



# *Hybridisation of small engines Challenges and Benefits*

***S. Jabez Dhinagar Ph.D***

*Vice President*

*Advanced Engineering*

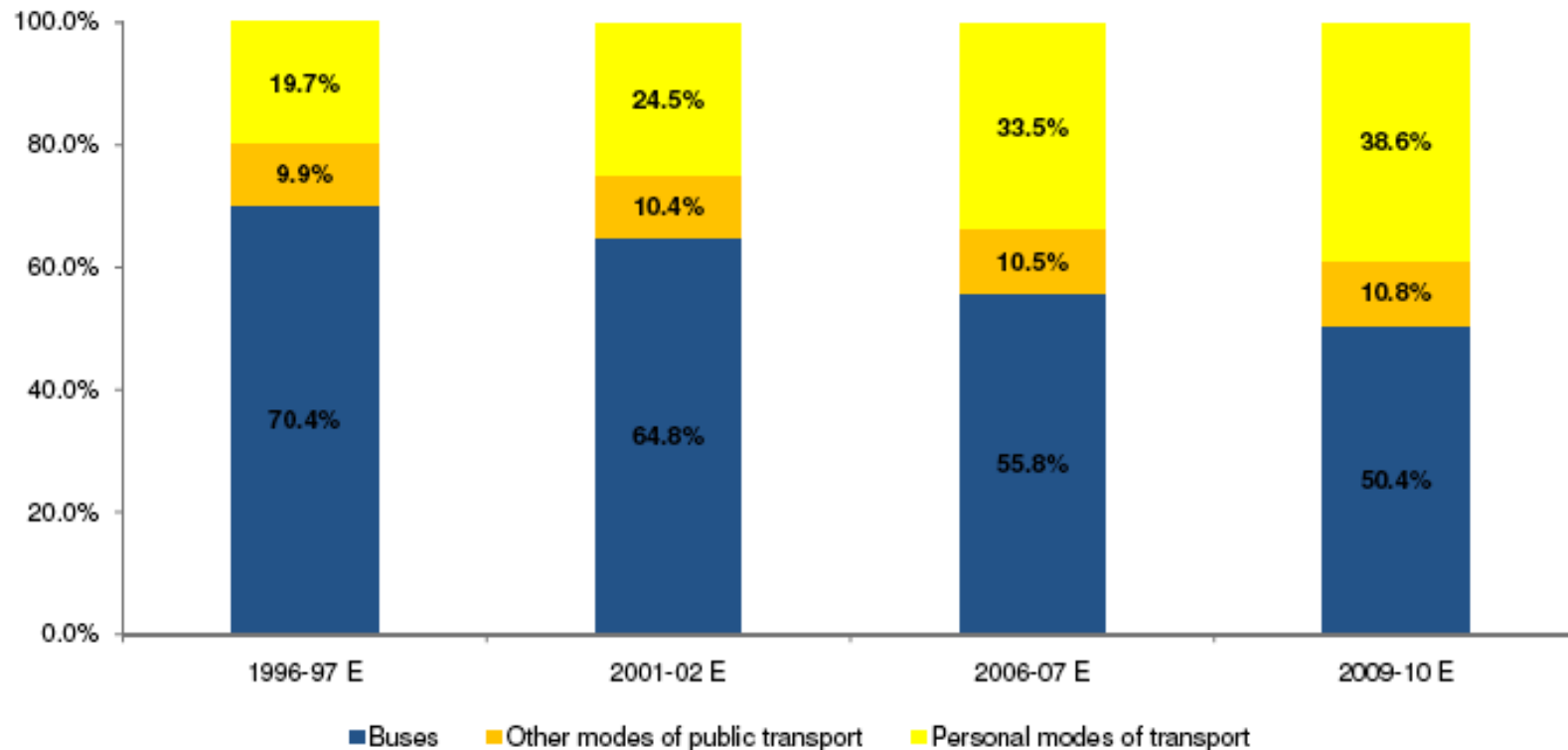
*TVS Motor Company Ltd.*

**18<sup>th</sup> May 2011, Engine Expo, Stuttgart**



Automotive Industry  
*Trends and Markets in India*

# Reducing Share of Public Transport



### Automobile industry domestic sales of vehicle (in Nos)

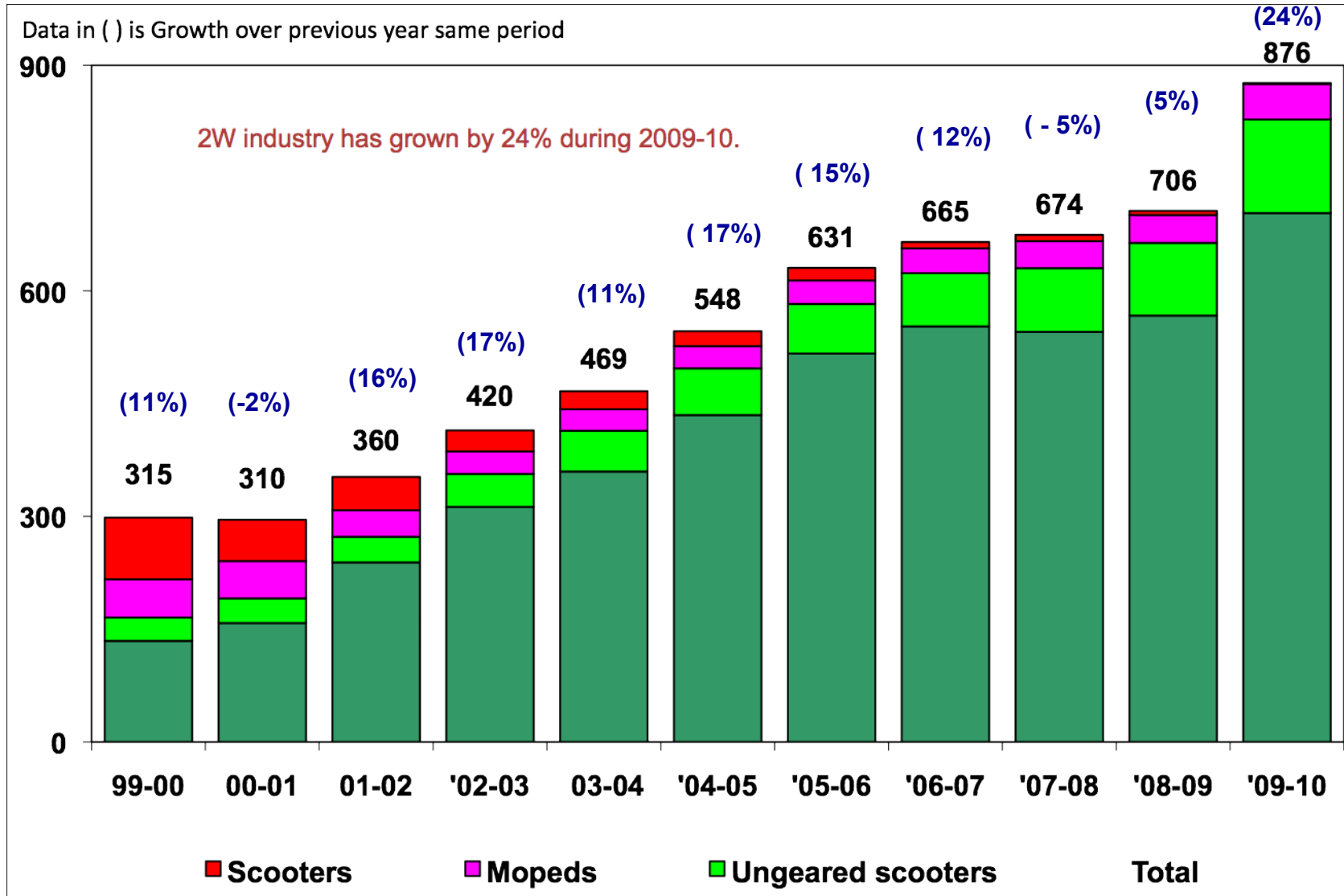
|                     | 2008-09          | 2009-10           |
|---------------------|------------------|-------------------|
| <b>Total</b>        | <b>9,724,243</b> | <b>12,292,770</b> |
| Two wheelers        | 7,437,619        | 9,371,231         |
| Three wheelers      | 349,727          | 440,368           |
| Cars and UVs        | 1,552,703        | 1,949,776         |
| Commercial vehicles | 384,194          | 531,395           |

**Source: SIAM annual report**



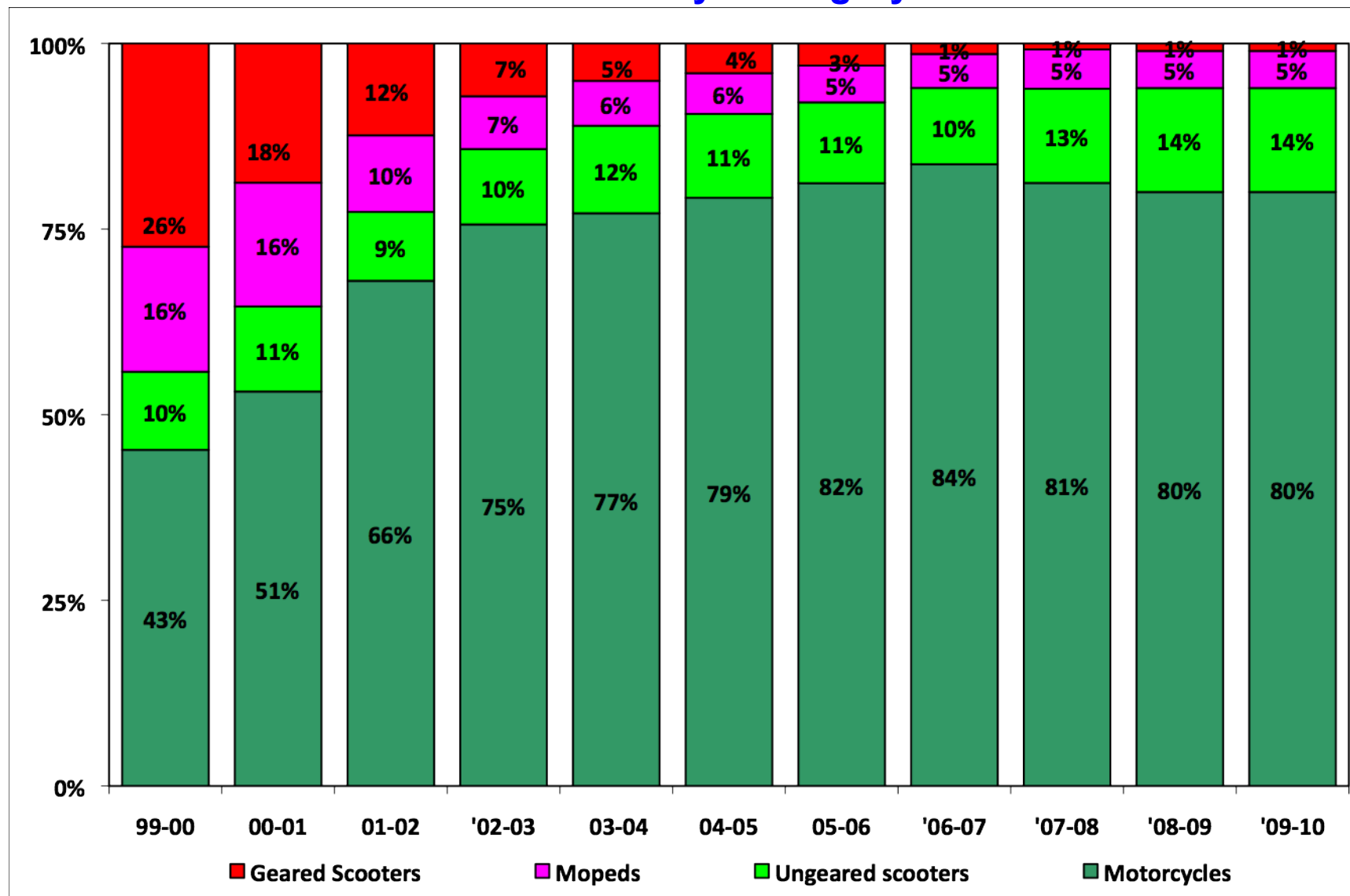
## Two Wheeler Industry

Monthly Average Sales ('000 Nos)



Note: Electric 2Wheelers not included. (est. 3000 per month)

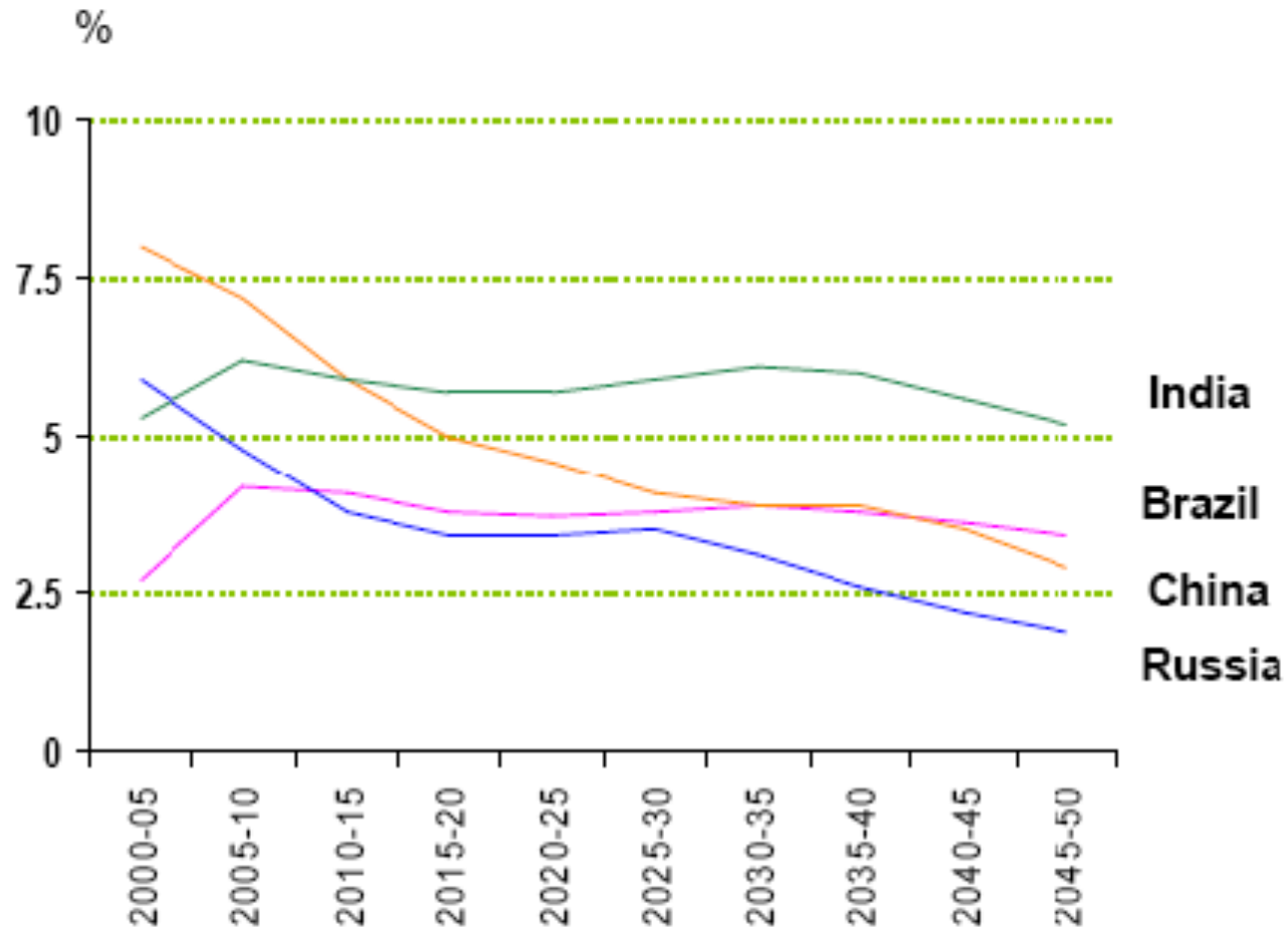
## Two Wheeler Industry - Category share



Share of M/c segment slips to 80%. Un-gearred scooters gain, Mopeds stable

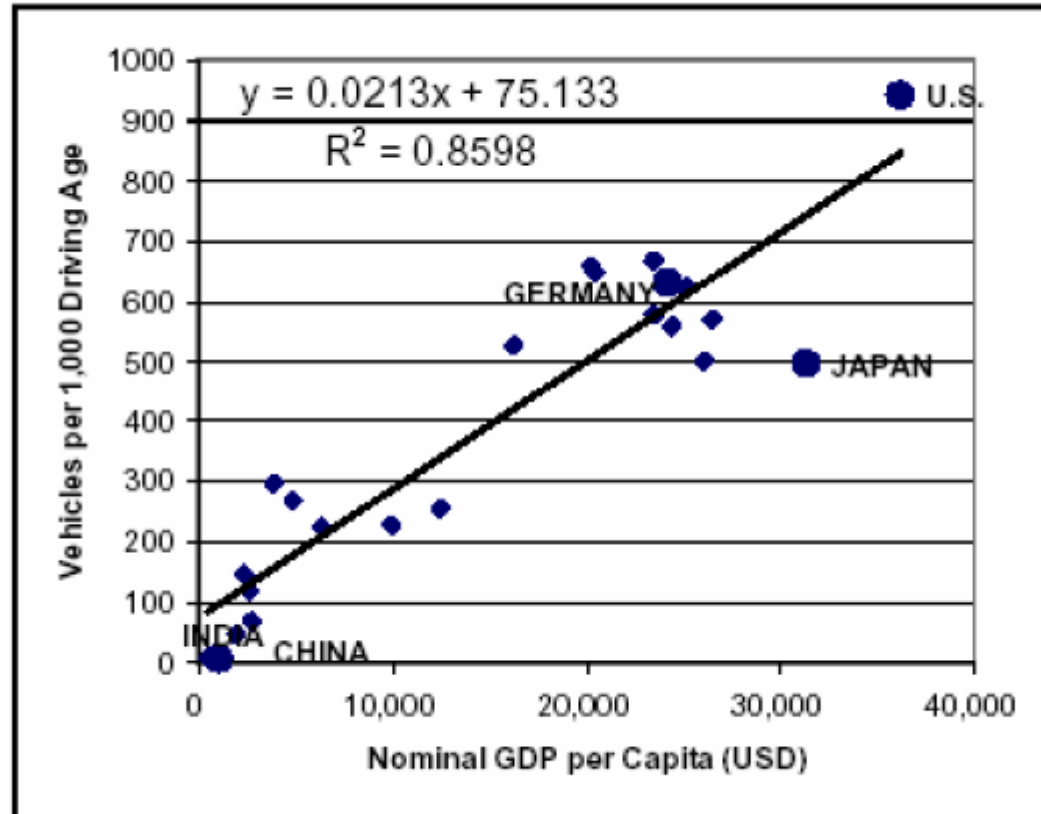
Note: Electric 2Wheelers not included. (est. 3000 per month)

## Forecasted GDP Growth



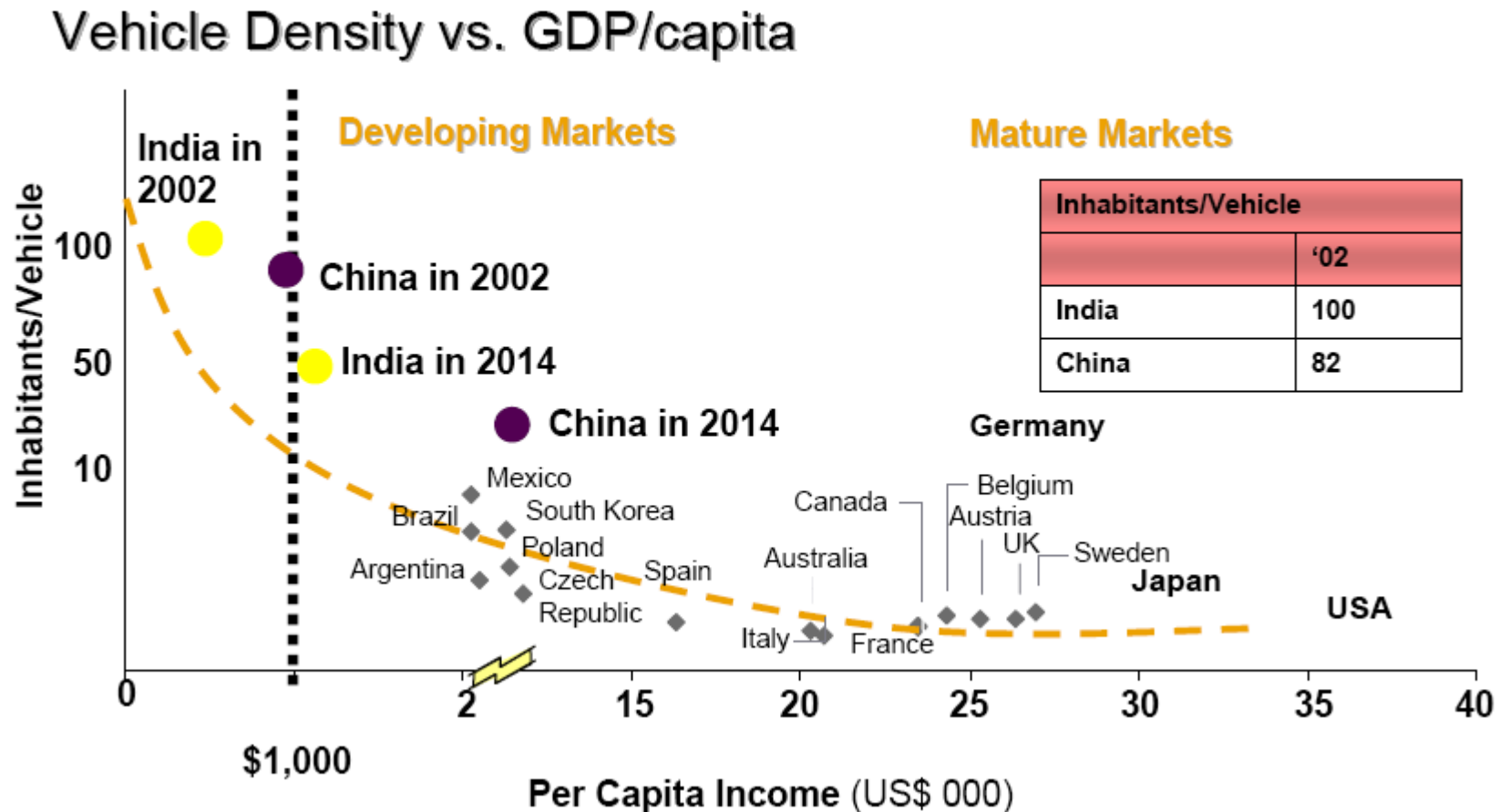
## Vehicle density connects well with GDP

GDP / Capita vs. Vehicle Density: Top 25 Auto Markets



Source: International Monetary Fund, LMC J.D. Power, Global Insight,

India expected to achieve mass motorization status in 2014



# The Case for change 100 cc Motorcycle in India

1983

2009

|                   |               |      |                  |
|-------------------|---------------|------|------------------|
| Fuel consumption  | 45 km/lit     | -67% | 75 km/lit        |
| Acceleration      | 12 s          | -30% | 8 s              |
| Emission          | No Regulation | -95% | Bharath stage IV |
| Stopping Distance | 12 m          | -16% | 10 m             |
| Weight            | 98 kg         | +8%  | 108 kg           |
| Power             | 4 kW          | +50% | 6 kW             |
| Engine torque     | 8 Nm          | +50% | 12 Nm            |



# Small Engine Hybrid Challenges

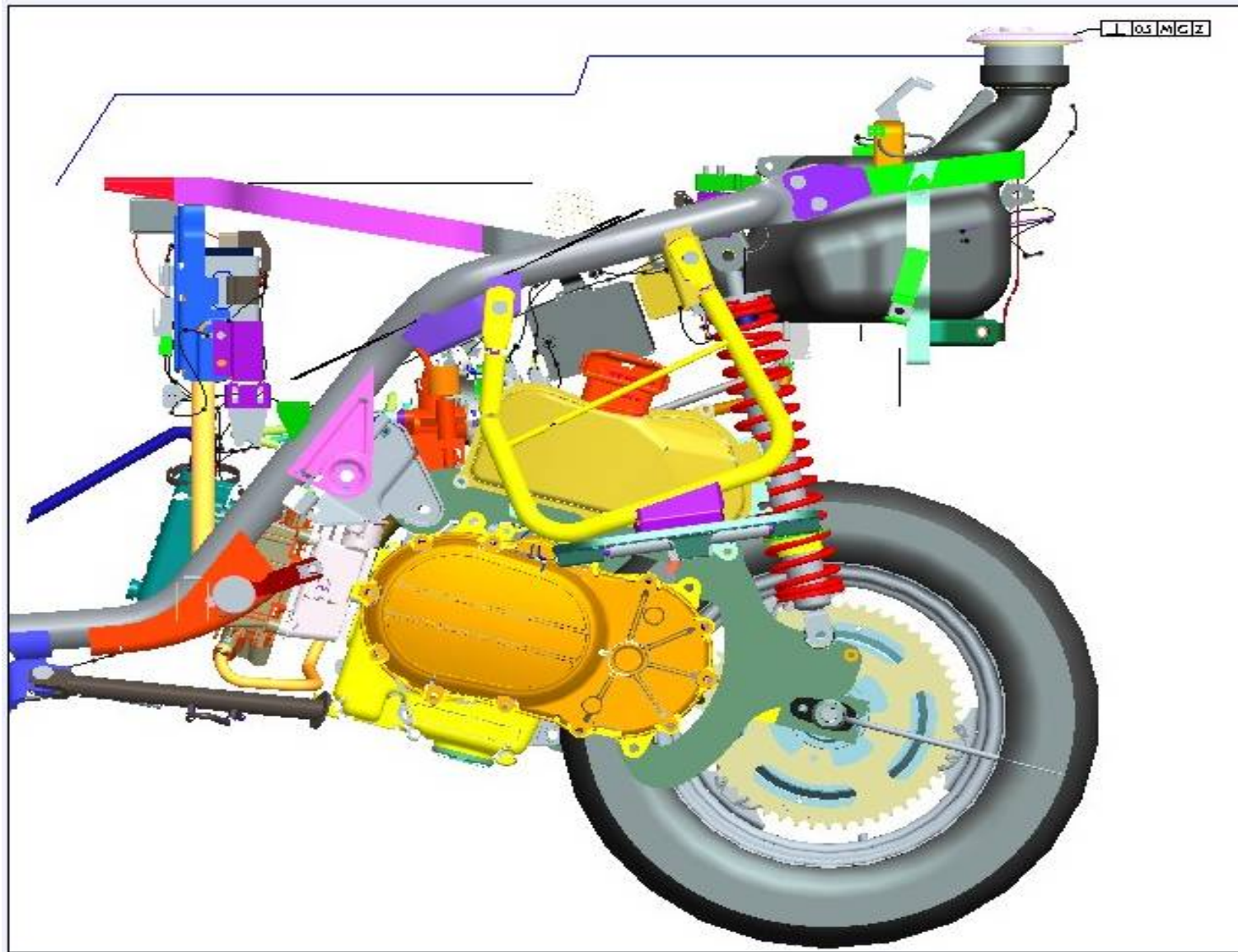
- System
- Motor
- Battery
- Controller
- Charger
- Cost



## Challenges - System Level

- **Integration of multiple functions**
  - Integrated controller
  
- **Trade off**
  - Cost vs Performance (initial investment)
  - Cost vs Performance (operating cost)
  - Commonisation across vehicle platforms
  - Utility space vs Range
  
- **Location**
  - Battery pack
  - Controller
  - Motor

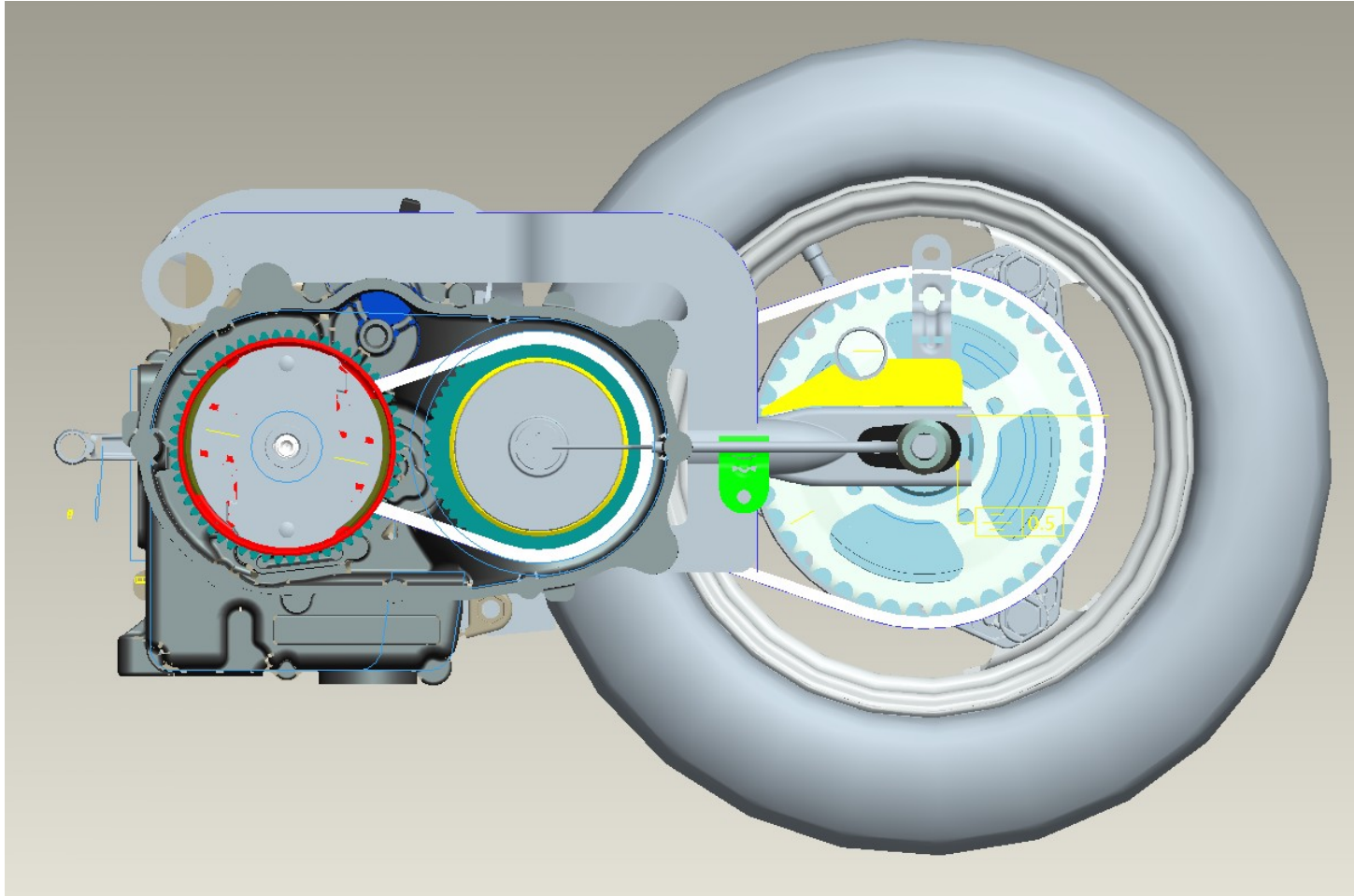
## Challenges - System Level



## Challenges - Motor

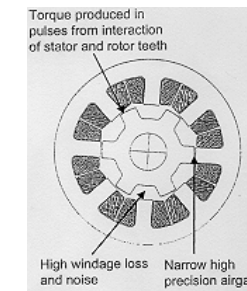
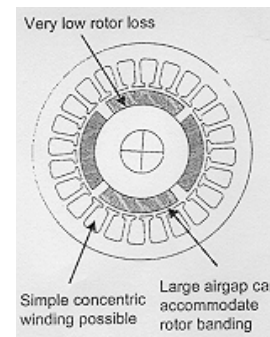
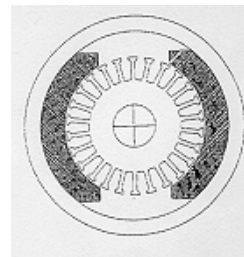
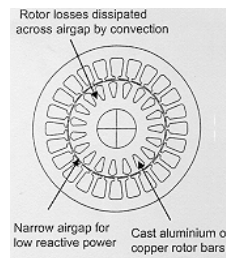
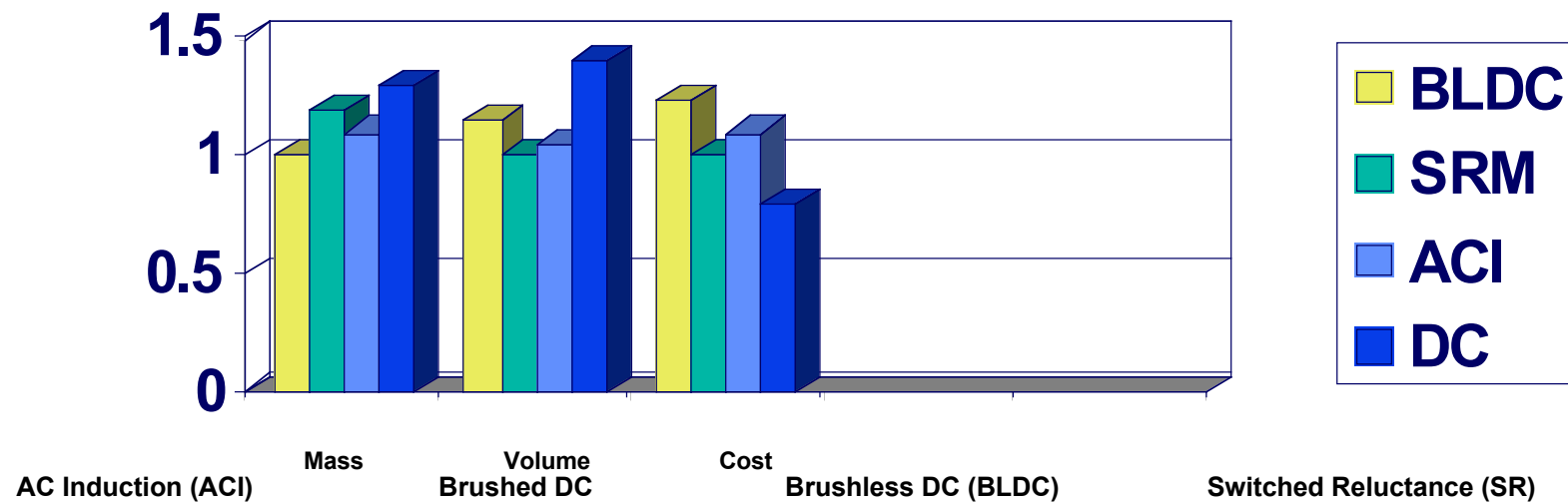
- **Type of Motor**
  - BLDC
  - PMSM
  - Induction
- **Capacity and Number of Motors**
  - EV mode Range and Performance
  - Cranking, Power assist and Regeneration
- **Location**
  - Hub Mounted
  - Integrated along with Transmission
  - Engine mounted
- **Cooling**
  - Air cooling

## Challenges - Motor



# Challenges - Motor

Motor comparison



## Challenges - Battery

- Type of Battery
  - Li-ion
  - Ni-Mh
  - Lead Acid
- Capacity and Number of Batteries
  - EV mode Range
  - Weight and effect on CG
- Location
  - Under floor
  - Near powertrain
- Cooling
  - Air cooling

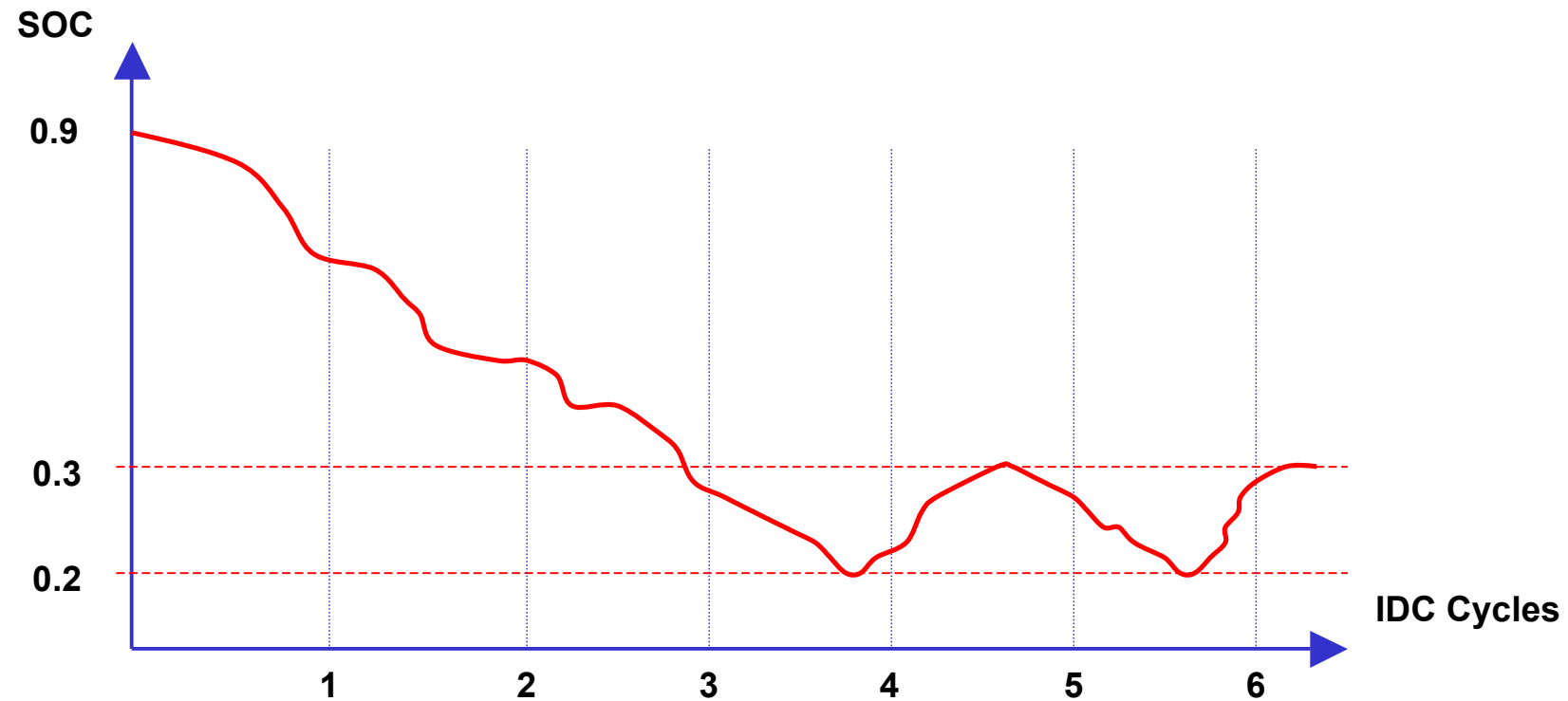
## Challenges - Battery

### Battery pack Data

|   |                            |
|---|----------------------------|
| Nominal voltage   | 48V (72 cells @ 3.6V/cell) |
| Maximum Voltage   | < 54.5V (3.8V /cell)       |
| Minimum voltage (@peak discharge current)                                       | > 42V (3.0V /cell)         |
| Nominal capacity<br>(at 35°C, discharge at 4C to 1V/cell)                       | > 10 Ahr (~0.5kWh)         |
| Peak discharge power<br><i>(Based on a peak delivered shaft power of 1.5kW)</i> | 4.0kW (~ 100A)             |
| Self discharge (@35°C)  | < 25% SOC over 30days      |
| Round trip efficiency (charge / discharge)                                      | > 85%                      |
| Peak current  | (>110A)                    |
| Energy density<br>(Ratio of energy output from the pack to its weight)          | > 55Wh/Kg                  |
| Operation of battery SOC range  | 20% - 90%                  |

## Challenges - Battery

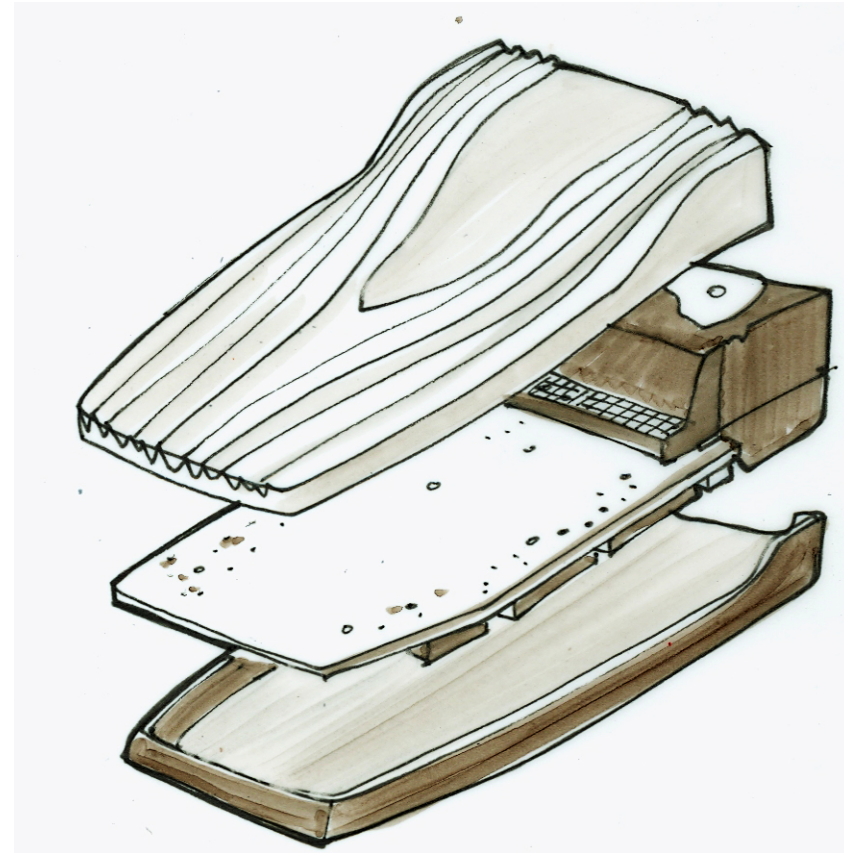
### Operating Range of SOC





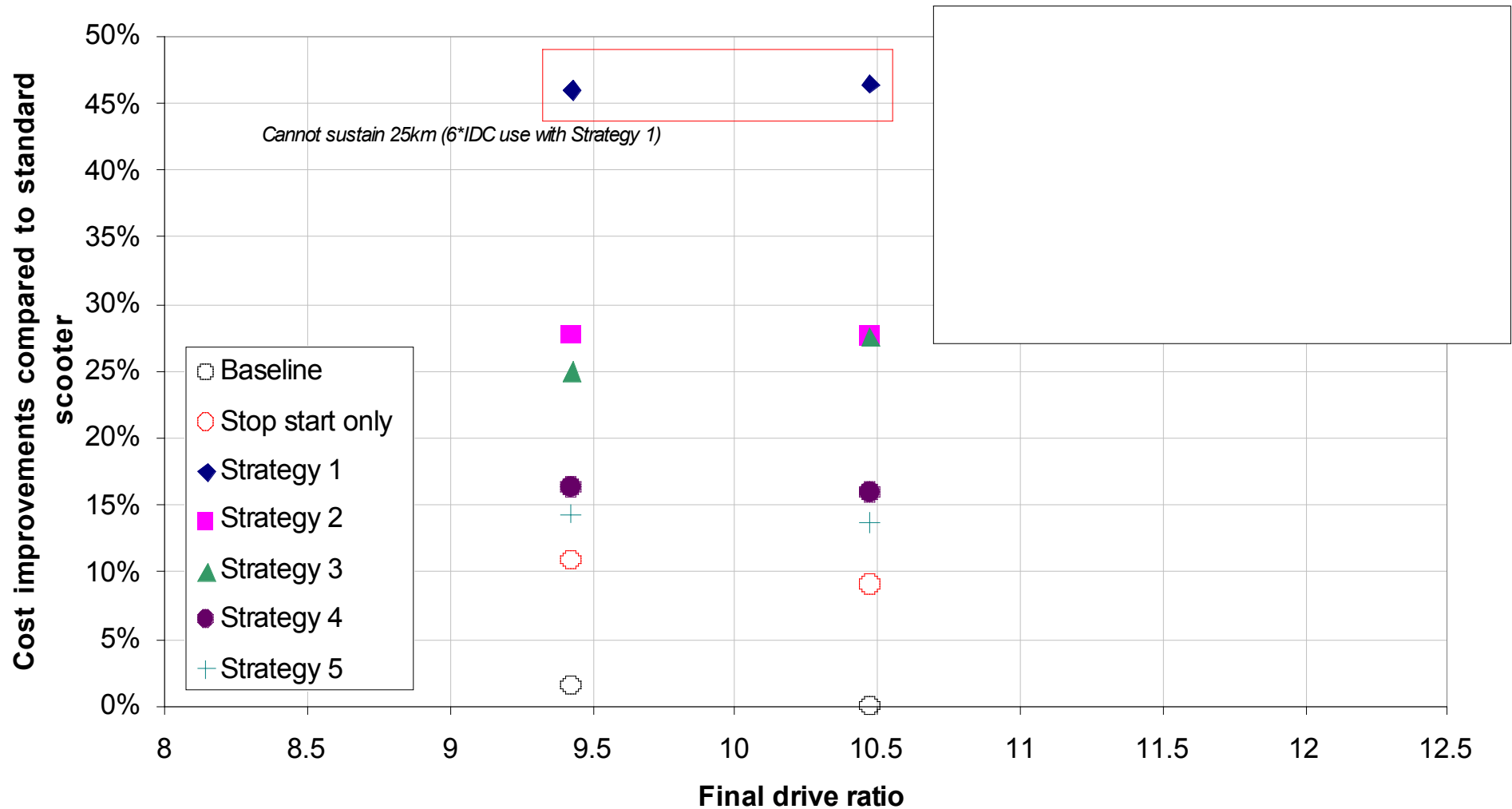
## Challenges - Controller

- Integration of Functions
  - System Control
  - Motor control
  - BMS
  - DC/ DC convertor
- Location
  - Near Battery
  - Inside Motor
- Cooling
  - Air cooling



## Challenges - Controller

Motor Power = 2.5kW IDC Comparison



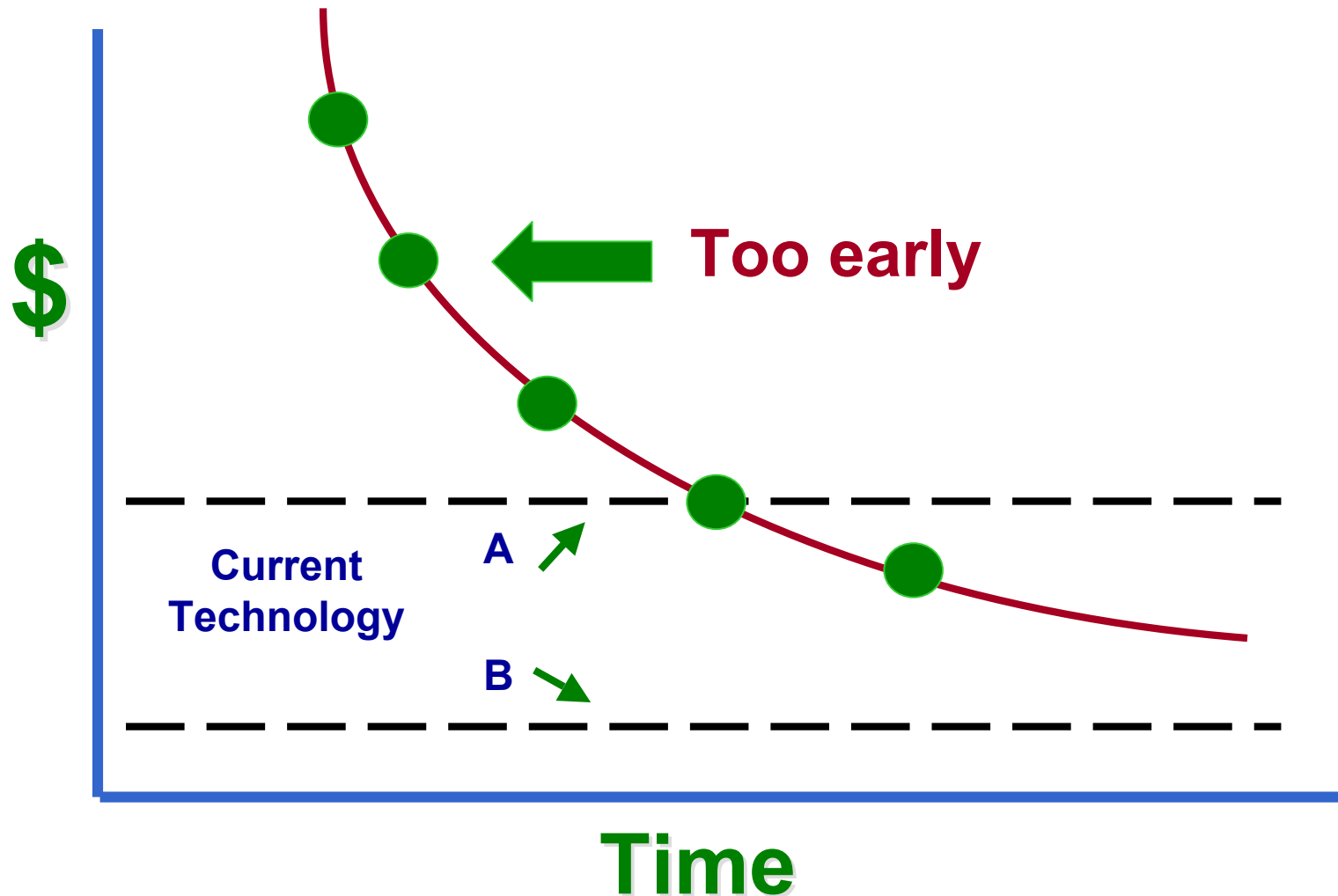
## Challenges - Charger

- Integrated design
  - Integrated with Motor Controller
  - On board but not integrated
- Operating Range
  - Wide operating voltage
  - Wide operating temperature
  - Sound levels
- Location
  - On vehicle

## Challenges - Cost

- **Cost of Procurement**
  - Current cost structure
  - Battery cost separated from vehicle
  - Cost drivers – Motor, Battery, Controller
- **Operating Cost**
  - Electricity cost
  - Battery cost
- **Government support**
  - Reduced duties on import of components
  - Vehicle level reduced tax

# Technological Progress—When to Commercialize





## Small Engine Hybrid : Benefits

- Fuel Consumption Reduction
- Emission Reduction
- Automotive Component Industry
- Societal Benefits

## Benefits – Fuel Consumption

- **City Fuel consumption reduction**
  - 35 % with reference to the Base vehicle
  - Overall range of vehicle including the EV increased by 50%
- **High way fuel consumption**
  - 25 % with reference to base vehicle
- **CO2 Reduction**
  - 32% reduction in with fully charged battery



## Benefits – Emission Reduction

- **CO2 emission**
  - 32 % reduction in drive cycle
- **Hydrocarbon emission**
  - 25 % reduction in drive cycle
  -
- **CO emission**
  - Reduced by 40% in drive cycle tests
- **Nox emssion**
  - Reduced by 20 % in drive cycle test

## Benefits - Society

- **Overall reduction in emission for 20% hybrid twowheelers by 2020**
  - 300 million kg of CO2 reduction
  - 120 million kg of Nox reduction
- **20 million motors in the range of 1- 3 kW need to be produced. Resulting in 150,000 direct and indirect employment.**
- **500 million cells of battery 10 WHr capacity will be required to support**

# TVS CUBE -Hybrid Electric Scooter



# TVS ELECTRA -HybridElectric Three wheeler



# TVS X-Fossil - Hybrid Electric Motorcycle



# Thank you