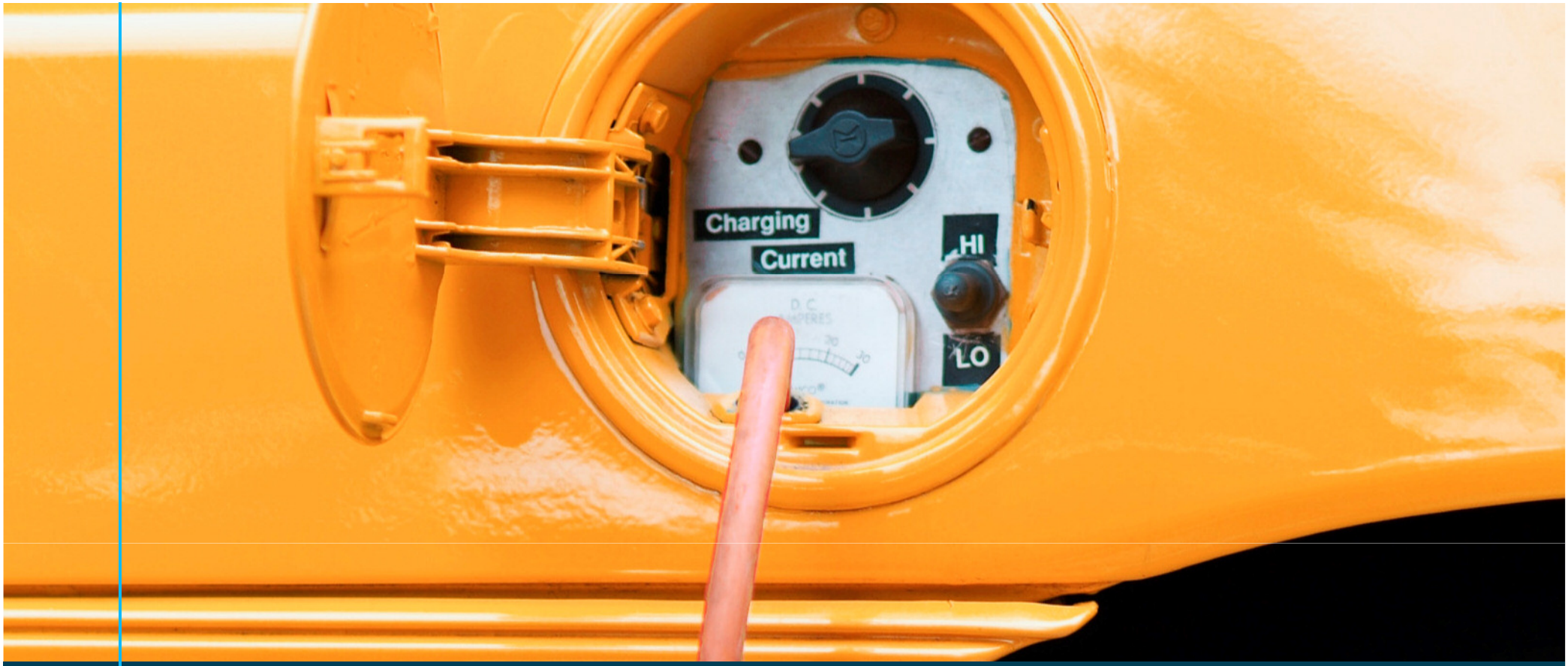


Powertrain 2020

China's ambition to become market leader in E-Vehicles

Munich/Shanghai, April, 2009

Roland Berger
Strategy Consultants

A. Government policy and market outlook:
China is pushing and moving towards electric driving

Roland Berger
Strategy Consultants

China is actively developing a domestic market for electrified powertrains – at least 15% EV and PHEV to be expected in 2020

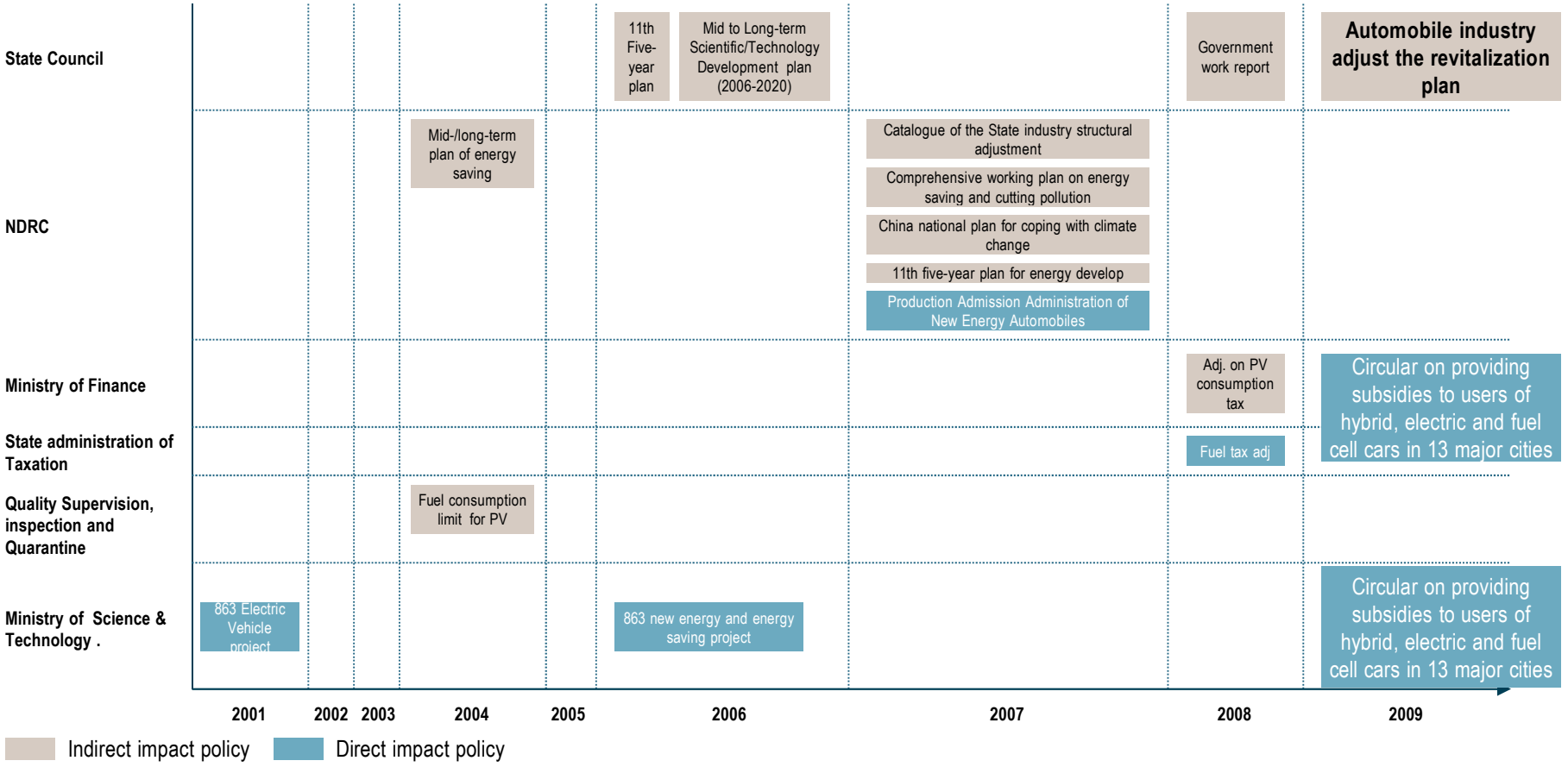
- The Chinese Government launched many new energy policies in recent years
- China realized that they can not close technology gap in internal combustion engine based mobility soon – focus new energy
- With the "Automobile Industry Revitalization" the government defines imported steps towards "New Energy Vehicles"
- According to recently published *Auto Industry Revitalization Plan*, new industry policies will likely bring substantial fiscal policy
- The MOST and MOF already gave out a circular on subsidy in 13 Tier1 and Tier 2 cities, in order to industrialize the PHEV/EV vehicles technology: EUR 6,800 for battery electric vehicles
- We expect EV infrastructure in 2020 to cover cities having > 1.000 USD GDP/capita – that accounts for 46% of total PV sales
- Domestic EV and PHEV sales volume are expected to exceed 15% (1,6 m. units) in 2020 – significant upside in 3-wheelers

Source: Roland Berger

Roland Berger Strategy Consultants

The Chinese Government launched many new energy policies in recent years – focus on new energy since 11th 5-years plan

Existing new energy policies launch calendar



Source: Relevant state policies

Roland Berger Strategy Consultants

China realized that they can not close technology gap in internal combustion engine based mobility soon – focus new energy

Government 'S RATIONALE TO MAKE POLICIES

> **Industrial development favors domestic OEMs**
  – China's laggard in internal combustion system is widely know, gov. wants to help domestic OEMs to achieve leading position through policy support

> **Policy support favors plug-in and pure electric**
  – Diesel lost priority from 10th to 11th 5-years plan – focus now on hybrid/electric vehicles
  – Hybrid is already rapidly developing, even without policy support, it would still be industrialized
  – Realizing China cannot compete in hybrid field, gov wants to help domestic OEMs achieve competitive advantage through plug-in &pure electric field
  – Support plug-in can help build infrastructure for future pure eletric

> **Release timing will favor domestic OEMs**
  – Too early release will benefit foreign OEMs, so, they will be released when domestic Parts and OEMs are mature
  – Gov will not impose "non-citizen treatment" to foreign OEMs but may use entry requirement and tech standards to inhibit foreign OEM

NEW ENERGY VEHICLE POLICY TREND

> **Policy based on energy saving level**
  – Offer subsidy to vehicle reaching energy saving and low emission requirement, subsidy is differentiated according to energy saving level

> **Support focus on plug-in and pure electric**
  – Pure electric receive highest subsidy, plug-in receive mid-level subsidy, other hybrid receive least

> **Offer low import duty for parts of hybrid cars**

Source: From interview with government department, OEM and institute auto experts

Roland Berger Strategy Consultants

According to recently published *Auto Industry Revitalization Plan*, new policies will likely bring substantial fiscal support

Auto Industry Reviving Plan

POLICY TYPE	POLICY CONTENTS	RELEASE TIME	DEPT
Fiscal/Tax policy	> Reduce vehicle purchase tax to 5% for 1.6L & below displacement > Grant RMB 10 bn fund to support enterprise tech innovation, tech reform, new energy car and parts development > Provide subsidy for application of energy saving and new energy vehicle in major cities	2009/1	NDRC, State council etc.
Macro policy	> Implement new energy vehicle strategy, foster industrialization of electric car and parts		

POLICY SUGGESTION FROM NEW ENERGY VEHICLE POLICY RESEARCH PANEL

Fiscal/Tax policy	> Foster pure electric, hybrid & other new energy car by subsidy and preferential taxes > Set fiscal/tax reward & penalty mechanism basing on product fuel economy level > Impose special penalty tax to low fuel economy level vehicles > More reward to production & consumption of low-displ., PHEV (Plug-in Hybrid Electric Vehicles), pure electric vehicles > Impose differential fuel taxes	2009/2	NDRC, State council etc.

> **Future fiscal/tax policy may benefit many new energy vehicles including hybrid, pure electric cars**
> **Fiscal/tax support may link to vehicle fuel economy indicator, with both rewards and penalties**
> **PHEV and pure electric vehicle may get more support, reflecting government preference in this field**
> **Execution details of fiscal/tax policy is pending further observation as they are not currently planned yet**

Source: Auto Industry Reviving Plan; China Tech Research Center; Energy Saving And New Energy Tech Policy Research by NDRC

Roland Berger Strategy Consultants

The MOST and MOF already gave out a circular on subsidy in order to industrialize the PHEV/EV/FC vehicles technology

PUBLIC SERVICE VEHICLES IN 13 CITIES

PLAN DETAILS

- **Objective**
  - Speed up structure adjustment to automotive industry, foster the industrialization of new energy vehicles and encourage automotive consumption
- **Target vehicles**
  - HV, Pure EV, Fuel cell vehicles with min. 5% fuel saving for PV & light CV and min. 10% fuel saving for bus
  - City bus, taxi, official car, environmental sanitation, post and other public service vehicles
- **Subsidy standard**
  - HV: different subsidy according to fuel saving rate
  - Pure EV: RMB 60,000 for PV and 500,000 for bus
  - Fuel Cell: RMB 250,000 for PV and 600,000 for bus

Roland Berger Strategy Consultants

Public use of EV and PHEV is heaviliy subsidized – EUR 6,800 for battery electric vehicles

SUBSIDY TO PUBLIC USE PV AND LCV (RMB'0000)

Vehicle type	Fuel saving rate	Max. Electric Power rate			
		BSG [1]	10%-20%	20%-30%	30%-100%
Hybrid vehicle	5%-10%		–	–	–
	10%-20%	0.4	2.8	3.2	–
	20%-30%	–	3.2	3.6	4.2
	30%-40%	–	–	4.2	4.5
	>40%	–	–	–	5.0
Pure EV	100%	–	–	–	6.0
Fuel cell Vehicle	100%	–	–	–	25.0

Note: the subsidy standard for HEV with max. Electric Power rate over 30% applies to plug-in

SUBSIDY TO PUBLIC CITY BUS OVER 10 METER (RMB'0000)

Energy saving & new energy Vehicle type	Fuel saving rate	Using -Lead Acid Battery	Using Nickel-Metal hydride battery, lithium-ion battery and super-capacity HYBRID	
			Max. electric power rate: 20%-50%	Max. electric power rate > 50%
Hybrid vehicle	10%-20%	5	20	–
	20%-30%	7	25	30
	30%-40%	8	30	36
	40%以上	–	35	42
Pure EV	100%	–	–	50
Fuel cell Vehicle	100%	–	–	60

1) BSG: Belt-Starter-Generator system, a start-stop system

Source: Official website of Ministry of Finance

Roland Berger Strategy Consultants

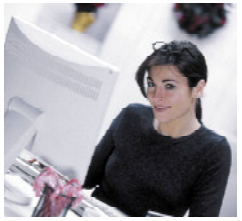
The market potential of EVs depends on their ability to fulfill customer mobility needs

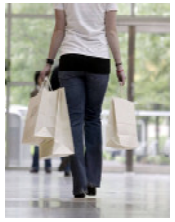
1 Fundamental mobility needs

Driving range needs

Need for unrestricted mobility

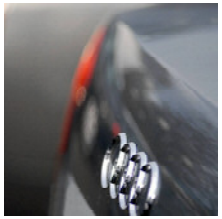
Specific trip pattern needs





2 Financial needs: purchase price and TCO

3 Car specific needs: brand/model/size/comfort



Source: Roland Berger Analysis

Roland Berger Strategy Consultants

Two scenarios are taken into account "Downsized Mobility" and "The Future Drives Electric"

Description of scenarios

DRIVERS		"DOWNSIZED MOBILITY"	"THE FUTURE DRIVES ELECTRIC"
1 Mobility needs	EV driving range 	> Limited range for EVs > No disadvantage for PHEV	> Limited range for EVs > No disadvantage for PHEV
	Infrastructure 	> Infrastructure roll-out in phases	> Infrastructure roll-out in phases > Accelerated roll-out
2 Cost	Fuel and battery prices 	> Stagnating fuel prices > Slow battery cost reduction	> Increasing oil prices > Accelerated battery cost reduction
	Taxes/ incentives 	> Low governmental support for fuel efficient technologies	> Higher governmental support for fuel efficient technologies
3 Image/ comfort needs	Segments 	> Limited segment offering, A00/A0 segments for EVs, A/B for PHEVs	> Wide segment offering; A00/A0/A for EVs, B or bigger for PHEVs
	Brands	> A few front runners > Most OEMs remain skeptical	> A bunch of OEMs in the 1st. phase > Many incumbent OEMs actively involved

Source: Roland Berger Analysis

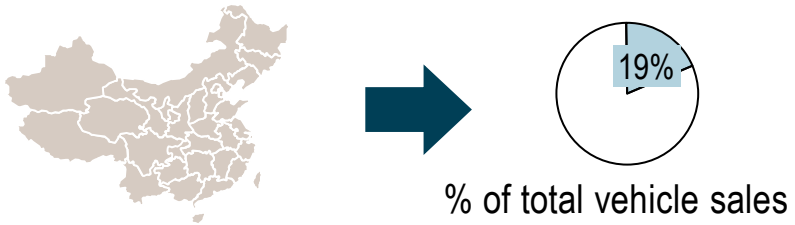
Roland Berger Strategy Consultants

We expect EV infrastructure in 2020 to cover cities having > 1.000 USD GDP/capita – that accounts for 46% of total PV sales

Passenger car sales share segmented by GDP per capita of cities, 2010/2020

INFRASTRUCTURE COVERAGE BY PHASES

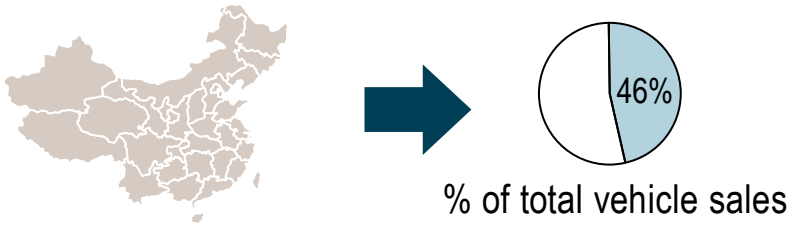
PHASE 1
Cities having announced an EV Pilot



Cities having announced an EV Pilot

- Changchun
- Dalian
- Beijing
- Jinan
- Hefei
- Shanghai
- Hangzhou
- Wuhan
- Nanchang
- Changsha
- Shenzhen
- Kunming
- Chongqing

PHASE 2
Cities with GDP/capita > 1.000 USD



Cities with GDP/capita > 1.000 USD

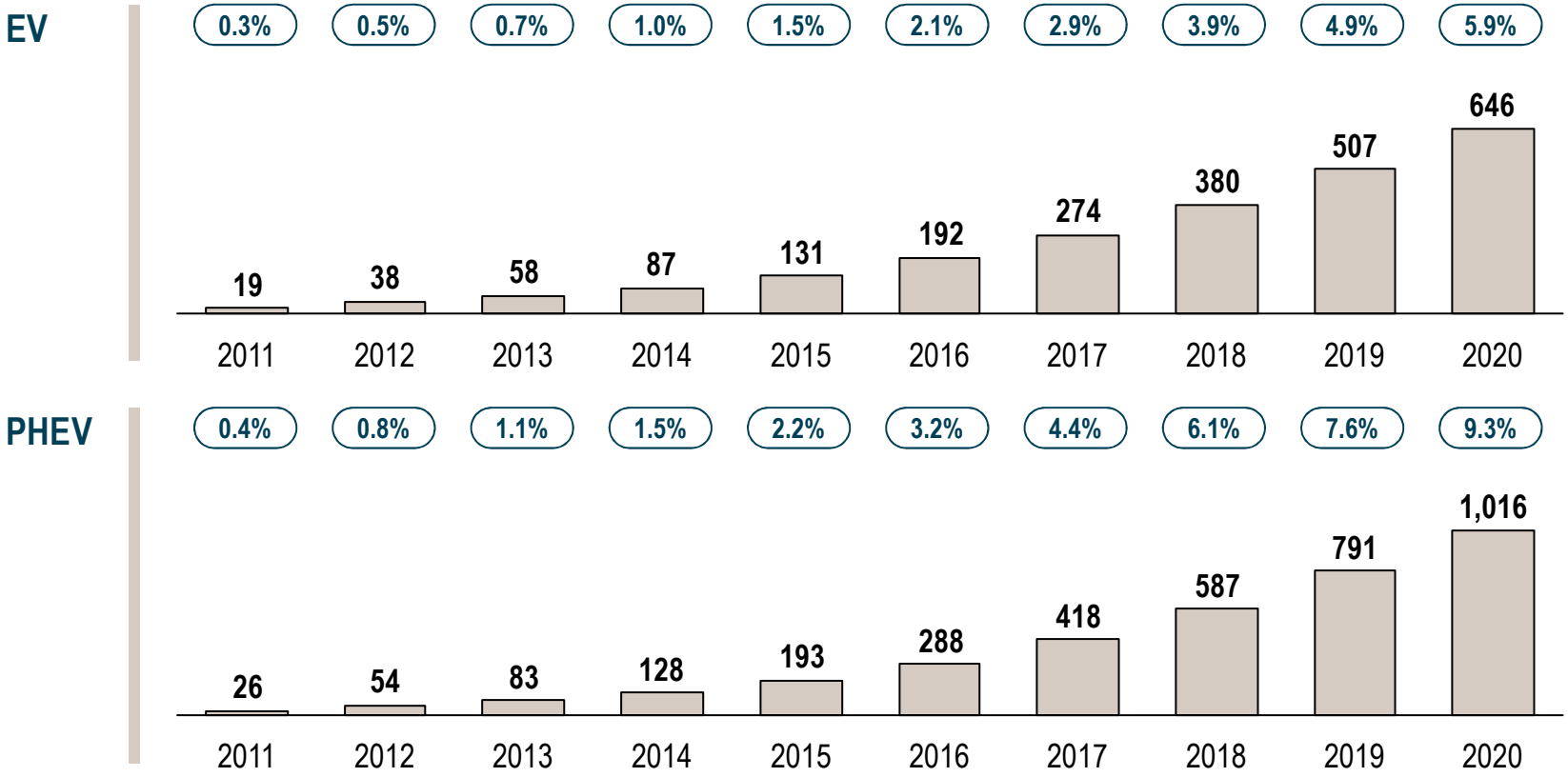
- More than 40 Chinese cities

Source: Roland Berger Analysis

Roland Berger Strategy Consultants

Domestic EV and PHEV sales volume are expected to exceed 15% (1,6 m. units) in 2020 – significant upside in 3-wheelers

The future drives electric scenario [units]



Source: Roland Berger Analysis

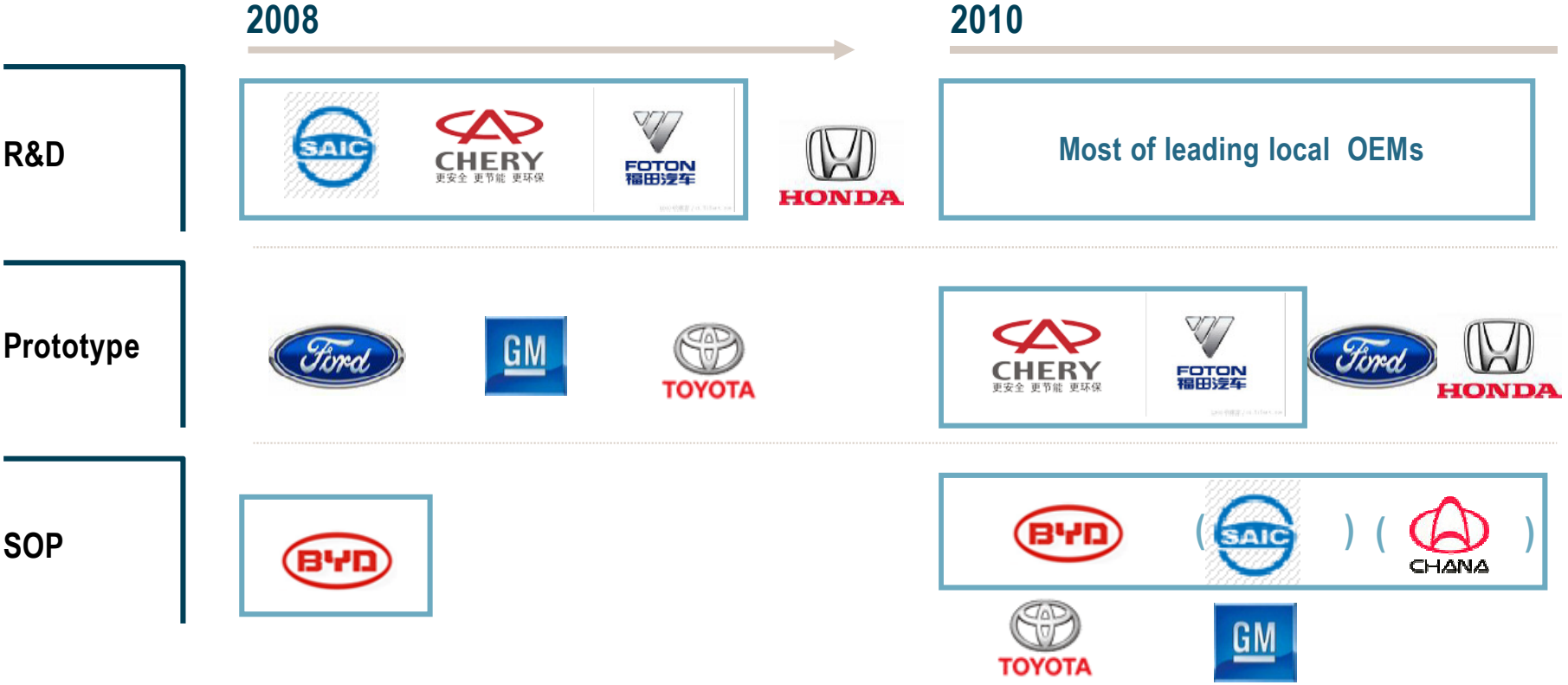
B. Chinese players:
Chinese OEMs are encouraged to launch EVs and PHEVs

Roland Berger
Strategy Consultants

Roland Berger Strategy Consultants

Currently BYD takes the lead in PHEV market, but more local players are expected to heat the competition in the coming years

PHEV (PV) development status of major players – 2008 vs 2010



GOVERNMENTAL TARGET ON NEW ENERGY VEHICLES SALES FOR CHINESE OEMS UNDER CONSIDERATION

Local OEMs ( ) Potential

Source: External and press research; Roland Berger research

Roland Berger Strategy Consultants

Currently BYD takes the lead in battery electric vehicles, but more local players are expected to heat the competition

Manufacturer	Model	Type / Price	2008	2009	2010	2011	2012	2013	2014	2015
BYD	F3e 	EV 150,000 RMB		SOP						
	F6 	EV			SOP					
	F3DM 	PHEV 100,000 - 150,000 RMB		SOP						
	F6DM 			SOP						
Cherry	ZC7050A 	EV 90,000 RMB					SOP			
SAIC	(open)	EV							SOP	

Source: Supplier informations, Roland Berger research

Roland Berger Strategy Consultants

Tianjin Qingyuan already exports to the US and is planning in addition electric three-wheelers for rural markets

Manufacturer	Model	Type / Price	2008	2009	2010	2011	2012	2013	2014	2015
Wanxiang	Car/Pickup 	EV			SOP					
Changan	(open)	EV					SOP			
Tianjin Qingyuan	Happy Messenger 	EV 68,500 RMB			Already export of small batch to US, so far no plan for China until standards released by government					
	Weile	EV			Already export of small batch to US, so far no plan for China until standards released by government					
	Saibao 	EV			SOP					

Source: Supplier informations, Roland Berger research

C. Hybrid/EV components:
China wants to become the technology hub for E-components

Roland Berger
Strategy Consultants

China wants to become the technology hub for E-components

- The share of electrified powertrains will increase in all major automotive markets
- The market for electric/electronic HEV/EV powertrain components will become a EUR 20 .. 50 bn p.a. business in major automotive markets
- Chinese suppliers already have some competitive advantages:
  - Lower raw material costs and ability to drive down manufacturing costs for Li-Ion battery cells fast by using domestically produced equipment
  - Li-Ion battery production will become a volume play – economies of scale necessary for future success. China already has a significant manufacturing base for Li-Ion cells and is putting vast ressources in research and production ramp-up
  - China suppliers have successfully developed leading quality permanent-energized synchronous machines – at significant lower price than overseas competitors. To do so, they can leverage the fact, that China possesses 80% of global Neodymium resources, the critical material to produce permanent magnets.

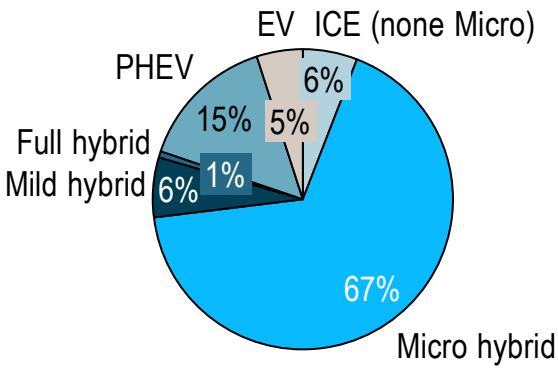
Source: Roland Berger

Roland Berger Strategy Consultants

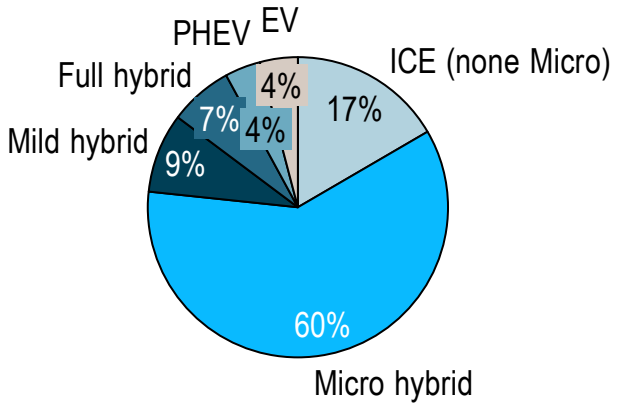
The share of electrified powertrains will increase in all major automotive markets

Share of powertrain technologies in major markets in 2020 – High scenario

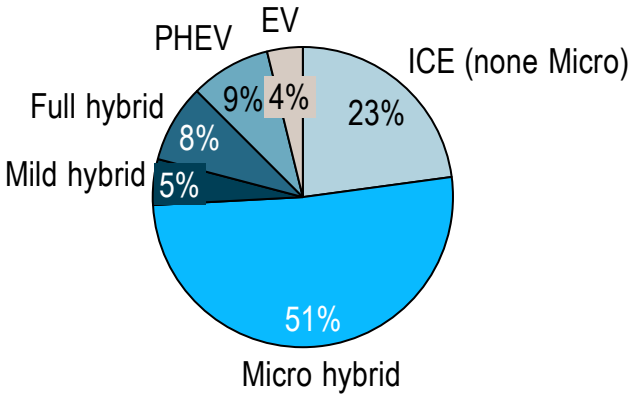
Western Europe



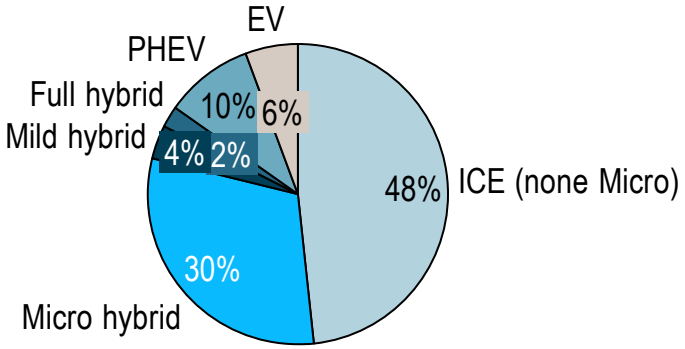
Japan



US



China

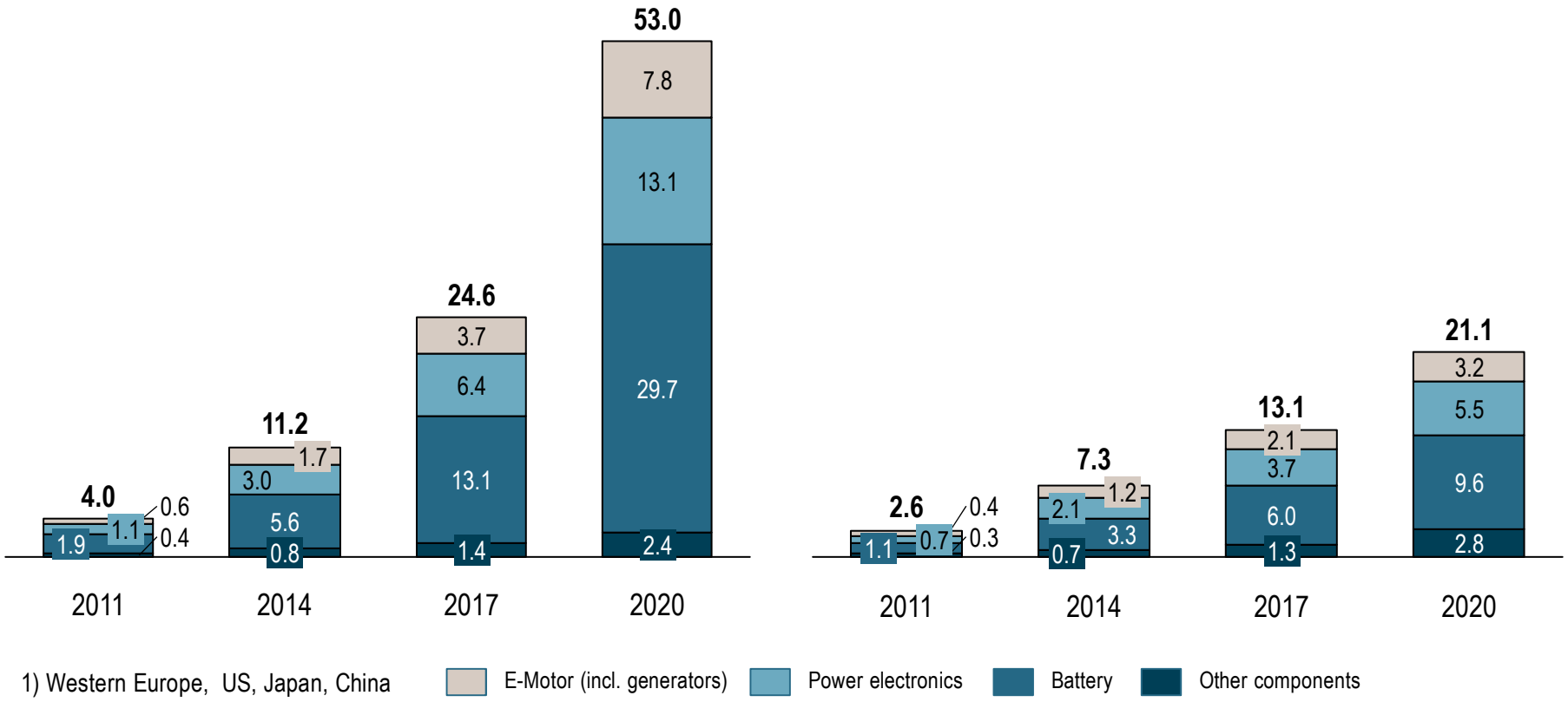


Source: Roland Berger

Roland Berger Strategy Consultants

The market for electric/electronic HEV/EV powertrain components will become a EUR 20 .. 50 bn p.a. business

Total market[1] value [EUR bn]



1) Western Europe, US, Japan, China

Source: Roland Berger

Roland Berger Strategy Consultants

Chinese suppliers already have some competetive advantages

Overview of Key Findings

1 Periphery Electronics / Power Electronics

> **Limited amount of BMS suppliers in China** - mainly university driven w/o mass commercialization
> **Lacking capability** in China **to mass-produce DC/DC converter** for EV applications
> **Foreign players still dominate** when it comes to **sourcing Power Inverter** components and system integration – some Chinese Tier-1 starting to improve (e.g. Wanxiang, Ananda)

2 Battery

> China's **Li-ion battery mass commercialization still evolving** whereas NiMH batteries have achieved industrialization stage
> China suppliers have **successfully developed LiFePO4 batteries** offering competitive performance in EV usage for local market – significant cost advantages to global competition
> **Many Li-ion suppliers** exist and need **to be validated for EV applications**

3 Electric Motor

> **Significant cost advantage in permanent energized synchonous machines for hybrid applications** (China posseses majority of "rare earths") and **already good technology**, technology gap in asynchronous machines to be closed

1) Focus on suppliers from mainland China only; w/o Taiwan

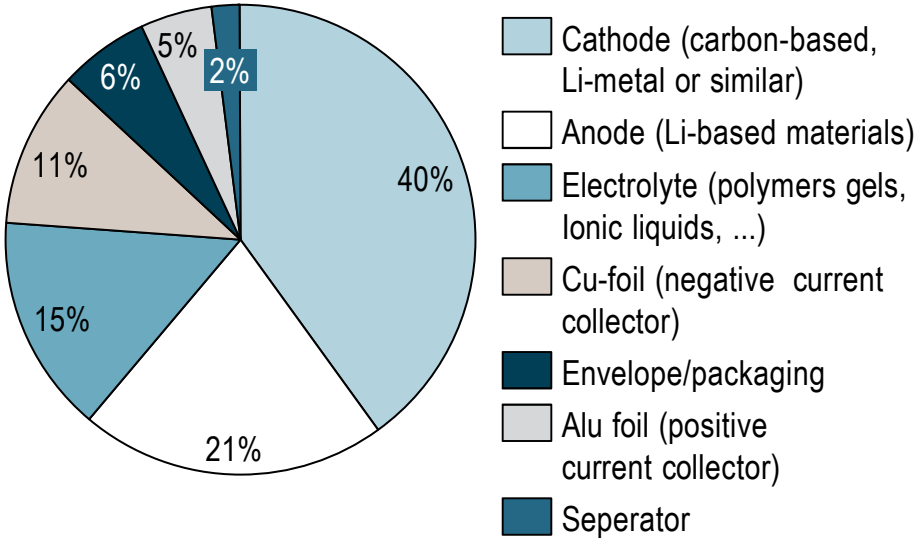
Source: Roland Berger analysis

Roland Berger Strategy Consultants

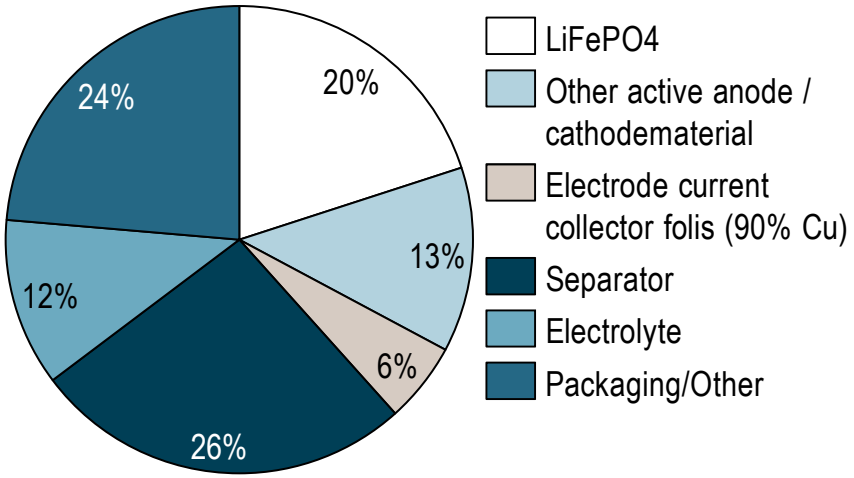
Approx. 2 kg of LiFePO4 are necessary per kWh today

Share of LiFePO4 in Li-Ion batteries

WEIGHT DISTRIBUTION (CELL LEVEL)



RAW MATERIAL COST SHARES (CELL LEVEL)[1)]



1) Outside China, 2009

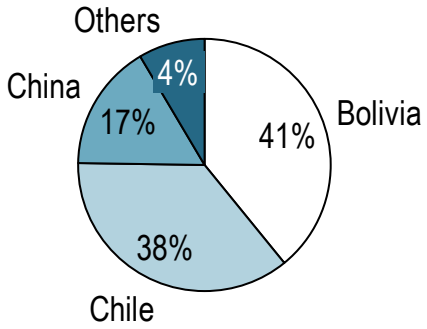
Source: EEI, US DoE, Roland Berger

Roland Berger Strategy Consultants

Lithium demand will increase significantly, China #3 in global reserves also securing access to South American reserves

Global reserves, production, supply and demand of Lithium for batteries

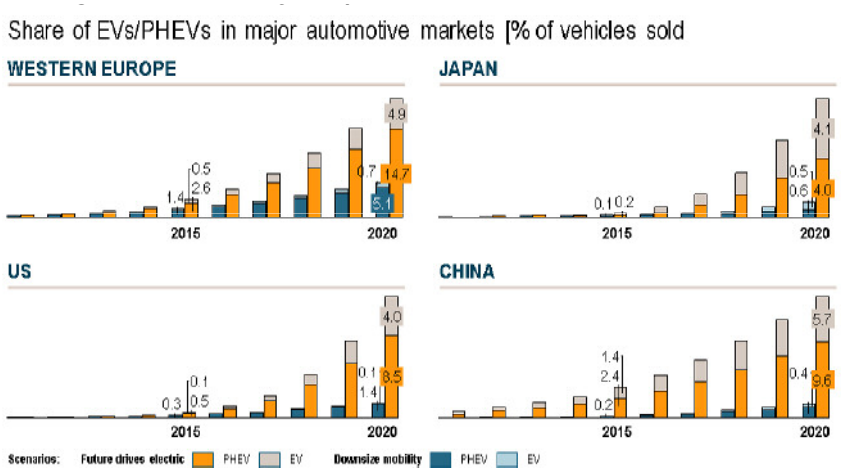
Global reserves (~30 mio. to Li, or 160 mio LiCarbonate equivalent)



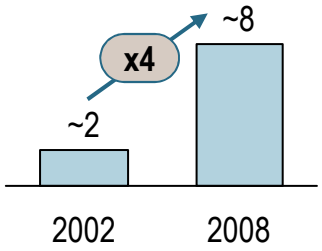
> Of approx 30 mio to, 50%.60% technically recoverable

> Approx 25% of 2008 production used for batteries

> LiCarbonate equivalent demand per kWh: ~1.5 kg

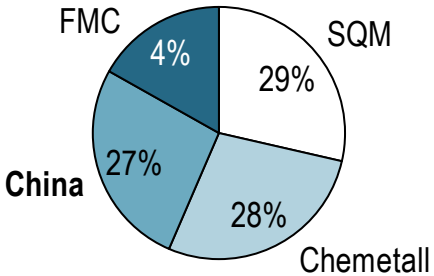


Li-Carbonate costs [USD/kg]



2009: $6,600/to

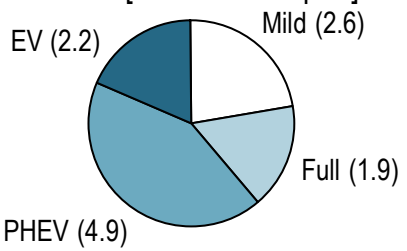
Supply structure – Market shares 2007 (LiCarbonate equivalent)



2008: 95k to

Market for hybrids/EV, batteries

Production (2020, high scenario)] [mio vehicles p.a.]



Li-demand 2020

92 mio kWh = 140..150 kto LiCarbonate equivalent

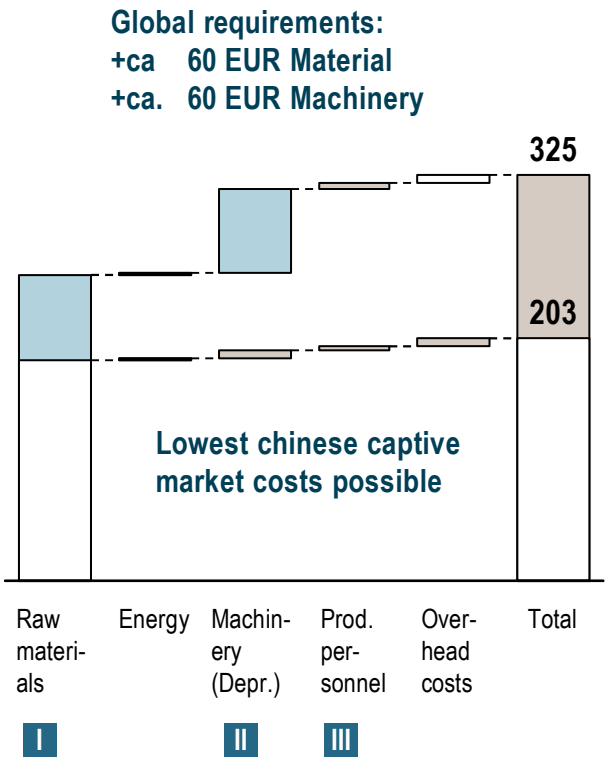
Source:DoE, Evans, FMC, SQM, Madison Avenue Research, Roland Berger

Roland Berger Strategy Consultants

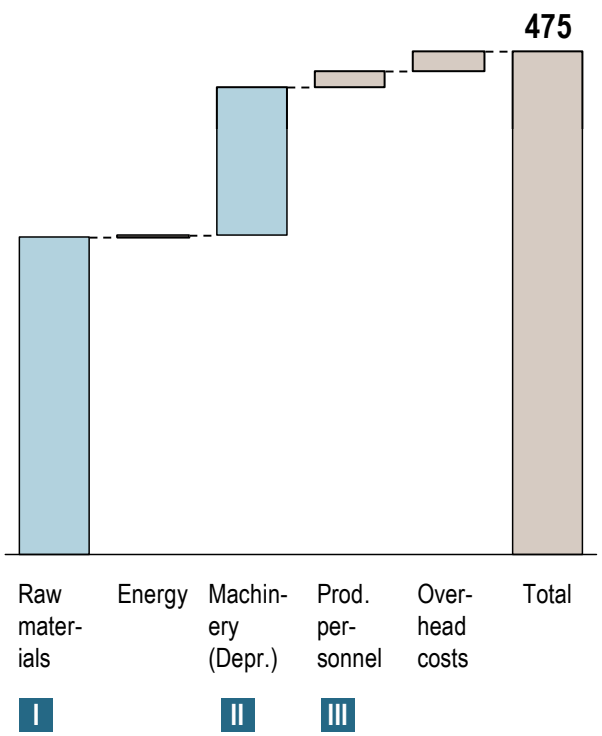
Costs of battery cells can decrease significantly from currently EUR 600...700 EUR/kWh – 30% cost advantage China

Cost split cell production (EUR/kWh)[1], calculation based on 2012 volumes

CHINA



WESTERN EUROPE



COMMENTS

- Raw material costs are lower in China due to strong IP protection outside China
- Machinery costs represent a third of total cost in Western Europe, striking difference to low-cost country
- Personnel costs are higher in EU, but higher productivity
- Calculations assume 100% yield rate

1) Assumed annual prod. capacity of approx. 10,000 EV-battery units (á 15 kW) – "High energy", 2009 costs

Source: Chinese and Western European battery manufacturer, Roland Berger analysis

Roland Berger Strategy Consultants

China suppliers have successfully developed LiFePO4 batteries offering more competitive performance in EV usage

ADVANTAGES OF LIFEPO4 (IRON) BATTERIES FOR VEHICLE USAGE (USING CHINESE RAW MATERIAL)

	Li-NiCoMn	$LiMn_2O_4$	$LiFePO_4$
Safety	◑	◕	●
Stable performance	◑	◕	●
Cost (USD/kg)	20~26	15~28	**15~18**
Lifecycle[1])	800	500	**2,000**

1) Laboratory results, will decrease up to 50% in real usage;
2) Consistency of battery voltages and capacities

CURRENT STATUS OF LI-FE BATTERY DEVELOPMENT IN CHINA

> Li-Fe batteries offers **much more safety** in variable temperature, and can offer **stable performance in extreme conditions**

> Meanwhile, Li-Fe battery is **more environmental friendly**

> **BYD** is leading the development of Li-Fe batteries in China

> The monthly consumption of LiFePO4 material of BYD is more than 40t at the moment

> **Lishen, Voltix, BAK, Chunlan, and Wanxiang make also use of the LiFePO4 material composites** and have demonstrated improvements

> **Südchemie AG patent not valid in China – Production capacity Südchemie estmated 500 to p.a., Chinese producers sum up to 10.000 to p.a.**

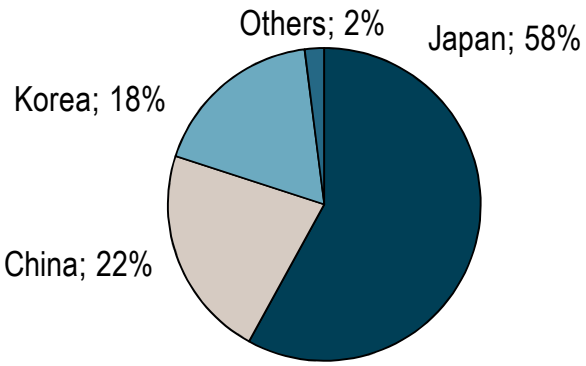
Source: Interviews; Roland Berger

Roland Berger Strategy Consultants

Li-Ion battery production will become a volume play – fast ramp-up of scale necessary for future success

Li-ion Battery Suppliers on a Global Scale and in China

GLOBAL DISTRIBUTION OF LI-ION BATTERY SUPPLIERS



> China has a leading position in global share of Li-ion suppliers

> Mature technology exists with capability for mass commercialization for various applications (such as electric bicycles)

LI-ION SUPPLIERS IN CHINA

> Li-ion battery suppliers manufacture already for mobile phone applications, computers, electric bicycles and others – **opportunity to finance basic research**

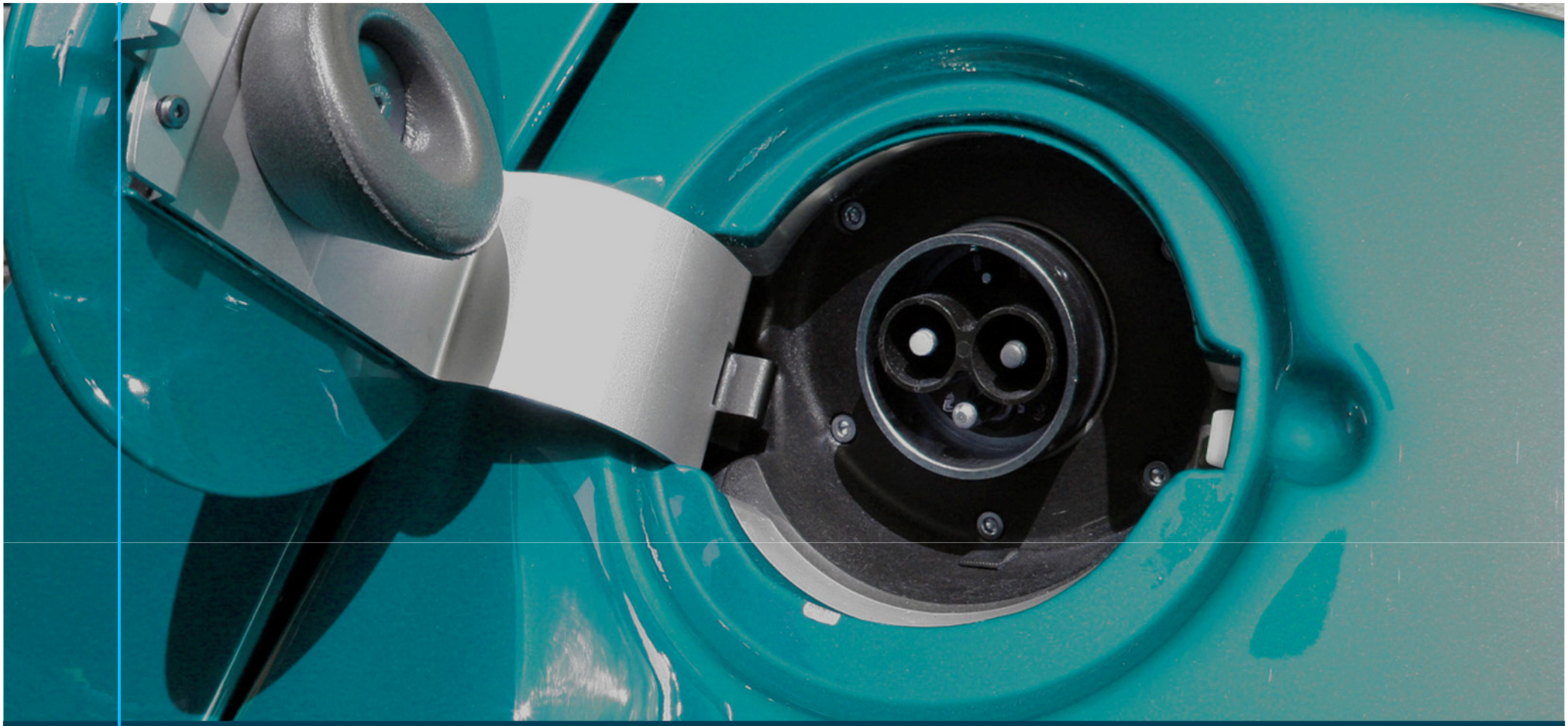
> Battery manufacturing process consists of **many manual assembly steps**, which makes it suitable for China's vast manufacturing base

> **More than 25 suppliers identified** that claim to have Li-ion batteries for automotive and in particular **electric vehicles applications**

COMMENTS

- **China** enjoys **much lower production costs,** however, for **quality reasons**, a significant **automation** of cell manufacturing is **necessary**
- **Chinese suppliers** have **a cost advantage >25% today / in 2010 (430 EUR / kWh vs. 580 EUR / kWh) .**
- This advantage can increase to **>30%** with **increased usage of Chinese equipment until 2012 (323 EUR / kWh vs. 475 EUR / kWh)**

Source: Roland Berger analysis



D. Implications

Roland Berger
Strategy Consultants

Roland Berger Strategy Consultants

China wants to become the technology hub for E-components - challenging suppliers, OEMs and industrialized countries

CHINA AS E-COMPONENT TECHNOLOGY HUB

- LARGE DOMESTIC MARKET
- RAW MATERIAL & LABOUR-COST ADVANTAGE
- SUPPORTING INDUSTRY POLICY OF CHINESE GOVERNMENT

Suppliers of batteries:

- **New business models** to drive down costs
- Include a broader business perspective - **secondary markets** for high power and high energy batteries

E-machines

- China production location

OEMs

- Partnering strategy to leverage economies of scale and drive down costs
- **Business model** for marketing

Governments

- **Support** the development of **advanced materials** and **production technologies**
- Focus on engineering and manufacturing of high precision equipment needed to secure value add . (low employment in battery production due to need for highly automated processes)

Source: Roland Berger