Hybrid, plug-in and electric cars – their batteries and their benefits to society.

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The 5th IFCBC, Tel Aviv 20-1-2008

The most advanced bio-fuel car

The dream car, a major technology breakthrough:

- Do not use oil
- Do not need to be charged from the electric grid

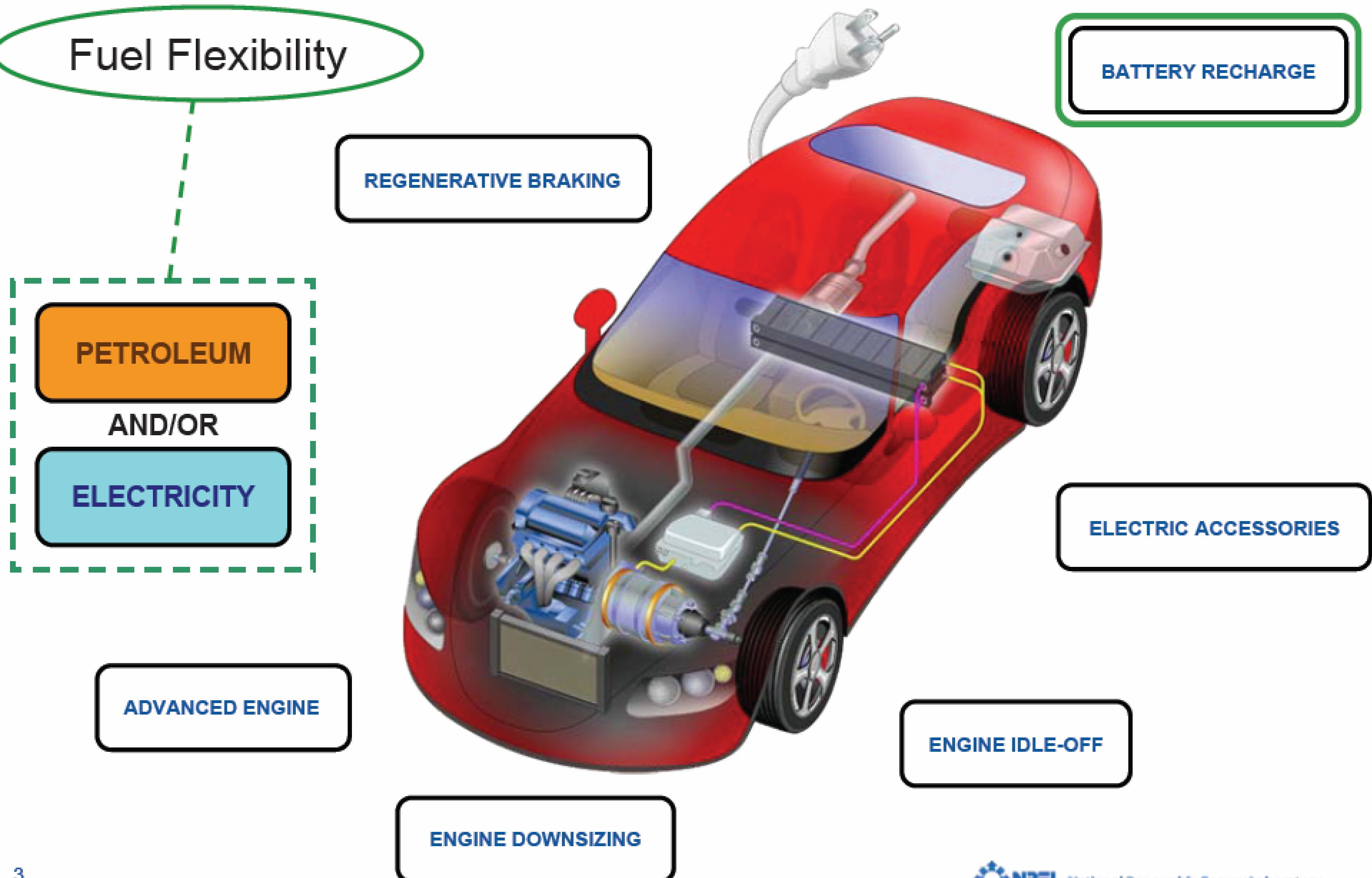
The solution to the oil crises and pollution

Outline

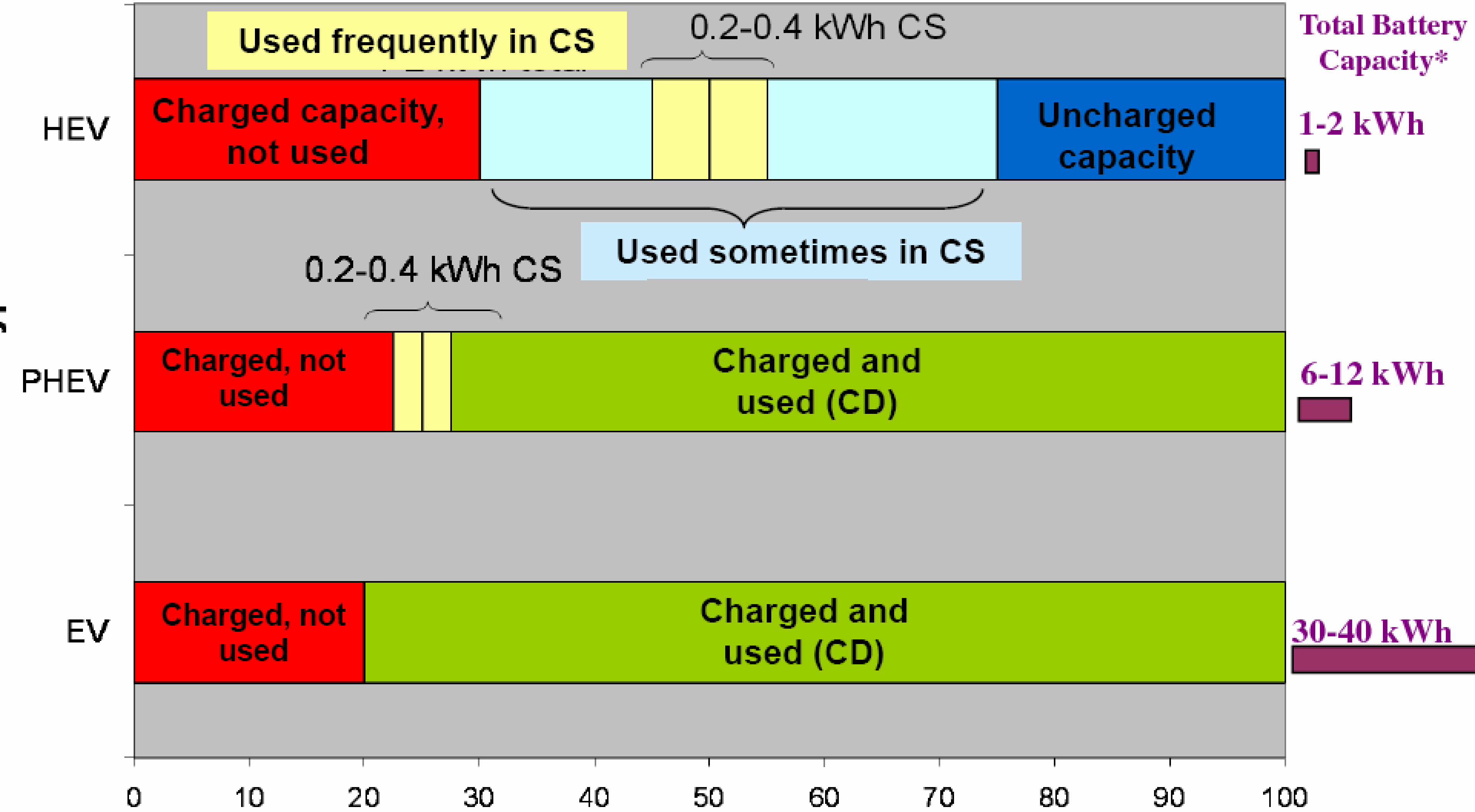
- The four types of electric vehicles (EV):

  Hybrid (HEV), Plug-in hybrid (PHEV), all Electric (EV) (and fuel cell hybrid EV (FCEV) – not to be covered) .
- Potential fuel saving and pollution reduction.
- Design and types of batteries.
- Anodes and cathodes for EVs batteries.
- Cost and market introduction.
- Summary

A Plug-In Hybrid-Electric Vehicle (PHEV)



Battery Usage in EVs, HEVs, and PHEVs

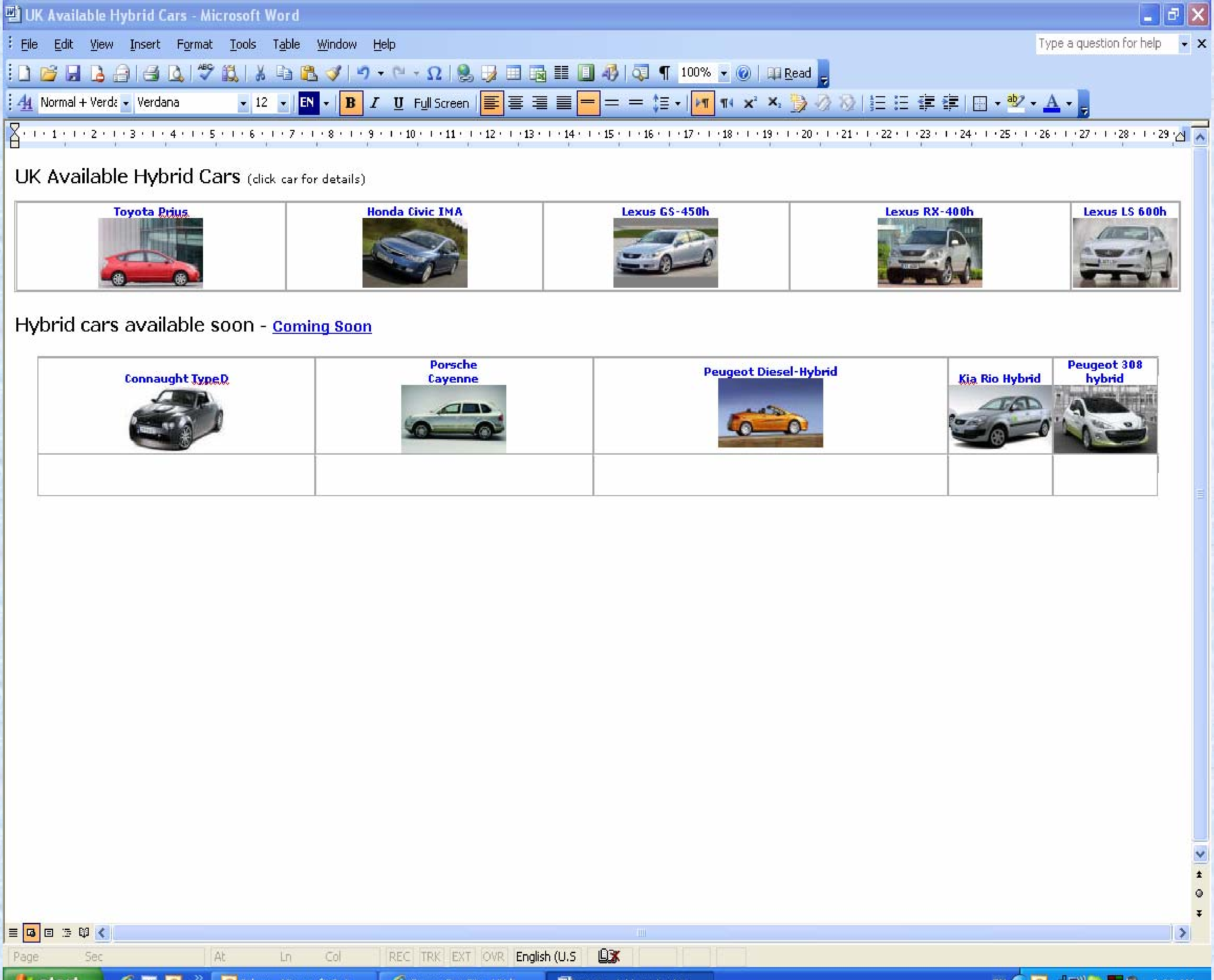


CD: Charge Depleting

CS: Charge Sustaining

*Battery capacity for a midsize car

U.S. Hybrid Sales



UK Available Hybrid Cars - Microsoft Word
UK Available Hybrid Cars (click car for details)
Toyota Prius
Honda Civic IMA
Lexus GS-450h
Lexus RX-400h
Lexus LS 600h
Hybrid cars available soon - Coming Soon
Connaught TypeD
Porsche Cayenne
Peugeot Diesel-Hybrid
Kia Rio Hybrid
Peugeot 308 hybrid

Some of PHEV Prototypes

EnergyCS Plug-In Prius

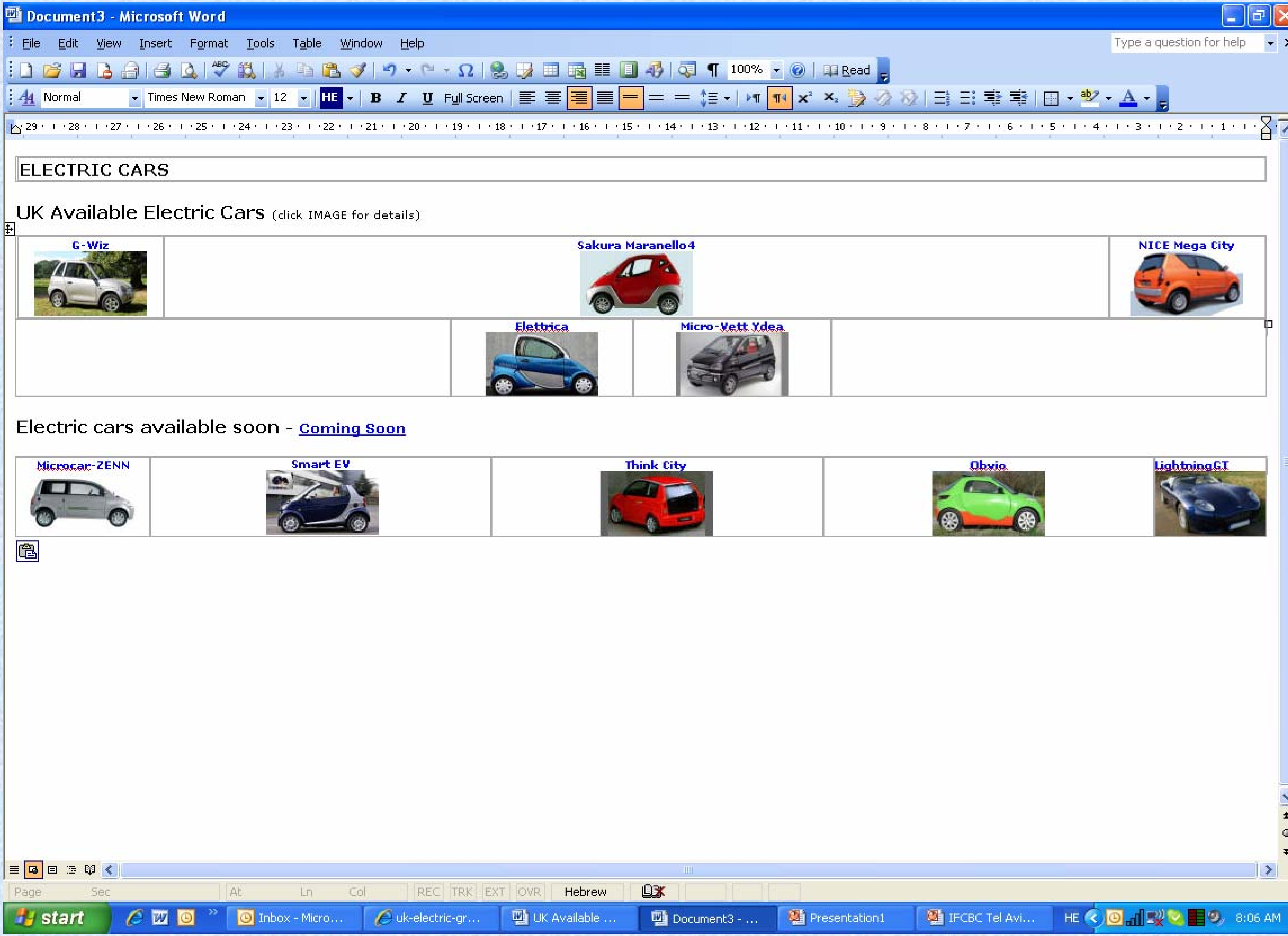
Hymotion Escape PHEV

AFS Trinity Extreme Hybrid™

DaimlerChrysler Sprinter Van PHEV

AC Propulsion Jetta PHEV

Renault Kangoo Elect'road



ELECTRIC CARS

UK Available Electric Cars (click IMAGE for details)

G-Wiz	Sakura Maranello4	NICE Mega City

	Elettrica	Micro-Vett Ydea	

Electric cars available soon - Coming Soon

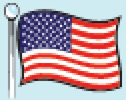
Microcar-ZENN	Smart EV	Think City	Obvio	LightningGT

PHEV Key Benefits and Challenges

KEY BENEFITS

Consumer:

- Lower "fuel" costs
- Fewer fill-ups
- Home recharging convenience
- Fuel flexibility



Nation:

- Less petroleum use
- Less greenhouse and regulated emissions
- Energy diversity/security

KEY CHALLENGES

- Recharging locations
- Battery life ?
- Component packaging
- Vehicle cost

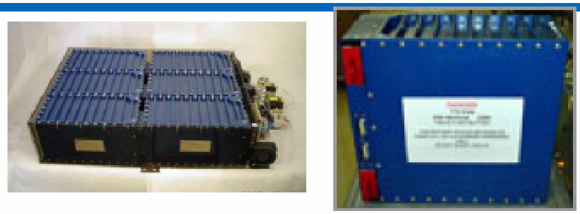
Cost-Benefit Analysis

Batteries in Current PHEVs

NiMH

14.4kWh, 280 X 40Ah cells

Johnson Controls / Varta

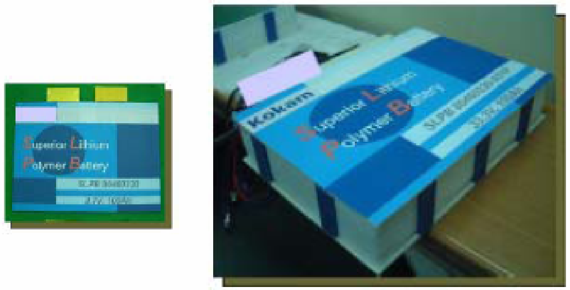


Electro Energy Inc.

Co/Ni based Li-Ion

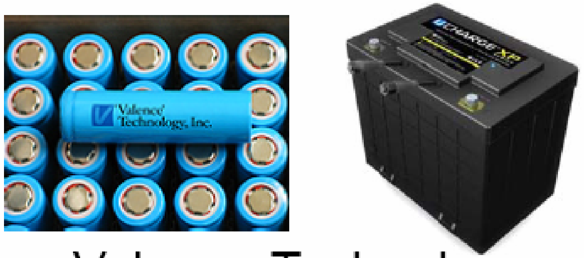
15.5kWh, 102 X 39Ah cells, 6 cells module,

Johnson Controls / SAFT



Kokam

Iron phosphate based Li-Ion



Valence Technology

Small cells, 2-5Ah

A123 Systems

Small cells, 2-5Ah

NREL

Project Status

- VARTA NiMH Battery (DNP2)
  - Battery went through **1950** cycles – 18.5 Months
  - No significant capacity degradation
  - ~ 6% of power degradation

- SAFT Li-Ion Battery
  - Battery went through **1450** cycles – 15.5 Months
  - ~ 5% of capacity degradation
  - ~ 4% of power degradation

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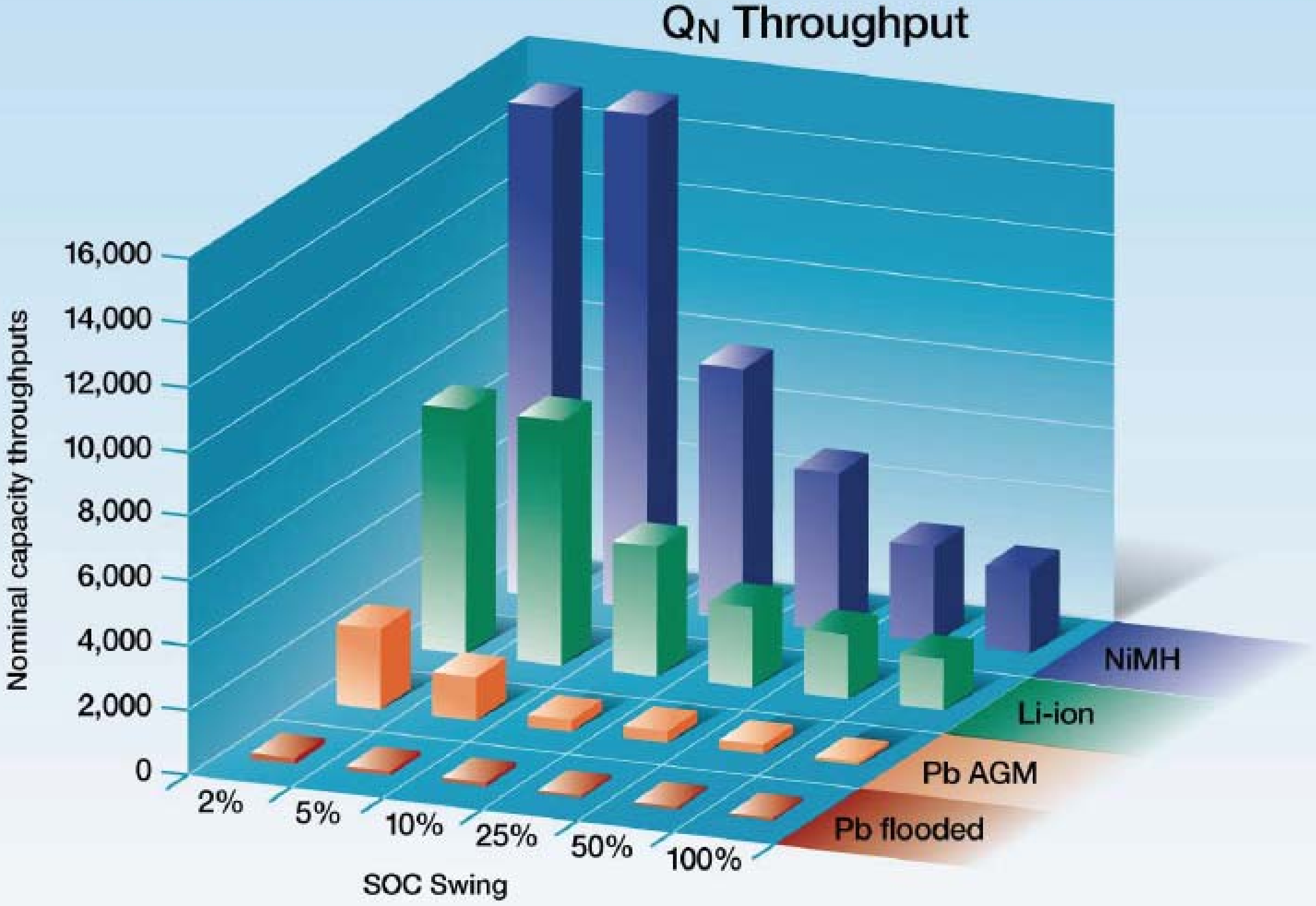
Battery Life vs. Charge Cycle



SOURCE: Christian Rosenkranz (VARTA) "Plug-in Hybrid Batteries" EPRI Workshop at EVS20

MIT ENERGY CONFERENCE

TOYOTA

The Bolloré Group BlueCar (EV) Battery

Electrical data: For a Module

Energy:	2,8 kWh
Voltage rating:	31 V
Voltage range:	24 V - 40 V
Capacity at C/3:	90 Ah
Peak power (30 sec.) at 80 % de PdD:	8 kW
Specific and volumic energy density	110 Wh/kg 110 Wh/l

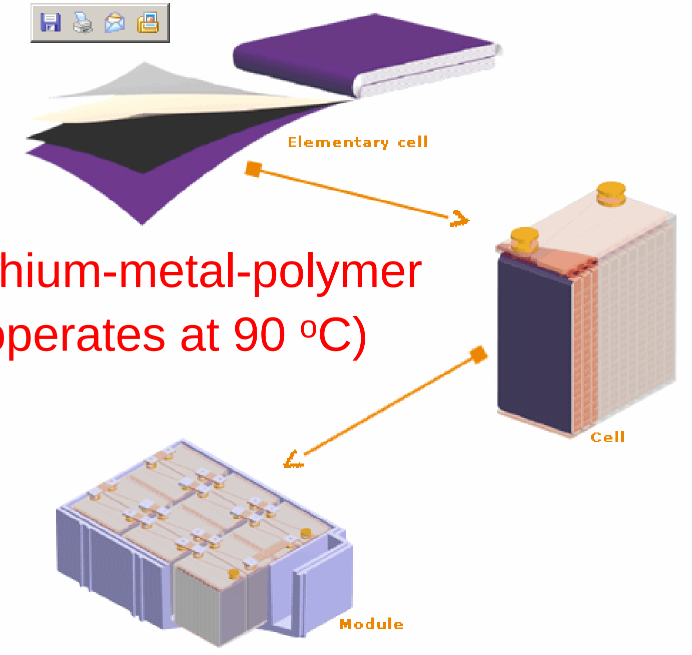
Physical data:

Volume:	25 litres
Weight:	25 kg
Communication bus:	CAN

Thermal data:

Internal temperature:	90°C
Operating temperature:	-20°C à + 60 °C

This totally autonomous module is remarkably light and compact, with specific and volumetric energy density figures greater than 100 Wh/kg and 100 Wh/l.



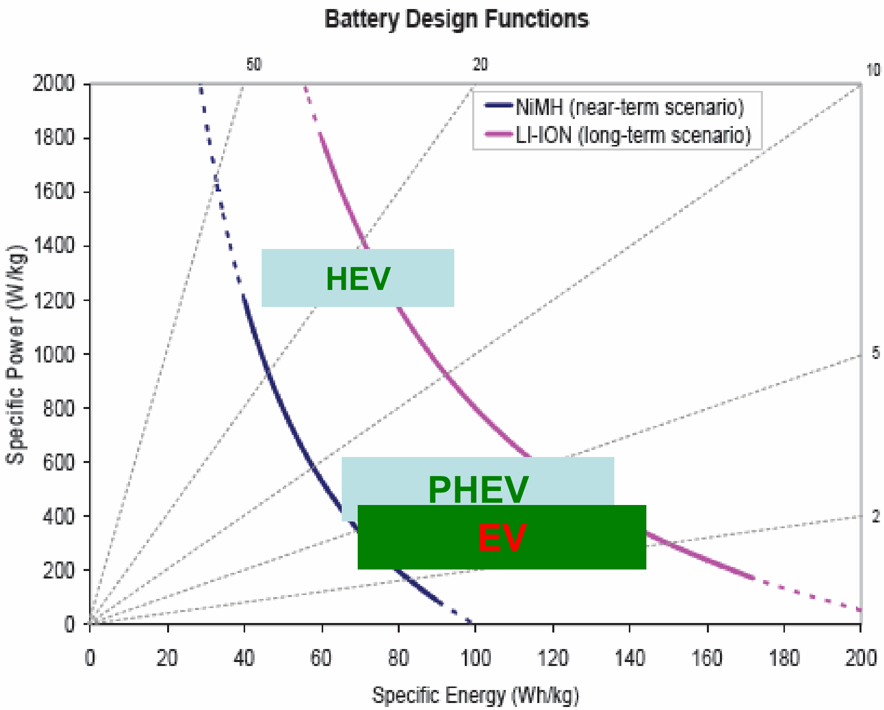
The different phases of module construction

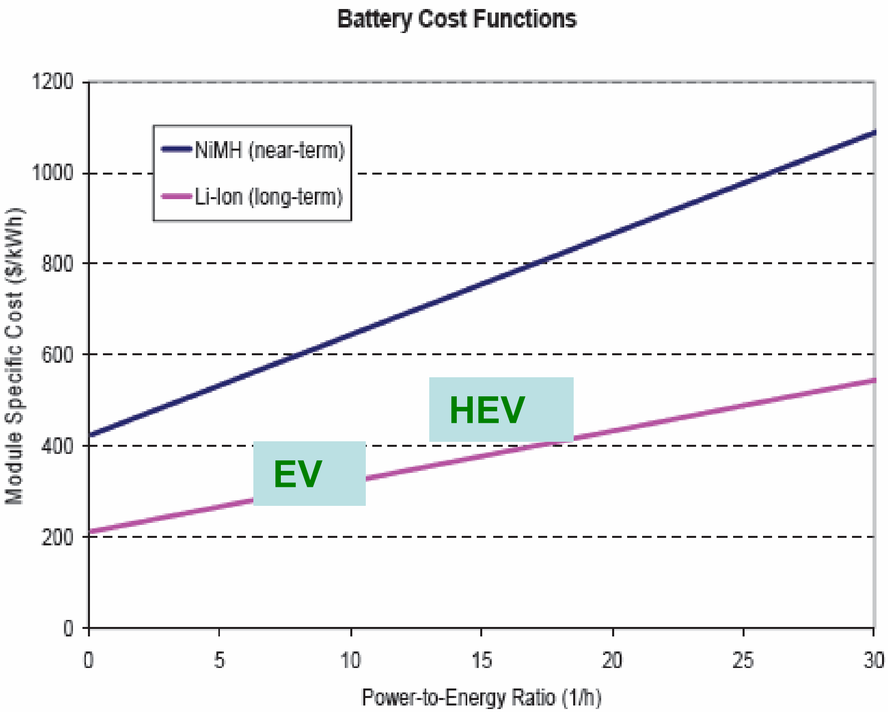
lithium-metal-polymer (operates at 90 ^{o}C)

BatScap battery pack 27 kWh
Battery pack weight: < 200kg
100% recharging time: 6 hours
Battery ED < 100 Wh/kg

http://www.batscap.com/en/la-batterie-lithium-metal-polymere/caracteristiques.php

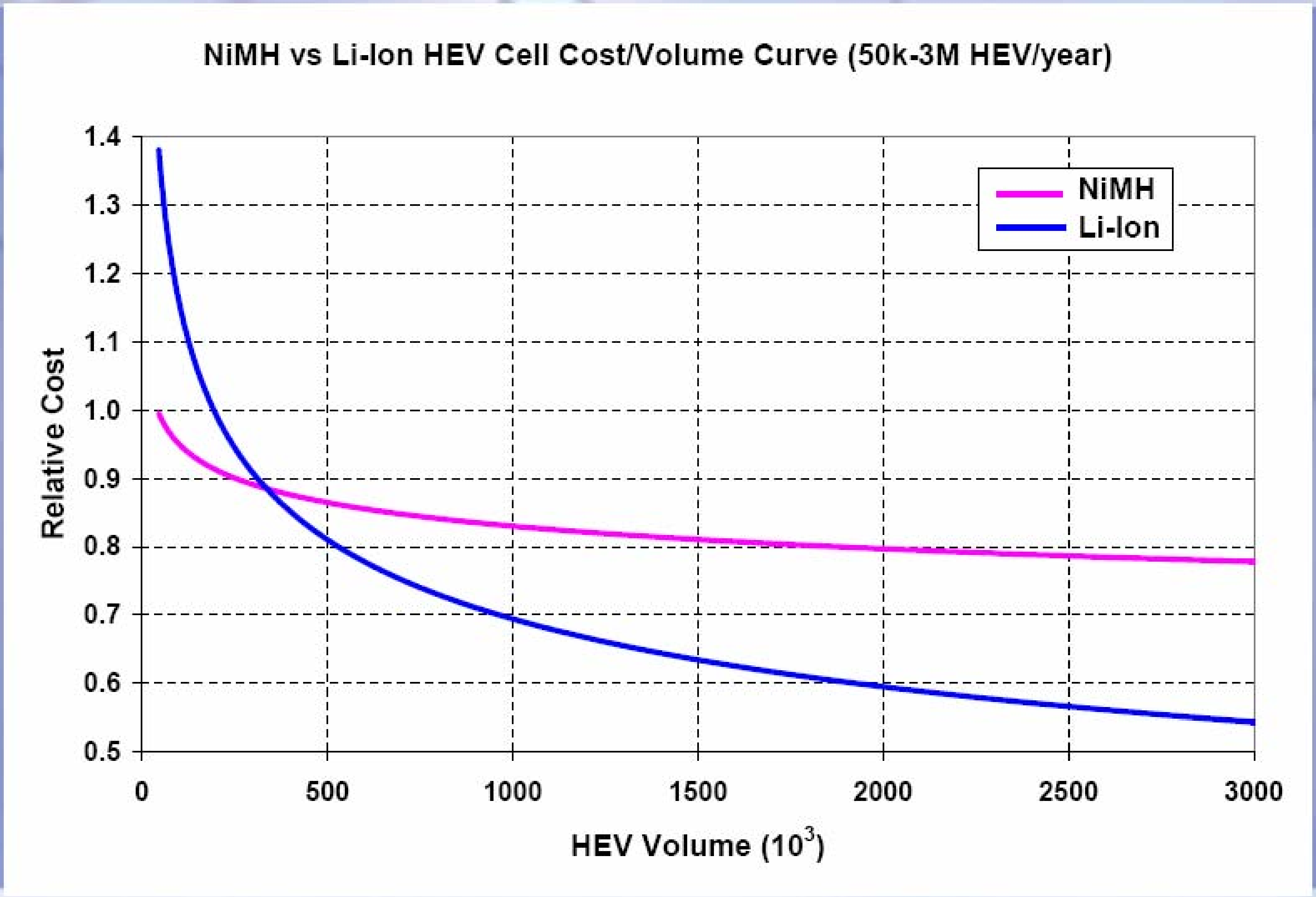
Battery Models (Scaleable)



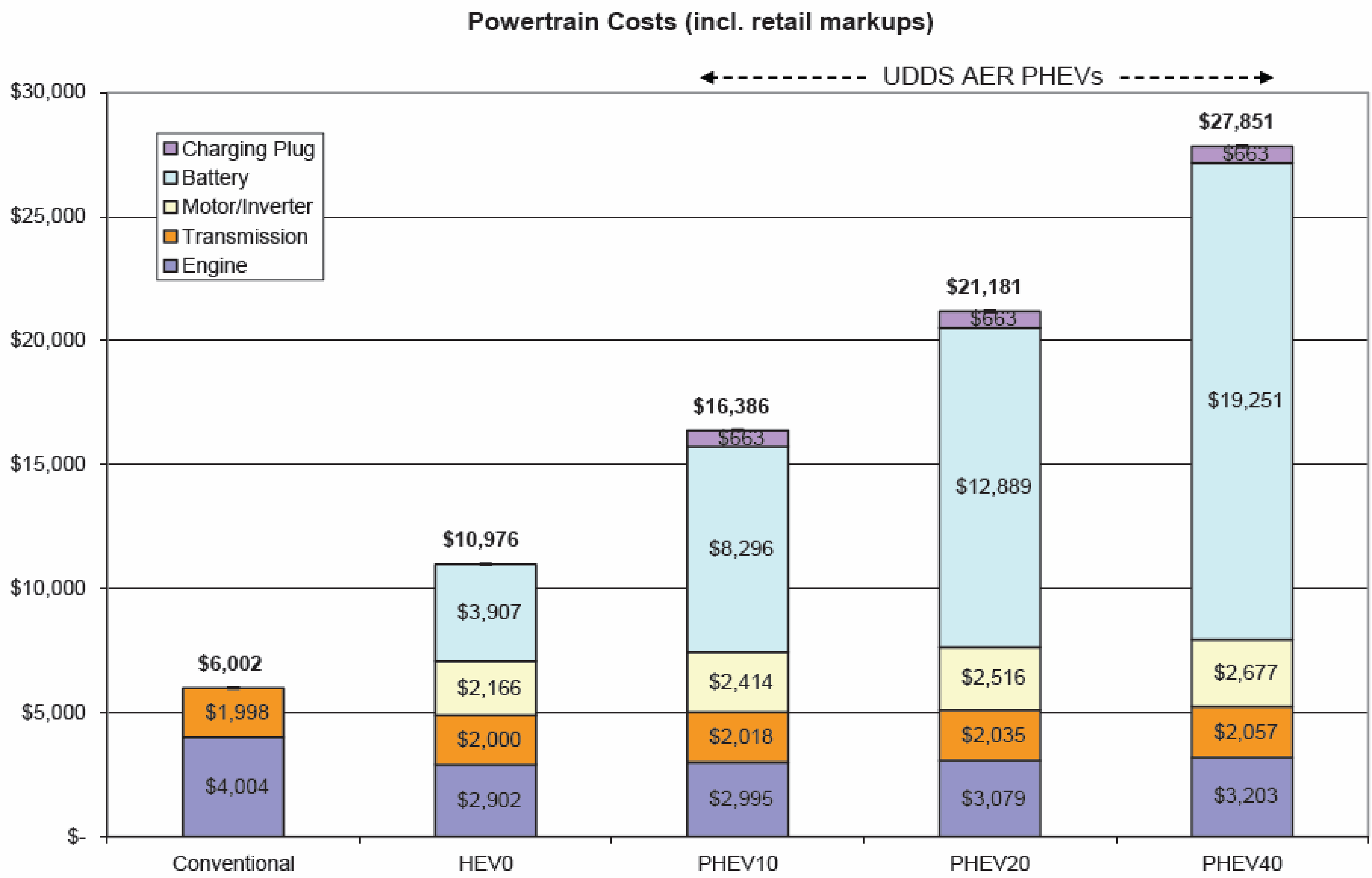


Relative Power

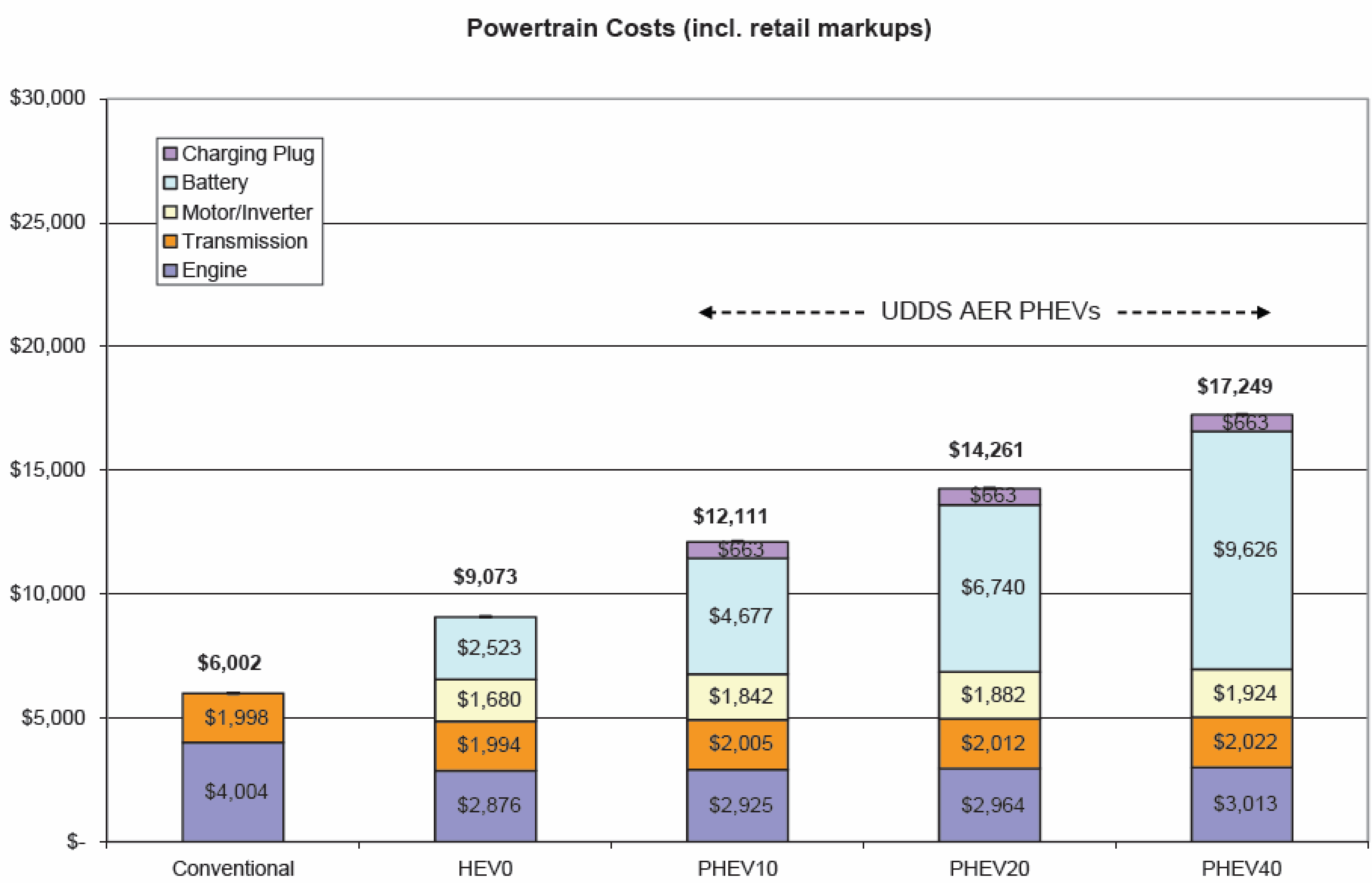
HEV Battery Cell Cost



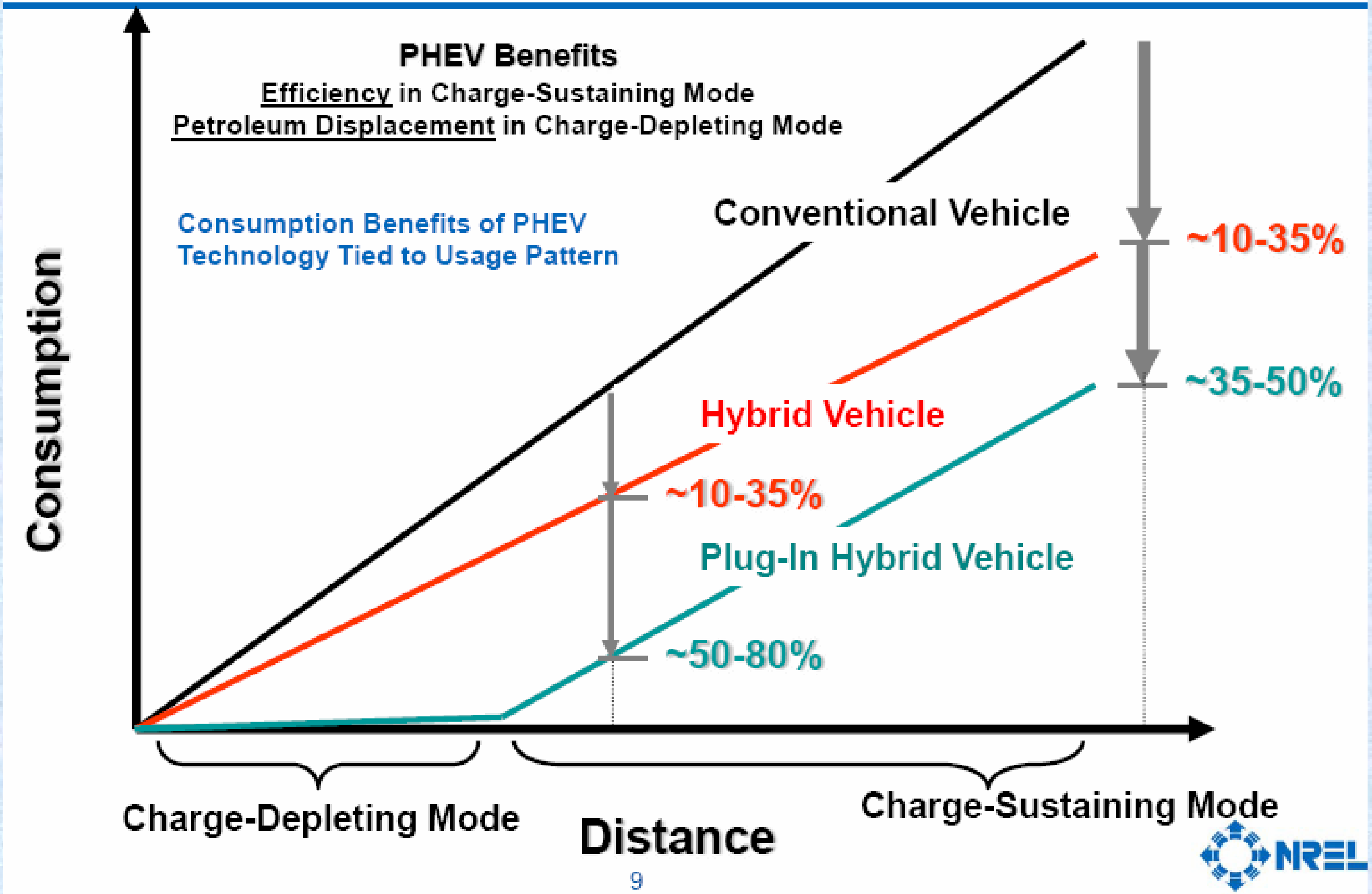
Powertrain Costs Comparison – Near Term



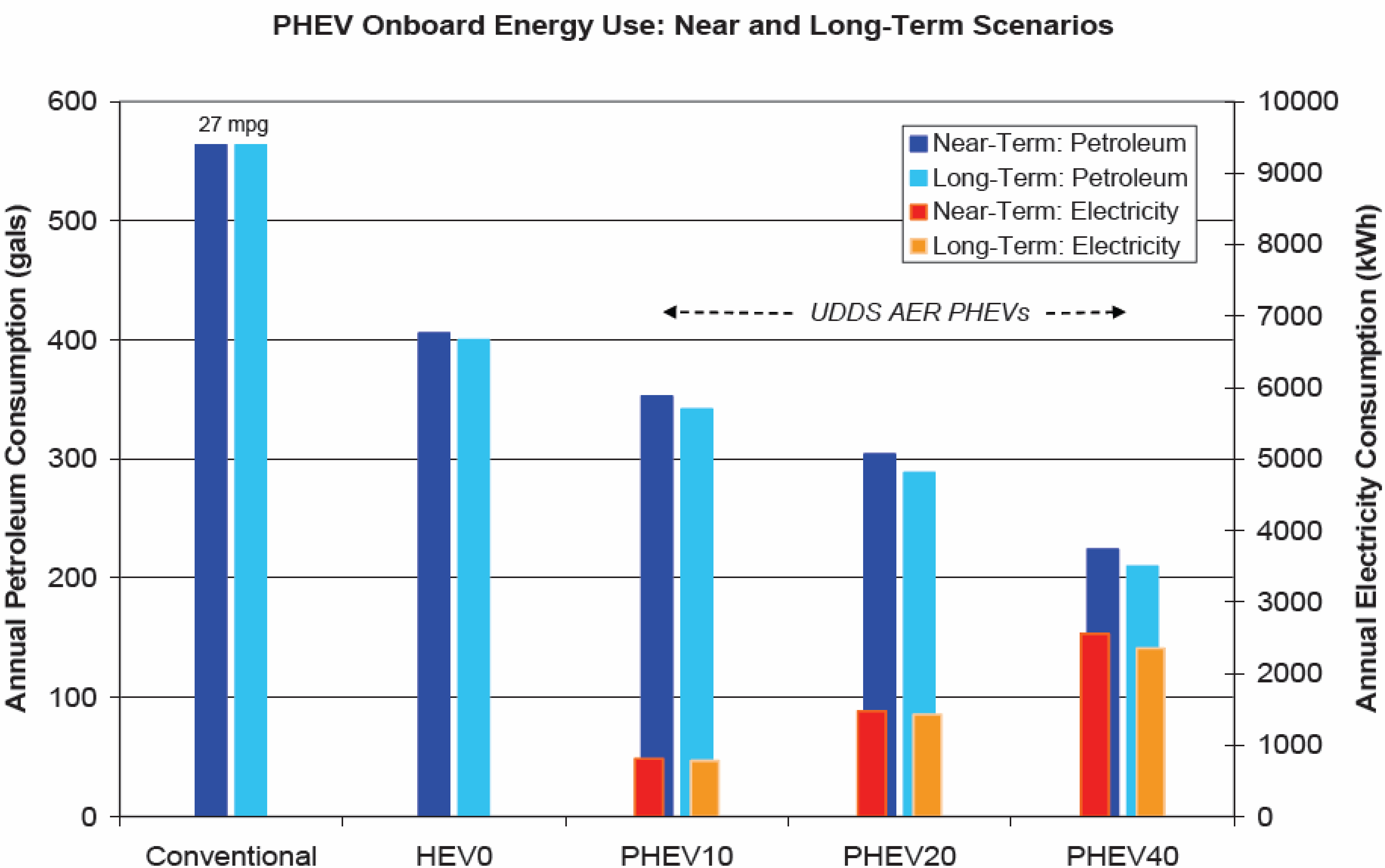
Powertrain Costs Comparison – Long Term



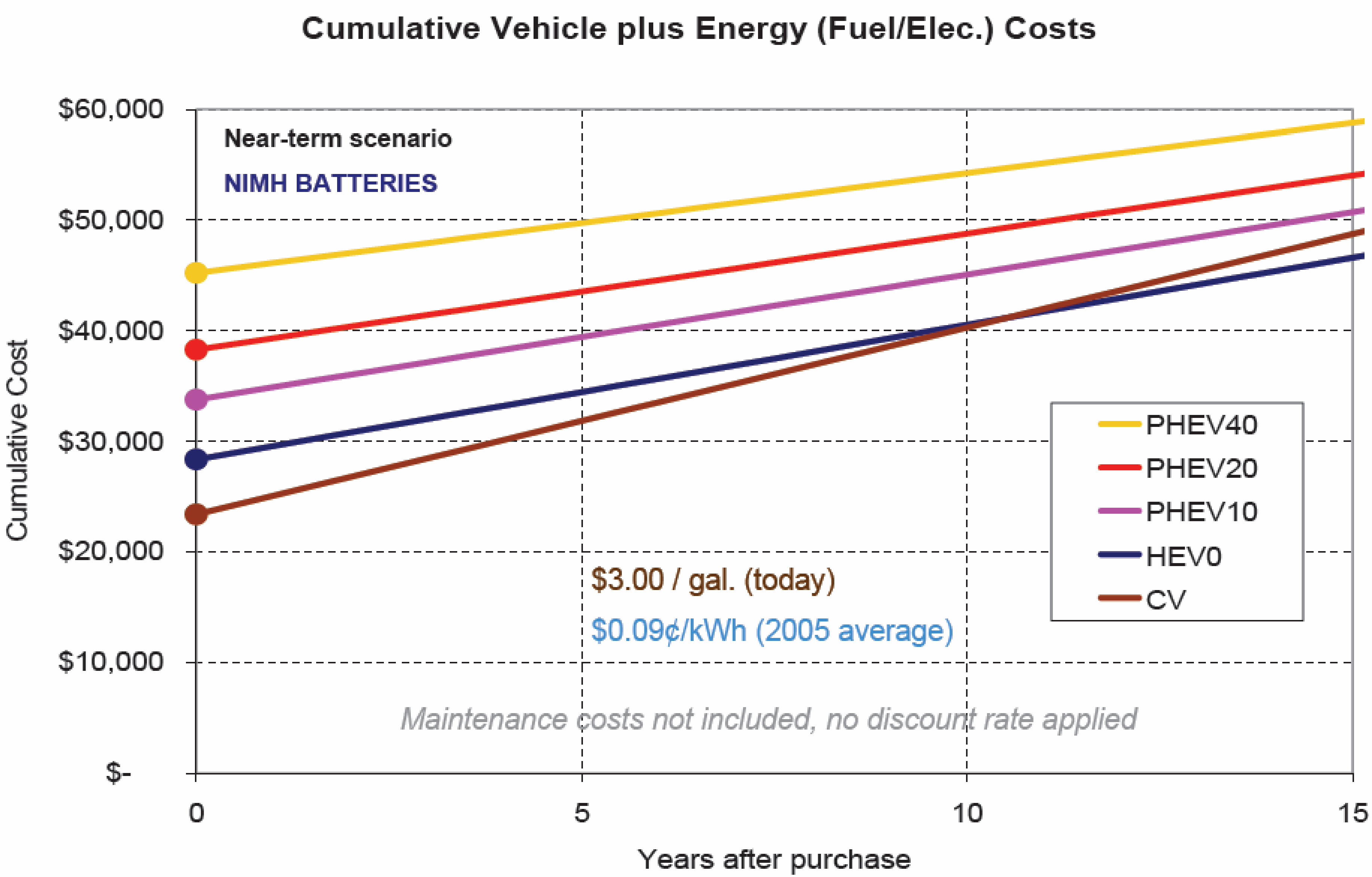
How Do PHEVs Reduce Petroleum Consumption?



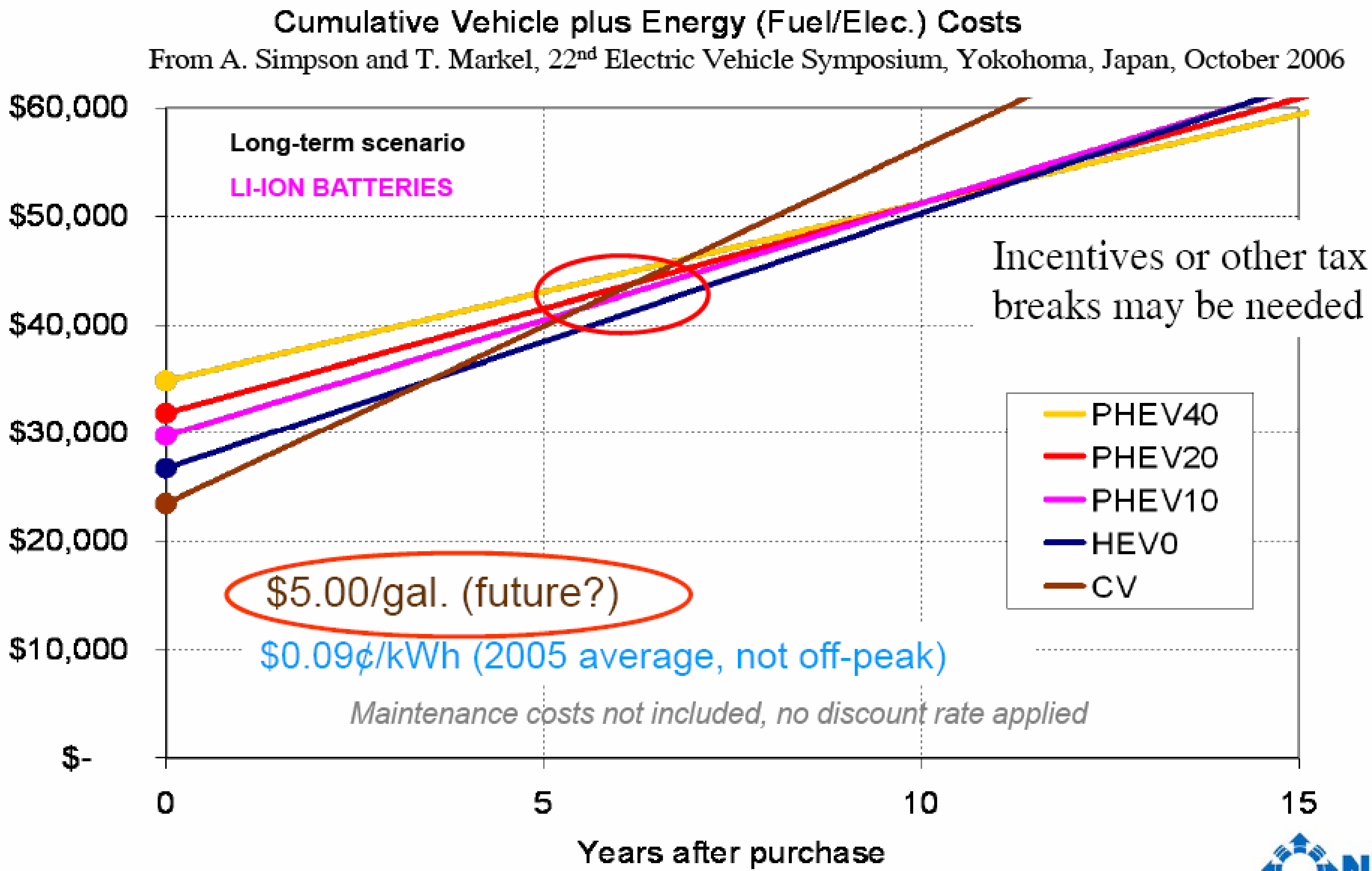
PHEV Energy Use



Overall Cost Comparison for HEVs and PHEVs



Both Higher Gas Prices and Lower Battery Costs Required for PHEV to Payback Relative to HEV



Anode Materials - Summary

Synthetic Graphite
Natural Graphite
Hard Carb
LTO ($Li_4Ti_5O_{12}$)

Cathode materials – Summary

Multiple chemistries (and cell configurations) are being pursued

$LiMn_2O_4$

$LiFePO_4$ (An interesting opportunity for HEV and PHEV)

$LiNiCoAlO_2$

$LiNiCoMnO_2$

and $LiNiCoTiMgO_2$

Li Ion Batteries for PHEV and EVs

- **An attractive choice but:**

  - Safety and life are more difficult to realize since battery is fully charged daily (in difference from HEV).

  - Cost must be reduced – batteries are larger.

- An interesting opportunity for $LiFePO_4$ cathode if life and safety is indeed established.

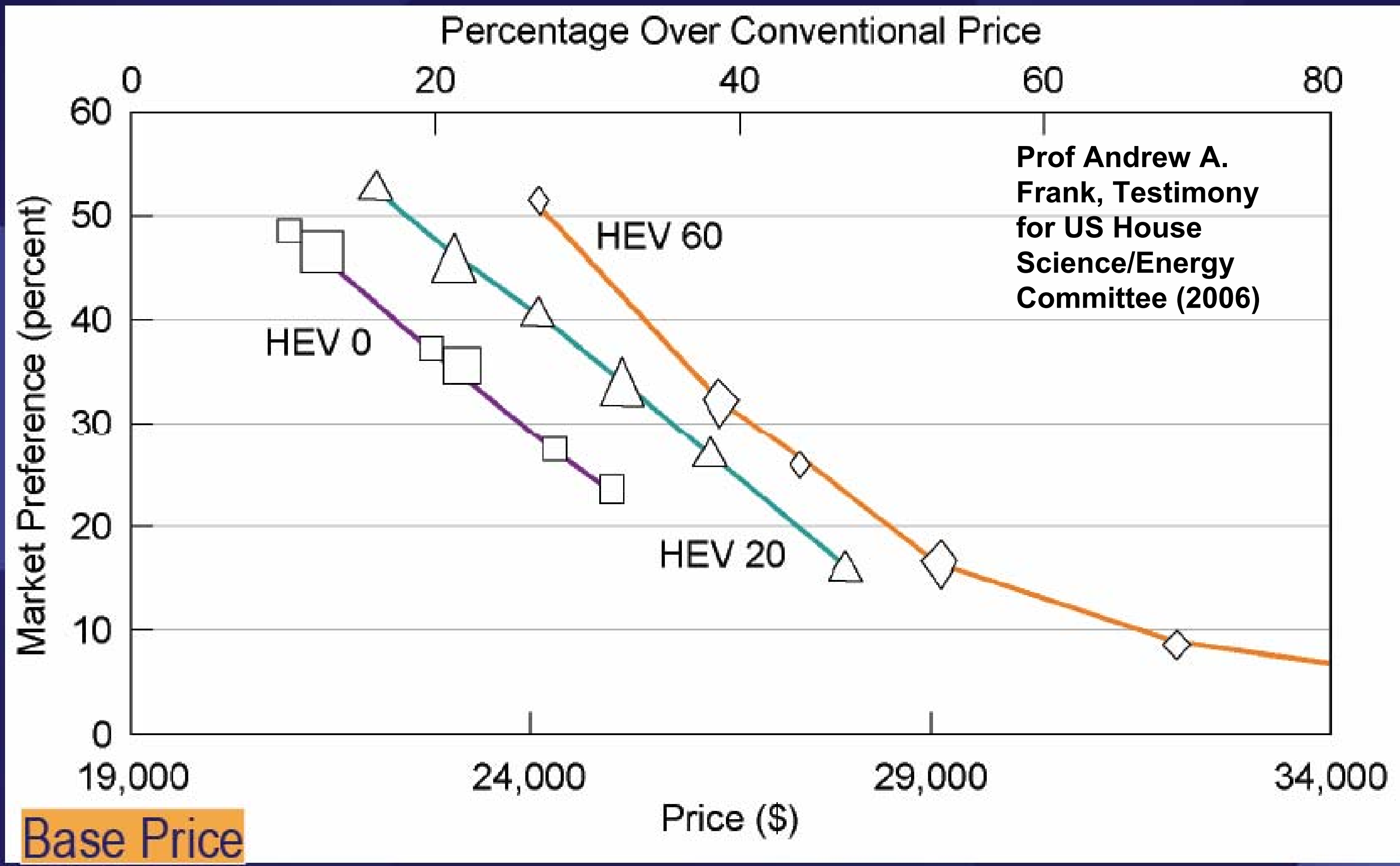
- Due to these challenges it is expected that market introduction will follow the order:

  HEV, PHEV, EV (and hybrid FC-EV)

- **Government regulations and subsidy can help earlier introduction of these cars.**

- **An attractive option is small rented EVs for city use.**

Mid-size HEV car Market Potential vs. Price



Each line represents market potential versus price for a simple market in 2010 where HEV 0 and conventional models are available in each mid-size model, or HEV 20 and conventional models compete. The six points on each line are calculated with a common methodology. The two enlarged points on each line show the base case range (before government or automaker incentives). The bas case range assumes costs using 100,000 HEVs per year and also reflect different methods of estimating the retail price estimate.

Inbox - Microso… POWER_10296… Prof Frank PHE… PDF EV HEV PIH… Microsoft Power… HP Solution Cen… EN 10:38 AM

How long will it take before we see PHEV's in the marketplace?

(Prof Andrew A. Frank, Testimony for US House Science/Energy Committee (2006)

- 2 year demonstrations and demand creation—government support needed!!
- 3 years total for volume production at about 50,000/year-with 2 OEM's
- 5 years-500,000 to 1million /year by 3 to 5 OEM's across 3 platforms
- **10 years -7.5 million cars/year (½the new car fleet). The PHEV introduction driver is the liquid fuel costs**

Conclusions

1. There is a very broad spectrum of HEV-PHEV designs.

2. Key factors in the HEV/PHEV cost-benefit equation include:
   - Battery costs
   - Fuel costs
   - Control strategy (particularly battery SOC window)
   - Driving habits (annual VMT and trip-length distribution)

3. Based on the assumptions of this study:
   - HEVs can reduce per-vehicle fuel use by approx. 30%.
   - PHEVs can reduce per-vehicle fuel use by up to 50% for PHEV20s and 65% for PHEV40s.
   - In the long term, powertrain cost increments are predicted to be $2-6k for HEVs, $7-11k for PHEV20s and $11-15k for PHEV40s assuming that projected component (battery) costs can be achieved.
   - Note this study did not consider benefits from platform engineering (i.e. mass/drag reduction).

Conclusion (cont)

- The large scale use of HEVs, PHEVs and EVs will reduce liquid oil import and its associate pollution by more than 50%.
- Oil price will be significantly reduced.
- Electrical power can be produced from renewable sources like wind and solar.
- In central production of electrical power (using gas or coal) pollution can be reduced by using filters and scrubbers.

What Israel can and should do?

Form a consortium of battery manufacturers and academic groups (a National Project) to solve the three major lithium battery problems:

safety, life and cost:

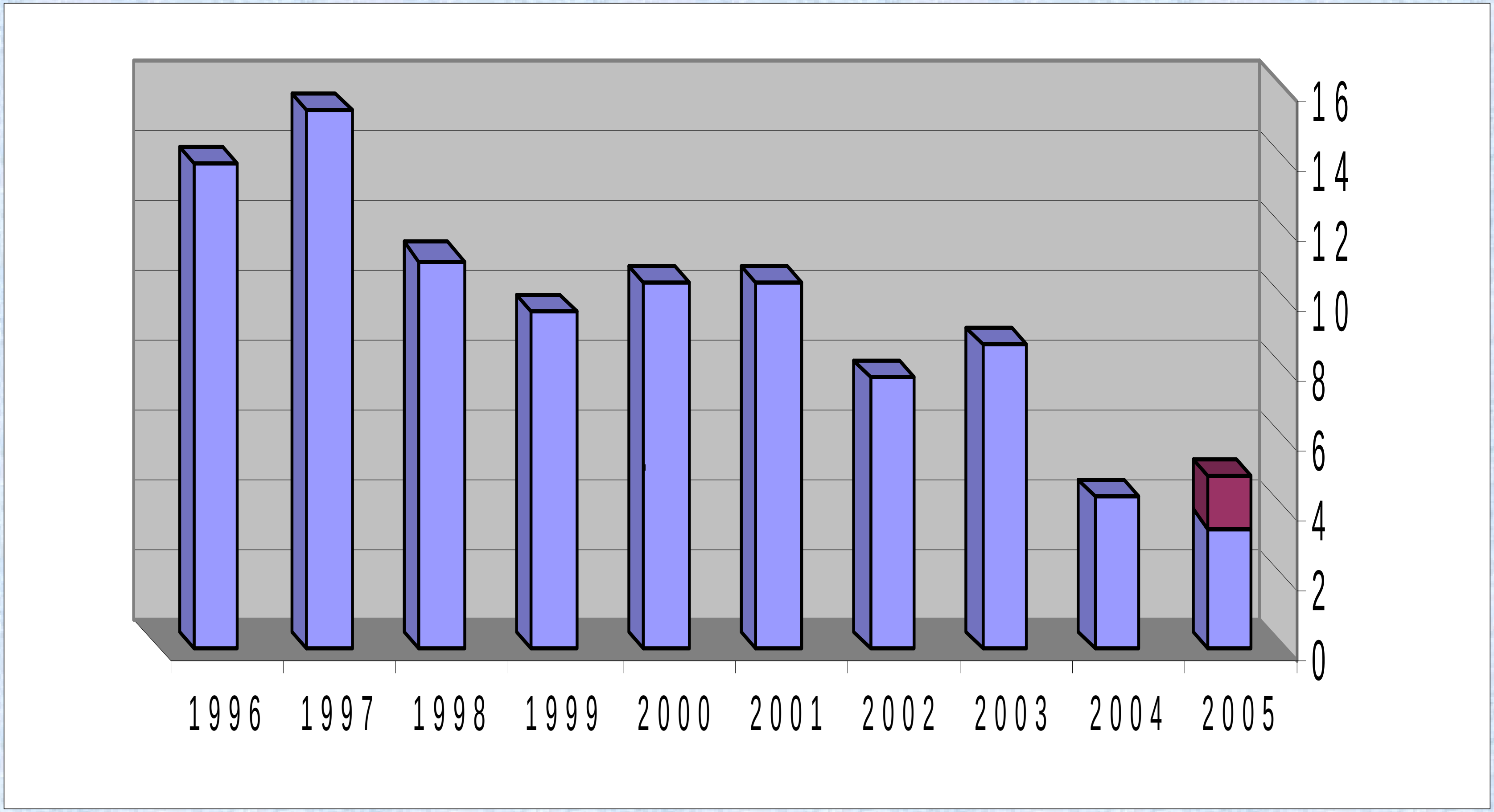
- Develop novel low-cost, better and safer anode and cathode materials
- Improve the safety of the state of the art Li ion batteries (including: electrode coatings, new and safer electrolytes and additives)
- A multi million dollar budget is needed.

University – industry potential synergism

- Tadiran is a lithium ion battery manufacturer.
- Tadiran is a part of SAFT.
- SAFT produces the largest lithium ion cells (140 Wh).
- Israel has two very large and well experienced lithium battery research groups in TAU and Bar Ilan (over 50 researchers, they can be listed in the top ten in Europe with respect to size), younger groups are in the Technion and in Ariel.
- **Thus cooperation can be fruitful**

Thanks for your attention

התקציב למו"פ באנרגיה של המשרד לתשתיות לאומיות (מיליוני ₪).
(מקור: פרופ' דן זסלבסקי)



Plug-In Hybrid Fuel Economy

Predicted fuel economy and operating costs for midsize sedan[1]

Vehicle Type	Gasoline Fuel Economy	Electricity Use	Annual Energy Use	Annual Energy Cost	Recharge Time[3]
Conventional	27 mpg	---	564 gal.	$1360	---
Hybrid-Electric	36 mpg	---	416 gal.	$1000	---
Plug-In Hybrid 20mi range	51 mpg	0.09 kWh/mi	297 gal. and 1394 kWh[2]	$716 + $125	< 4 hrs
Plug-In Hybrid 40mi range	69 mpg	0.16 kWh/mi	218 gal. and 2342 kWh[2]	$525 + $211	< 8 hrs

1) Assumes 15,000 miles annually, gasoline price of $2.40 per gallon, electricity price of 9c/kWh
2) Note that average US household consumes 10,700 kWh of electricity each year
3) Using 110V, 20A household outlet

Example of Battery Requirements for Plug-in Hybrid Vehicles

	Characteristics at EOL (End of Life) [1]		Long-Term[2]
Sysetm Targets	Maximum System Production Price @ 100k units/yr	$	**$3,500**
	Calendar Life, 40°C	Years	**15**
	Maximum System Weight	kg	**125**
	Maximum System Volume	Liter	**85**
	SOC Range	%	**70**
Charge Depleting HEV Mode	Equivalent Electric Range	miles	**40**
	Available Energy for CD Mode, 10 kW Rate	kWh	**12**
	CD Life / Discharge Throughput	Cycles / MWh	**4000 / 50**
	Total Energy (at 10 kW rate)	kWh	**17**
	Maximum System Recharge Rate at 30°C	kW	**1.5 (120V/12A)**
Charge Sustaing HEV Mode	Peak Pulse Discharge Power (10 sec)	kW	**40**
	Peak Regen Pulse Power (10 sec)	kW	**25**
	Available Energy for CS (Charge Sustaining) Mode	kWh	**0.3**
	Minimum Round-trip Energy Efficiency (USABC HEV Cycle)	%	**90**
	Cold Cranking Power at -30°C, 2 sec - 3 Pulses	kW	**5**
	CS HEV Cycle Life, 50 Wh Profile	Cycles	**300,000**
Battery Limits	Max. Current (10 sec pulse)	A	**300**
	Maximum Operating Voltage	Vdc	**400**
	Minimum Operating Voltage	Vdc	**>0.55 x Vmax**
	Maximum Self-discharge	Wh/day	**50**
	Survival Temperature Range	°C	**-46 to +66**
	Unassisted Operating & Charging Temperature Range	°C	**-30 to +52**

1. These categories are similar to the ones proposed for USABC charge-depleting electric vehicles and FreedomCAR charge-depleting power-assist HEVs
2. Typical numbers, final USABC numbers could be found in http://www.uscar.org/commands/files_download.php?files_id=118