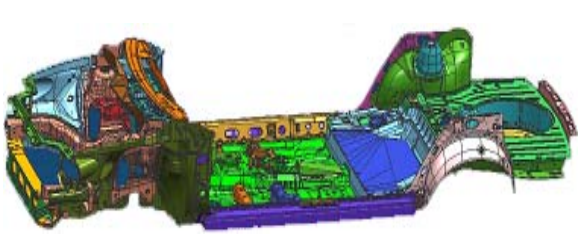






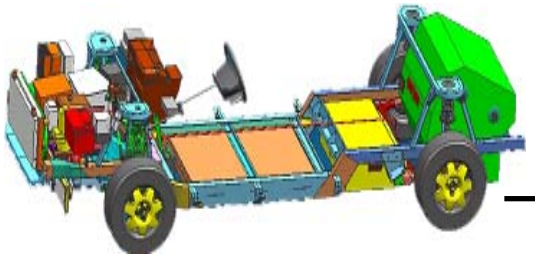
Improvement of Li Ion Batteries: Safety Testing

Fuel Cell Vehicles Development

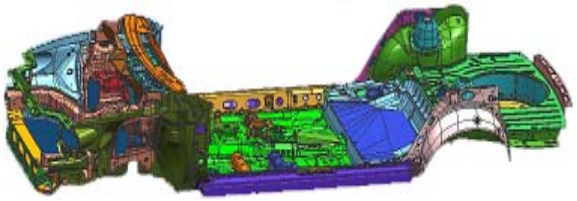


SAIC Chassis

SAIC FCV



Powertrain Platform



V W Chassis

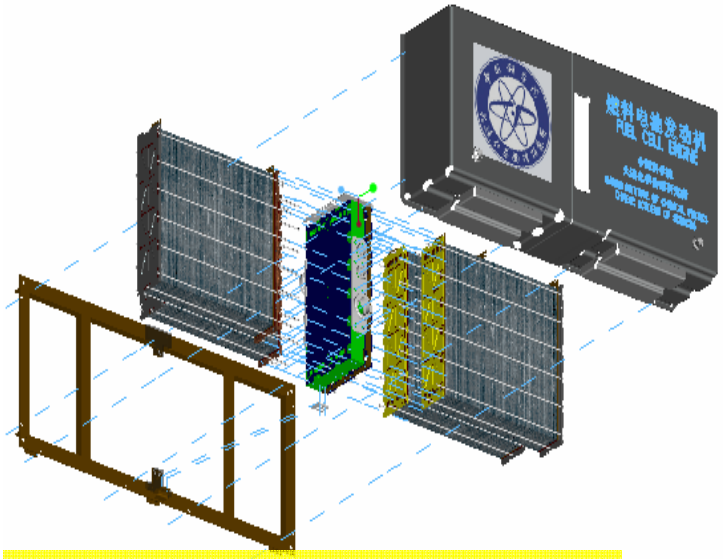
V W FCV

Cherry Chassis

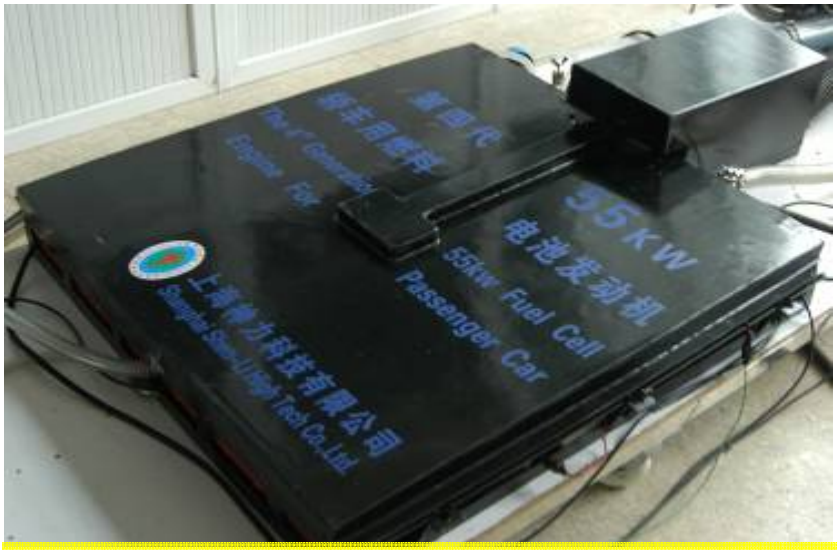
Cherry FCV

Fuel Cell System Development

	Power kW	System Efficiency (Net)	Specific Power W/kg
FC Buses	80	45%(Rated); 52.7%(Max)	171.2
FC Sedan	50	42.52%(Rated); 58.54%(Max)	204



Xin Yuan FC Module



Shen Li FC System

More Electric is Vehicle Trends

- BEV, Pulg-In Hybrid, Range Extender


- Micro EVs have great potential







Promotion of EV/HEV in 13 Cities

- *Each city over 1000 vehicles within 3 years*
- *Priority in public transportation*
- *Incentives from central and local governments*
- *Incubation of demand and market*

Beijing Olympic 2008 – EV,HEV, FCV

600 EVs, HEVs, FCVs;
3,714,000km, 44,170,000 person-trp

Olympic Beijing – 50 Electric Buses

- 北理工、北京公交京华客车50辆纯电动客车在媒体村和运动员村作为摆渡巴士搭载中外媒体和运动员，诠释中心区交通零排放。

Olympic Beijing – 415 EVs
266,500km, 592,200 person-trip

- 东风纯电动场地车共计415 辆，致力于核心区和场馆交通零排放。

普京驾驶东风电动车

奥运冠军何可欣乘坐东风电动车

- **运行里程（截至8月24日奥运闭幕）共计26.65万公里；载客人数累计592200人次；35个场馆(24个竞赛场馆、11个非竞赛场馆)运行线路38条。**

Olympic Beijing – 10 FAW Hybrid Buses
155,000km, 660,000 person-trip,
Fuel economy 39.83/100km, Saving 17.38%

•10辆一汽混合动力电动客车运送乘客累计约66万人次。累计行驶里程达15.5万公里。

•油耗为39.83L/100km,相对燃油车节油17.38%

Olympic Beijing – 15 Dong Feng Hybrid Buses

145,000 km, 750,000 person-trip,Fuel economy 50L/100km, saving 20.14%

•15辆东风混合动力电动客车累计行驶14.5万公里，运送乘客75万人次

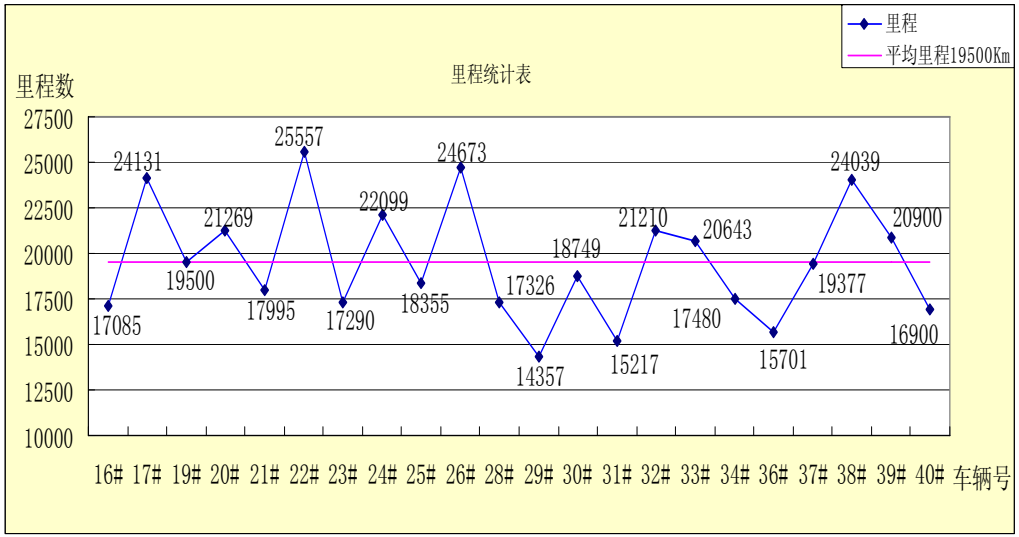
•油耗为38.50L/100km，相对燃油车分别节油20.14%

Olympic Beijing – 50 Cherry Mild HEVs
1735,000km, BSG Fuel Saving 5.7%-10.3%,
ISG Fuel Saving 13%-20.4%

- 截至9月16日， 奇瑞50辆混合动力轿车累计总里程：173.5万公里
- A5 BSG节油率在5.7%至10.3%，ISG节油率达到13%至20.4%。

Olympic Beijing – 22 Chang An Mild HEVs
87 Days, 429,000km, 708,000 person-trip,

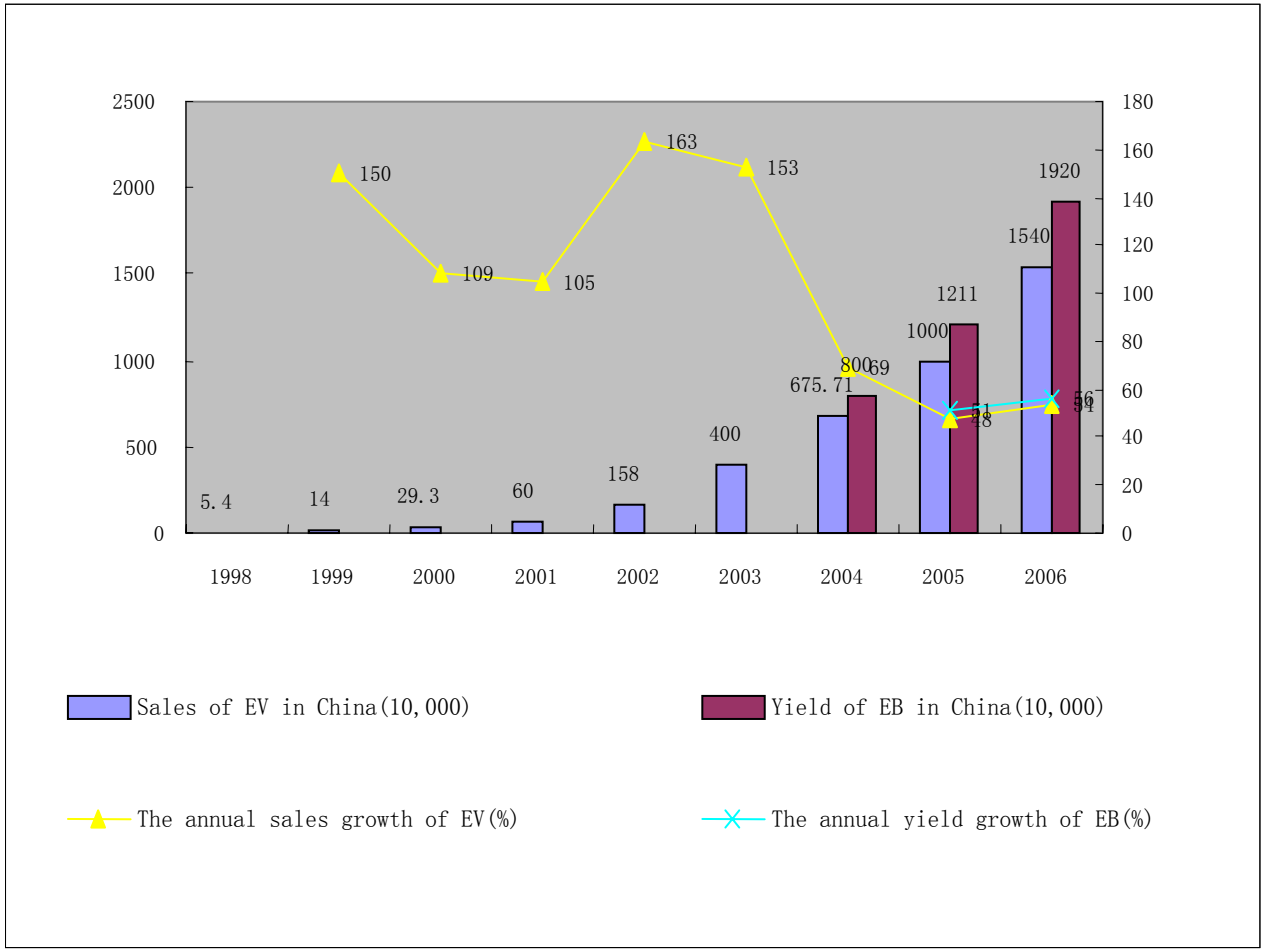
Fuel saving 20% - 30%



- 22辆杰勋混合动力轿车，运行87天期间共载客7.08万人次，累计行驶里程42.9万公里。
- 长安杰勋混合动力轿车的节油率达到20%至30%。

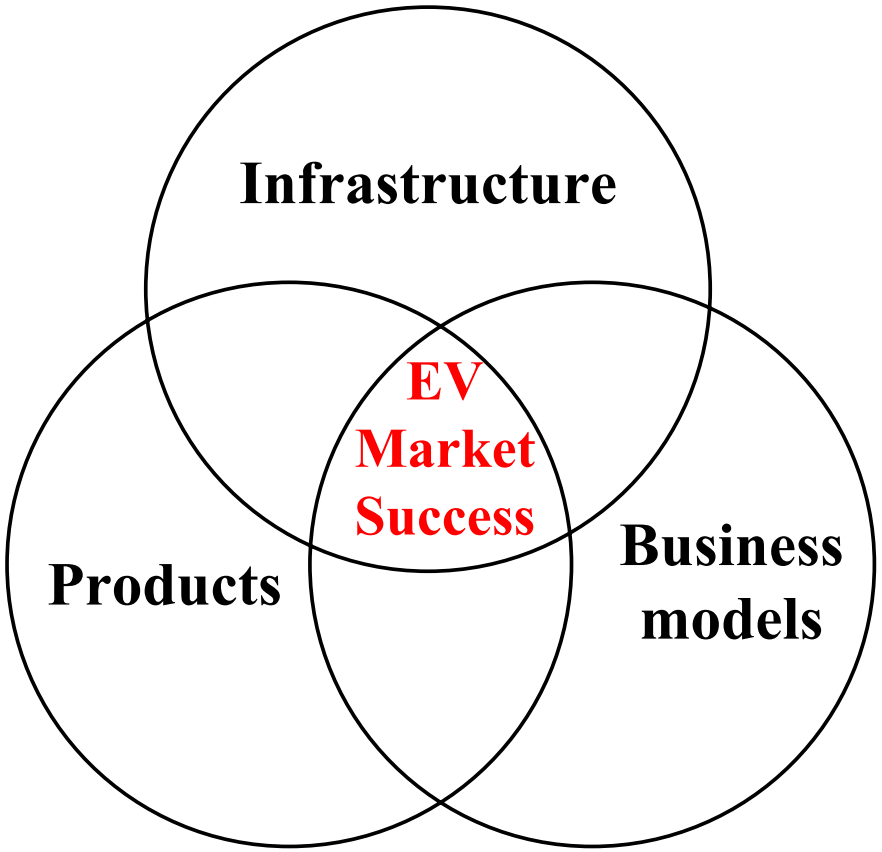
FCV Demonstration in 2008 Beijing Olympics

LEV Development in China

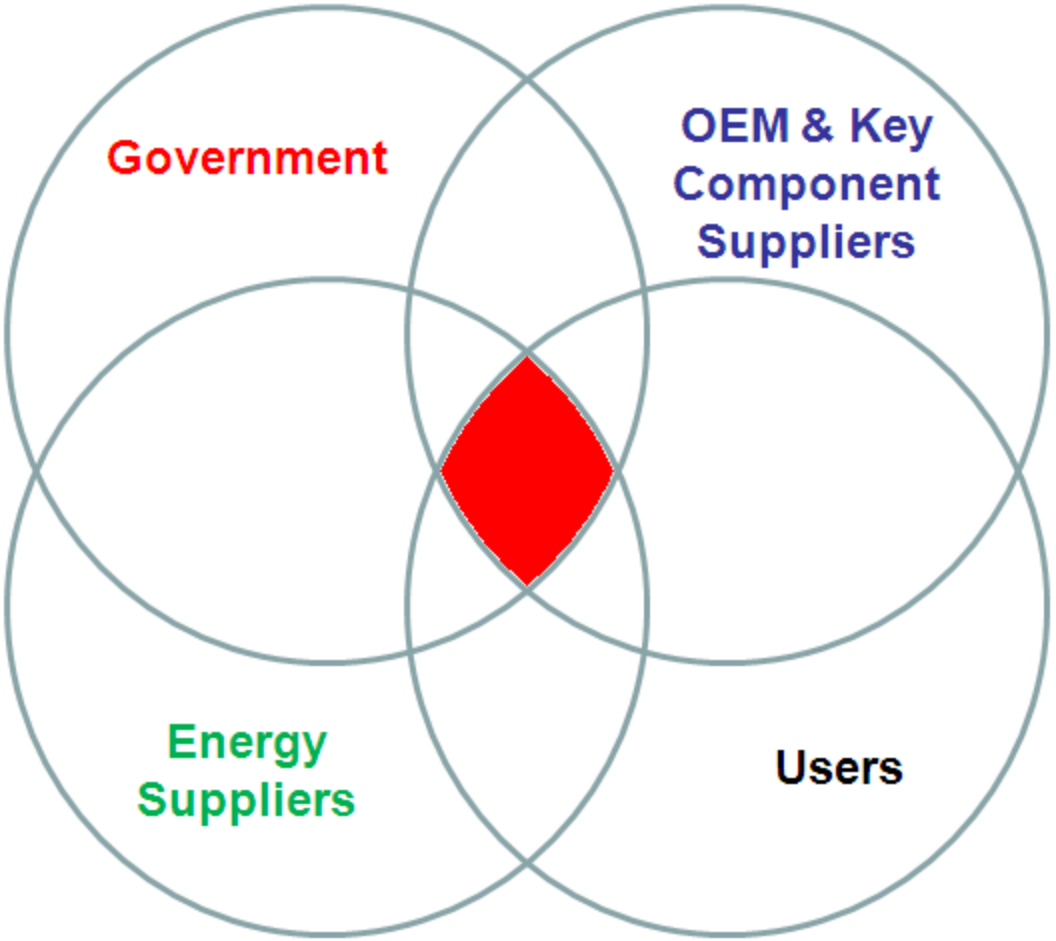


Wind & Solar Power Charger

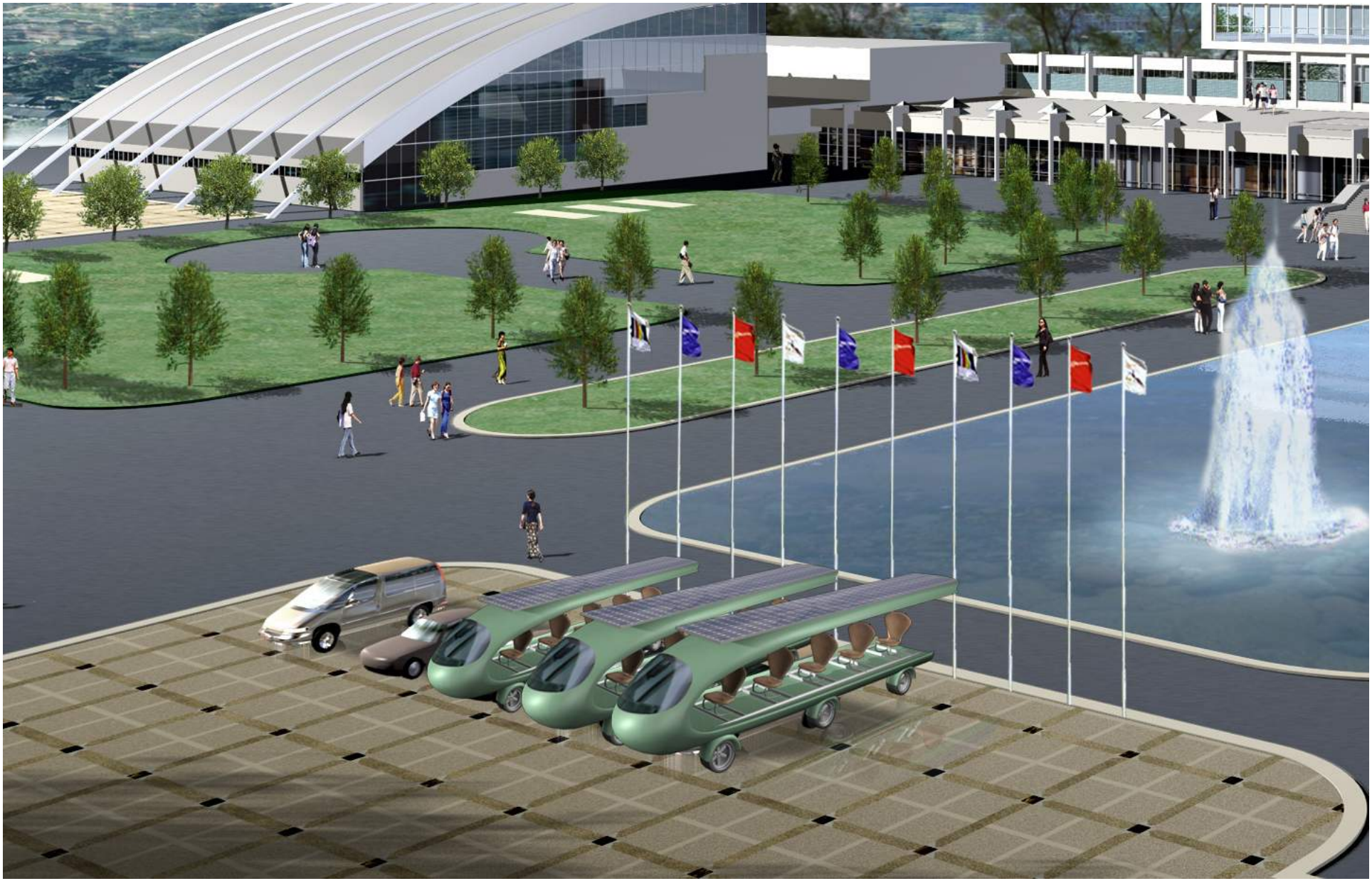
Success of EV/PHEV Markets



Innovative EV/PHEV Business Model



ADAPTING: THE NEW ENERGY PARADIGM



SUCCESS

SUCCESS

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

Thank you!