

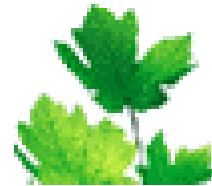
GE Transportation

Hybrid Locomotives, OHV and Marine Tugs

Hybridization of Industrial Transportation

GE Battery Symposium

October 23, 2008



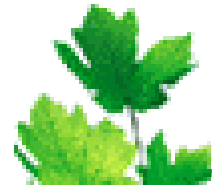
ecomaginationSM



imagination at work

Outline

- Drivers for Industrial Transportation
- Drivers for Battery Critical Parameters
- Battery Center of Excellence @ GE
- Battery System Architecture
- Hybrid Vehicle Development Timeline
- Conclusion

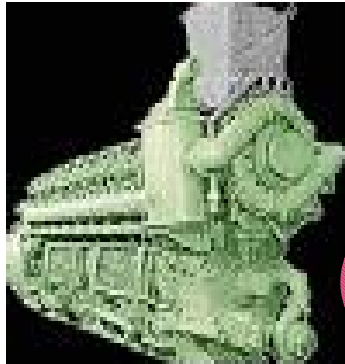


ecomaginationSM

Drivers for Industrial Transportation

Hybrid Locomotive

Diesel Engine



Alternator
Rectifier

Grid
Resistors

Power
Electronics

Traction
Motor

10%

Braking

Energy
Storage

Loco Weight : 200T
Trailing Tonnage : 1000-7000T
Power : 3 – 5 MW

90%



Wheels & Rail

Motoring

- ✓ Fuel savings
- ✓ Emissions reduction
- ✓ HP boost
- ✓ Extended overhaul
- ✓ Reduced Noise

Hybrid Locomotive - Benefits

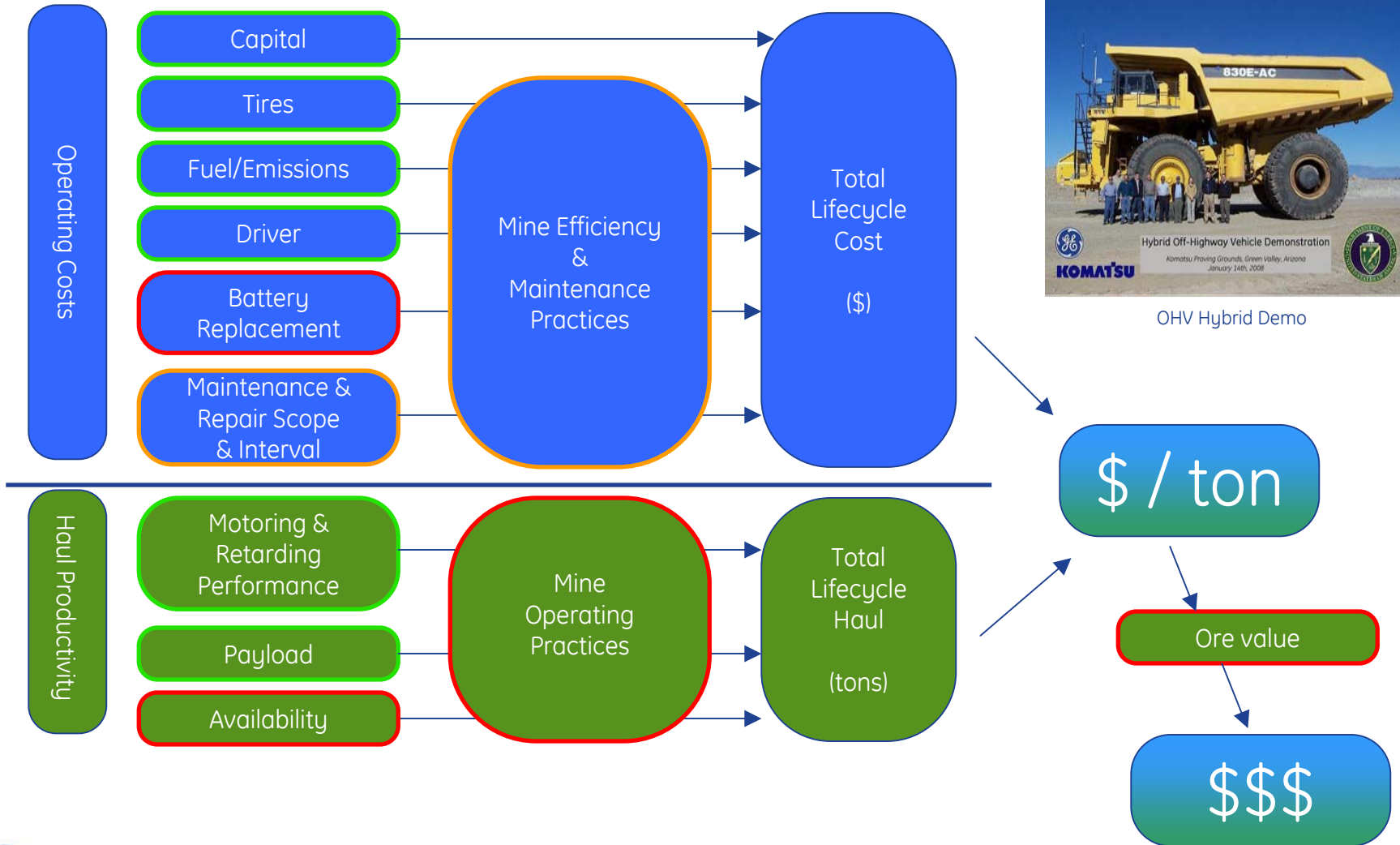
Environmental Benefits

- ✓ **Save Diesel Fuel**
25,000 gal/year/unit
- ✓ **Cleaner Air**
10% Less Emissions
- ✓ **Less Loco Noise**

- 10% fuel
- +50% Accel.
- +2k HP "Boost"
- Emissions Credit
- Longer AESS Cycle
- Reduced Cab Noise
- Limp Home Capable
- Time Duty Cycle at Notch
- Reduce Cranking Batteries
- Run Auxiliaries w/o Engine
- 1-2 Years Longer to Overhaul
- Improved Tunnel Performance

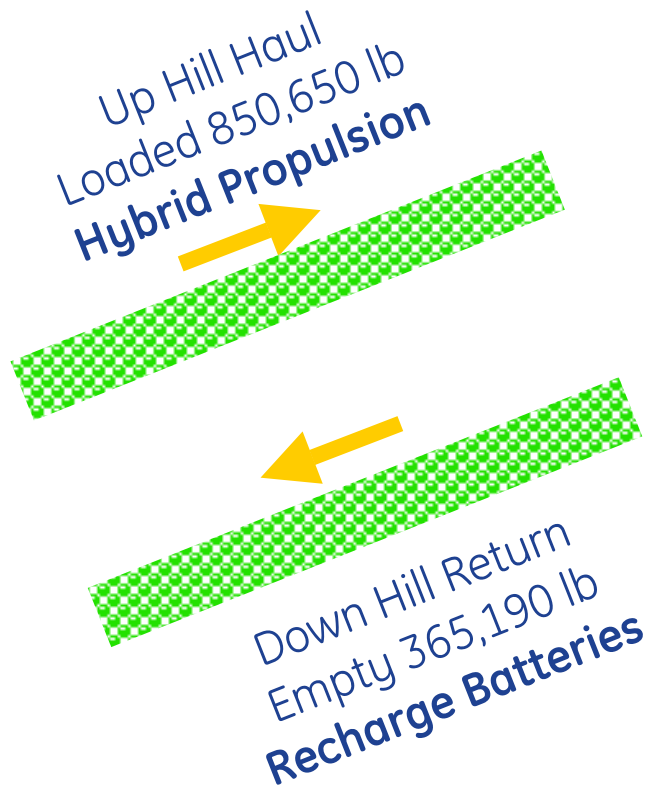
Railroad Benefits

OHV Customer CTQ = \$ / ton



OHV Hybrid Demo

Hybrid Off-Highway Vehicles



Battery weight needs to be taken into consideration for haul productivity



Hybrid OHV Test Track

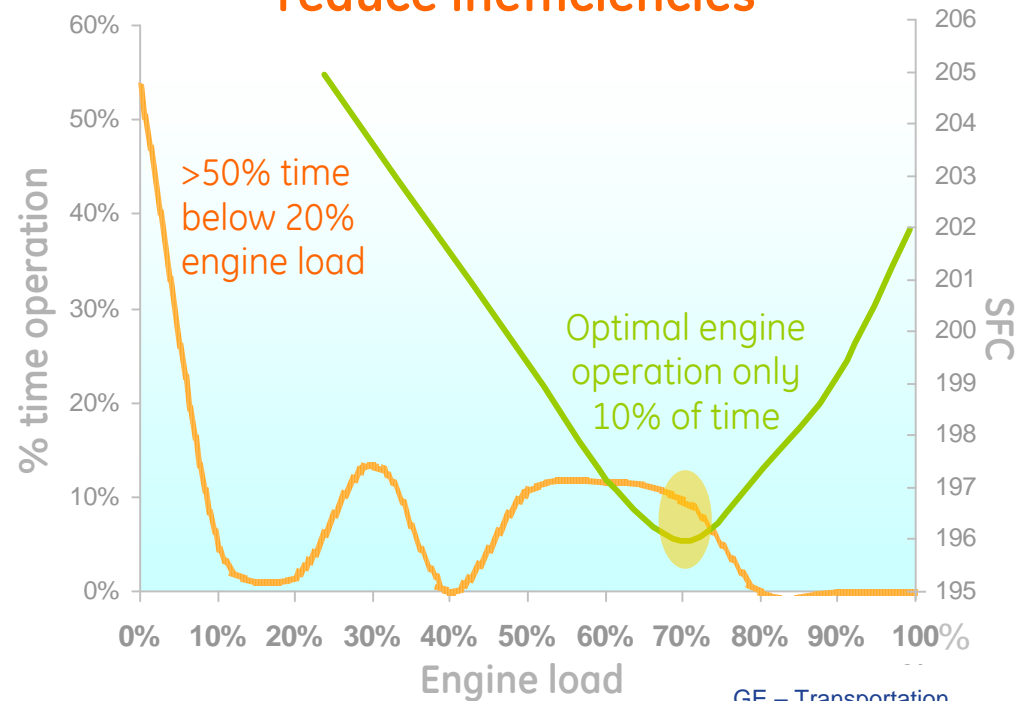
Electric Hybrid Tugboat

- Reduced fuel usage and emissions
 - ✓ “Quiet Time” propulsion
 - ✓ “Quiet Time” auxiliary load
- Reduced engine sizing ... cost and optimal operation range
- Shore power charging ... 50% lower than diesel gensets

Relatively lower charging rate and higher discharge rate compared to Loco/OHV



Potential value of hybrid ...
reduce inefficiencies



Drivers for Battery CTQ's

Battery Considerations

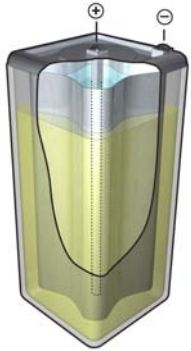
Key Critical Parameters

- Cost (ACO,LCC)Competitive , ROI
- Life..... 20 years in high vibratory environment
- Safety.....No operational impact
- Specific Power.....150 W/Kg
- Energy Density.....80 Wh/Kg
- Operations temperature -40C to +60C
- Reliability.....<< 0.05 FLY
- DisposalEnvironmentally safe

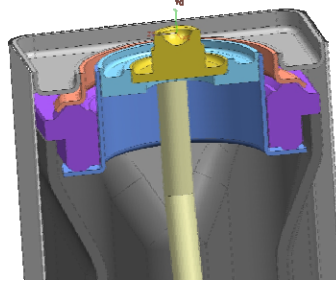
Sodium Battery
Center of Excellence at GE

GEMx Battery Center of Excellence

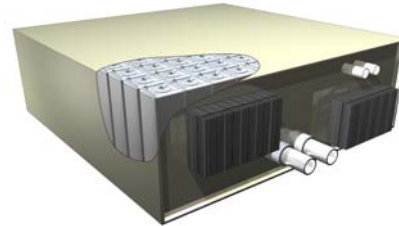
Chemistry
(GRC)



Cell Technology
(Beta R&D)



Battery Pack
(Beta R&D)



System Integration
(GET)



- 2010 Pre-Production
- System Optimization for Reliability & Life
- Vibration Hardened Pack Design

Battery Systems Integration

Hybrid Locomotive Development

Control - I-Services

- Develop QNX6 apps to collect INC/SNP data

Services - MDSC

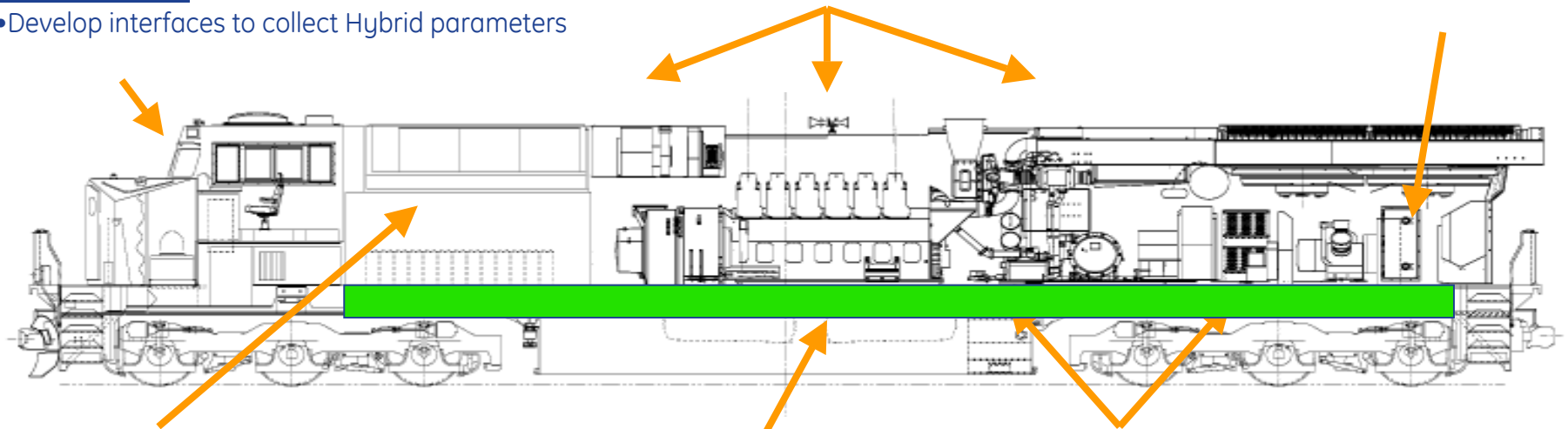
- Develop interfaces to collect Hybrid parameters

Cabs

- AUX & RAD Cab design & analysis
- All Cabs accommodate hybrid subsystem

Loco - Equipment Ventilation

- Hybrid Forced Air Cooling Network



Control - Traction

- Interface with hybrid controller

Control - Software

- Hybrid Controller software
- Loco Control software upgrade
- Simulator HITL

Control - EDDC

- Software development

Control - Electronics

- Hybrid Controller design
- Component eNCI

Systems Integration

- Hybrid analysis, requirements, validation
- Program management

Electrical / Mechanical Integration

- Electrical Integration of hybrid electronics
- Mechanical integration of all new interfaces

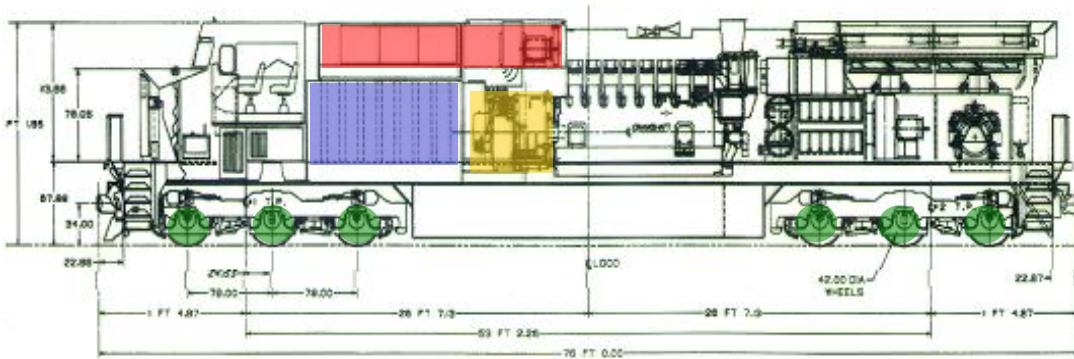
Platform

- Platform length increase
- Reduce weight from platform
- Integrate platform / walkway / hybrid

Requisition Support

- Aux Power
- Train Control, EV Control, Cooling Control
- Principle Engineering
- Engine Engineering
- Product Safety
- Propulsion
- Global Labs
- Trucks

Leveraging Hybrid Loco in OHV



AC Control Group

- Microprocessor Cards / Algorithms
- IGBT / Power Electronics

Dynamic Retarding Group

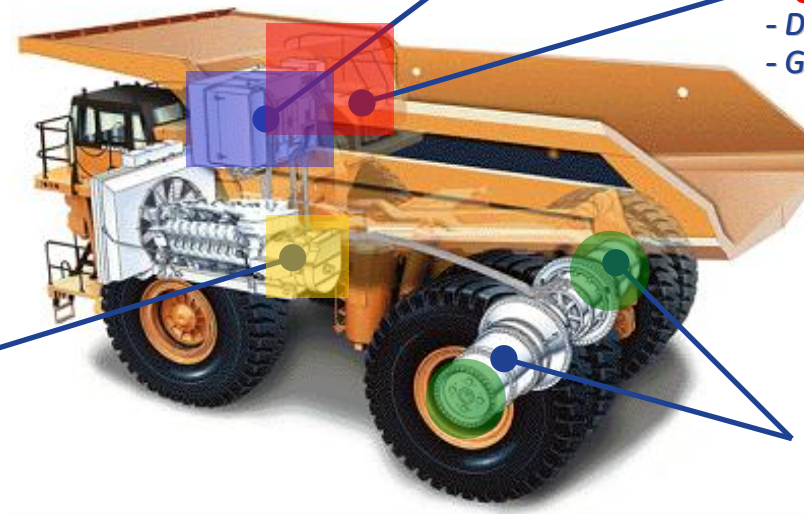
- Dynamic Retarding Grids
- Grid Blowers

Alternator

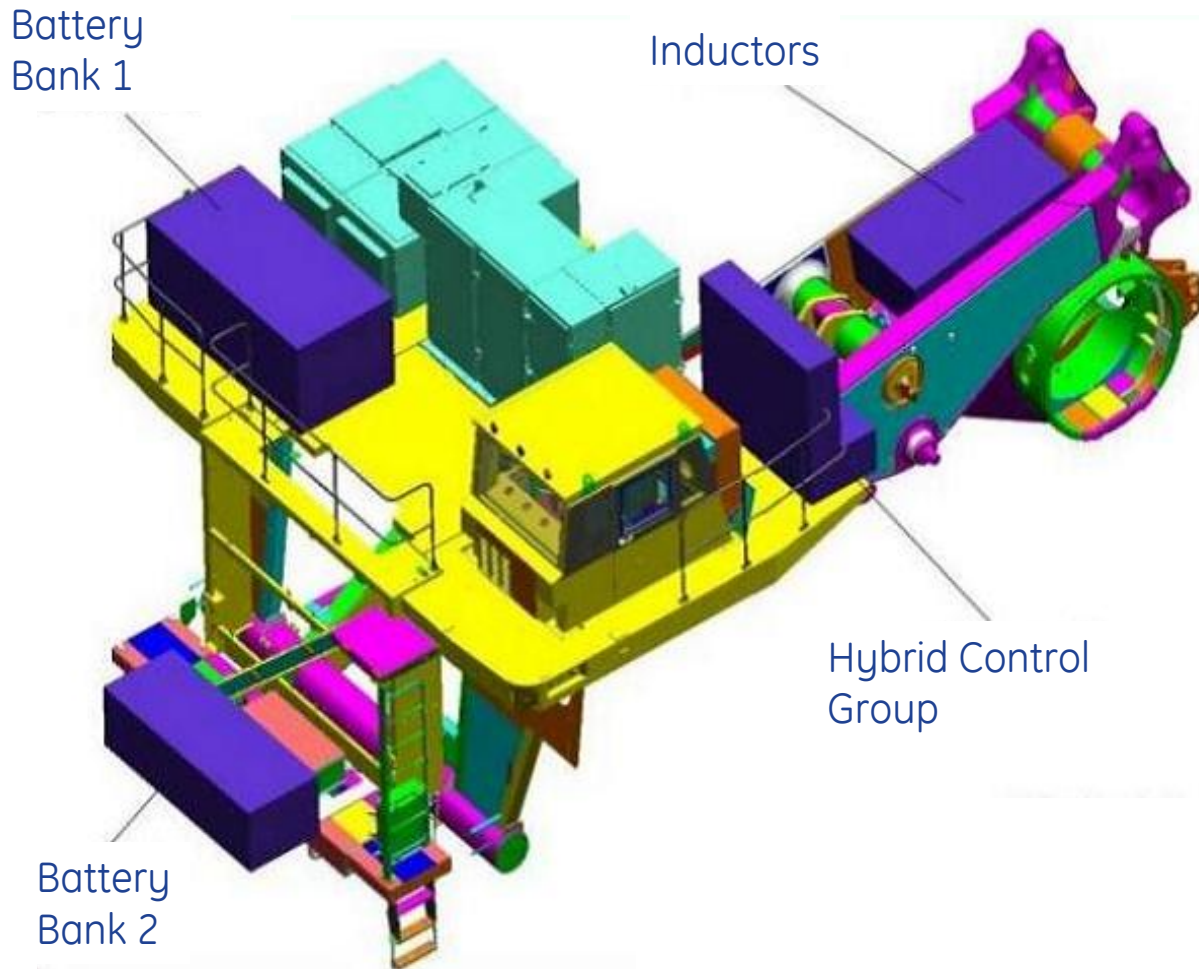
- Traction Alternator Technology

Motorized AC Wheels

- AC Induction Motors



Hybrid System Layout



Conclusions

- Hybrids yield value to both end Customer and OEM
- Sodium metal halide battery technology is the most appropriate choice for Loco/OHV/Marine
- Future enhancements in:
 - i) Battery performance
 - ii) Cost
 - iii) Systems integration and
 - iv) Smart vehicle operation will yield more value to customers & OEM's

