Overview on Technology & Market Progress of HEV and Advanced Batteries Outlook

2nd HEV Market & Advanced Battery Technology Development Seminar

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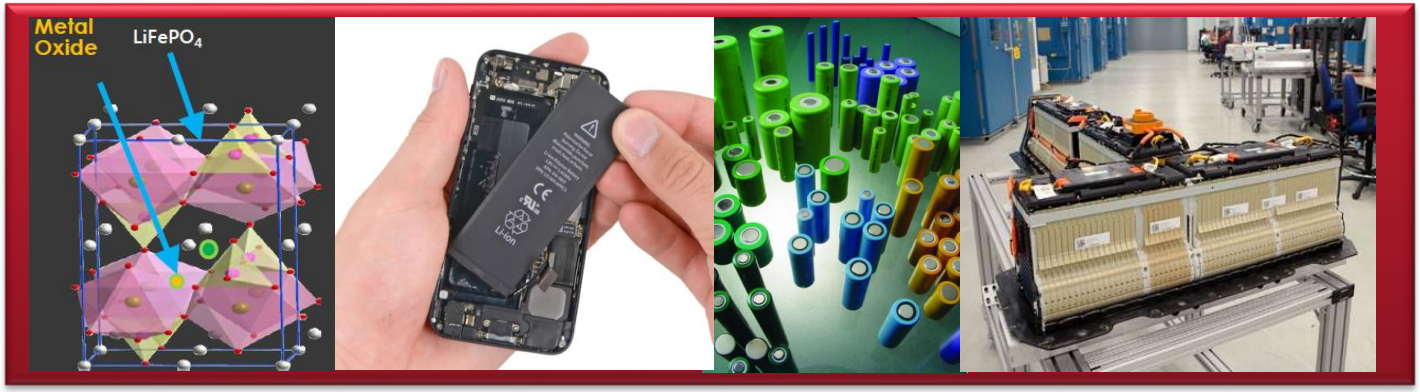
Industrial Economics & Knowledge Center (IEK)
Industrial Technology Research Institute (ITRI) ,Taiwan

2016/10/13



ITRI – Home of Taiwan's High-tech Research

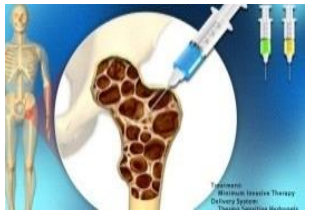
Information and Communications

Electronics and Optoelectronics

Material, Chemical and Nanotechnology

Industrial Economics & Knowledge Center (IEK)

- **Cross-disciplinary research**
- **Provide market planning service**
- **Consultation for Taiwan government**
- **Promote international collaboration**



Medical Device and Biomedical

Mechanical and Systems

Green Energy and Environment

Total Staff: 5,806

Ph.D:	1,372
Master:	3,207
Bachelor:	1,227
Alumni:	23,717

Total Patents

24,010

Startups &Spinoffs (~2015)

240

Industry Services (~2015)

Provided Services：18,351

Transferred Technologies：642

2016.2.1

Outline

- The reason to discuss the HEV/ LVS
- The market trends of HEV and related batteries technology development
- The market trends of ISSV/Micro HEV and related batteries technology development
- The future potentials and key factors to develop 48V market
- For the battery industry: How can we prepare?

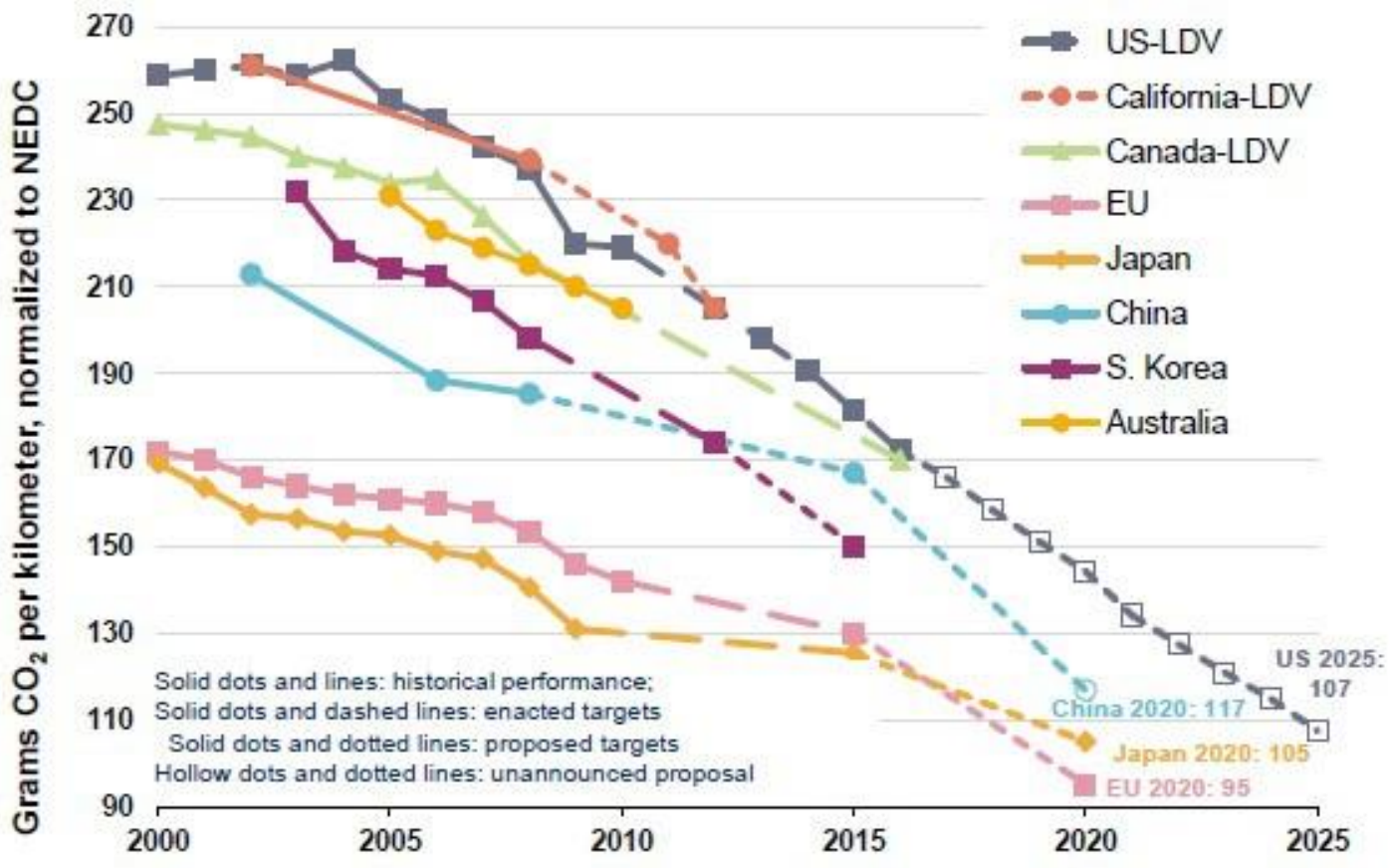
Focus to Discuss on LVS/HEV

xHEV system / Function	ISS (Start/stop)	Micro	Mild	Moderate	Strong	Plug-in
Start cranking	★	★	★	★	★	★
Regenerative braking		★	★★	★★★	★★★	★★★
Start assist			★	★★	★★★	★★★
Power assist			★	★★	★★★	★★★
EV driving				★	★★	★★★
Battery voltage/V	12	12	36-48	100-200	> 150	> 150
Battery type	Fluid-type lead storage battery					
	Control valve-type lead storage battery					
			Ni-MH			
			Li-ion			
CO2 reduction effect/ % *	< 4	4-7	8-12	12-15	15-20	> 20
System cost ratio *	100	150	1,000	2,500	3,000	6,000
Cost per percent reduction *	> 33	22-40	80-125	170-210	150-200	< 300

Source: Furukawa Battery, ITRI/IEK Analysis (2016/10)

Reasons to Promote LVS/HEV/xEV: Vehicle Energy-Saving Control/ CO_2 Emission

- All the developed/developing countries have to follow the target
- 159g CO_2/km is challenge for ICE, China: 117g CO_2/km in 2020?!
- Lower CO2 emissions in long-term are the most important driver for society and government both, average reduction target is 40% from 2015 to 2025



Source: CEPRI, ITRI/IEK Analysis (2016/05)

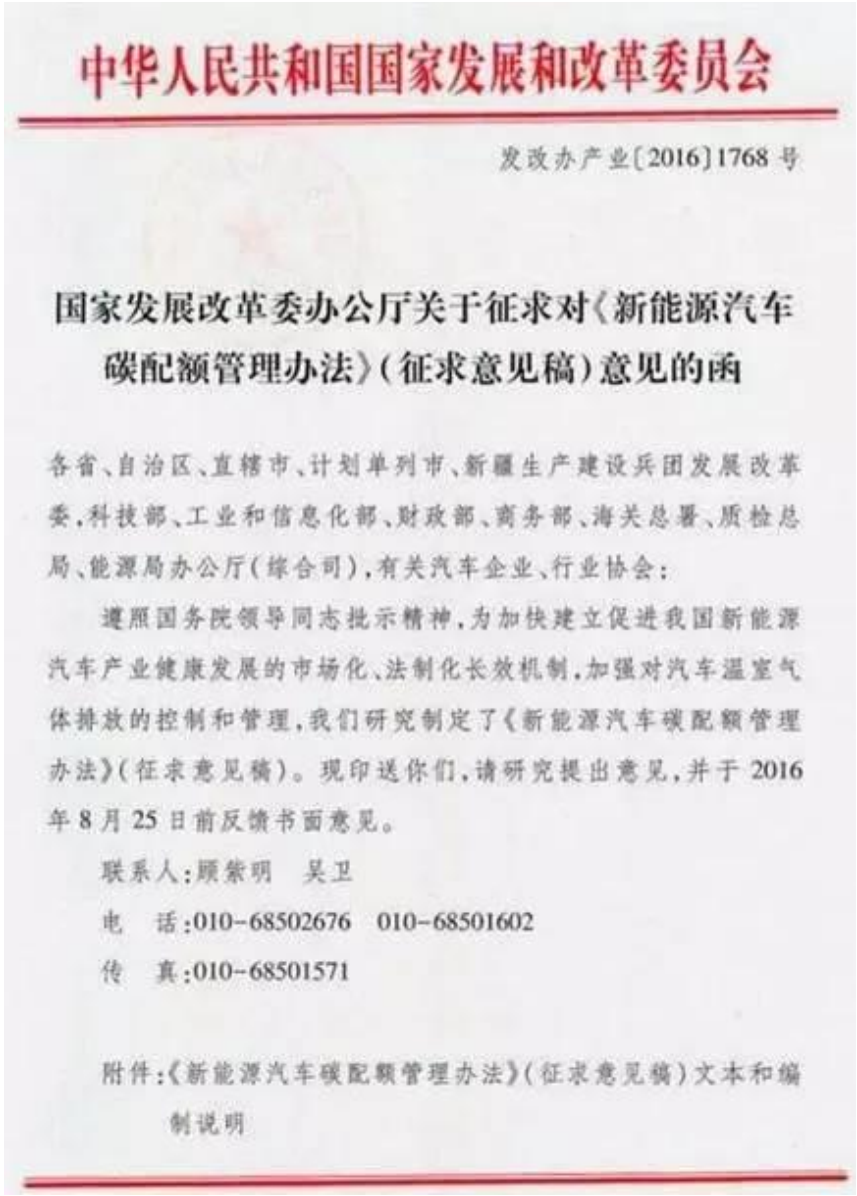
CO_2 Emission Target & Annually Deduct Rate by Main OEMs in China

CO2 Emission in China	CO2 Emission in 2014 (g/km)	CO2 Emission Target in 2025 (g/km)	Annually Reduct Qty (Annually Deduct %)
Toyota	171.1	103.7	6.2 (4.5%)
Honda	167.9	102.8	5.9 (4.4%)
Nissan	159.6	98	5.6 (4.3%)
Mitsubishi	184.5	106.4	7.1 (4.9%)
Mazda	146.1	98.5	4.3 (3.5%)
VW	161.4	102	5.4 (4.1%)
GM	170.4	98.4	6.5 (4.9%)
Ford	168.8	106.1	5.7 (4.1%)
Daimler	191.1	124.4	6.1 (3.8%)
BMW	172.1	118.1	4.9 (3.4%)
Renault	197	112.8	7.7 (4.9%)
PSA	173.6	101.8	6.5 (4.7%)

CO2 Emission in China	CO2 Emission in 2014 (g/km)	CO2 Emission Target in 2025 (g/km)	Annually Reduct Qty (Annually Deduct %)
Fiat	219.9	123.5	8.8 (5.1%)
Hyundai/KIA	165.4	97	6.2 (4.7%)
SAIC	169.1	99.2	6.4 (4.7%)
FAW	179.1	103.9	6.8 (4.8%)
DFM	173.2	100.5	6.6 (4.8%)
BYD Auto	156.5	98.5	5.3 (4.1%)
Chery	165.9	97.2	6.2 (4.7%)
Changan	154	93.1	5.5 (4.5%)
Geely	151.8	98.9	4.8 (3.8%)
BAIC	170.8	94.6	6.9 (5.2%)
JAC	177.7	108.6	6.3 (4.4%)
GAC	197	107.9	8.1 (5.3%)

Source: MIIT, EEA, NHTSA, ITRI/IEK Analysis (2016/10)

The Effect of Carbon/ZEV Trading System



中华人民共和国国家发展和改革委员会

发改办产业〔2016〕1768号

国家发展改革委办公厅关于征求对《新能源汽车碳配额管理办法》（征求意见稿）意见的函

各省、自治区、直辖市、计划单列市、新疆生产建设兵团发展改革委，科技部、工业和信息化部、财政部、商务部、海关总署、质检总局、能源局办公厅（综合司），有关汽车企业、行业协会：

遵照国务院领导同志批示精神，为加快建立促进我国新能源汽车产业健康发展的市场化、法制化长效机制，加强对汽车温室气体排放的控制和管理，我们研究制定了《新能源汽车碳配额管理办法》（征求意见稿）。现印送你们，请研究提出意见，并于2016年8月25日前反馈书面意见。

联系人：顾紫明　吴卫

电　话：010-68502676　010-68501602

传　真：010-68501571

附件：《新能源汽车碳配额管理办法》（征求意见稿）文本和编制说明

- Detailed draft of **carbon/ZEV trading for ICE** has been disclosed
  - National target: 117g CO2/km, 5L/100km in 2020
  - ICE improvement: 1.5~2% per yr
  - Chinese OEMs need to be allocated by the market share
  - Carbon emission right can be traded
  - xEV promoting will be treated as “positive factor” to the judgment of production identification
  - xEV promoting will be treated as the worthy right to sell
- Wondering:
  - How to judge the price?
  - HEV, LVS still can deduct some CO_2 emission, how to treat them?

Source: ITRI/IEK Analysis (2016/10)

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HEV Sales in 2015: 1.61M, YoY=-9%

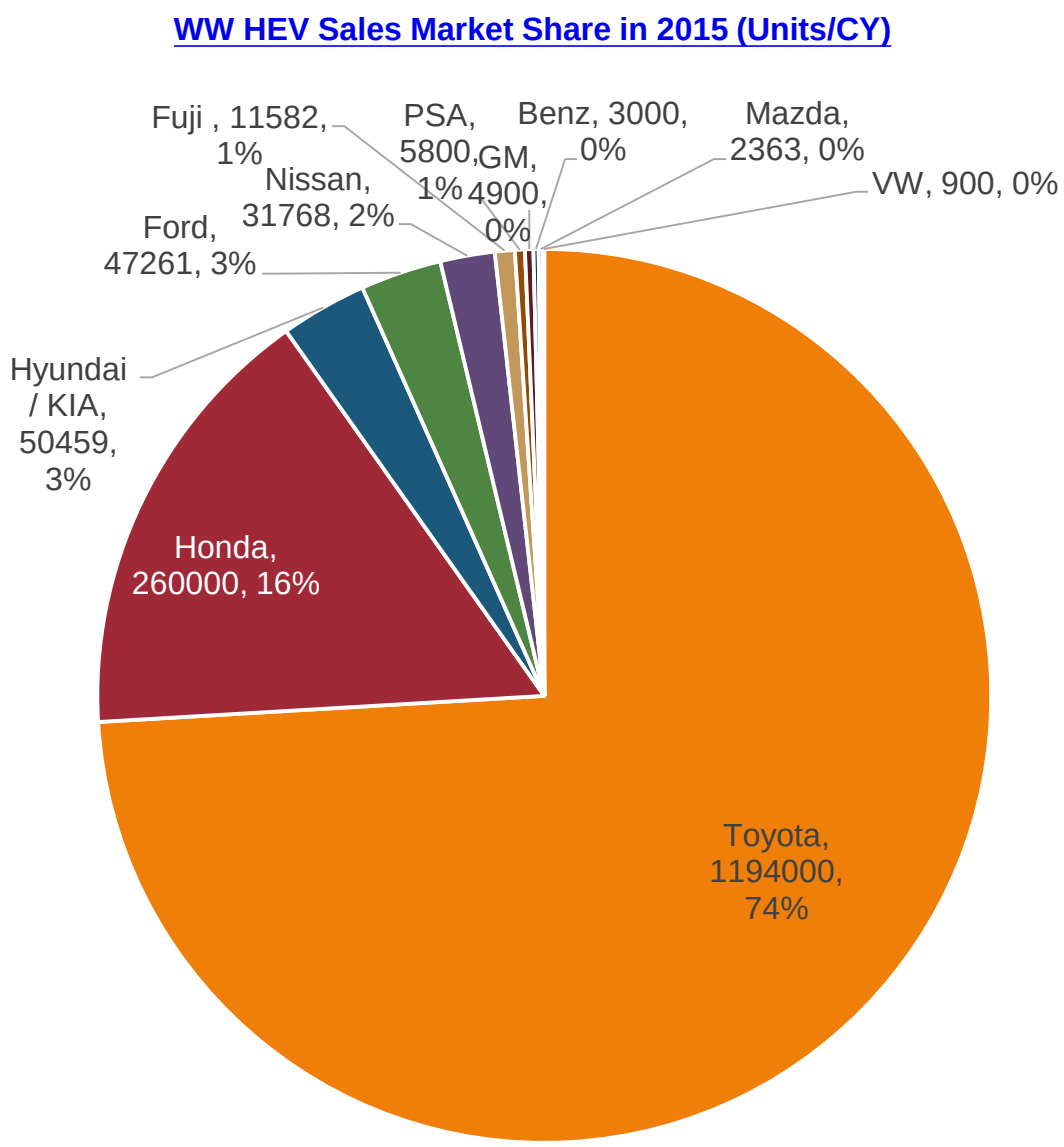
- Effected by low petroleum price, cancellation of subsidies (parts of US, UK) & models progress
- The biggest market JP: 869,100 units sold and YoY= -8.1%
- US: 384,404 and YoY= -15%!!!
- EU & China was growing: 21.5% & 124%

2008-2016H1 WW HEV Sales by Region (Units/CY)

	2008	2009	2010	2011	2012	2013	2014	2015	2016H1
Others	26400	28900	84000	77000	163000	247000	172000	110000	32500
China			1830	1460	6000	6350	6769	14665	7772
Euro	73300	84700	101500	103500	127000	171740	192664	234170	96008
USA	313700	292500	275000	276500	434500	495700	452152	384404	142292
Japan	110900	349570	483200	456200	863550	838550	945745	869100	344670

Source: FOURIN Database, ITRI/IEK Analysis (2016/10)

HEV Market Share: Almost Monopoly Market

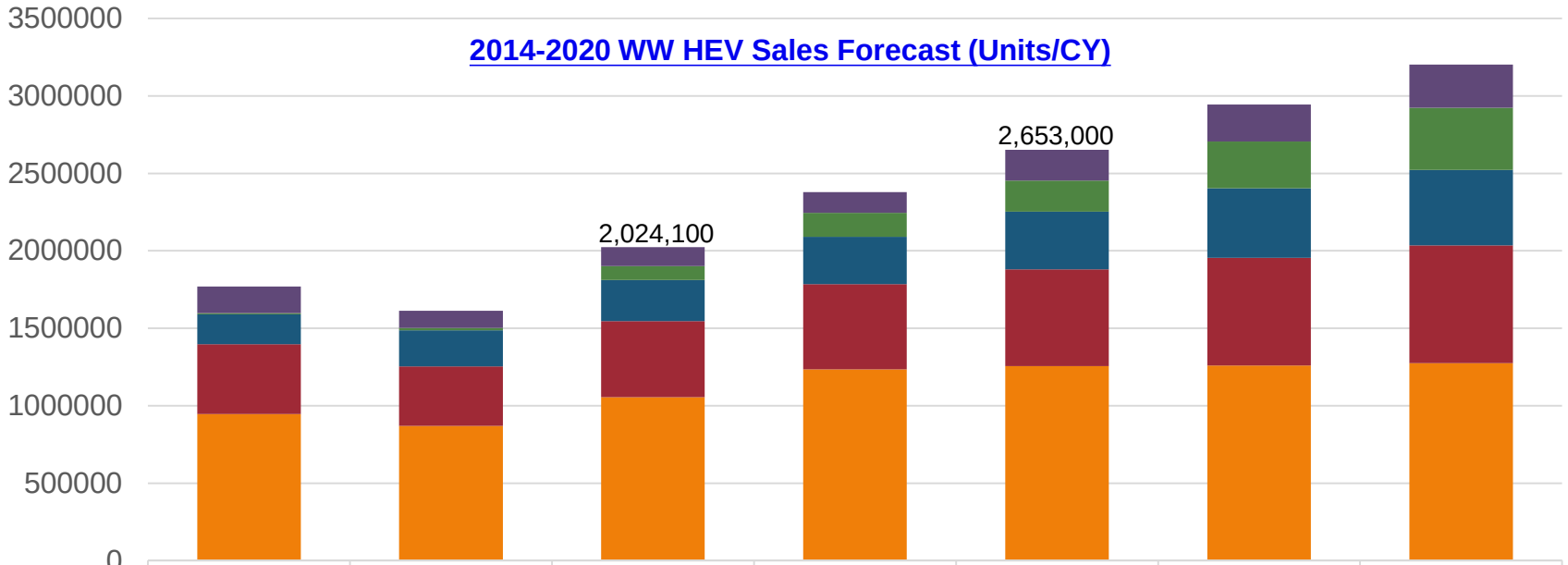


- At current fuel pricing, value proposition of HEV to potential customers is difficult
- Only 4~8 companies are active in HEV:
  - Toyota: 74%!!!, leading in sales, product and technologies
  - Honda: Continue to fight and deliver LIB HEVs in 2016~2017
  - Hyundai/ KIA: Good Sonata sales in KR but decreased in US, IONIQ with LIB in 2016
  - Ford: C-MAX & Fusion with LIB in 2018
  - Nissan:
- From 2017, Honda (GAC), Ford, BMW will begin to deliver new models and join in

Source: FOURIN Database, ITRI/IEK Analysis (2016/10)

Future Forecast Effected by Oil Price and New Models Reputation

- Nothing will worse than 2015…..
- Both New models promoted in JP & US can enhance customer's confidence
- EU & China showed better performance in 2016H1
- Unless oil price becomes lower, we can predict 8~11% growth and occupy ~3% of WW vehicle sales



	2014	2015	2016E	2017F	2018F	2019F	2020F
Others	172000	110000	122600	134000	200000	240000	280000
China	6769	14665	90000	155000	200000	300000	400000
Euro	192664	234170	265000	306000	372000	450000	488000
USA	452152	384404	492000	550000	625000	695000	760000
Japan	945745	869100	1054500	1235000	1256000	1260000	1275000

Source: ITRI/IEK Analysis (2016/10)

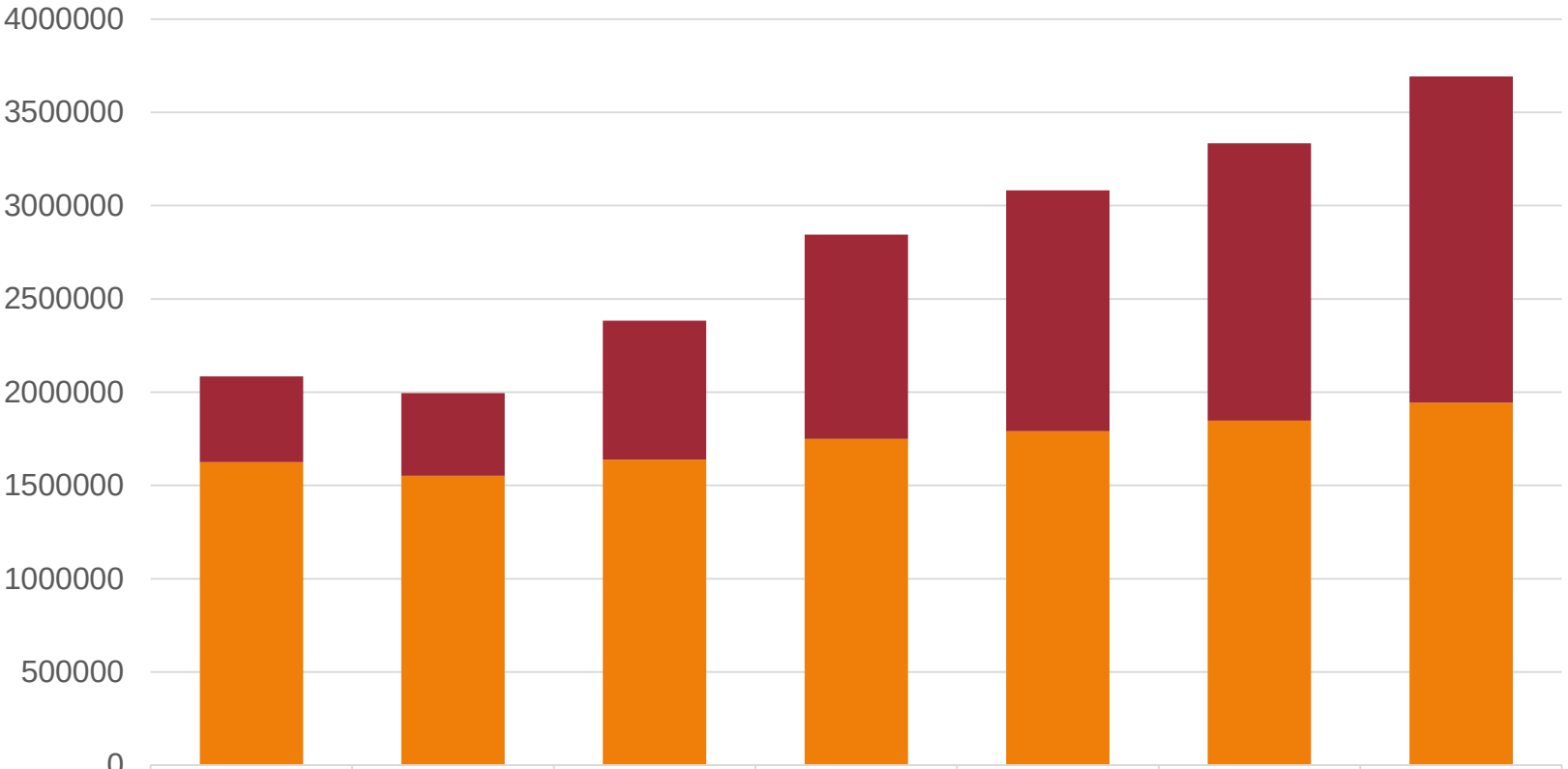
xEV Alliances Effect the Technology and Format

	12V/48V		HEV		Notes
TOYOTA			EV ENERGY	Panasonic	NiMH: average 200V/1.4kWh, only Prius 4th & Prius α adopt LIB
NISSAN			Automotive Energy Supply Corporation	Hitachi	Pouch/245.6V/1.4kWh from AESC & Cy/144V/0.7kWh from Hitachi
RENAULT		LG Chem			
HONDA			BEC	TOSHIBA	Pr/ 144~259.2V/0.68~1.3kWh LIB mainly
MITSUBISHI MOTORS			TOSHIBA	Automotive Energy Supply Corporation	
SUZUKI	TOSHIBA	Hitachi			
GM			Hitachi		115V/0.5~1.5kWh Cy & Pr LIB
Ford	SAMSUNG		Panasonic	SAMSUNG	280V/1.4kWh/Pr
VW	SAMSUNG		Panasonic		Parts from 288V/1.7kWh/Cy NiMH, Others are 266V/1.3kWh/Pr LIB
Audi	SAMSUNG	LG Chem	Panasonic		
BMW	LG Chem	Johnson Controls	Johnson Controls	中国万向 CHINA WANXIANG	317V/1.35kWh/Cy LIB
DAIMLER		SK innovation	Johnson Controls	SK innovation	126V/0.82kWh/Cy LIB
HYUNDAI			LG Chem		270V/1.43kWh/Po LIB
CHRYSLER	SAMSUNG	LG Chem	SAMSUNG		
VOLVO			LG Chem		

Source: ITRI/IEK Analysis (2016/10)

NiMH is Still Mainstream in WW HEV Battery

- Almost every HEV OEMs choose LIB for further models **except Toyota**
- Toyota: Only Prius 4th & Prius α adopt prismatic LIB
- Other OEMs: LIB for further new models
- Both average pack price from NiMH and LIB: USD650~780/kWh

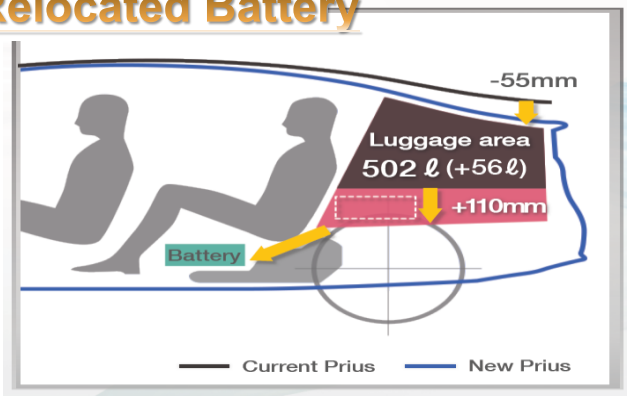


	2014	2015	2016E	2017F	2018F	2019F	2020F
HEV LIB	459900	443500	745000	1095000	1292000	1488000	1750000
HEV NiMH	1625000	1552000	1638000	1750000	1790500	1847000	1943000

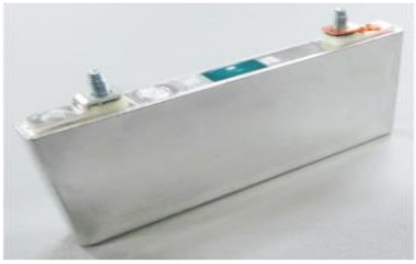
Source: ITRI/IEK Analysis (2016/10)

Development of Li-ion Battery for Toyota Hybrid Vehicle

Relocated Battery

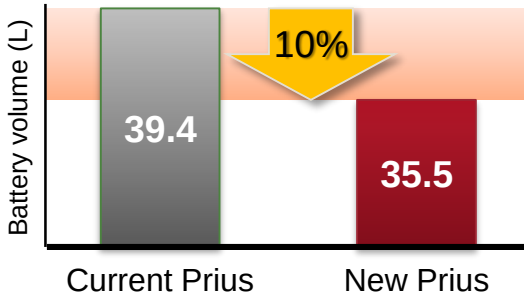


Newly Developed Lithium-Ion Battery

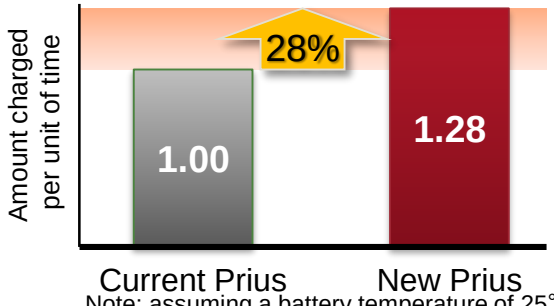
	1st generation cell	2nd generation cell
		
Voltage	3.6 V	3.7 V
Capacity	5.0 Ah	3.6 Ah
Specific power	2950 W/kg	3920 W/kg
Weight	245 g	204 g
Dimensions	111(W)×14.1(T)×91.8(h) mm	137(W)×13.3(T)×63.3(h) mm

Newly Developed Nickel-Metal Hydride Battery

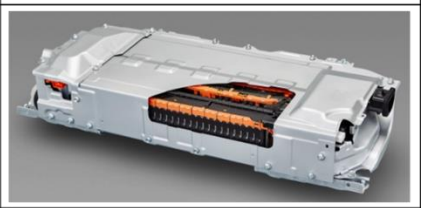
Size reduced by 10%



Charging performance improved by 28%



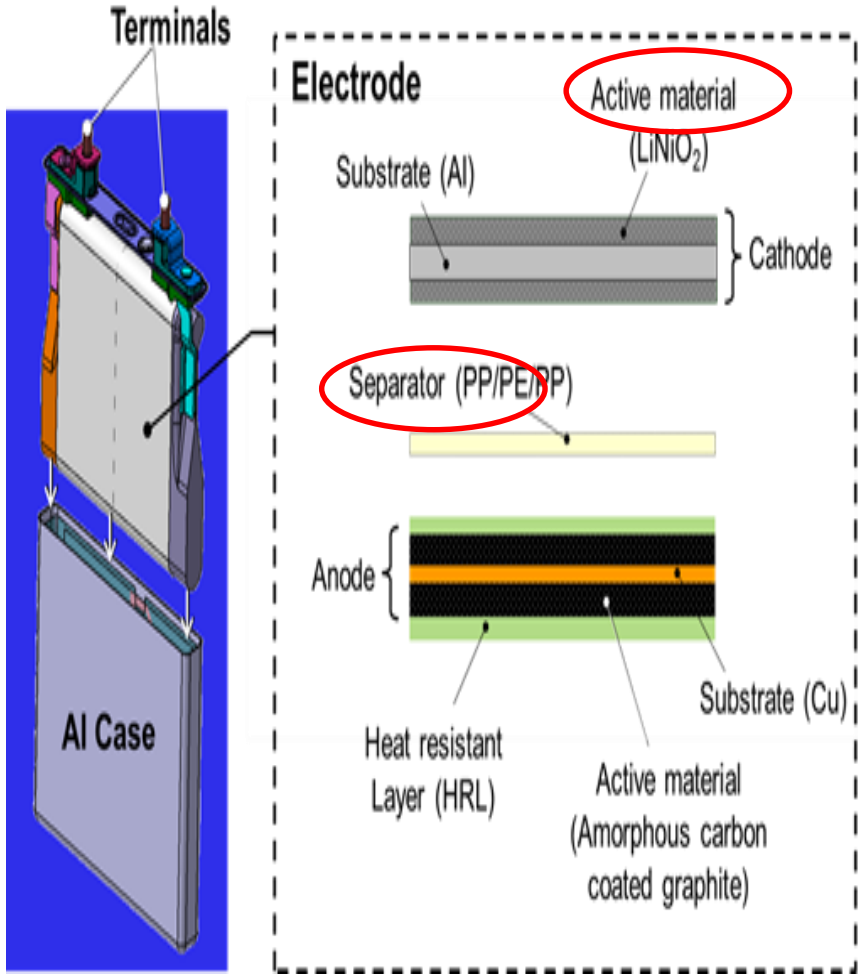
Note: assuming a battery temperature of 25℃

	4th generation Prius Li-ion battery pack
	
Cell quantity	56 cells (28 cells × 2 stacks)
Voltage	207.2V
Energy	0.75 kWh
Weight	24.5 kg
Volume	30.5 L

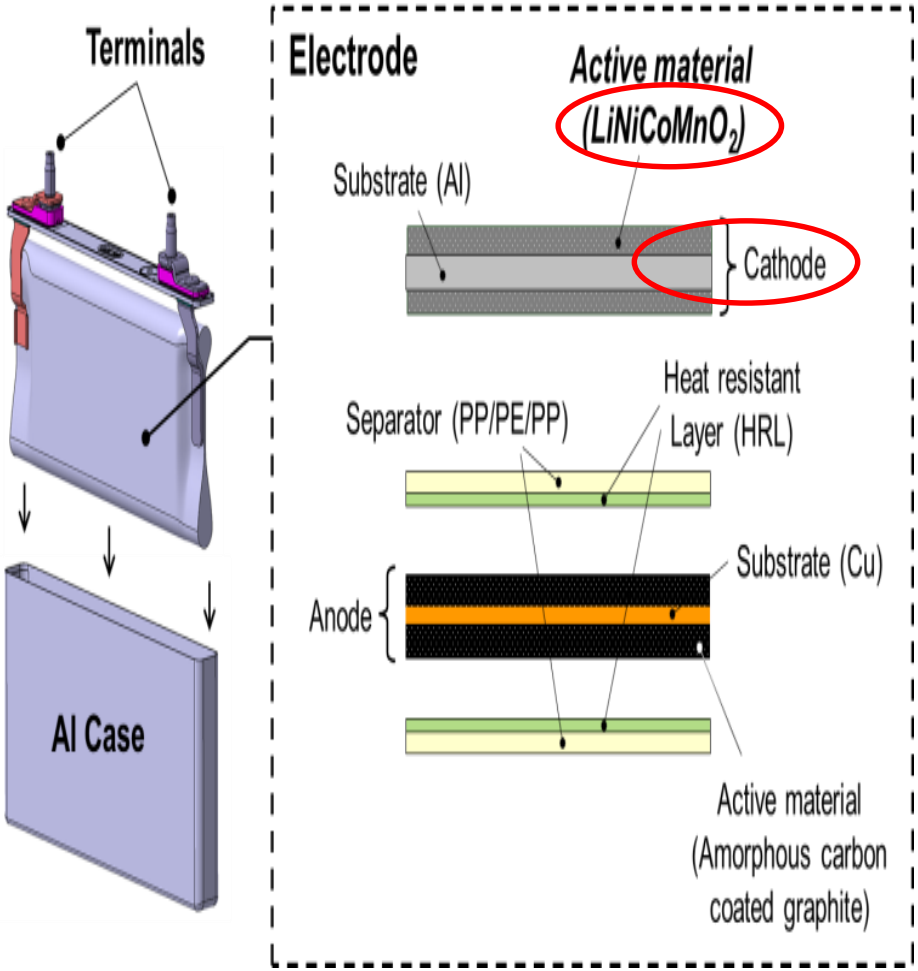
Source: Toyota (2016/01)

Development of Li-ion Battery for Toyota Hybrid Vehicle

2011 Prius α Cell Design



2016 Prius Cell Design



Source: Toyota (2016/01)

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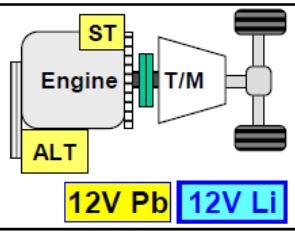
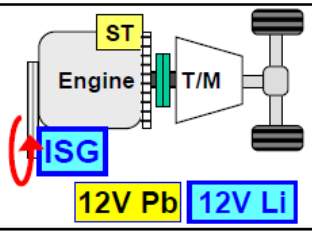
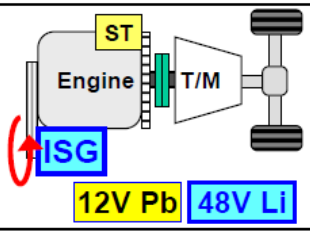
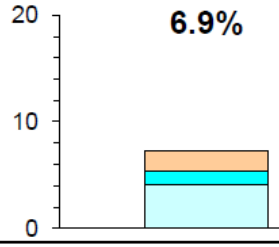
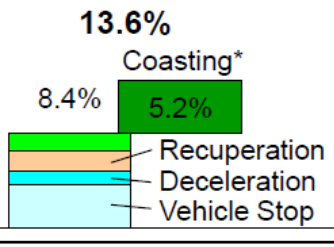
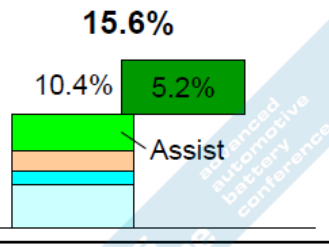
Concept of Micro/Mild Hybrid

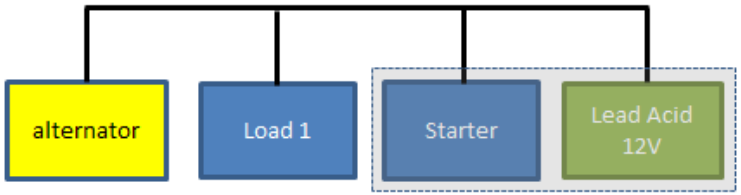
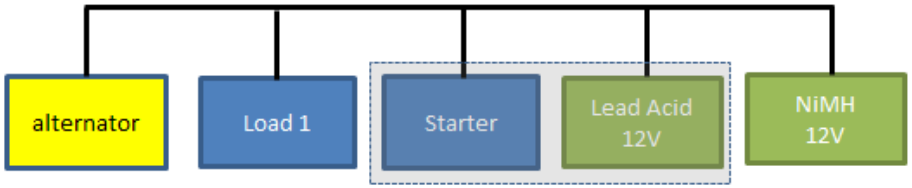
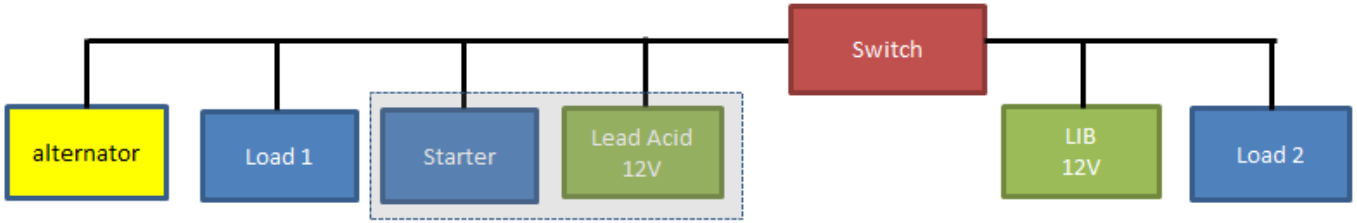
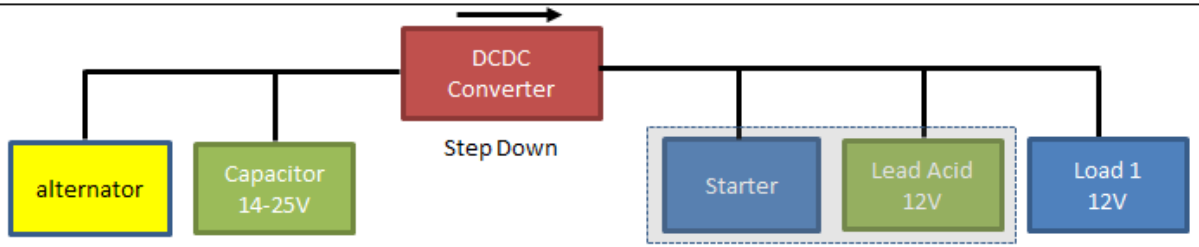
- **Include ISS, 12V & 48V system**
- **ISS & SLI can be handled by lead acid battery, but enhance the fuel economy needs to consider multiple choices**

System		ISS dual power system	12V/ISG	48V/ISG
				
Electric machine		Starter, Alternator	ISG ~ 5kW(12V)	ISG ~ 10kW(48V)
Recuperation		✓	✓	✓
ISS	Vehicle Stop/Deceleration	✓	✓	✓
	Coasting		✓	✓
Power Assist		Additional assist	~	High output ✓
EV (Creep)				~
48V High power source				✓
Power supply redundancy		Safety equipment for drive& Power redundancy		+Actuator (Safety devices)
Fuel saving [%] (compared to non-ISS car) NEDC 1.8ℓ Gasoline (CVT)				

*Coasting in EU currently considered an Eco-Innovation (max. 7g/km CO_2 fleet average benefit) using a Modified version of the NEDC (mNEDC) defined by EU Commission

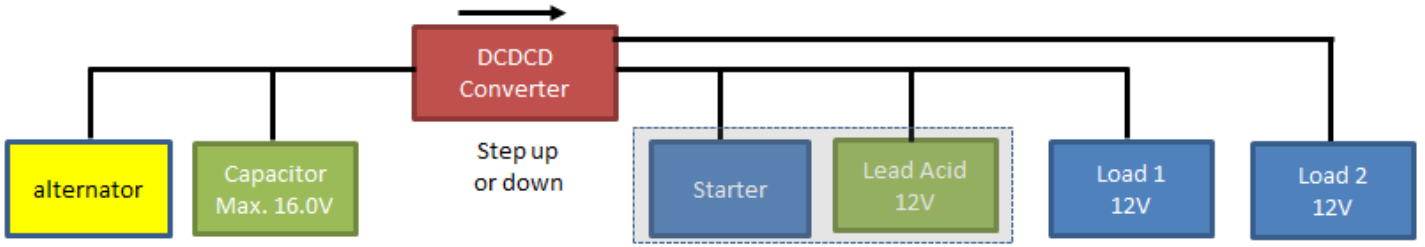
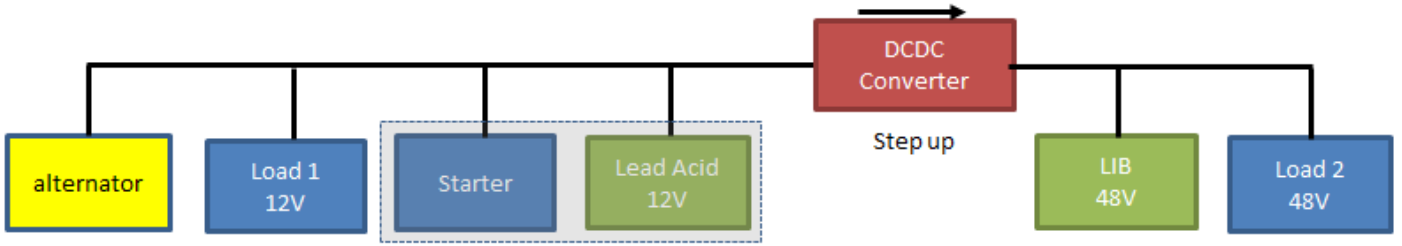
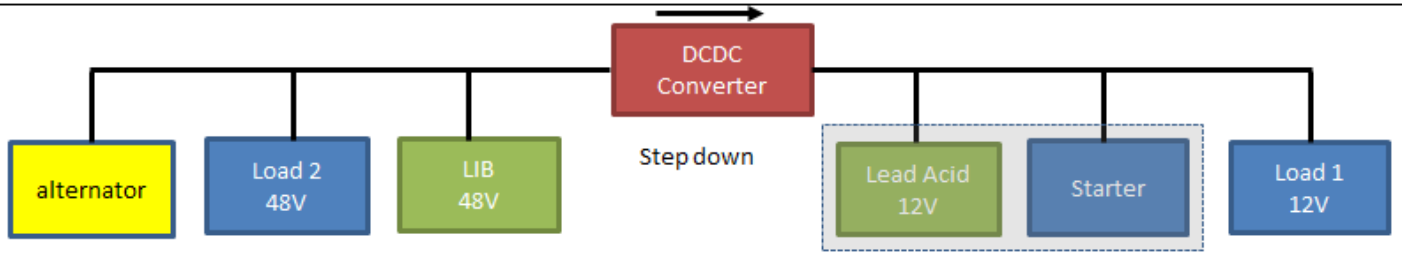
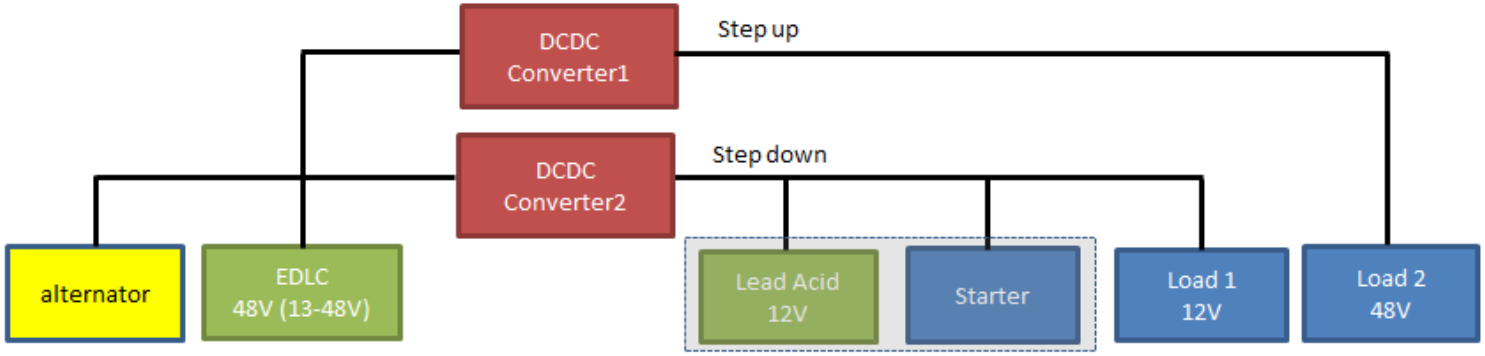
Source: DENSO in AABC Europe 2015 (2015/01)

The Main LVS System Configurations

No.	Company	System Block Diagram
1	Conventional	
2	Nissan· Mitsubishi	
3	Suzuki	
4	Mazda	

Source: ITRI/IEK Analysis (2014/04)

The Main LVS System Configurations

5	Honda	
6	48V System Load Sided Extension	
7	48V System Generator Sided Extension	
8	48V System EDLC Method	

Source: ITRI/IEK Analysis (2014/04)

LVS Occupied 16.6% in WW Vehicles Sales

- EIA：penetration rate may achieve 42% in 2024
- 2015: Euro and Japan are the leading shipment region
  - Euro: 6.2M within ISS/LVS, JP: 2.13M, China penetration rate is lower 4%?
  - Susuki: 41.1%, PSA=19.1%, Mazda=14.8%, Nissan=12.6%, Honda=7.9%
  - Lead acid: over 90% (JCI & others), LIB: 2.5% (Toshiba & others)
- Become standard part of high-end models design
- Target: build in WLTP in 2017 or solutions of 95g/km emission target in 2020

	2013	2014	2015	2016E	2017F	2018F	2019F	2020F
Units of Micro/Mild Hybrid cars (Million)	6.03	12.57	14.44	17.05	19.51	22.32	26.57	32.3
Battery capacity of Micro/Mild Hybrid (MWh)	2940	6725	10860	14112	19974	23446	36400	45562

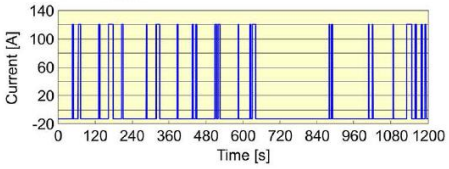
Source: ITRI/IEK Analysis (2015/06)

DENSO以鋰電池設計12V-ISS，已有百萬套應用經驗

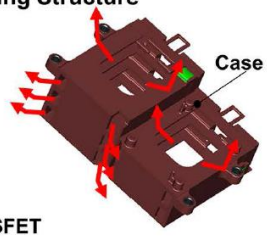
- No assistance for moving off and acceleration
- Toshiba SCiB，total cost of the LIB pack=USD$140，節油效率4.2%
- 2012年量產後，現已有超過50萬套安裝應用經驗

1st Generation	2nd Generation
SOP September 2012	SOP October 2014
3Ah	3Ah
Kei car & A-Segment	Kei car & A-Segment
ISS & Recuperation only	ISG operation

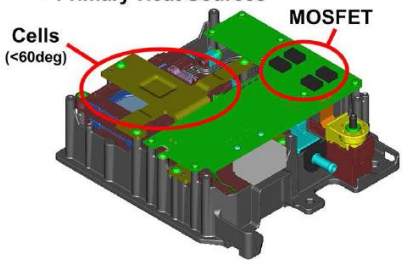
■ Heat Sources
• Test Pattern



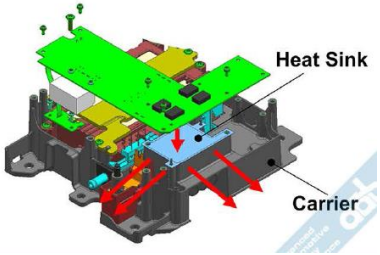
■ Cooling Structure
• Cell

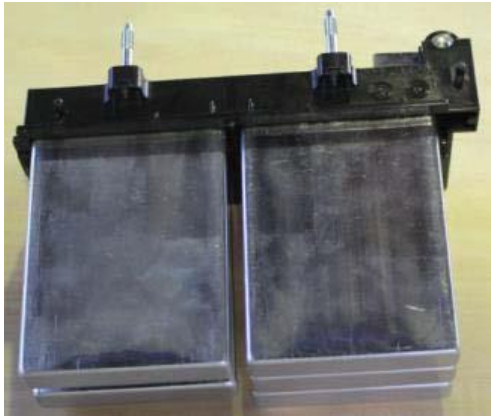


• Primary Heat Sources



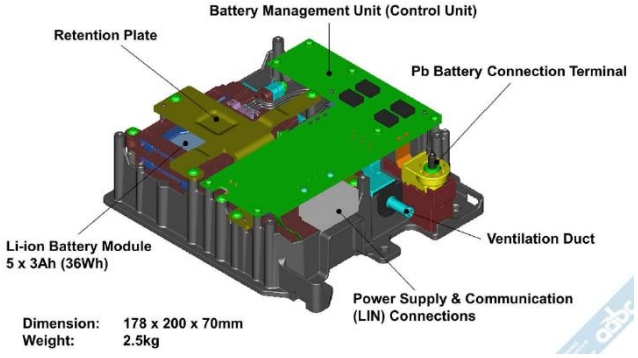
• MOSFET





Terms	Value
Assembling	DENSO
Nominal Voltage	12.0V
Capacity (5S1P)	36Wh (3.0Ah)
Size (mm)	200 x 178 x 70 (2.49 L)
Weight (g)	2,500

Structure



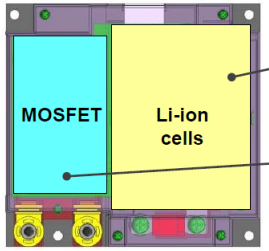
Source: DENSO, ITRI/IEK Analysis (2015/01)

DENSO以鋰電池設計12V-ISS，已有百萬套應用經驗

- 自2012年起，Denso投入12V鋰離子電池系統設計，迄今已累積百萬套以上的應用
- 認為在12V系統所使用的電池容量上，所需考量的因素因國別而有所不同，但通常在68.5%的歐美日區域車型，所需要搭配的鋰電池容量僅需5Ah以下，若是以整車重量在2千公斤以上者，通常也會在10Ah以下的需求範圍
- 其他的設計考量重點為低溫環境下啟動能力、電壓操作區間、SOC可控範圍、電池壽命以及模組的組裝設計走向等
- 針對其10Ah之新一代產品，是以8~15.5V操作電壓/10Ah電容量/鋰錳系正極搭配鋰鈦氧負極/5顆方形電芯搭配MOSFET Switch的方式設計，系統重量低於6公斤，體積約5公升之設計。

Items	Performance
Operating Voltage	8V to 15.5V
Nominal Capacity	10Ah
Battery cell type	LMO/LTO prismatic can
Number of cells	5
Weight	<6kg
Volume	~5ℓ

Key technical developments



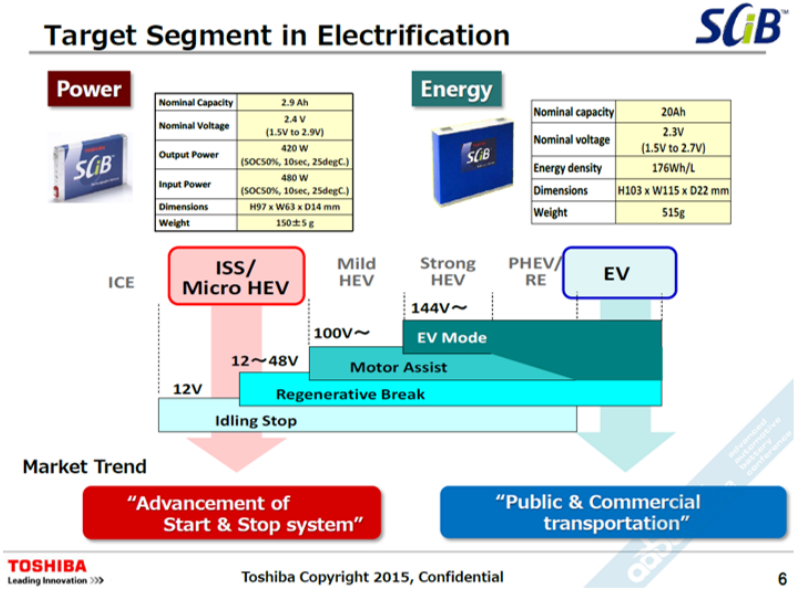
1. Advanced Manufacturing Techniques
- High quality / low resistance welding integrated into a proven assembly line technology refined by DENSO's mass production expertise

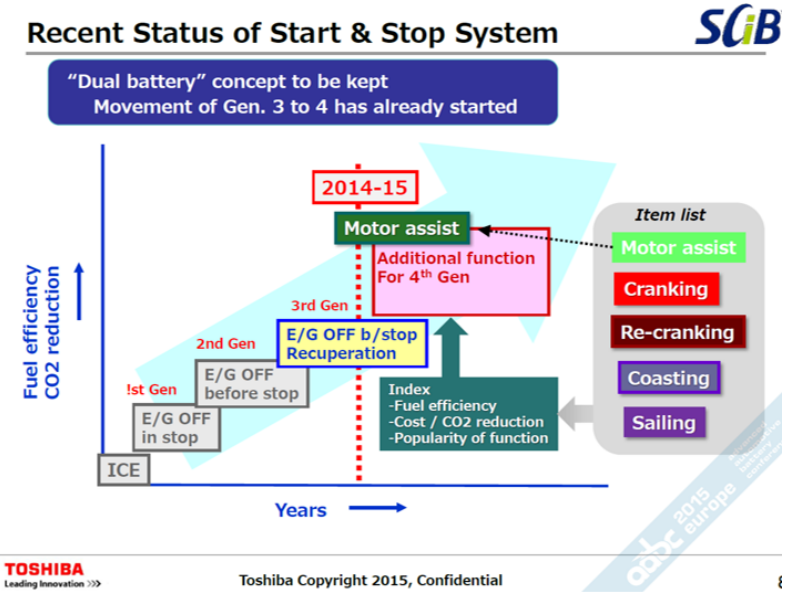
2. High Performance MOS-FET Switch
- High power density MOSFETs developed using proven technology leveraged from power devices division

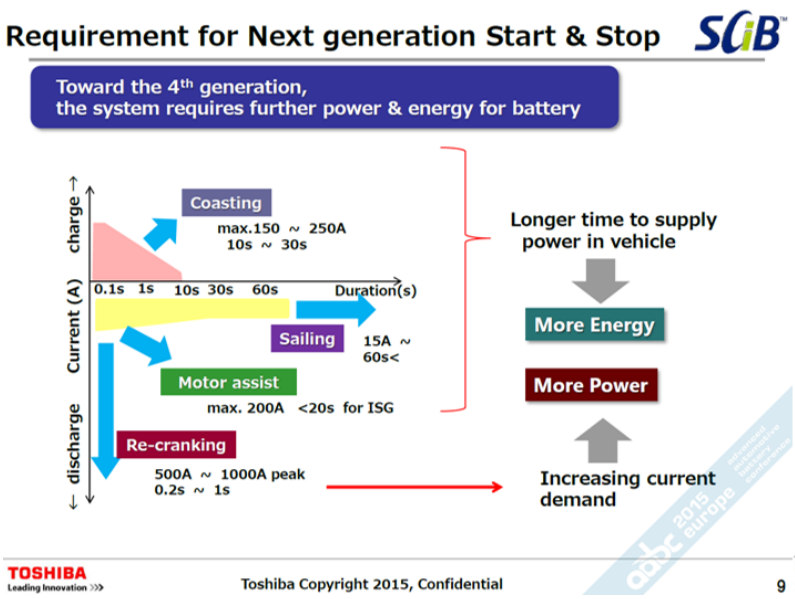
Source: DENSO, ITRI/IEK Analysis (2015/01)

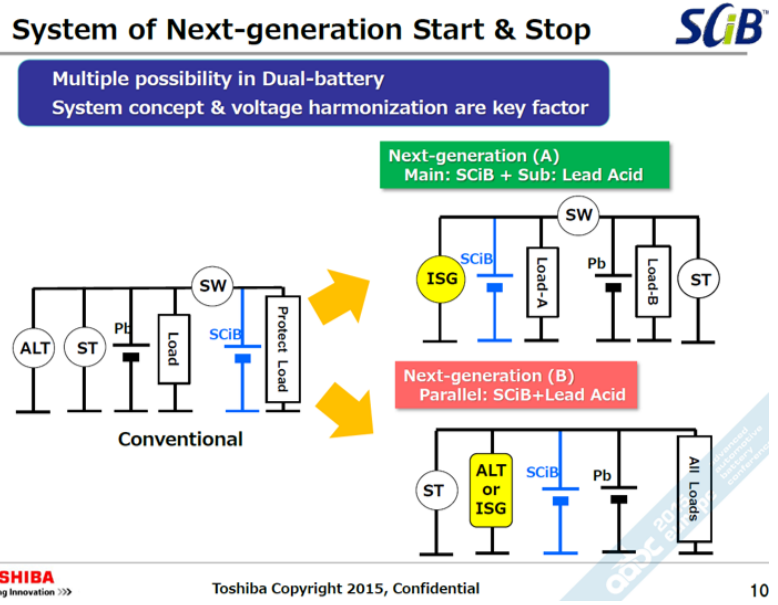
採用Toshiba LTO 電池技術SCiB

■ 由





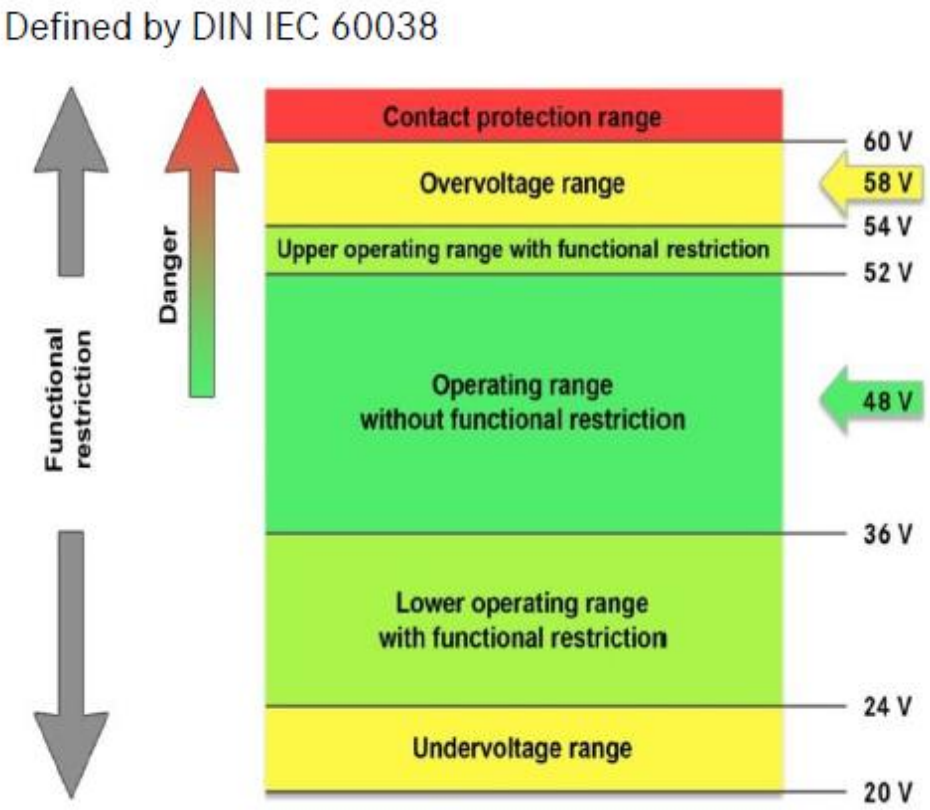




Source: Toshiba, ITRI/IEK Analysis (2015/01)

Mild Hybrid/48V系統優勢與缺點

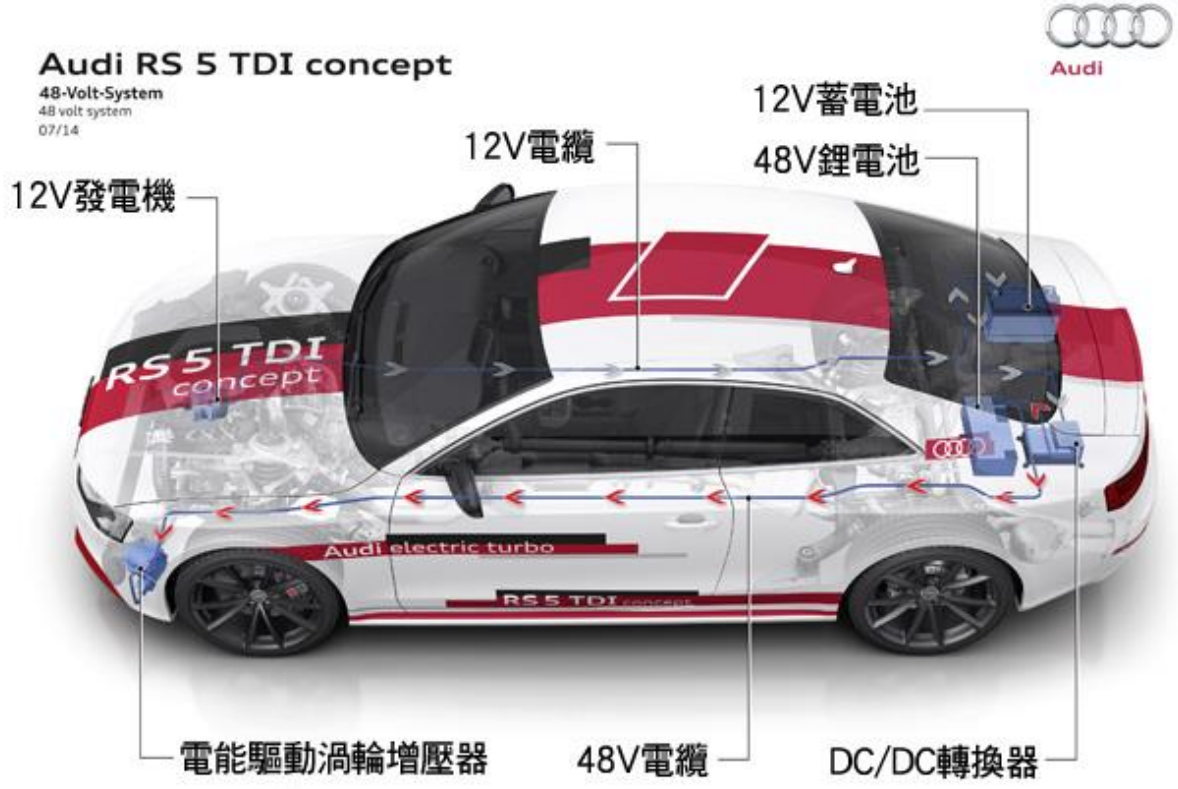
- 改善電機功率與為車電系統提供更高負載、在引擎啟停技術上達到更高效率、更為有效回收汽車剎車能量、同時提高10%-15%的節油效率
- 電壓提高至48V，電流與電阻均較低，可使用較細的電纜降低車輛負重與減少線束成本
- ECE-R100之歐盟安全標準中，當系統電壓在60V以上時，電器絕緣等安全要求大幅提升，且車用半導體在較高電壓要求下成本以倍數增加
- 12V轉48V意味著系統重新設計與元件重新選配，另如EMC電池兼容性問題尚待克服



Source: ITRI/IEK Analysis (2015/06)

投入48V系統車廠以歐系為主

- 德系車廠(Audi, BMW, Mercedes Benz, Porsche, VW)目前積極導入48V系統設計
- 除原本12V電系配置基礎之外，額外添加一套獨立48V做為輔助動力再生、下行斜坡等
- 發電機產生的電力經由12V電纜傳輸至鉛酸電池外，一部分電力傳送至DC/DC直流電交流器，經過升壓後儲存於48V鋰電池，並供應電子渦輪增壓器所需的電力
- 獨立48V電系可提供10kW電能，同時值入於RS 5 TDI概念車和A6 TDI概念車



Source: Audi, ITRI/IEK Analysis (2014/08)

Johnson Control以鋰電池搭配鉛酸電池整合設計

- 認為2017年為12V與48V之分水嶺
- 2017年前導入12V技術較為普遍，但2017後車廠將因技術累積逐漸轉向48V

Micro Hybrid energy storage development

Technology roadmap tied to evolving vehicle architecture

Vehicle Evolution

	2016	2020+
Vehicle Architecture	Integrated starter/generator ■ Dual power net and Power conversion (48V → 12V) ■ Accessory electrification (electric power steering, boost, ...)	■ Load migration to 48V ■ System reliability
ESS Development Path	**Dual Energy Storage System (ESS)** **12V Lead-acid** ■ Cold-cranking ■ Key-off loads **48V Li-Ion** ■ Boost / regeneration	**Optimized Dual ESS** **12V Lead-acid** ■ Key-off loads **48V Li-Ion** ■ Boost / regeneration ■ **Cold-cranking**	**Single ESS** **48V Li-Ion – optimized** ■ Boost / regeneration ■ Cold-cranking ■ **Key-off loads**

Source: Johnson Control(2014/08)

Outline

- The reason to discuss the HEV/ LVS
- The market trends of HEV and related batteries technology development
- The market trends of ISSV/Micro HEV and related batteries technology development
- The future potentials and key factors to develop 48V market
- For the battery industry: How can we prepare?

Policies & Regulations for 48V System

in use: ECE-R100 amended for 48V-Systeme (insulation resistance not applicable for 48V-Systems)		✔
crash: four options in ECE-R94/-95	• insulation resistance • absence of high voltage • barrier protection • low energy	✔
Battery: ECE-R100.02 amended for requirements for traction batteries		✔

in use: no requirements		✔
crash: two options in FMVSS 305	• insulation resistance • absence of high voltage , crashed within a velocity range from 0 till 48 km/h at front impact on a barrier, till 80 km/h at side impact, till 80 km/h at impact of a moveable barrier, therefore additionally barrier option necessary	tbd.
Battery: no requirements		✔

in use: GB/T 18384, GB/T 19751 ? **crash**: GB/T 19751 ? **Battery**: QC/T 743 ?	Are there any regulatory issues in China regarding 48V systems? ⇨ We would like to cooperate in future	?

Source: Mercede Benz, ITRI/IEK Analysis (2014/08)

Thank you

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