



ASHOK LEYLAND

# An Overview on the Road Transportation Sector CO<sub>2</sub> Emission Reduction Technologies



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HINDUJA GROUP

ECT 2019

# Need for CO<sub>2</sub> Reduction



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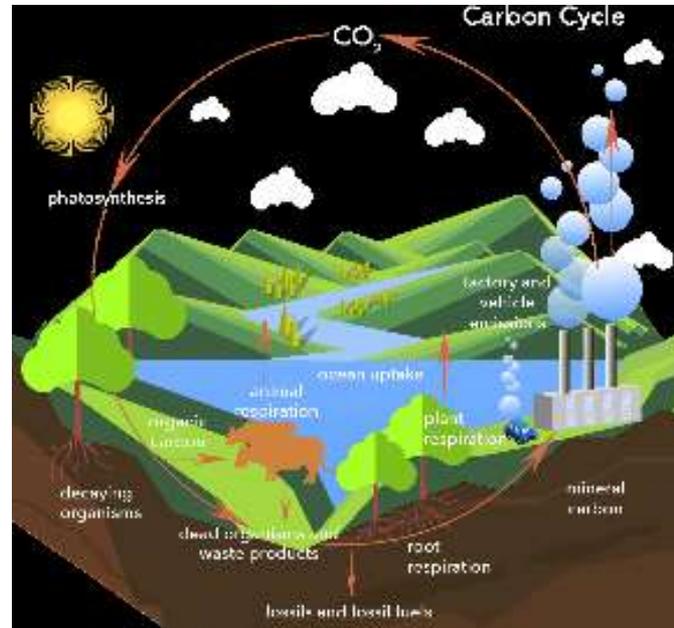
CO<sub>2</sub> EMISSION



GLOBAL WARMING



INCREASE WATER LEVELS



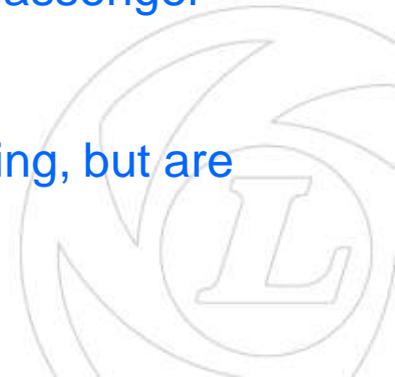
CO<sub>2</sub> reduction initiatives not only helps environment but also reduces TCO for end user and helps in National energy security

ENERGY SECURITY



# Greenhouse Gas Emission

- The principal emissions from motor vehicles (by volume) are greenhouse gases (CO<sub>2</sub>,N<sub>2</sub>O) , which contribute to climate change.
- Not all vehicles have the same impact though.
- The vehicle's level of CO<sub>2</sub> emissions is linked to the amount of fuel consumed and the type of fuel used
- Earlier California regulators finalized the first CO<sub>2</sub> regulations for passenger cars in 2005, followed by Europe in 2009
- Regulations governing vehicle CO<sub>2</sub> emissions are just now emerging, but are poised to be a long term trend.



# Drivers for CO<sub>2</sub> Regulation

- The United Nations Intergovernmental Panel on Climate Change (IPCC) is proposing CO<sub>2</sub> targets for 2050 and beyond, which will likely drive CO<sub>2</sub> regulations into other vehicle and equipment segments.

## Light Commercial Vehicles Emission Targets.

The regulations are applicable to vehicles category N<sub>1</sub> with a reference mass not exceeding 2,610 kg (LCVs must meet the following emission targets (NEDC test):

- 2017: A fleet-average CO<sub>2</sub> emission target of 175 g/km has been fully phased-in by 2017 .
- 2020: The average CO<sub>2</sub> emissions of new LCVs registered from 2020 have to meet 147g CO<sub>2</sub>/km.
- 2025: A CO<sub>2</sub> emission target equal to a 15% emission reduction from the 2021 target .
- 2030: A CO<sub>2</sub> emission target equal to a 31% emission reduction from the 2021 target.

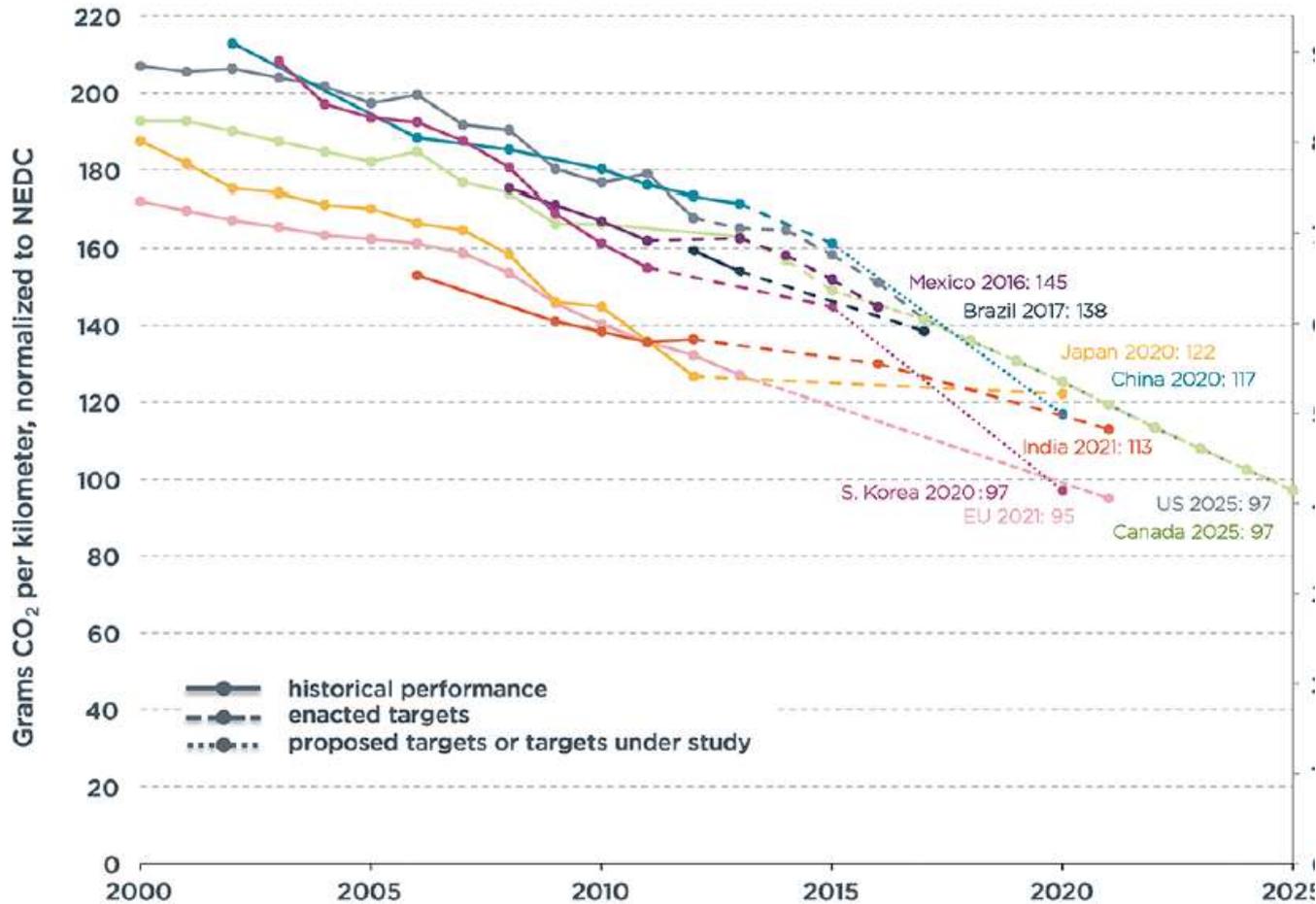
## •Heavy Commercial Vehicles Emission Targets

- In 2025, 15% lower than in 2019
- In 2030, at least 30% lower than in 2019





# CO<sub>2</sub> Regulations World wide



In India Fuel efficiency Regulations for Light and Medium duty Vehicles has been mandated from 1<sup>st</sup> April 2020 ( As Per S.O. 2450 (E) dated 16<sup>th</sup> Jul 2019.  
HD Fuel efficiency regulation is still under discussion –Draft standard AIS 149.



# Technologies for CO<sub>2</sub> Reduction

There are numerous technologies being considered to reduce CO<sub>2</sub> emissions.

a. Low carbon fuels (e.g. biofuels);

b. Advances in diesel engine technologies:

- Advanced combustion :
- Advanced fuel injection system,
- Better Thermal management ,
- Smart engine Controls & Sensors
- Waste Heat Recovery,
- High efficiency & low cost after-treatment system.

c. Electrification of the drivetrain:

Hybrid electric vehicles (HEV),  
Plug-in hybrid electric vehicles (PHEV),  
Battery electric vehicles (BEV).

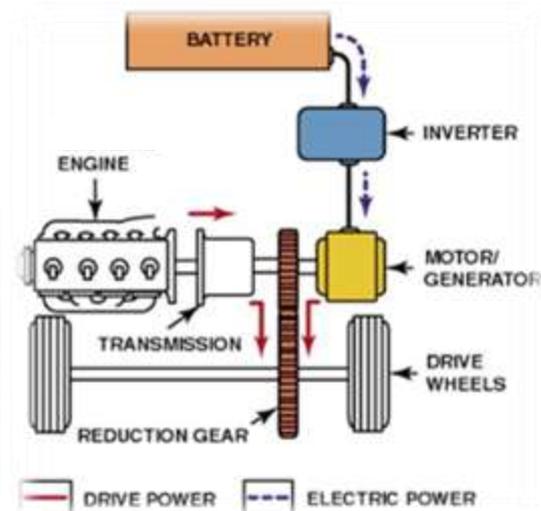


## Biofuels Today!

Available  
Cost effective



Safe  
Low Carbon



CO<sub>2</sub> reduction initiatives not only helps environment but also reduces TCO for end user and helps in National energy security

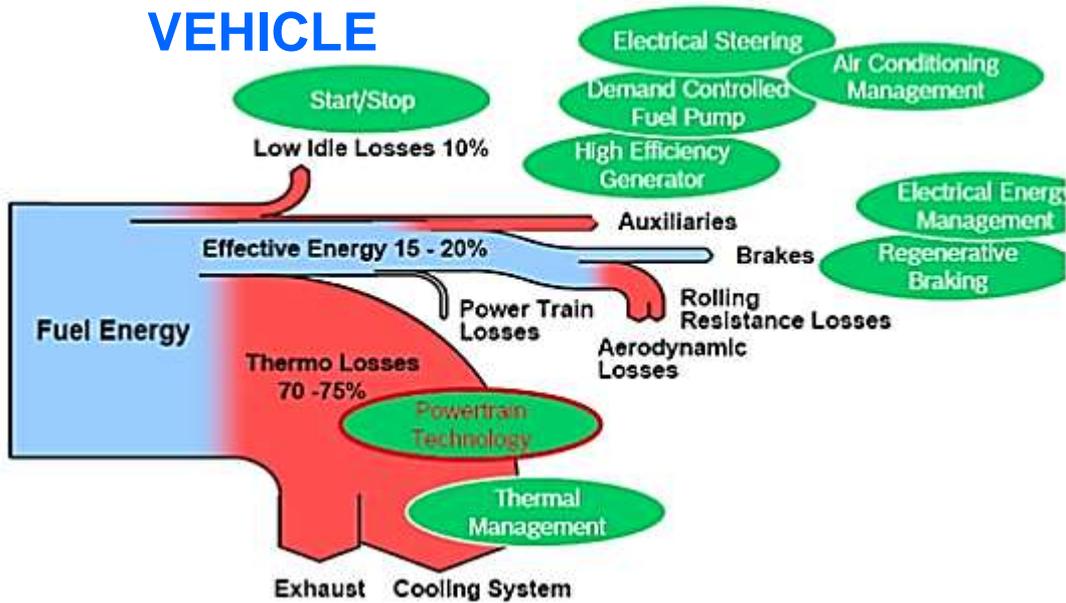
- Governments are beginning to address energy diversity, energy security, and climate change issues with biofuel mandates.
- Current Bio Fuels are generally plant cellulose or waste products based.
- It appears that the long term trend is towards integrating bio feed stocks into refinery operations.
- Biodiesel has about 5-10% lower energy content than diesel but a higher cetane value.
- HC, CO, and PM emissions are about 10-20% less for B20 than for diesel fuel, but NOx emissions are roughly similar.
- Ethanol has about 30% lower energy content than gasoline, but higher octane levels.





# Light Duty Powertrain Technologies

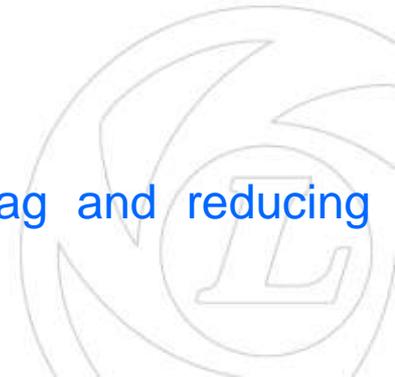
## ENERGY FLOW IN VEHICLE



Due to control of fuel economy and CO<sub>2</sub> by regulatory authority automotive companies to aggressively move to increase efficiency.

### Leading approaches for fuel efficiency involve:

- ✓ Improving the powertrain with improved engine performance
- ✓ Hybridization
- ✓ New transmissions
- ✓ Improving vehicle performance by reducing weight, reducing drag and reducing rolling resistance.





# Improved Engine Performance

The leading gasoline and diesel technology choices for meeting the tighter European and US CO<sub>2</sub> standards include:

- ✓ Direct injection gasoline, gasoline turbocharging, dual clutch transmissions, and stop-start systems.

Enablers to these technologies are cooled-EGR (exhaust gas recirculation) for gasoline engines, cylinder de-activation, and variable valve technology.

Overall, specific power will increase, enabling significant engine downsizing.

High Power Density and Higher BMEP Engines is a trend to improve Fuel economy and hence CO<sub>2</sub> reduction

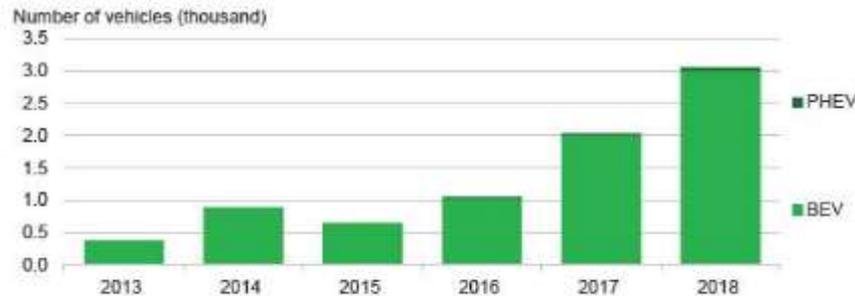




# Hybridization

- Full hybrids have the low CO<sub>2</sub> emissions, with the best delivering >50% reductions from conventional vehicles.
- However, despite incentives, their market penetration is low for BEV and PHEV

## Thus far passenger EV sales in India have been very low



Source: BloombergNEF, Society of Manufacturers of Electric Vehicles.  
Note: Only four-wheelers. BEV means battery electric vehicle. PHEV means plug-in hybrid electric vehicle

Electrification of transport would be more beneficial in City Cycle as compared to Highway Cycles

# HEAVY DUTY POWERTRAIN TECHNOLOGIES



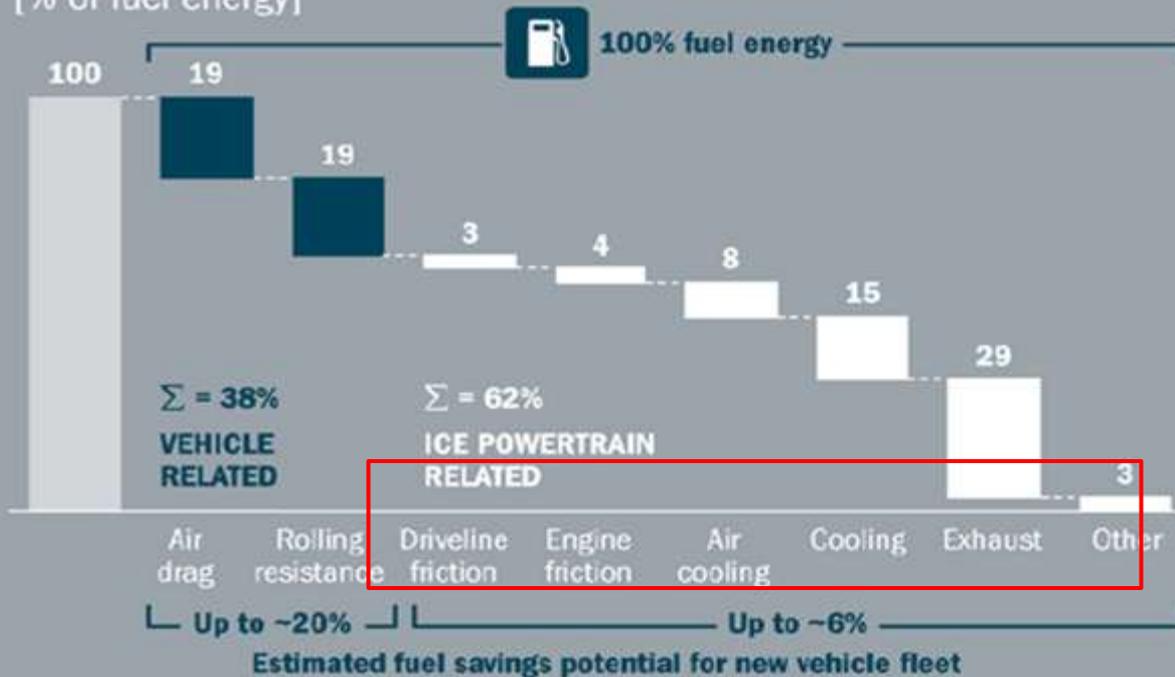
- About 6-8% of GHG emissions come from the heavy-duty (HD) truck sectors in the US, Europe, and Japan (1, 2, 3).
- In the US, about 75% is emitted by the large Class 8 trucks.
- As fuel costs represent 20 to 30% of the total life cycle cost of the truck, it can be represented 2 to 2.5X the cost of the truck itself (4).
- Hence HD truck sector is strongly driven to reduce the fuel consumption.



# Roadmaps and Scenarios

## How long-haul trucks consume energy

Energy usage by long-haul trucks fitted with conventional internal combustion engines  
[% of fuel energy]



### Comments

- > Vehicle improvements focus on reducing **rolling resistance** (e.g. tires, weight) and **air drag** (e.g. side skirts)
- > Further improvements can be achieved by reducing **usage of the combustion engine** (e.g. by using more electric components)

Source: Renault; Daimler; Roland Berger

Source: Truck Powertrain 2020 – Mastering the CO2 challenge: Roland Berger strategy Consultant

Typical heavy duty engines energy chart shows:

- 20 % of fuel energy can be saved from vehicle optimization
- 62% of fuel energy saving by powertrain optimization

# Roadmaps and Scenarios

Selected powertrain improvements to reduce commercial vehicle CO<sub>2</sub> emissions in triad markets

	Automated transmission	Waste heat recovery	Ancillary units	Other <sup>1)</sup>	<b>Comments</b> > New emission standards have a <b>negative impact</b> (e.g. Euro VI)  > <b>Automated transmissions</b> offer <b>considerable potential</b> but have already penetrated certain segments
 City truck, 12 tons	✓		✓	✓	
 Intercity truck, 18 tons		✓	✓	✓	
 City bus, 18 meters			✓	✓	
 Long-haul truck, 40 tons		✓	✓	✓	

1) E.g. Optimized turbochargers, injection systems with very high pressure

## Segment wise possibilities of technologies

- For a common technology incorporation to reduce CO<sub>2</sub> among all segments, main concentration should be on ancillary units optimization and ICE optimization

# Roadmaps and Scenarios

## Indian Scenario



Non-powertrain enhancement technologies	Description	Fuel economy gain in India			Current market penetration
		PV/ LCV	M&HCV	2W/ 3W	
1 <b>Aerodynamics optimization</b>	<ul style="list-style-type: none"> <li>Streamlined vehicle body design to minimize energy losses due to air drag</li> </ul>	1- 2%	3- 4%	Very limited	<ul style="list-style-type: none"> <li>Ongoing</li> </ul>
2 <b>Weight optimization</b>	<ul style="list-style-type: none"> <li>Use of light-weight materials and structural redesign for weight reduction</li> <li>New manufacturing technologies</li> </ul>	3- 4% <sup>1</sup>	1- 2%	1- 2%	<ul style="list-style-type: none"> <li>Ongoing</li> </ul>
3 <b>Tyres optimization</b>	<ul style="list-style-type: none"> <li>Reduction in tyre rolling resistance towards minimizing rolling friction losses</li> </ul>	1- 2%	3- 4%	1- 2%	<ul style="list-style-type: none"> <li>Ongoing</li> </ul>
4 <b>Ancillaries optimization</b>	<ul style="list-style-type: none"> <li>Reduction in power consumption in ancillaries and load systems based on                             <ul style="list-style-type: none"> <li>Electrification of currently mechanical systems of actuation and loads</li> <li>Optimization of electrical systems and use of electronic control, where possible</li> </ul> </li> </ul>	2- 3%	2- 3%	1- 2%	

1. FE impact numbers based on 100 kg reduction in weight

2. Payload-to- kerb mass ratio in India is ~1.5-2 vs. global benchmarks of <1; in practical situations, this factor is higher given heavy overloading in Indian trucking conditions

Source: IEEP-TNO Study 2011, EPA TSD 2011, A.T. Kearney research

Source: CII-ATK Cost Effective Green Mobility –Vision 2020 Joint A.T. Kearney & CII Study March 2013

○ Low → ● High

- Unlike in European scenario, here the aerodynamic and tyre optimization together shows ~8% reduction only .
- This is because in Europe the HCV average speed is 75 kmph whereas in India it is 35 kmph.

# Roadmaps and Scenarios

## Indian Scenario



Advanced IC engine Technology <sup>1,2</sup>	Description	Fuel Economy Benefit (% FE improvement)			Current Market Penetration in India		
		PVs	2/3 Wheelers	CVs	PVs	2/3 Wheelers	CVs
1 Engine friction reduction	• Reduced engine friction through multiple levers e.g. conversion to electrical drives, use of roller bearings etc.	2-3%	1-2%	2-3%	Ongoing R&D by OEMs, suppliers		
2 Start-stop systems (micro-hybrid)	• Reduced idle-state fuel consumption through engine shut down	3-5%	2-3%	2-5%			
3 Fuel Injection	3a Direct Injection – Gasoline • Injection of fuel directly in combustion chamber leading to more efficient fuel utilization	2-3%	13-16% <sup>3</sup>	-			-
	3b Port Fuel Injection – Gasoline • Injection of fuel into an intake port for mixing with air followed by introduction in combustion chamber	Base Case	5-10%	-			-
	3c Common Rail – Diesel • A high pressure common fuel rail injecting all engine cylinders allowing for better injection control	4-5%	4-5%	4-5%			
4 Downsizing (with turbo)	4a Diesel (New-gen turbos) • Use of new-gen variable geometry turbos offering better control on air intake and engine efficiency	3-5%	-	4-6%			
	4b Gasoline engines • Replacing a larger engine with a smaller, more efficient engine while matching performance through turbocharging	4-15%	-	-			
5 Variable Valve Timing & Lift	• Varied timing and lift of engine valves depending on engine load to optimize air intake and exhaust	3-7%	3-5%	1-2%			
6 Cylinder deactivation	• Reduced engine losses through partial deactivation of engine cylinders depending on load	4-5%	-	1-2%			
7 Automated manual transmission	• Lower gear shift losses through electronic control of clutch and shift	3-5%	-	3-5%			
8 NOx control systems	Selective catalytic reduction • High efficiency aftertreatment system that allows for optimized engine combustion; injection of a urea-based compound removes NOx	4-6%	-	4-6%			
	Exhaust gas recirculation • Mixing of cooled exhaust gases with fresh air intake to reduce combustion temperature and hence NOx	0%	-	0%			

• An overall of ~30 % fuel economy can be benefited from IC engine optimization.

Note: The percentage showed differs for different vehicle application segments.

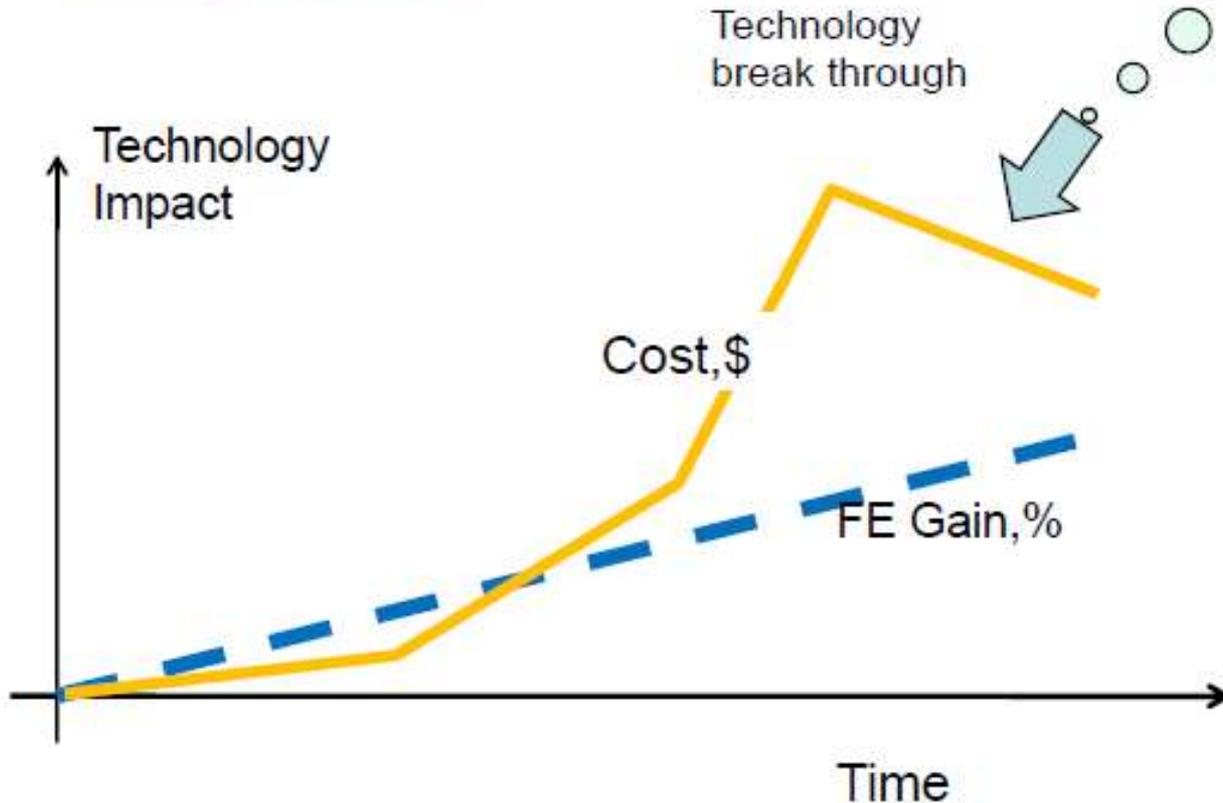
1. Several other technologies also exist to improve fuel economy – Petrol: Thermodynamic cycle improvements e.g. split cycle, PCCI/HCCI, CAI, Thermo-electric waste heat recovery; secondary heat recovery cycle; efficiency improvements in auxiliary systems  
 2. Diesel: Engine combustion improvements; Thermo-electric conversion; secondary heat recovery cycle; auxiliary systems efficiency improvements; Thermal management systems  
 3. Gasoline direct injection is relevant for 4 stroke engines. For 2 stroke engines, air-assisted direct injection is the next generation technology and has 30-50% FE improvement  
 Source: TNO-IEEP Report 2011 for European Commission, EPA TSD 2011, A.T. Kearney research



# Technology Impact

## Challenges and barrier to Commercialization

- ✓ Product cost
- ✓ Technology maturity and complexity
- ✓ Supplier base readiness
- ✓ Product development time





# Developments to optimize CO2

- **Engine friction**
  - Hydrogen free DLC\*
- **Air cooling**
  - Fan on request
- **Exhaust**
  - Waste heat recovery
  - Hybrid
  - Electric
- Variable compression ratio
- Variable valve timing/lift
- Start/Stop system
- Two stage turbocharging
- High injection pressure
- Exact gear box ratio match
- Variable Compression ratio
- Flywheel technology
- Bio-fuels, fuel cells
- Weight optimization
- Ancillary units current consumption optimization
- Nozzle Dia reduction
- Fuel cell driven auxillaries (Auxillary power unit APU)

\*DLC – Diamond Like Carbon coating on piston walls

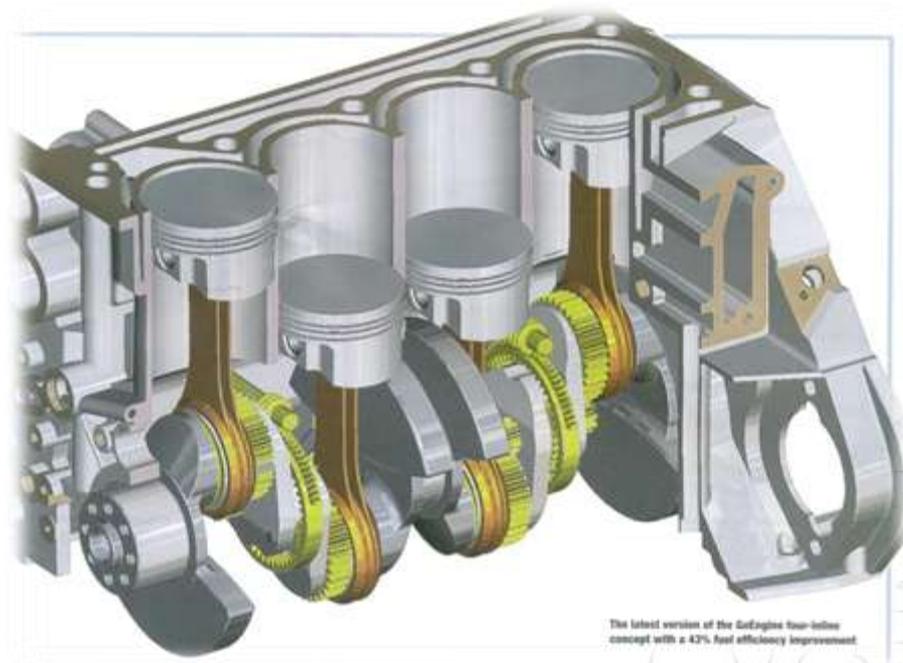
Source: Bosch study report

Technologies to improve 6% fuel energy in Engine,  
With all the above “Other” technologies combined, even the CO<sub>2</sub> targets of 70 grams per kilometer,  
in discussion for 2025, are achievable.

# Developments to optimize CO2

## Improved combustion

- Variable compression ratio
- Best efficiency at all loads



# Developments to optimize CO2

## Variable valve timing

- Both the cams are phased dynamically with speed for optimum volumetric efficiency
- 1-2% fuel efficiency



Direct-injection systems from Delphi use electronic controls to time the many injections made every second.

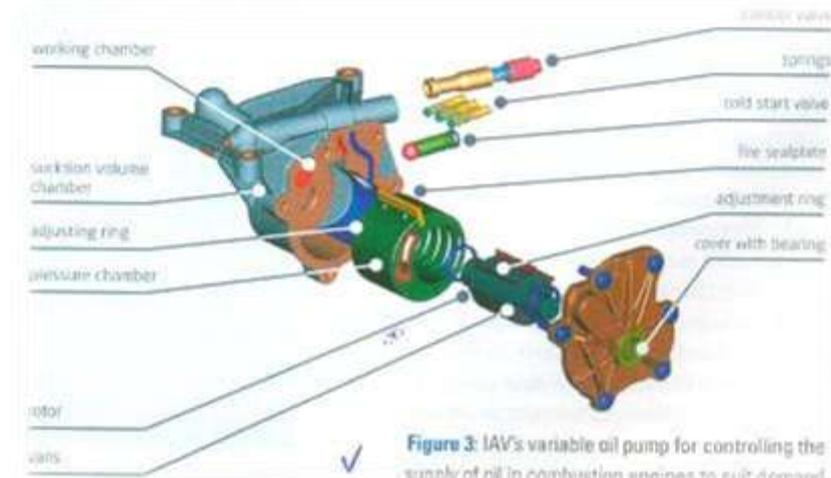
# Developments to optimize CO2 Optimization on Ancillary units

- Combined Module for a Oil Pump, Vacuum Pump and Mass Balancer System.
  - It helps in reduction of power consumption/ friction losses.



Source: SAE paper No:2013-26-0116

- Variable oil pump for controlling supply of oil in combustion engines to suit demand.



# Developments to optimize CO2

## Start-Stop technology

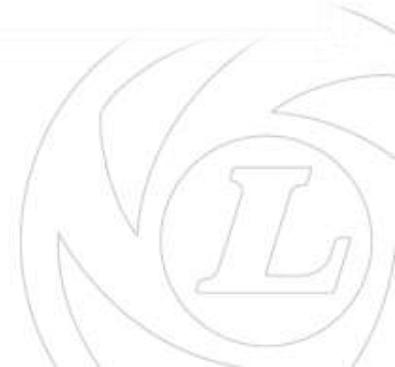
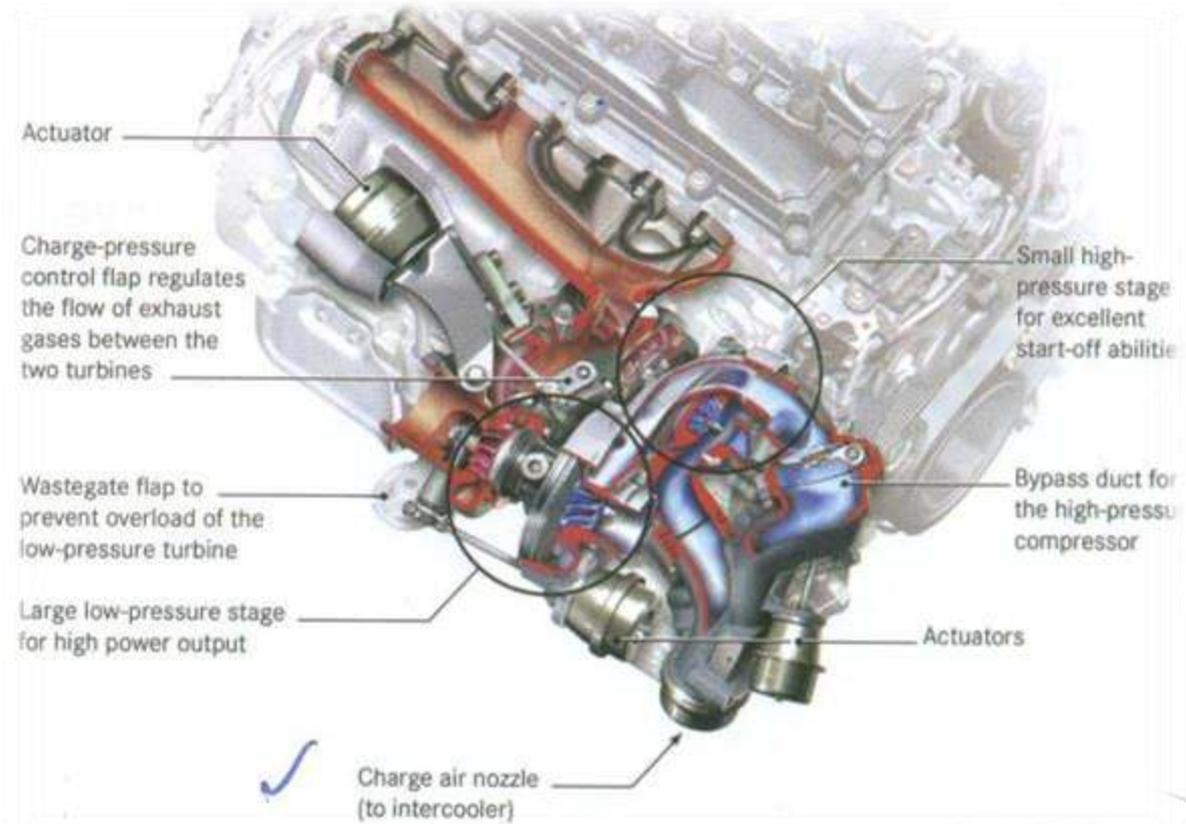
- Start/stop system - where the engine is stopped while the vehicle is on standstill in order to improve on fuel economy
- 2-5% reduction in fuel economy
- ~5% reduction in CO<sub>2</sub>



# Developments to optimize CO2

## Two stage turbocharging

- Improved efficiency in the entire speed range
- High low-end torque
- Fuel efficiency



# Developments to optimize CO2 Recovery of Kinetic Energy Flywheel

- Up to 25% CO<sub>2</sub> is reduced



# Weight Optimization Developments to optimize CO2

## Material substitution<sup>1</sup>

Key alternate materials  
replacing iron and steel..



Aluminium



High  
strength  
steel



Plastics  
and  
composites

Evolving materials...



Carbon-  
fibre  
technology



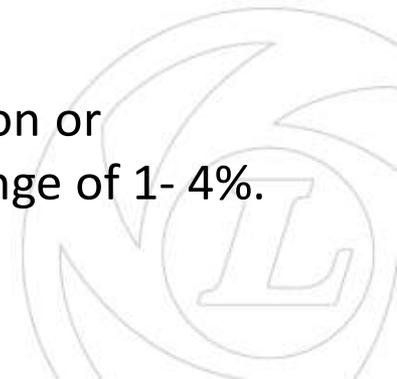
Magnesium  
and alloys



Glass fibre  
technology

- 8- 10% reduction in vehicle kerb mass through material substitution or structural redesign is likely to yield fuel economy benefit in the range of 1- 4%.

Source: CII-ATK Cost Effective Green Mobility –Vision 2020 Joint A.T. Kearney & CII Study March 2013



# Ashok Leyland initiated technology projects In turn reducing CO2



- Effi – 20 – Fuel efficient truck
- Waste Heat recovery
- Sturman Hydraulic Valve Actuation
- Weight optimization: 4 counter weight crankshaft instead of 8 counter weight
- Start/Stop technology
- HCCI – Homogeneous charged Compression ignition



# Ashok Leyland initiated technology projects EFFi - 20



**EFFi-20**

**20** different enhancements **over 20%** fuel saving **over 20%** reduction in CO<sub>2</sub>

**System-wise contribution to improved fuel-efficiency**

		Steady Speed* ≥90km/hr	On Road**
Engine system**	BS III SCR Differential mapping Cruise control	~5%	~8%
Thermal Management System***	Cooling system Air intake system Thermal insulation Coolants and lubricants	~4%	~5%
Driveline***	New tyres and rims Optimised transmission Lift and two speed axle	~10%	~12%
Improved Auxiliaries	Aerodynamic add-ons Driver assist system Skewness elimination Steering system Braking system	~3%	~5%

\*Tested by ARAI  
 \*\*Highway application for rated load-return empty  
 \*\*\*Patents applied for

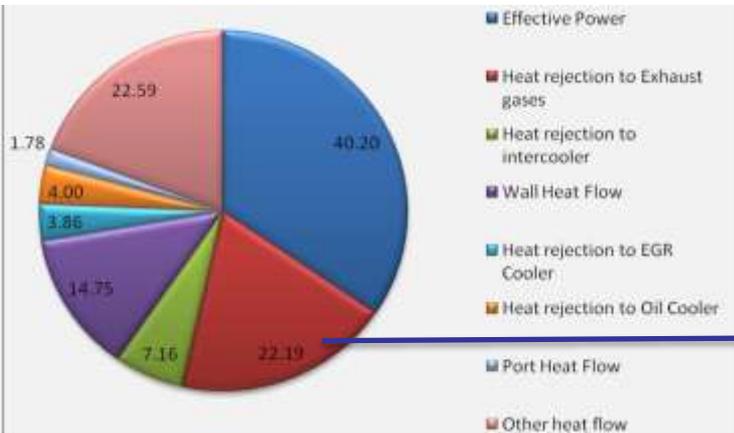
**CO<sub>2</sub> Emission**

Vehicle	KMPL (50 km/hr)	CO <sub>2</sub> emission gm/km*	gm/t km**
EFFi 20	3.26	817	81

\* As per EPA calculation combustion of 1L diesel emits 2884gm of CO<sub>2</sub>  
 \*\* Payload 95 Tonnes  
 Over 20% CO<sub>2</sub> reduction compared to current vehicles on the road

- Vehicle with effi-20 technologies was showcased in Auto Expo Delhi 2010
- Over 20% reduction in Fuel consumption and CO<sub>2</sub> achieved

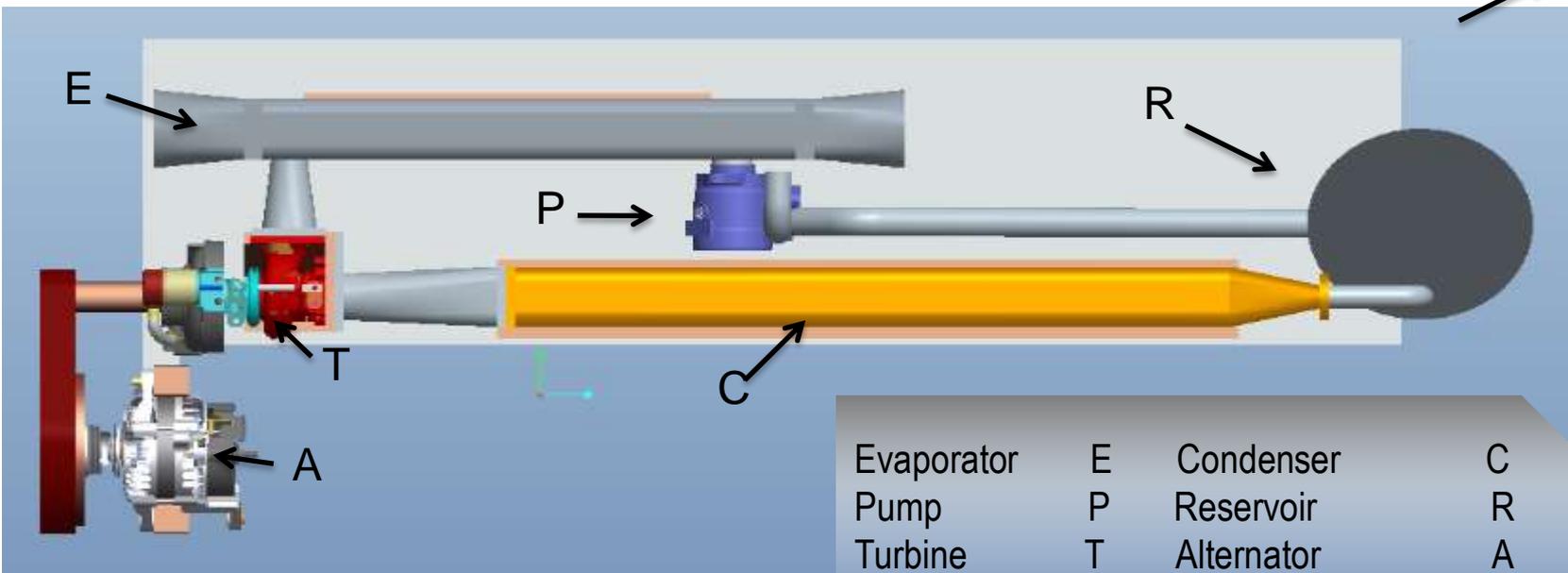
# Ashok Leyland Engine R&D initiated technology projects Waste Heat Recovery



- Exhaust gas waste heat is transferred to a refrigerant and converted to high pressure saturated vapor.
- Sudden expansion of vapor leads to rotation of a turbine blades
- This power can be used as input to run auxiliaries / power add up to flywheel

*Plan is to use the available exhaust energy to produce the work.*

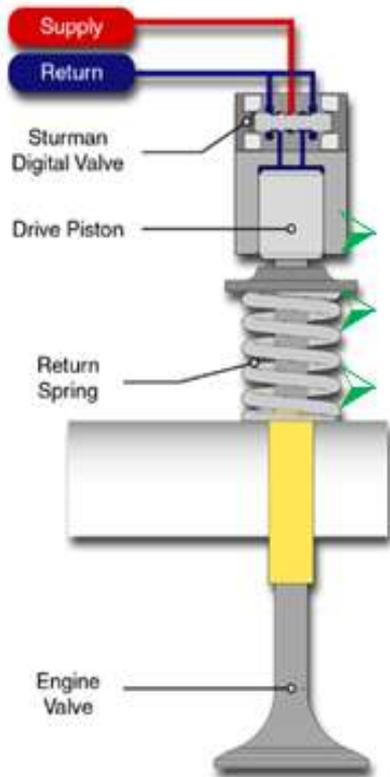
*Schematic of stand alone rig to prove the concept of Organic Rankine Cycle*



# Ashok Leyland Engine R&D initiated technology projects :Sturman Hydraulic Valve Actuation



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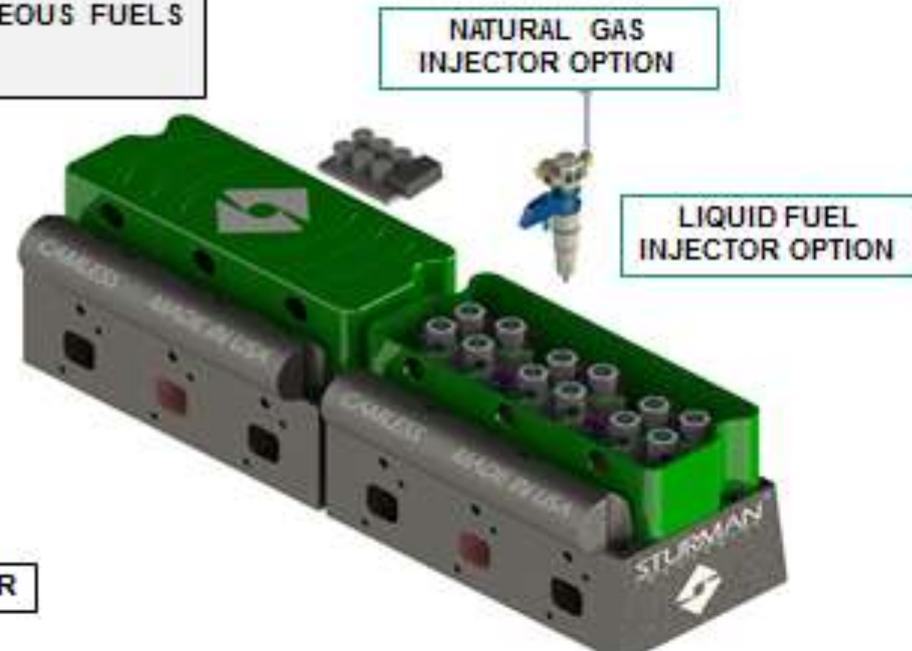


✓ OPTIMALLY EFFICIENT  
ENGINE COMBUSTION SYSTEM

✓ USES LIQUID OR GASEOUS FUELS



CONTROLLER



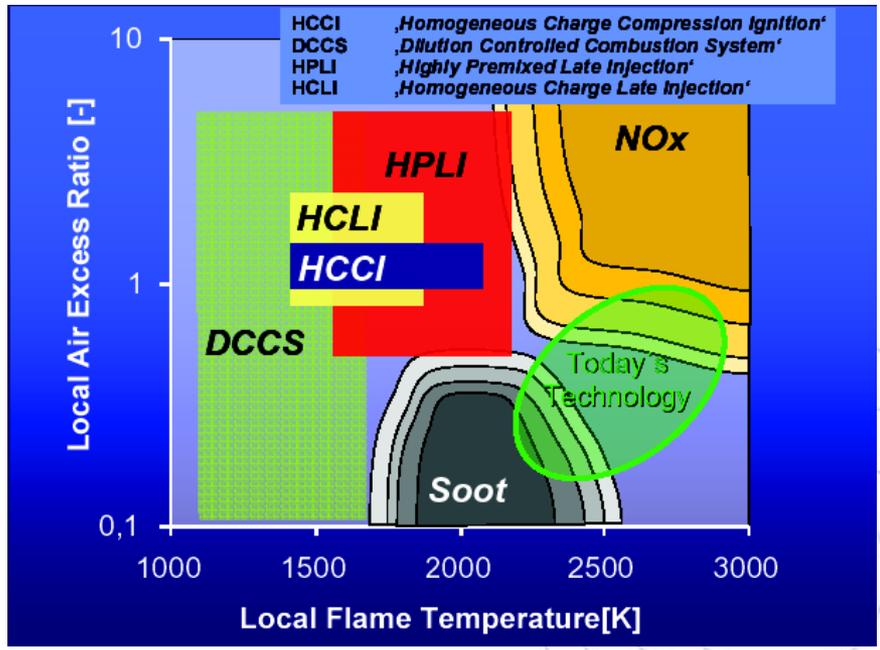
- Individual Valve lift, allows accurate percentage of gas exchange to happen.
- A/F ratio is optimized as per requirement leading to optimized fuel consumption

# Ashok Leyland Engine R&D initiated technology projects: Advanced Combustion Strategy - HCCI



## Mixed mode control:

- Advanced combustion like HCCI at low load, traditional diesel combustion at high load.
- HCCI (Homogeneous Charge Compression Ignition) combustion is the ideal combination that can give high efficiency like diesel engines and very low emissions of gasoline engines with catalytic converters.
- With mixed mode combustion, filter regeneration would be passive.
- This would be an integrated control for PM & NOx.





# OVERALL SUMMARY/CONCLUSION

- Regulations governing vehicle CO<sub>2</sub> emissions are just now emerging, but are poised to be a long term trend.
- Like criteria pollutant regulations, CO<sub>2</sub> regulations will force technologies on the vehicles that might not go commercial otherwise.
- Many of the goals on emissions and fuel diversity are met with new fuels, If the governments are implementing biofuel mandates.
- For light duty vehicles, most of the potential savings comes from improvements in the powertrain.
- Some of the technologies are favored for light-load or city operation, like hybridization and engine downsizing, and some do better in high-load or highway operation, like diesel.



# OVERALL SUMMARY/CONCLUSION

- In the HD truck sector, most of the energy saving opportunity is in the vehicle design and truck operations optimization.
- Although low fuel consumption in this segment is critical to a successful product today, 8 to 18% of fuel savings can come from wider use of technologies that are already on some trucks.
- Hybrid HD trucks are emerging in the vocational market, with payback periods of 2 to 4 years becoming possible.
- The amount of CO2 reduction witnessed in Transition from BSIII to BSIV is more than from BSIV to BSVI





People, Planet and Profit for all stakeholders especially our customers is at the core of Ashok Leyland which resonates with our Philosophy of

**AAPKI JEET  
HAMARI JEET**



THANK YOU



# Bio-Fuels

- Biofuel technology is rapidly evolving to try to meet the regulatory mandates like decreasing the CO<sub>2</sub> emissions from transportation and reducing dependency on petroleum by moving towards low-carbon fuels.

- Various feedstocks accessible ranging from sugar sources to organic waste to “ designer” crops like algae.

- Processing routes evolve from the current ethanol processes (fermentation and purification) and biodiesel route (vegetable oil esterification and purification), to second generation processes using enzymes or thermal

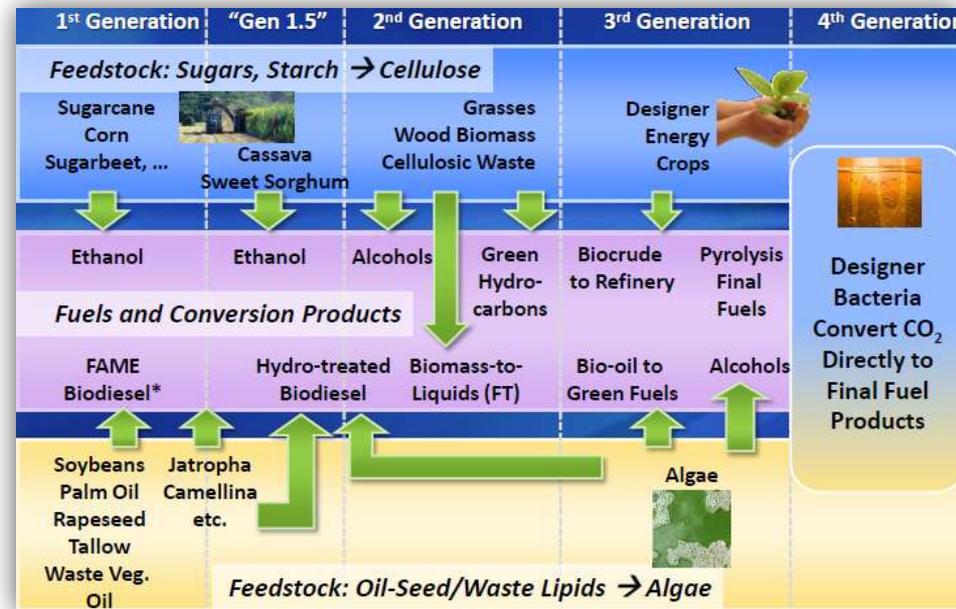


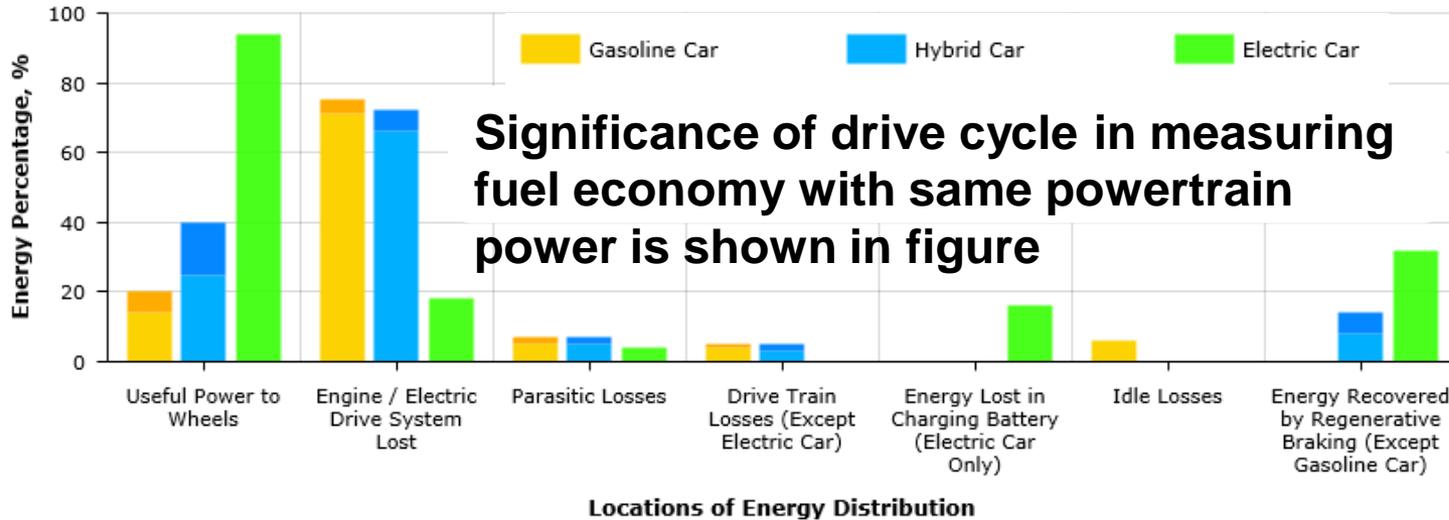
Illustration of biofuel process diversity and evolution (6).

- Normally engine manufacturers & oil companies desire a refinery integrated refinery approach. The 3rd generation encompassed in this approach.

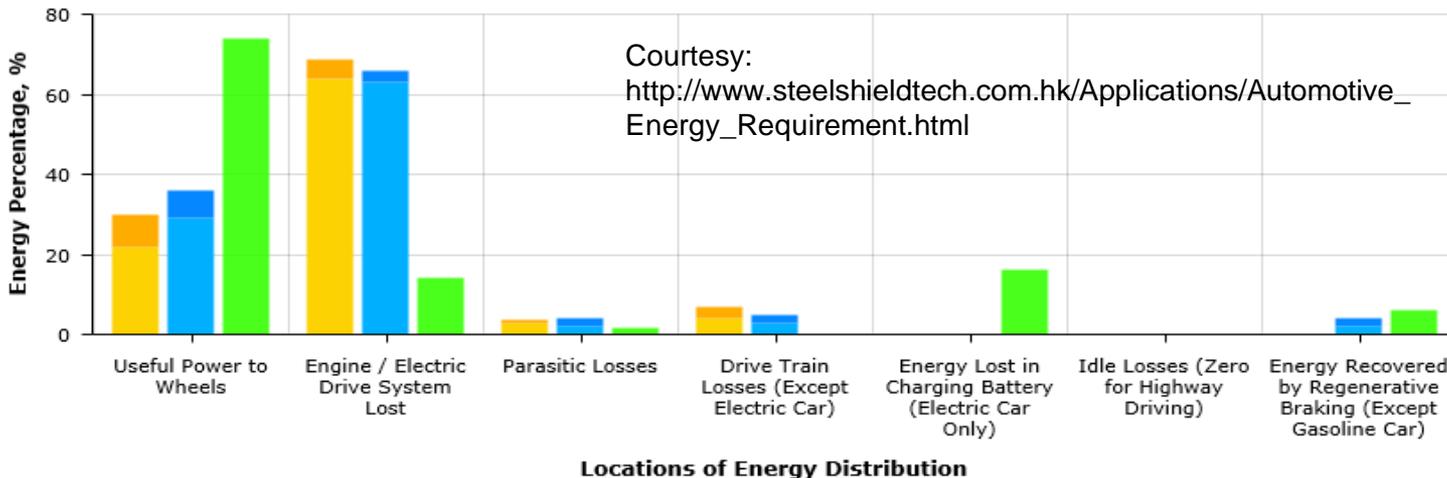


# Vehicle Energy Distribution

### Vehicle Energy Requirements for City Driving



### Vehicle Energy Requirements for Highway Driving

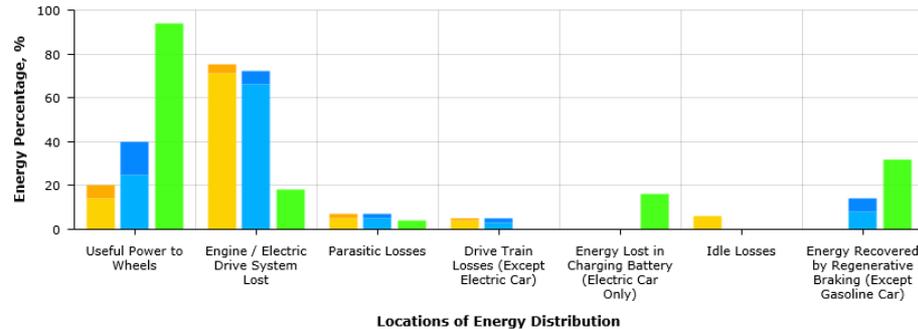


- Measured fuel efficiency depends on the drive cycle being used.
- The US Corporate Average Fuel Economy (CAFÉ) and CO2 values for certification are based on a weighting of 55% city and 45% highway driving.

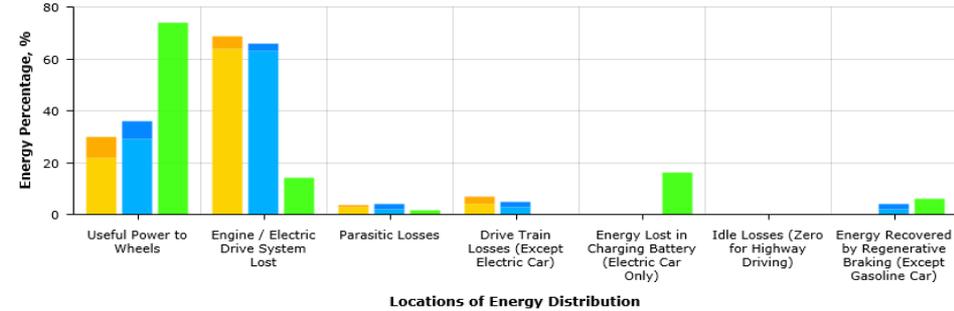


# Vehicle Energy Distribution

### Vehicle Energy Requirements for City Driving

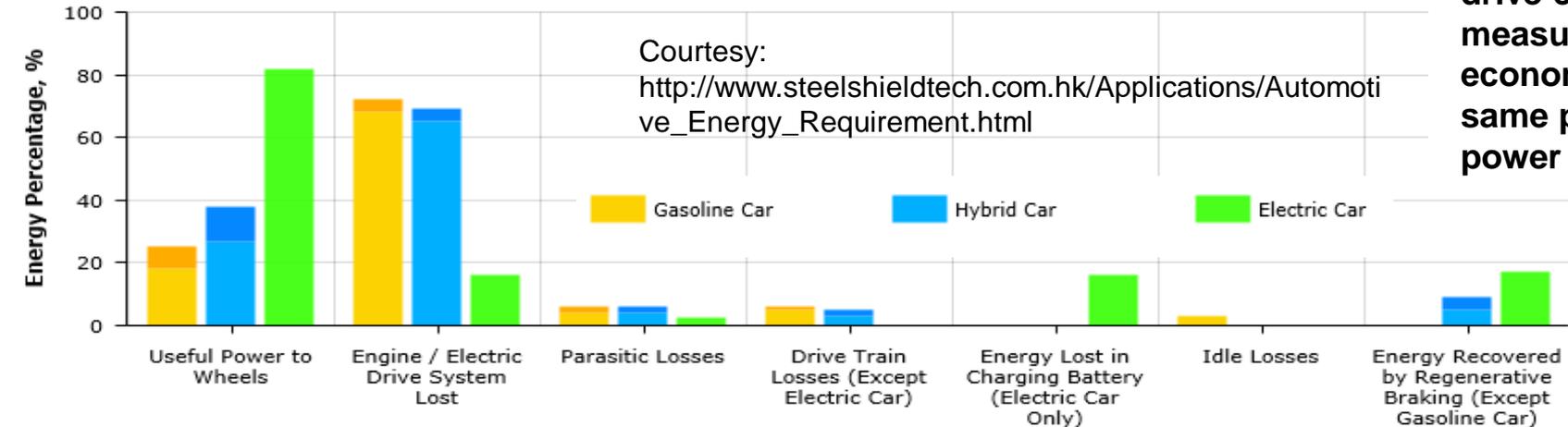


### Vehicle Energy Requirements for Highway Driving



### Vehicle Energy Requirements for Combined (City & Highway) Driving

Courtesy:  
[http://www.steelshieldtech.com.hk/Applications/Automotive\\_Energy\\_Requirement.html](http://www.steelshieldtech.com.hk/Applications/Automotive_Energy_Requirement.html)



**Significance of drive cycle in measuring fuel economy with same powertrain power**

- The connection between test cycle CO<sub>2</sub> measurement and real-world emission will depend on vehicle choice and driver patterns.
- It should be noted that certified CO<sub>2</sub> emissions could vary from actual real world emissions due to fuel differences.