Fuel Economy Technology

Workshop on Fuel Efficiency Standards
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K.G. Duleep,
Managing Director, EEA - ICF

Fuel Consumption and Greenhouse Gas Emissions

- Global warming and vehicle fuel consumption are very important and connected issues
- As petroleum supplies decrease, fuel availability at reasonable cost will also become a big issue by 2020.
- Developing strategies to reduce fuel consumption and GHG emissions from vehicles will be a key requirement in the future for all countries.
- Low cost methods must be used for developing countries where vehicles are small and cheap.

Alternative Fuels

- Petroleum based fuels like natural gas or LPG can provide some benefit in GHG emissions but cost benefit requires study.
- Bio-fuels do not reduce vehicle emissions but take up GHG gases when produced from plant material like sugarcane.
- Bio-fuels have very big effects on land use and water use, as well as food prices. Their use must be carefully considered in India.

Improving Vehicle Fuel Economy

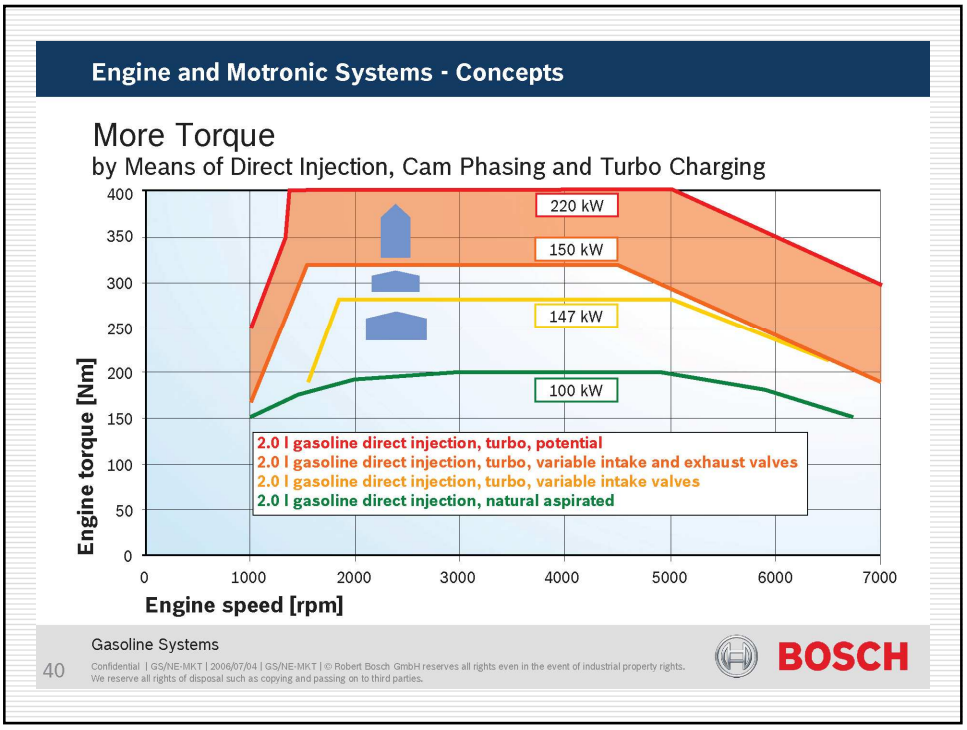
- Methods to improve vehicle fuel economy are well understood theoretically.
- Many new technologies continue to be introduced in new cars and trucks
- General methods are
  - improve engine peak efficiency potential
  - reduce losses at light load from throttling
  - reduce weight, drag and rolling resistance
  - reduce accessory load and eliminate idle
  - capture braking energy loss

EEA Methodology

- EEA monitors technology developments worldwide through the trade press and key conferences.
- Preliminary analysis of potential based on research papers or prototype data.
- Extensive follow up on technology attributes and lead time with manufacturers /suppliers.
- All cost data obtained from high level contacts at Tier I suppliers, who are now the major source for technology developments.

Short Term Engine Technologies – EU and USA

- Technologies in the pipeline now
  - Variable Valve Lift (step/continuous)
  - Gasoline Direct Injection with CR increased by ~2 points (lean burn long term for US, used in Europe)
  - Cylinder cutout (V6/8 only)
  - Turbo- GDI- VVT combination
  - Reduced Engine Friction



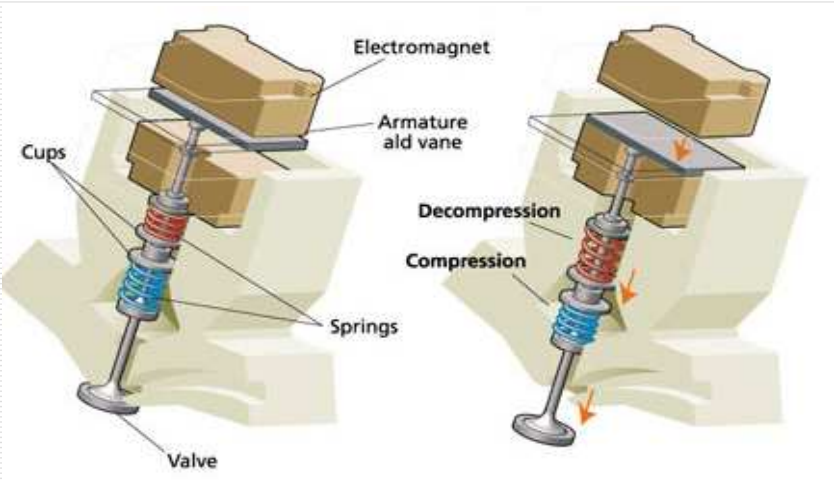
Engine Technology Potential EU and USA

2 –step valve lift	4 to 5%	$125 -175
Continuous valve lift	7 to 8%	$300 -400
Gasoline Direct Injection (GDI)	3 to 4%	$160 – 250
Turbo – GDI	13 to 15%	$ 0 to 650
Friction Reduction	2 to 4%	$30 to 70

Mid-term Engine Technology EU and USA

- Most promising development is cam-less valve actuation which offers potential to reduce throttling loss to near zero, and make Atkinson cycle possible at light load.
- Cam-less engine will be key enabler for gasoline HCCI in longer term
- These technologies are quite expensive and may not be suitable for India.
- Gasoline engine technology will close the gap with diesel efficiency, but diesel will still have advantage due to energy/volume.

Valeo Electromagnetic Camless Valve Actuation Schematic



Mid-term Engine Technology Potential- EU and USA

"Half cam-less" engine	15 – 16%	$400 to 600
Full cam-less HCCI with GDI	19 – 22%	$1000 to 1500
Advanced friction reduction	4 to 6 %	~$100
GDI lean burn	17 to 19 %	$1000 to 1500
Combination with turbo	~ 25% ?	~ $1500

Transmission Technology

- Future transmission options seem to be shaping up as follows:
  - Six/Seven speed automatics for RWD and larger FWD cars
  - CVT for smaller FWD cars and small unibody trucks
  - AMT (6-/ 7-speed) for sporty cars.
  - may be unsuitable for India due to low speeds

Transmission Technology Benefits

Six speed automatic	4 to 5 %	$100 to 150
CVT (small cars)	6 to 8 %	$150 to 200
AMT (sports cars)	7 to 8 %	$150 to 200
Torque converter elimination	3 to 4 %	~ 0

Reducing Vehicle Energy Demand

- Weight reduction is possible but quite expensive. While up to 20% weight reduction is technically possible, only 5 to 10% may be practical at reasonable cost ~ $60 per percent
- Drag and rolling resistance reductions of 10 to 20% can be achieved by 2020.
- Driving the accessories electrically is more efficient than belt drive. Power Steering and Water Pump are cost-effective.

Idle Stop- Start

- New "intelligent" starter motor design pre engages engine when stopped, resulting in faster, quieter start, even with 14V system.
- Electrical system must be upgraded with additional battery to withstand start cycles.
- System is very suitable for reducing fuel consumption in cities in India with high traffic congestion in cities.
- Electrical upgrades will facilitate electrification of other accessories and provide more benefits.

Maximum Potential of Conventional Technology (FE Increase)

	2006 – 2015	2016 – 2025
Engine & Transmission	15 – 19 %	22 – 28 %
Weight, drag and tire loss reduction	7– 11 %	11 – 16 %
Accessories	2 – 3 %	3 – 5 %
Idle Stop	3 – 4 %	2 - 3 %

Total Vehicle Improvement

- Integration of multiple technologies into same vehicle requires selection of appropriate technology by vehicle size/ use.
- Estimates of total improvement must account for (dis)- synergy between technologies.
- EEA uses a simplified "lumped parameter" version of a full scale simulation model like PSAT which is difficult to apply at the fleet-wide level.

Summary of Conventional Technology Potential

- Overall, the sum of all the technologies can lead to a 25 $\pm$ 3% FC reduction in 10 yrs. Reduction up to 33 $\pm$ 4 % FC reduction in 20 yrs. is possible but expensive.
- The inability of manufacturers to change technology rapidly will limit the reduction actually attainable to lower values.
- Of course, consumers can nullify much of the technology benefits by choosing more powerful and larger vehicles!

Impact for India

- Sales mix in India is primarily small cars unlike US and EU and vehicle cost is low, FE is quite good.
- Many US and EU technologies are not suitable for Indian cars due to high cost and low benefit in local market.
- High congestion and low speeds suggest good prospects for low cost hybrids and start-stop technology.

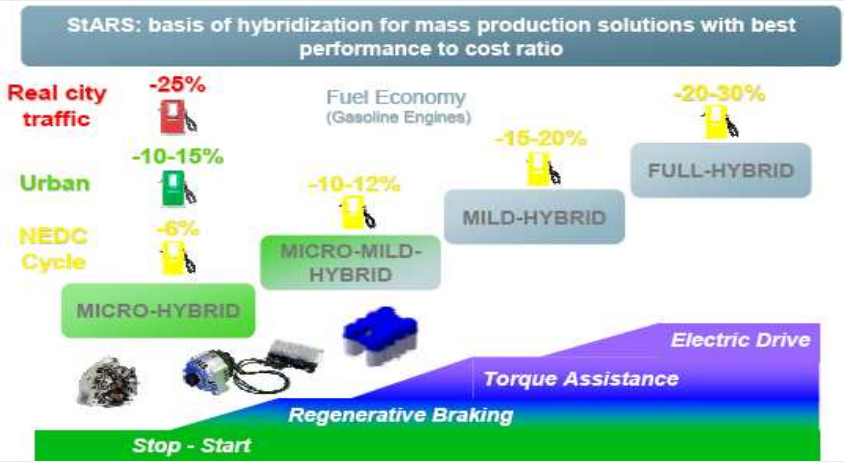
Rising Affluence in India

Segment		2002 Share	2007 Share
A1		21%	6%
A2		53%	65%
A3		15%	18%
Larger		11%	11%

Types of Hybrids

- A large number of "hybrid" designs have been unveiled.
- Four types that will be in the US market and span the range of designs
  - Belt drive Alternator Starter (BAS)
  - Crankshaft mounted single motor (IMA/ISAD)
  - Dual Motor "full" hybrids (Prius/Escape)
  - Plug-in hybrids.

Overview of Hybrid Benefits



Common Attributes of Hybrids

- Hybrids must fully exploit all synergy with drive train and accessories to provide large improvements in FE.
- Hybrids provide large fuel economy gains only in stop-and go driving.
- Benefits deteriorate in very hot/cold weather due to space conditioning.
- Hybrids not suited for cargo hauling.

Plug-in Hybrids

- Both series and parallel plug-in hybrids are being developed but parallel hybrids are cheaper and can deliver much of the benefit of a series hybrid.
- At present, plug-in hybrids are very expensive and no economic case can be made for their adoption.
- Future prospects for plug-in hybrids are dependent on battery costs, battery durability and fuel prices.

Hybrid System Benefits

- BAS systems can be cheap but it will provide limited FC reduction, 10-15%
- The Toyota system can be very efficient but has the disadvantages of high price, ~$5000
- One- motor systems of the Honda IMA type could be more cost effective while offering significant fuel consumption reduction, 25-30%

Hybrid Cost-Effectiveness

- Even the IMA type hybrid will add cost of about Rs.1lakh to A3 vehicle
- Typical cost of fuel for urban vehicle is about Rs. 50,000 per year.
- Implied payback period is 6 to7 years which may be too long for consumer.
- High hybrid penetration will require some incentive and higher fuel price.
- Given the electricity supply situation in India, and the state of plug-in hybrid technology, it is not a short term prospect.

FE Standards for India?

- Justification for standards in US and EU is due to short consumer payback horizon for new technology.
- Indian situation is quite different: mostly small cars with good fuel economy and high consumer valuation of fuel savings
- Incentives for technology introduction may work better than standards in a developing country environment.
- Cost-effectiveness of standards is a key issue for policy makers.

Summary

- SI engine technology improvements continue to be far more cost-effective than alternatives like hybrid or diesel
- Several low cost technologies are available over the next 10 to 15 years to reduce fuel consumption and GHG gases in India
- Hybrids can be one element of a future strategy but are NOT suitable for everyone.
- Bio- fuels can also help but water use and land use should be considered by India.

Recommendations

- Due to mix of cars sold in India, fleet of vehicles has good fuel economy.
- Cost effectiveness of new technology in Indian context is very important.
- Justification for FE standards in India is not as evident as in the West
- Incentives for new technology can be a powerful consumer force to improve FE in India