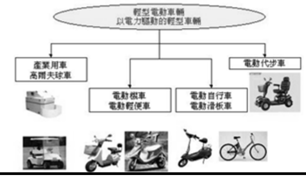
What are EVs?

- EVs (Electric Vehicles), are vehicles that are powered by an electric motor instead of an internal combustion engine (ICE).
- Electricity <=> Combustible fuel
- Major auto manufacturers are producing high-performance EVs in a wide range of styles and sizes, including passenger cars, mini-vans, sport utility vehicles and pickup trucks.
- EVs today come as small as bicycles and motor scooter and as big as buses.

What are EVs?



EVs

- 現今發展**純電動車(Pure Electric Vehicle, PEV; Battery EV)**的最大考驗在於續航力問題，因此採用內燃機與電動馬達的**混合(節能)動力車**(Hybrid Electric Vehicle；HEV)為目前最佳的解決方案，其特點在於可以提供引擎與馬達混合驅動力的並聯架構，或者以引擎來發電將電能儲存於電池，再以電池電能來驅動馬達使車運行的串聯架構，目前節能動力車在市場的需求逐漸取代傳統純內燃機引擎車輛。由於電池的種類和容量在最近十年飛快成長，以及為儘量使用高效率馬達來做為車輛驅動力的目的，**可充式節能動力車**(Plug-in HEV)可能逐漸取代HEV成為主流。

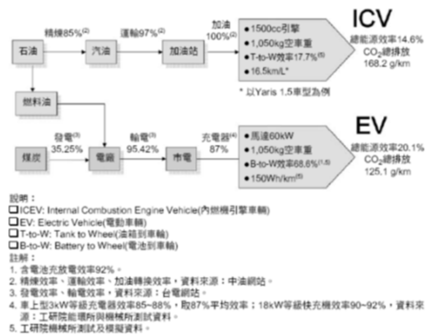
- 近年來由於燃料電池(Fuel Cell)相對於可充式電池的高能量與質量比，在電動車當為主儲能系統的技術應用也有增加的趨勢。不過在**燃料電池電動車**(FCEV)發展上，其幾乎無廢氣排放污染及氫燃料可取之於石油之外之其他能源，曾於2000年造成全球主要車廠重視並成為車輛研發之主要潮流，目前FCEV已具與傳統汽油引擎車同等性能表現，但考量其製造成本、加氫環境建立及氫氣取得成本，仍以車隊運行展示為主，目前技術瓶頸達商業化程度不易。

EVs

(1)ICV之能量來源路徑為石油→汽油→加油站→整車，總能源效率約為14.6%。

(2) EV之電能來源為(煤炭+石油→燃料油)→電廠→市電→整車，總能源效率約為20.1%，EV改善約27%的總能源效率。

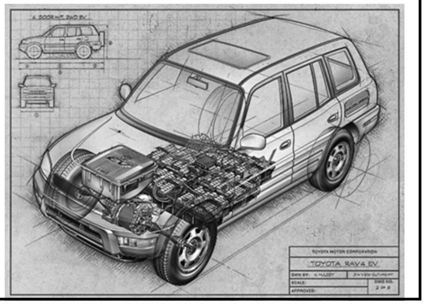
(3) 可估算每公里行駛之二氧化碳排放量分別為168.2g/km與125.1g/km，EV改善約34%的二氧化碳排放量。



EVs

The five main operating components of EVs :

- Energy System: Batteries
- Power System: Motors
- Drive System
- Charger System
- Auxiliary System



Battery

- Lead-Acid (Pb-acid)
- Nickel cadmium (NiCd)
- Nickel metal hydride (NiMH, 鎳氫電池)
- Lithium-Ion (Li-ion, 鋰離子電池)

- 目前HEV及部分PHEV以電動動力做為車輛加減速啟動輔助，需要具有高功率密度的電池系統，使用**鎳氫電池**為主，已進入商業化市場。

- PHEV及BEV以電動動力提供車輛限定及完全的里程行駛，需要具有高能量密度的電池系統，市場上以**鋰離子電池**為主，目前電動車輛應用尚在商業化起步階段。

二次電池（Secondary battery）

可充電電池又稱二次電池（Secondary battery）、蓄電池。可充電電池按製作材料和工藝上的不同，其優點是在充電後可多次循環使用，它們可全充放電兩百多次甚至達1500次，充電電池的負荷力要比大部分一次性電池高。常見的類型有：

鉛酸電池—電壓約2V，容量低但可輸出較大的功率、電池，常使用於汽車中作啟動引擎用，或用於不斷電系統(UPS)、無線電機、通信機。
鎳鎘電池NiCd—電壓約1.2V，有較強烈的記憶效應，而且容量較低，含有毒物質。
鎳氫電池NiMH—電壓約1.2V，有極輕微的記憶效應，容量較鎳鎘電池大（也比鹼性電池大）。舊鎳氫電池有較大的自放電，新的鎳氫電池自放電低至與鹼性電池相約，而且可在低溫下使用（-20℃），充電裝置、電壓與鎳鎘電池相同，已取代了鎳鎘電池，同時也可取代絕大部份鹼性電池的用途。
鋰離子電池Li-ion—電壓約3.6、3.7V，容量較高、重量較輕，但價錢也較貴，常用於行動電話及數位相機。

Lead-Acid (Pb-A)

- The cell has one plate made of lead and another plate made of lead dioxide, with a strong sulfuric acid electrolyte in which the plates are immersed.
- Lead combines with SO4 (sulfate) to create PbSO4 (lead sulfate), plus one electron.
- Lead dioxide, hydrogen ions and SO4 ions, plus electrons from the lead plate, create PbSO4 and water on the lead dioxide plate.
- As the battery discharges, both plates build up PbSO4 and water builds up in the acid. The characteristic voltage is about 2 volts per cell, so by combining six cells you get a 12-volt battery.
- By applying a current to the battery at the right voltage, lead and lead dioxide form again on the plates.

Battery

- **Lead-Acid (Pb-A)** batteries are being used in first EVs.

-Have been significantly improved with a number of innovations →higher power and longer life.

-The advantage of proven performance and relatively low cost.

- **Nickel-Metal Hydride (NiMh)** batteries are another popular option.

-Commonly used in laptop computers and other small applications.

-A greater driving range, but are still expensive because large-scale production is only now being started.

Battery

- **Lithium-Ion (Li-ion)** batteries—the main choice for high-performance portable electronics like video camcorders and laptop computers, are now being "up-sized" for use in electric vehicles.

- Li-ion batteries offer longer range, are relatively lightweight and have a long life cycle. But their cost is extremely high.

- **Nickel-cadmium (NiCd)** batteries, a popular choice for EVs sold in Europe.
- Other options being tested or developed for use in future commercial EVs include zinc-air, lithium polymer and sodium-nickel chloride batteries.

Battery

目前以鉛酸電池和鎳鎘電池較為普遍使用，但鉛酸電池的能量密度較低，自放電率高且循環使用壽命也較差；另外，鎳鎘電池又有環保（鎘污染）的問題。因此，目前大家正致力於高性能電池的研發，其中又以具有較高能量密度和比功率的鋰離子最具發展潛力，但鋰離子電池在高功率和容量大型化方面，仍面臨了安全性和高成本的問題。

	鉛酸電池 Pb-acid	鎳鎘電池 Ni-Cd	鎳氫電池 Ni-MH	鋰電池 Li-ion
商品化	1890	1956	1990	1992
工作電壓	2.0V	1.2V	1.2V	3.6V
體積能量密度	100 Wh/l	150 Wh/l	250 Wh/l	350-400 Wh/l
重量能量密度	30Wh/kg	50Wh/kg	80Wh/kg	150Wh/kg
循環壽命	300次	1,000次	500次	500次
自放電率	20%/月	20%/月	20%/月	5%/月
記憶效應	無	有	有	無
價格	<0.2 $/Wh	0.5 $/Wh	0.5-1 $/Wh	0.5-1 $/Wh
綠色產品	否	否	是	是

Battery

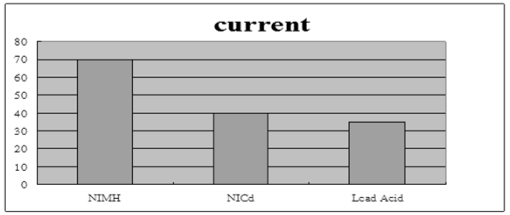
(1) Lead-Acid (Pb-acid)
(2) Nickel cadmium (NiCd)
(3) Nickel metal hydride (NiMH, 鎳氫電池)

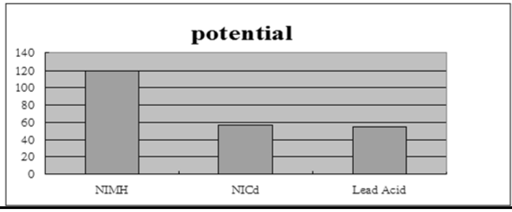
Characteristics of batteries:

- Specific energy (Wh/kg)
- Specific power (W/kg),
- Specific cost ($/kWh)
- Cycle life (cycles to 80% depth of discharge)

Battery Specific Energy

(Wh/kg)



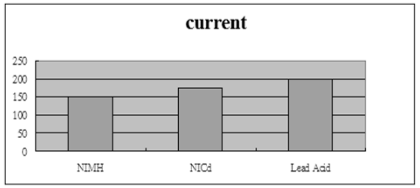


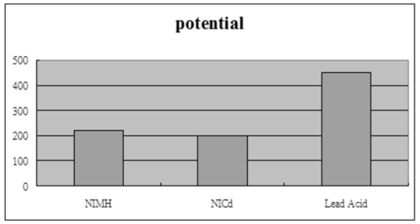
Battery

- Specific energy affects the number of batteries, and hence the mass of batteries
- Most important factor for EVs → It determines their total range. Not as critical for HEVs.
- NiMH batteries currently have the most energy per unit mass of the three battery chemistries, and in the future, are projected to maintain a specific energy of over 2 times that of lead-acid and NiCd batteries.

Battery Specific Power

(W/kg)



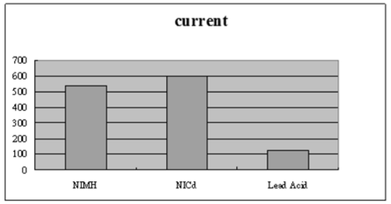


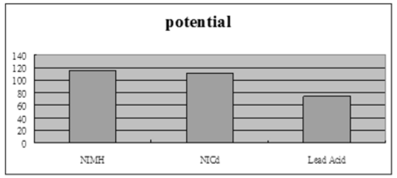
Battery

- The most important parameter measuring electrical energy storage requirements for hybrid electric vehicles → to provide the power for acceleration and hill climbs.
- High specific power batteries are critical to success of HEVs.
- In the future, it is anticipated that bi-polar lead-acid batteries will have twice the specific power of both NiCd and NIMH batteries.

Battery Specific Cost

($/kWh)



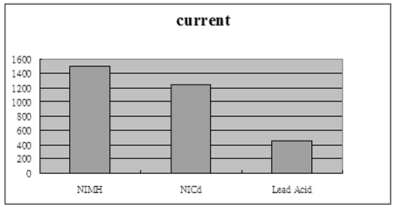


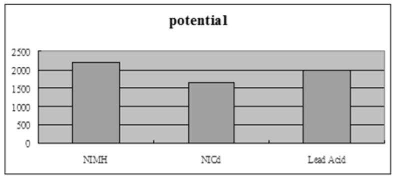
Battery

- Specific cost is the cost per unit energy (kWh) of battery. Related to the economic viability of the battery.
- Lead-acid have the lowest $75 with bi-polar batteries. (longest and most fully developed battery technology)
- Nicd and NiMh batteries are 4 to 5 times more expensive than lead- acid.

Battery Cycle-Life

(Cycles)

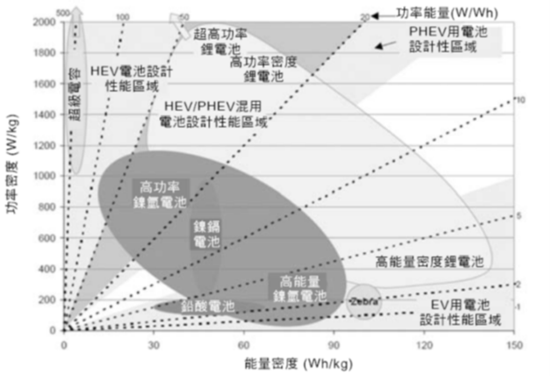




Battery

- The cycle life is a measure of how long the battery will last before it needs to be replaced.
- Pb-acid batteries have historically had a relatively short life.
- NiCd and NiMH have 3-4 times the cycle life of lead-acid.
- Future bi-polar lead-acid batteries may eventually have comparable life to other two technologies.

Battery



Battery

Example:

- A series range-extender hybrid vehicle with a 10 kWh battery pack. If this vehicle had an energy economy of 5 miles/kWh, one cycle would provide 50 miles of operation, and then perhaps another 50 miles form the range-extender HPU (Hybrid Power Unit).

- When selecting current Pb-acid batteries for this vehicle (450 cycle life) → the battery pack would have to be replaced every 45,000 miles, or roughly every three years.

Battery

The National Electric Vehicle Infrastructure Working Council (IWC) has established three charging levels for EVs:

- Level 1 (slow) - Uses a common 120-volt, three-prong receptacle found in homes and offices→ “convenience charging”
  - Charging at any location, but secondary due to the long charging time
  - Level 1 charging will typically take between 8 to 14 hours or more to fully charge a vehicle (~size of the battery pack).

Battery

- Level 2 (normal) – This is the primary method for charging an EV and requires special EV supply equipment to provide charging at 240 volts with a current of 32-40 amps.

-Level 2 charging usually takes from 4 to 8 hours depending on how “low” the battery is.

- Level 3 (fast) – This level operates at high voltage levels and will be able to charge an EV in about 10 to 20 minutes.

-Still under development.

Electric Vehicles

EVs

Why do people like driving an EV?

- Quiet, Clean Driving Experience (no “idle” noise)
- High Performance
- Lower Operating Costs
- No Gas Stations
- Environmentally Friendly
- Energy Security

TOYOTA : RAV4 EV

Powertrain:
-45 kW@ 2600-2800 rpm (67HP)

Batteries and Charging System :
-battery type: sealed Ni-MH
-Voltage: 288 (24 x12V)
-Auxiliary:1 12 V Pb-acid

Performance:
-Range (miles): 126
-Acceleration: 0 - 50 mph in 12.8s
-Maximum Speed: 79 mph
-Recharging Time: 6-8 hours

EVs

- 在考慮油價、平均油耗、電池售價與壽命、電池續航力、電池折舊、充電電價等因素後，大致可估算出ICV每公里之耗費成本約為1.5NT/km，而EV為4.3NT/km，且EV在此估算並未加入基礎充電設施攤提。
- 綜整環保效益與成本而言，目前EV雖然具有量產潛力，但仍侷限在電能系統成本過高，此外充電時間過長亦是考慮因素。除了市電充電、快速充電站充電外，電池交換站設置亦為可評估之方向，已使消費者等待能源補充時間，能與傳動引擎車加油時同樣快速。

EVs

EV核心技術為：**電池與電池管理系統之高充放電性能與安全性、驅動馬達之高效率與高功率/扭力密度、馬達驅控器之寬域操作、電動附件系統之性能提升、延距式發電機之多元燃油與燃燒控制技術**等，藉由以上技術，便可應用至圖中更外圈之關鍵次系統中，如：**輪轂馬達、低碳延距動力模組、高能量密度鋰電池**等，再由不同之系統規格需求，組合出不同款式與功能之電動車，包含EV、輕型EV等。

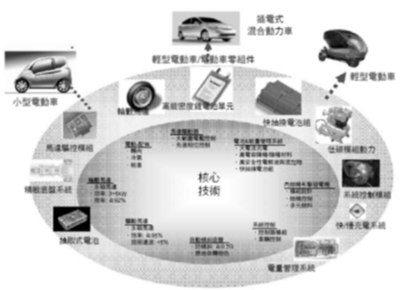

資料來源：工研院整體與電能管理系統

圖3-3-3-3 EV關鍵次系統技術發展

Hybrid Electric Vehicles

- HEVs are powered by **two energy sources** — an **energy conversion unit**, eg. a combustion engine or fuel cell, and **an energy storage device**, eg. batteries or ultracapacitors.
- HEVs are efficient vehicles that use a small motor and an electric engine to generate the power to drive the vehicle. (2-3 times more fuel-efficient than conventional vehicles)
- Hybrid electric vehicles (HEVs) are offered by numerous auto manufacturers and are becoming increasingly more available.

HEVs

Advantages of HEVS:

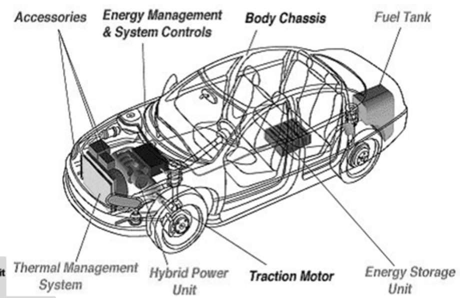
- Regenerative braking capability, which helps minimize the energy lost when driving.
- Engine is sized to average load, not peak load, which reduces the weight of the engine.
- Fuel efficiency is greatly increased ,while emissions are greatly decreased.
- HEVs can be operated using alternative fuels, therefore they need not be dependent on fossil fuels.

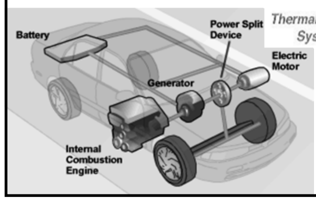
HEV Maintenance and Safety

- Hybrid vehicles need the same general maintenance as conventional vehicles.
- Today's vehicles come with very solid warranties, which include the battery packs of the HEVs.
- They undergo the same rigorous testing as conventional vehicles and must meet all of the same standards for safety.

HEVs

Components

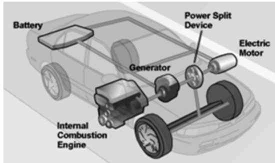




HEVs

HEV Drivetrain Components

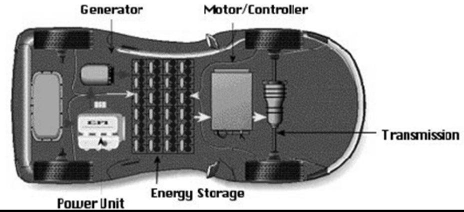
- Electric traction motors/controllers
- Electric energy storage systems, such as batteries and ultracapacitors
- Fuel systems for hybrid power units
- Hybrid power units such as spark ignition engines, compression ignition direct injection (diesel) engines, gas turbines, and fuel cells
- Transmissions



HEVs

HEV Series Design

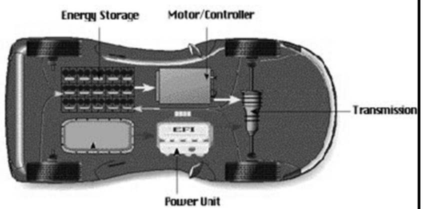
- The engine never idles, which reduces vehicle emissions.
- The engine can continuously operate in its most efficient region.
- The engine drives a generator to run at optimum performance.
- The design allows for a variety of options when mounting the engine and vehicle components.



HEVs

HEV Parallel Design

- A smaller engine provides more efficient operation and therefore better fuel economy without sacrificing acceleration power.
- Most parallel vehicles do not need a separate generator because the motor regenerates the batteries.
- Power does not need to be redirected through the batteries and can therefore be more efficient.

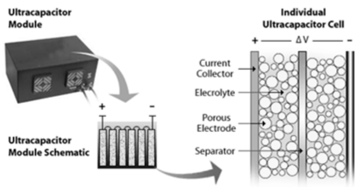


HEVs

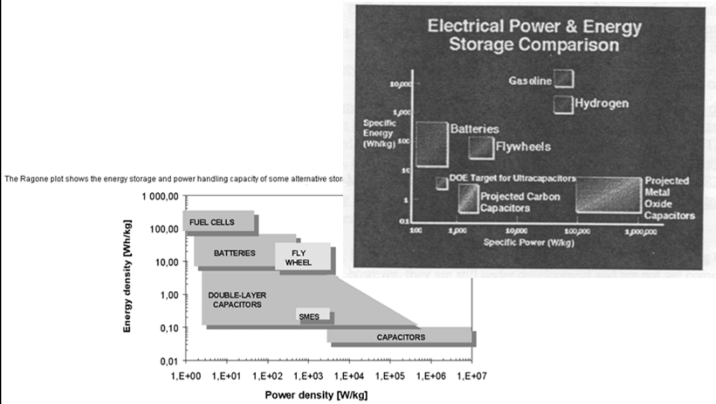
Hybrid Power Unit (HPU)

- =>An HPU converts fuel into energy
- Spark ignition (SI) engine、Diesel engine、Gas turbine engine、Stirling engine…

Electric Energy Storage: batteries, flywheels, and ultracapacitors..



HEVs



HEVs

Batteries

- **Pros:**
  - batteries are a relatively mature technology compared to flywheels and ultracapacitors.
  - Pb-A batteries are fairly inexpensive and are economical today.
  - Have no moving parts
  - Have a higher specific energy than flywheels and ultracapacitors
- Cons:
  - new battery technologies such as Li-ion may be still too expensive commercially viable today.
  - Most batteries have a shorter life than that of the vehicle they would be put into, necessitating battery replacement

HEVs

Flywheels

- Flywheels store energy mechanically. To absorb energy, the flywheel converts electrical energy to kinetic energy (using a built-in motor), making the flywheel's high-strength rotor spin faster.
- To deliver energy, some of the kinetic energy stored in the rotor is converted to electrical energy using the motor in reverse (as a generator), slowing the rotor down.
- Pros: Flywheels store energy very efficiently (high turn-around efficiency) and have the potential for very high specific power compared with batteries.
- Cons: (1) Current flywheels have a low specific energy. (2) Safety concerns: the possibility of high speed rotor breaking loosing. (3) Less mature technology. High cost.

HEVs

Flywheels Physics Background

- The equation for the kinetic energy stored in a $(1/2)*I*\omega^2$, where I is the moment of inertia (ability of an object to resist changes in its rotational velocity) and ω is the rotational velocity. **$\rightarrow$ I$\uparrow$ or $\omega\uparrow$**
- $\omega\uparrow\rightarrow$ centrifugal forces ($\sim M\omega^2 r$)$\uparrow$ & tensile stresses $\uparrow$
- A high density rim stores more energy than a low density one, but also experiences higher stresses. A low density rim can spin faster than a high density rim before experiencing failure.
- Kinetic energy ~ I & $\omega^2\rightarrow$ the optimum flywheel will be made of a strong material with low density (high tensile strength to density ratio)

HEVs

Ultracapacitors (electric double-layer capacitor)

- Ultracapacitors store electrical energy by accumulating and separating unlike charges. To discharge the ultracapacitors, a load is applied between the two terminals so that charge can flow through it.
- Compared to conventional electrolytic capacitors, the energy density is typically on the order of hundreds of times greater. In comparison with conventional batteries or fuel cells, EDLCs also have a much higher power density
- Pros: Ultracapacitors have no moving parts and a very long cycle life. Very high specific power. The ability to capture large amounts of energy from regenerative braking at high power rates.
- Cons: Ultracapacitors have low specific energy and are less mature technology than batteries.

HEVs

Materials of Ultracapacitors

- Current trends—higher energy densities will be achievable with a carbon composite electrode using an organic electrolyte rather than with carbon/metal fiber composite electrode devices with an aqueous electrolyte.

Ultracapacitors Performance

- Excellent cycle life
- High cycle efficiency compared with chemical batteries
- Their voltage is directly proportional to their state-of-charge (the measure of how much energy is left)
- One of the keys to successfully developing ultracapacitors for vehicle applications is the development of interface electronics to allow the ultracapacitor to optimally load-level the batteries.

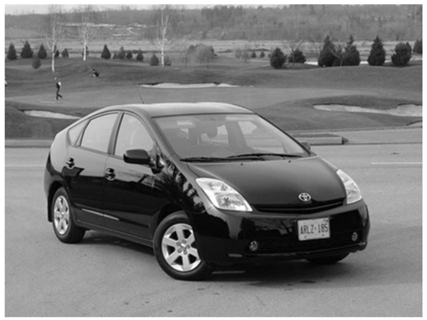
HEVs

Toyota	超過1百萬輛銷售量(Prius 一、二代)	第三代Prius
General Motors	Saturn Vue 車型	Saturn Vue Green Line車型與Chevy Volt launch 2009車型
Ford	Mercury Milan車型and Lincoln MKZ 車型	Escape車型測試中 Edison與Toyota 合作開發
Volkswagen (Group)	BMW & Daimler共同開發	
Honda	銷售量40萬以上	只開發電動車(BEV)
PSA	與van合作延距式燃料電池車	
Nissan	Nissan Altima 車型	
Chrysler	ENVI開始於 2007年後發展	Sprinter van車型測試中
Renault	Renault Ondelios Hybrid Concept Car 2008	
Hyundai	I-Blue 燃料電池概念車發表於2007年	

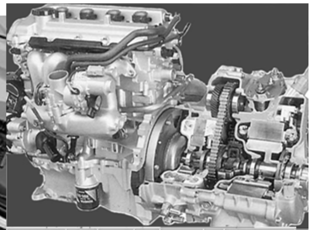
HEVs

- **Engine**: Highly efficient 76-hp VVT-I gas engine
- **Power Split Device**: Electronically controlled continuously variable transmission (ECVT)
- **Generator**
- **Electric Motor**: 500V motor with over 50% more power than prior generation
- **Traction Battery**: Compact durable nickel-metal hydride battery

Toyota Prius



HEVs



ETC Test Number		Test Date	Test Type	Test Temp (F)	Fuel Economy (mpg)	Delta Ah	Emissions (g/mi)			
Cont. Emissions Data	Cont. Vehicle Data						HC	CO	NO_x	CO_2
101104	101104	2-Aug-01	**FTP75**	80.9	54.7	n/a	0.007	0.095	0.008	162.6
101121	101121	3-Aug-01	FTP75 (3 bag weighting)	77.3	57.3	0.457	0.009	0.12	0.003	155.3
			FTP75 (4 bag weighting)		58.3	0.634	0.009	0.116	0.003	158
				Average	**56**		**0.009**	**0.116**	**0.003**	**158**
10868	10868	29-Jun-01	HWFET	72.7	54.9	n/a	0.002	0.168	0.002	161.8
101105	101105	2-Aug-01	HWFET	74.5	59.1	-0.038	0.001	0.036	0.015	150.5
				Average	**57.2**		**0.001**	**0.091**	**0.008**	**155.7**
101153	101153	7-Aug-01	SC03 with AC on	98.9	37	0.237	0.004	0.152	0.002	240.3
101154	101154	7-Aug-01	SC03 with AC off	94.8	53.3	0.085	0.002	0.028	0.025	167.1
101123	101123	8-Aug-01	US06	75.6	41.8	0.068	0.006	0.243	0.003	212.6
101165	101165	8-Aug-01	US06	31.5	36.6	0.078	0.004	0.583	0.005	242.2

HEVs

Low speed: From initial acceleration to low speeds, power is provided by Prius' quiet electric motor using energy supplied by the battery. Whenever supply is low, Prius automatically recharges the battery using the gas engine to power generator.

Heavy acceleration: Prius delivers smooth, seamless power as the power split device manages input from the gas engine and electric motor. Additional energy is supplied by the battery.

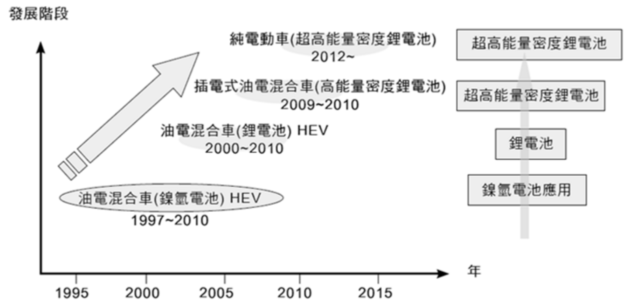
Highway cruising: For exceptional highway performance, Prius' gas engine power the wheels and electric motor via the generator. As with low-speed driving, battery recharging may also occur – the key to why Prius never needs plugging-in.

Deceleration/Braking: Prius' electric motor becomes a generator converting otherwise wasted kinetic energy into electricity for the battery. For sudden stops, Prius' conventional brakes are also applied.

At a stop: Prius' gas engine shuts off to prevent idling and conserve fuel, as the electric motor stands silently ready for action.

HEVs

HEVs



資料來源：工研院機械所整理