# LEV market trend in Japan
# and
# LEV development at Tokyo R&D

March 9, 2006
2006 Taipei International Cycle Show
Light Electric Vehicle International Conference

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# LEV market trend in Japan

- EV and HEV sold in Japan
  - Power Assist Bicycle
  - Electric Scooter
  - Electric Micro Car
  - Electric K Car
  - Passenger EV
  - Hybrid Electric Vehicle

# Power Assist Bicycle

National Vivi
￥115,800

Yamaha PAS Lithium L
￥117,800

# Electric Scooter


Tokyo R&D ELE-ZOO

Yamaha Passol-L
￥209,790

# Electric Micro Car (**原付4輪車**)

Toyota Auto Body
Coms
￥792,750～￥929,250

# Electric K Car (**軽自動車**)

Daihatsu Hijet EV
￥2,900,000

Suzuki Every EV
￥3,000,000

Subaru Samber EV
￥3,000,000

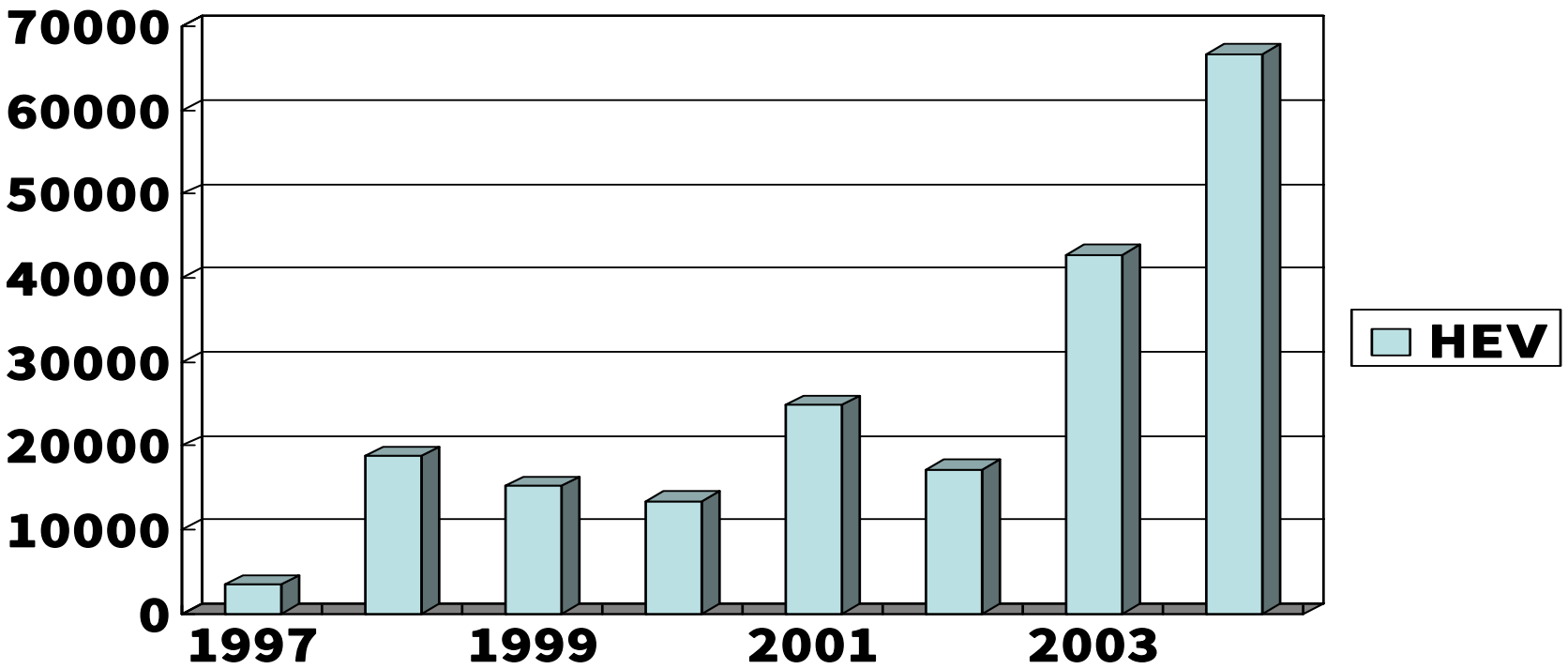
# Passenger EV

- Toyota RAV4 EV
- Honda EV Plus

# Hybrid Electric Vehicle

Toyota Prius
¥2,263,000～¥3,255,000

# Sales statistics
## Hybrid Vehicle




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| HEV | 3456 | 18773 | 15176 | 13343 | 24851 | 17236 | 42786 | 66577 |

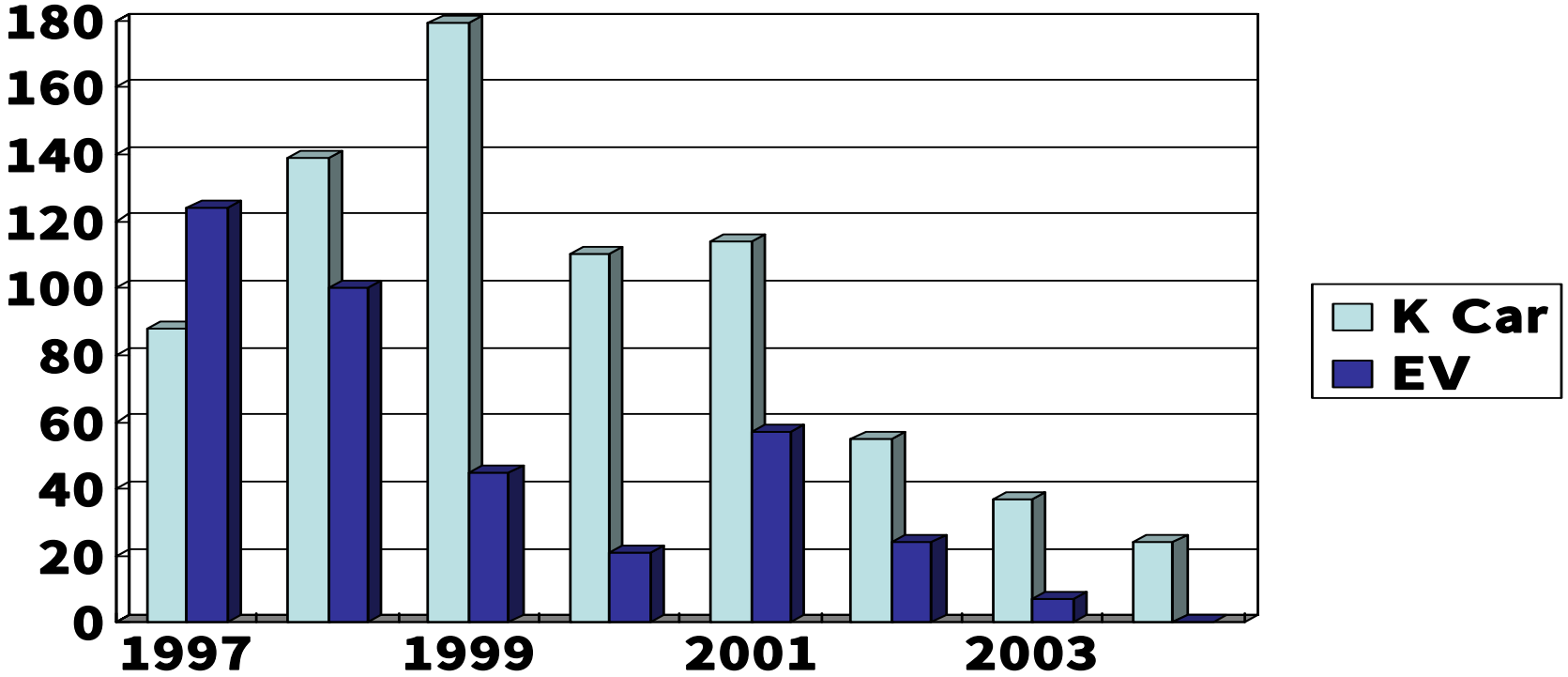
Data: Japan Automobile Research Institute

# HEV market trend

- Since the introduction of Toyota Prius in 1997, the market has gradually grown.
- The market will grow at significantly higher speed in the coming years due to the escalating oil price and the introduction of new products by Toyota, Honda and other car manufacturers.
- Many people buy Prius because buying or owning one is a statement that he or she is conscious about the environment.

# Sales statistics

## K Car, Passenger EV



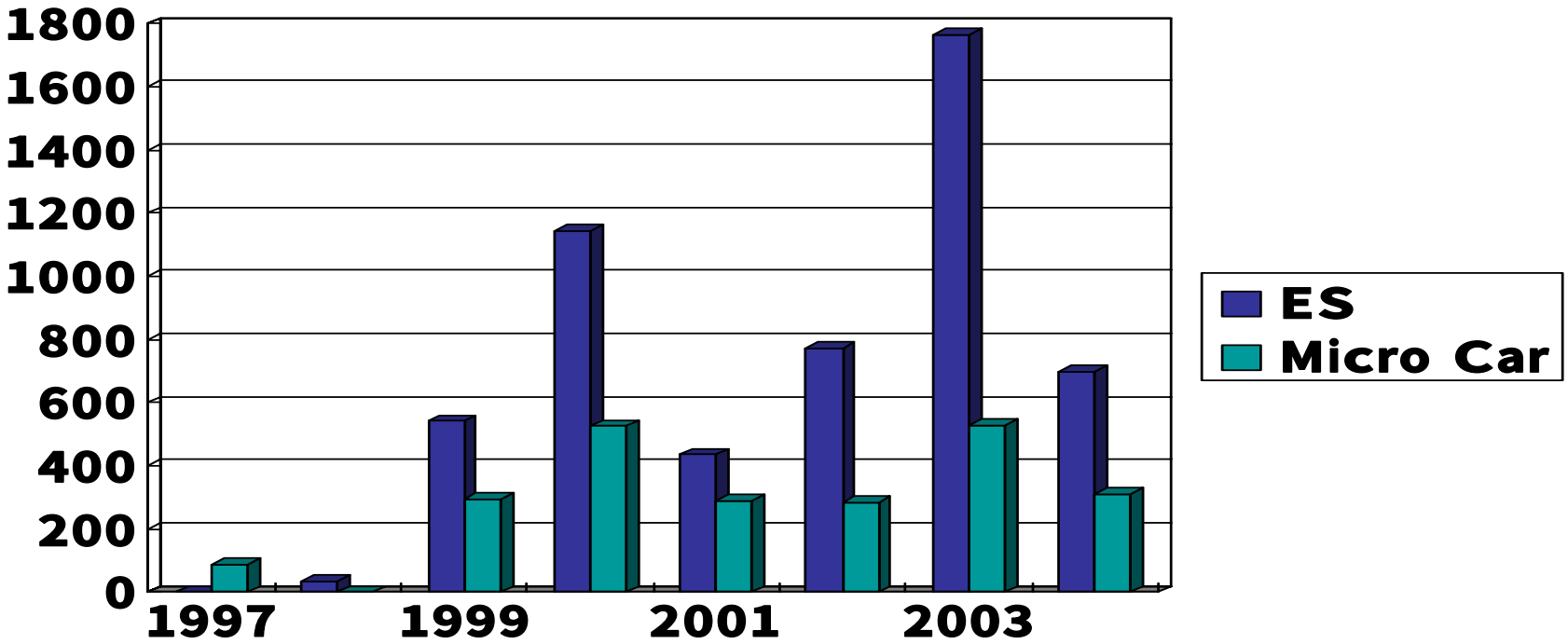

| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| K Car | 88 | 139 | 179 | 110 | 114 | 55 | 37 | 24 |
| EV | 124 | 100 | 45 | 21 | 57 | 24 | 7 | 0 |

Data: Japan Automobile Research Institute

# K Car, Passenger EV market trend

- The effort by Toyota and Honda to meet the California legislation resulted in the introduction of RAV4EV and EV Plus into Japanese market around 1998.
- The high initial cost limited the sales, and the car manufacturers ceased the production.
- Electric utility companies bought electric K-Cars for their fleet, but the number was limited, and the car manufacturers ceased the production.
- Recent development in lithium-ion technology promoted car manufacturers to resume the development of EVs. Fuji Heavy Industry (Subaru) and Mitsubishi announced that they are developing and will produce EVs in the near future.

# Sales statistics
## Electric Scooter, Micro Car




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| ES | 1 | 37 | 542 | 1144 | 435 | 773 | 1764 | 699 |
| Micro Car | 88 | 0 | 296 | 527 | 289 | 285 | 529 | 310 |

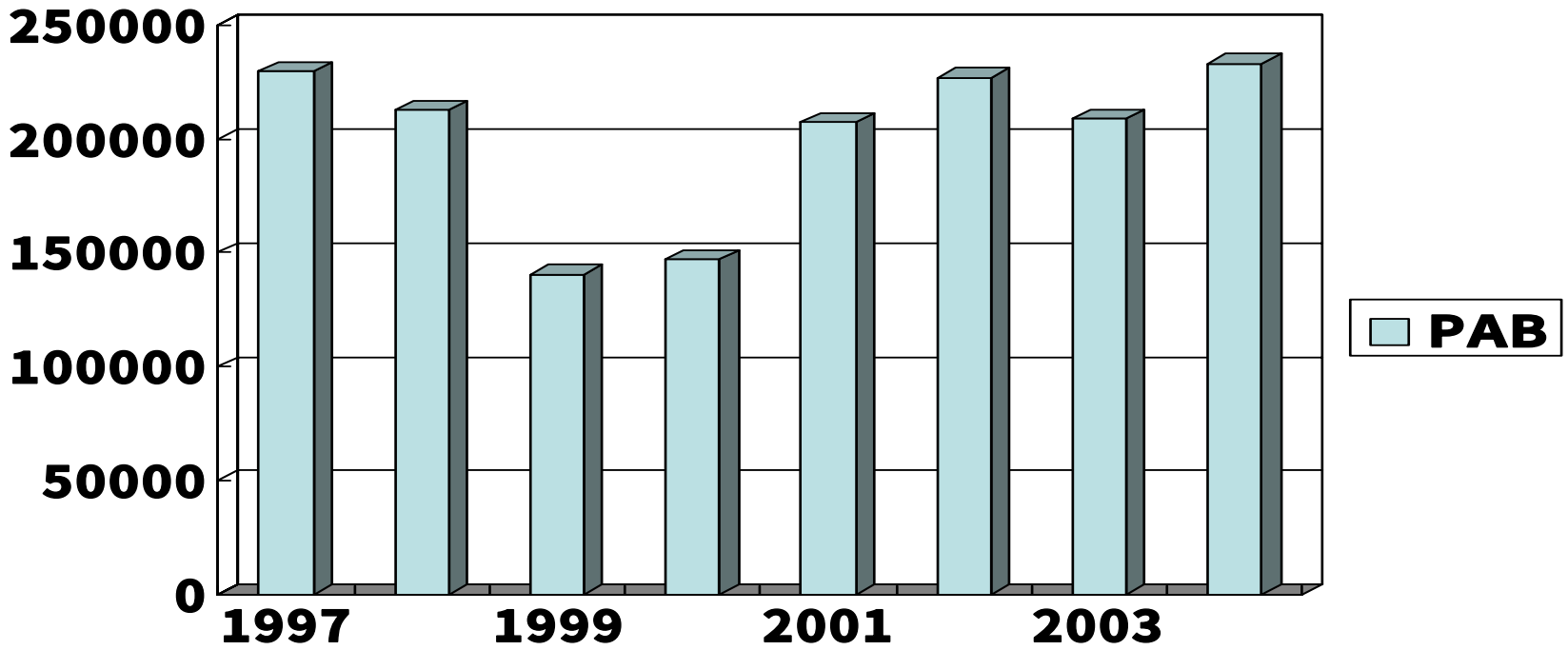
Data: Japan Automobile Research Institute

# Electric Scooter, Micro Car market trend

- Electric Scooters imported from Taiwan were sold in some numbers.
- Passol from Yamaha has increased the sales significantly in 2003, but after the first year, the sales volume decreased. The introduction of higher performance Passol-L last year may increase the sales again.
- Mitsuoka, Toyota Auto Body, and CQ Motors are selling electric Micro Car. Recently Toyota Auto Body announced the new version of Coms with higher performance. These vehicles are used for light goods delivery and business commuting.

# Sales statistics

## Power Assist Bicycle




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| PAB | 229577 | 212666 | 140609 | 147072 | 207356 | 227005 | 208913 | 233332 |

Data: Japan Bicycle Promotion Institute

# Power Assist Bicycle market trend in Japan

- Sales decreased around year 1999, but introduction of new products with lithium-ion battery brought back the sales over 200,000 units per year.
- Users of Power Assist Bicycles tend to buy new one again once his or her one becomes too old, or breaks down.

# The reasons why the electric scooter and electric micro car sales in Japan are stagnated.

- Performance
- Initial cost
- Life cycle cost: Cost for replacing battery
- Infrastructure

# Why power assist bicycles are successful

- The manufacturers succeeded in lobbying and the government sees power assist bicycle as ordinary bicycles.
  - No driving license required
  - No registration number required
  - Can be ridden on pedestrian path
- Small battery pack are easier to re-charge.

# LEV development at Tokyo R&D

- About Tokyo R&D
- EV development at Tokyo R&D
- LEV development at Tokyo R&D
- Next Step

# About Tokyo R&D

- Independent Automotive Engineering Company
- Founded in 1981
- Number of employee: 170
- 5 Divisions
  - Automotive
  - Electric Vehicles
  - Embedded Systems
  - Composite Materials
  - Racing

# EV development at Tokyo R&D

- NAV 1990
  - 4WD, in-wheel motor

- IZA 1991
  - 4WD, in-wheel motor
  - Max speed: 176km/h
  - 0-400m: 18.05 sec.
  - Range: 550km(40km/h)

- Dream mini 1992
  - 2WD, in-wheel motor

# EV Development at Tokyo R&D

- Z.E.R.O.-1 1994
  - Max speed:210km/h

- Eliica  2003
  - 8WD, In-wheel motor
  - 640kW
  - Max speed: 370km/h

# LEV development at Tokyo R&D

# Chemistry is right for lightweight vehicle to go pure electric

- Lightweight small vehicles are to be used for transportation over fairly short distance, hence demand for cruising range is less.
- Accessories such as A/C are less equipped, hence power consumption is less.
- Vehicle mass is less due to simple body structure, hence energy required for running is less.
- Consequently, amount of onboard battery can be reduced.
- Less battery means less vehicle cost.
- Because of the nature of simple structure, unpleasant vibration of the internal combustion engine on lightweight small vehicles are easily and excessively transmitted to driver and passenger. Less vibration of the electric motor assures better riding comfort.

# LEV development at Tokyo R&D

- Experimental trial bike 1984
  - 2WD, in-wheel motor

- Experimental electric scooter ESX 1987

# LEV development at Tokyo R&D

- Electric scooter E20 1989

- Production electric scooter ES600 1992

# Lessons learned

- Running performance such as acceleration and maximum speed were same as gasoline engine scooters.
- Scooters are used for short distance and the cruising range during spring, summer, and autumn was acceptable, but because lead-acid batteries were used, the range reduced significantly in winter.
- Weight of the vehicle was heavy due to lead-acid batteries.
- Reliability and endurance are good.
- The absence of noise and vibration are big advantage over normal single cylinder gasoline engine scooter.
- Scooters are better suited to electric, because you do not have to worry about air conditioning.
- High price due to limited volume of production hampered the sales.

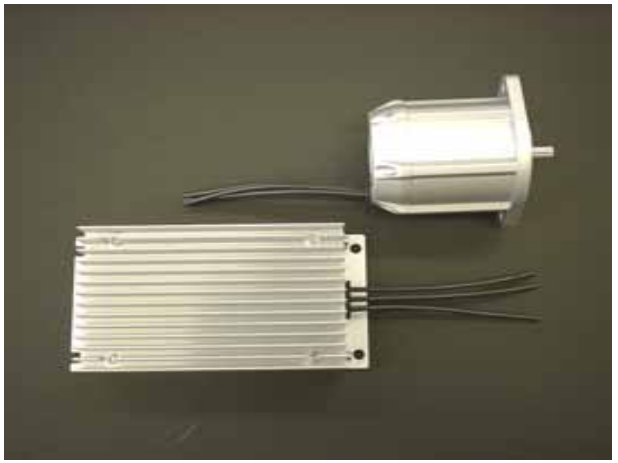
# LEV development at Tokyo R&D

- Electric 3 wheeler EC1000 1993

- Experimental electric scooter es-X2 2001

# Foundation of PUES Corporation

- PUES Corporation was founded in 1999 to focus on the development and manufacturing of electric motor, inverter, battery pack for electric vehicles.
- At the beginning, PUES meant Power Unit for Electric Scooter, but now it means Power Unit for Electric Systems, and PUES now develops and manufactures electric components for various types of electric vehicles including electric hybrid vehicles.
  - Electric Motor and Inverter 100w – 35kW
  - Battery management system
  - Battery pack



# LEV development at Tokyo R&D

- Production electric scooter ELE-ZOO 2004
  - Ni-MH battery
  - 10kg heavier than ICE scooter
  - Running performance equivalent to ICE scooter
  - Range: 25km


- At the price of ¥420,000, we could not find enough users and we ceased the production.

# Next Step

- With Ni-MH battery we could only realize the cruising range of 25km (real world cruising range), and this was not enough.
- We are evaluating various types of lithium-ion batteries from various manufacturers and some of them are showing promising performance.
- Once such battery becomes available at realistic cost, the real world cruising range will exceed 50km and this performance will satisfy significant number of users.

⇨ Dawn of electric scooter age.

# ESX-3

Experimental Electric Scooter
with Lithium-Ion Battery


**PUES Corporation**

TOKYO R&D CO.,LTD.

# *Performance of* ESX-3

| Description | ESX-3 | | ELE-ZOO | Remarks |
|---|---|---|---|---|
| Type of battery | Li-ion | ← | Ni-MH | |
| Spec of cell | 3.6 V – 15 Ah | ← | 1.2 V – 6.5 Ah | |
| Weight of cell | 0.43 KG | ← | 0.17 KG | |
| Structure of battery module | 20 series | 20 series<br>2 parallel | 60 series<br>2 parallel | |
| Weight of battery module | 8.6 KG | 17.2 KG | 20.4 KG | |
| Capacity of battery module | 1,080 Wh | 2,160 Wh | 936 Wh | |
| Complete vehicle curb weight | 84 KG | 92 KG | 95 KG | Original base vehicle: 85 KG |
| Driving range at one charge | 28 km | 56 km | 25 km | Urban roads |
| Acceleration<br>0 – 20 m<br>0 – 50 m<br>0 – 100 m | <br>3.6 sec<br>6.5 sec<br>10.5 sec | <br>3.7 sec<br>6.7 sec<br>10.7 sec | <br>3.7 sec<br>6.7 sec<br>10.7 sec | |

# Indication of PEV Resurrection

- Li-ion Battery performance is rapidly improving
  - Practical duration of approx 200km is now achievable
  - Battery cost depends on capital investment…?
- Reality of FCEV is ascertained
  - Cost exceeds HEV way over
  - Uncertain hydrogen infrastructure
  - Uncertain overall efficiency
- As a next generation low-emission vehicle after HEV
  - Pure EV
  - Plug-in Hybrid

# Conclusion

- Pure EVs, irrespective of the size, are struggling to find the market, while both Hybrid Electric Vehicles and Power Assist Bicycles are gaining market popularity.
- The main reason is a classic one; the lack of performance and high cost of the battery.
- The recent development of lithium-ion batteries may finally break the barrier and the dawn of LEV age may well come in the near future.