

Powertrain Development considerations in Indian Scenario

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Disclaimer

**The contents presented here are my individual perceptions
and
shall not be considered as the view points of my organisation – ARAI.**

Three aims (Ms) of a modern mankind life style

Mobility

Mobile

Moon habitation

Three aims (Ms) of a modern mankind life style

Mobility

- Land
- Air
- Water



Conventional Powertrain to power the motion

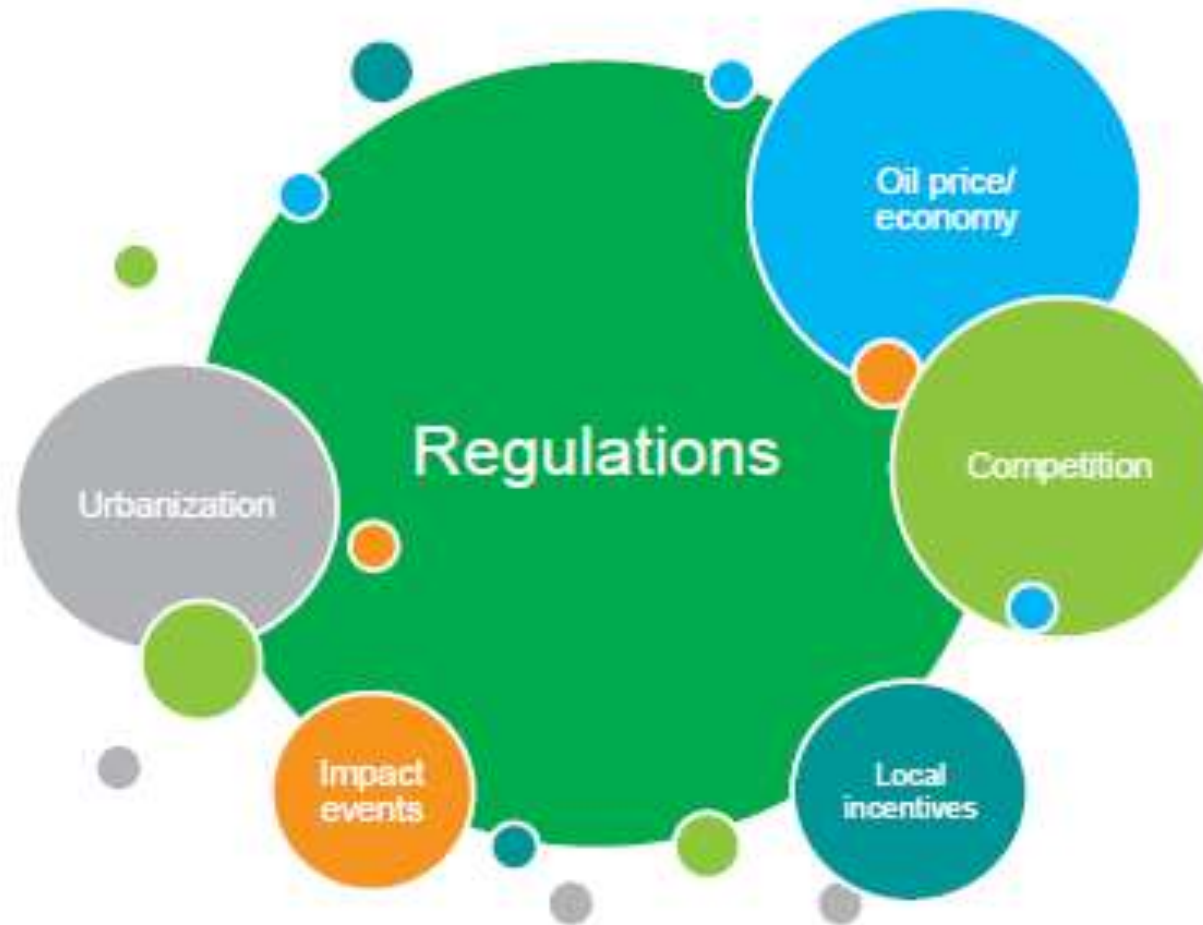


Fuel + Air (Combustion) = Force (products of combustion discharging into atmosphere)

Mobile

Moon habitation

Market drivers for powertrain production



- Oil price / Economy
- Competition
- Local Incentives
- Impact Events
- Urbanisation
- Regulations

Fuel options

- **Conventional High Carbon Fuels**
- **Alternative Low Carbon Fuels – liquid and gaseous**
- **Dual fuels**
- **Futuristic Zero Carbon Fuels**
- **NO FUEL**

Powertrain options

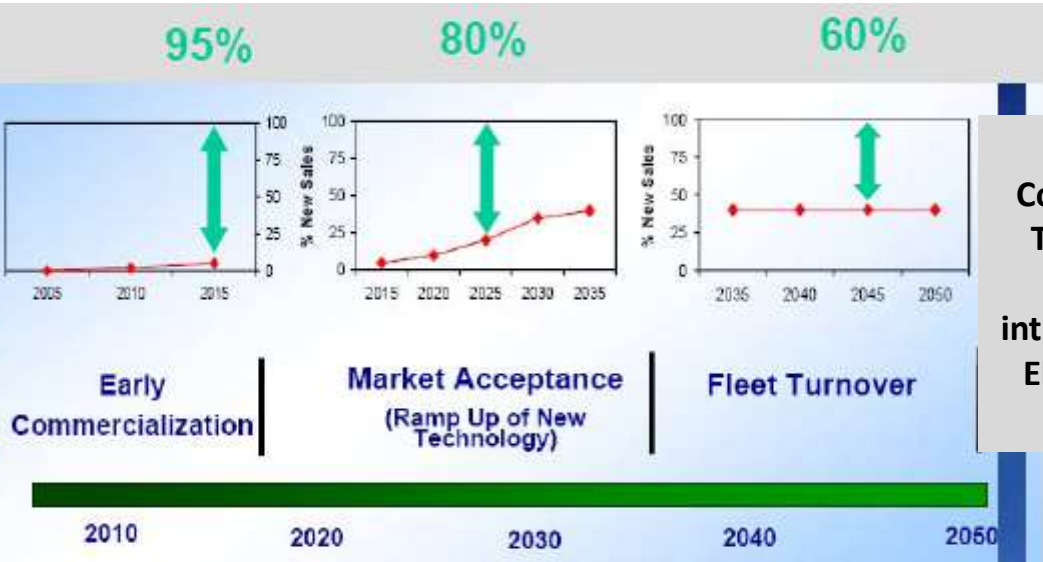
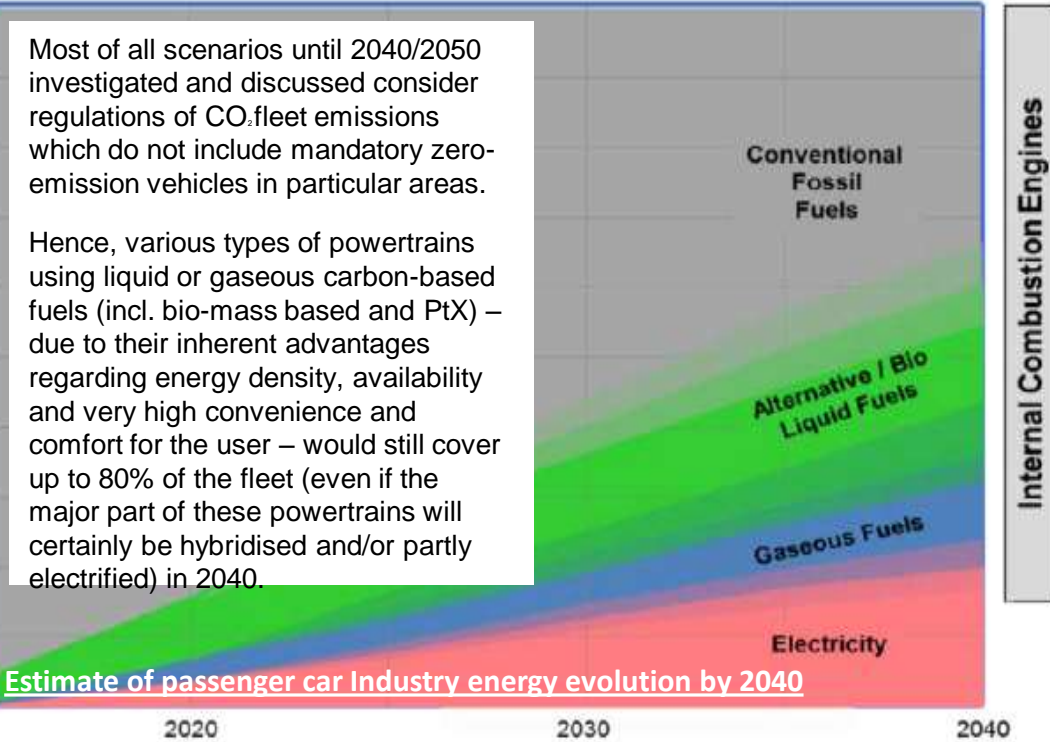
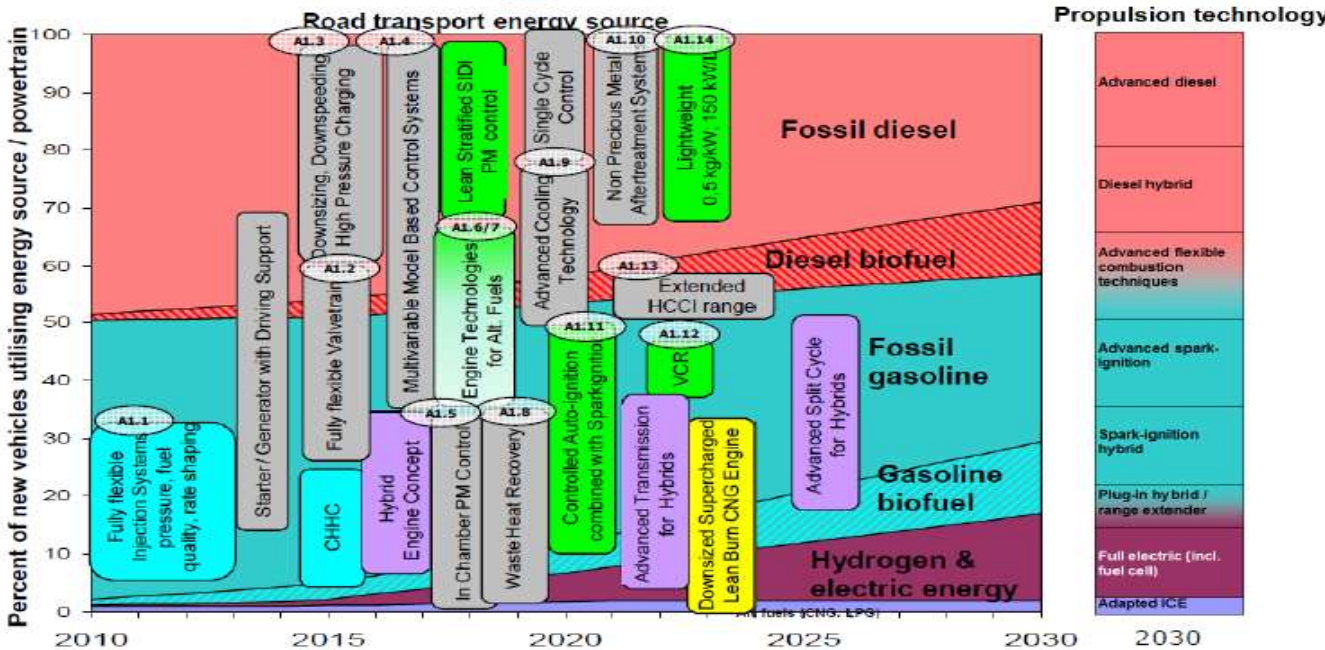
- **Internal combustion Engine based Powertrain**
- **Fully Electric based powertrain**
- **Hybrid Powertrain**

- **Cost and the profitability** will be the deciding factor in **determining the success** of **alternatives for fuel and technologies**.
- Providing the **alternative fuels and the powertrain concepts** are still **under various stages of development**.
- The most important for future fuel potential are; raw material, energy efficiency, production technology, technical maturity or stage of development.

New Passenger Cars & Light Commercial Vehicle (<3.5t)

- Gasoline technologies
- Gasoline + diesel technologies
- Diesel technologies

- MPI = Multi Point Injection
- DI = Direct Injection
- CHHC = Combined Homogeneous/Heterogeneous Combust.
- HCCI = Homogeneous Charge Compression Ignition



Share of Conventional Technology and introduction of Electric Cars - CARB -

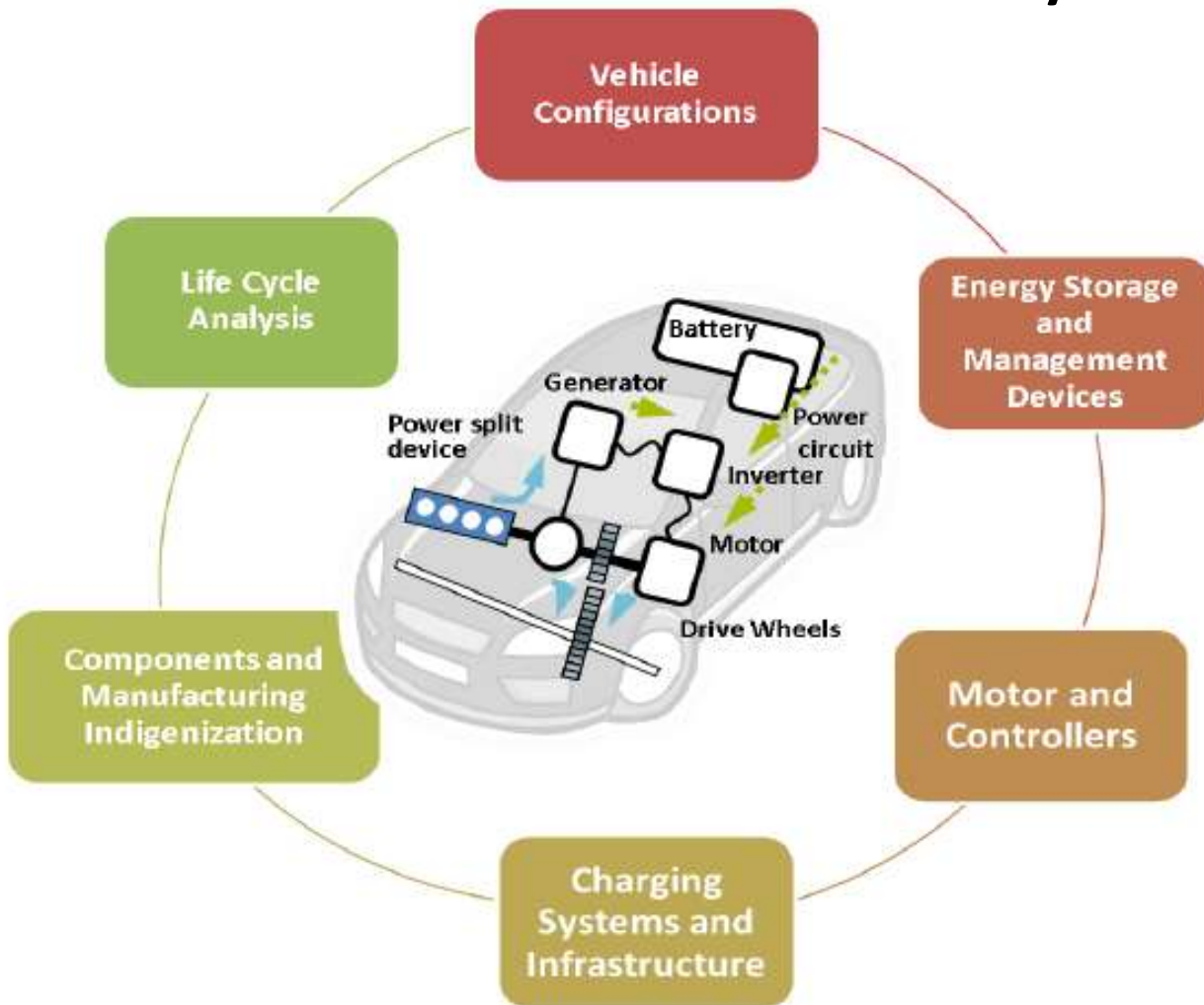
Within the evolution of the transportation sector, it is expected that fossil-based fuels will dominate the energy pool for road transport till 2030, and even on the longer time horizon (2040).

- The road transport energy supply mix will be composed of four main sectors:
- oil based fuels,
 - natural gas,
 - renewable liquid fuels and
 - electricity, itself mostly produced from renewables.

While electrification will progressively penetrate the powertrain sector, conventional fuels, power to liquid and gaseous fuels (PtX), and advanced biofuels together with an increasing amount of natural gas will play a major role in combination with Internal Combustion Engine technologies.

E-Mobility is the future and final destination

Transformation towards E-Mobility



CO-EXISTANCE

- Conventional I C Engine Powertrain
- Electric Powertrain
- Hybrid Powertrain

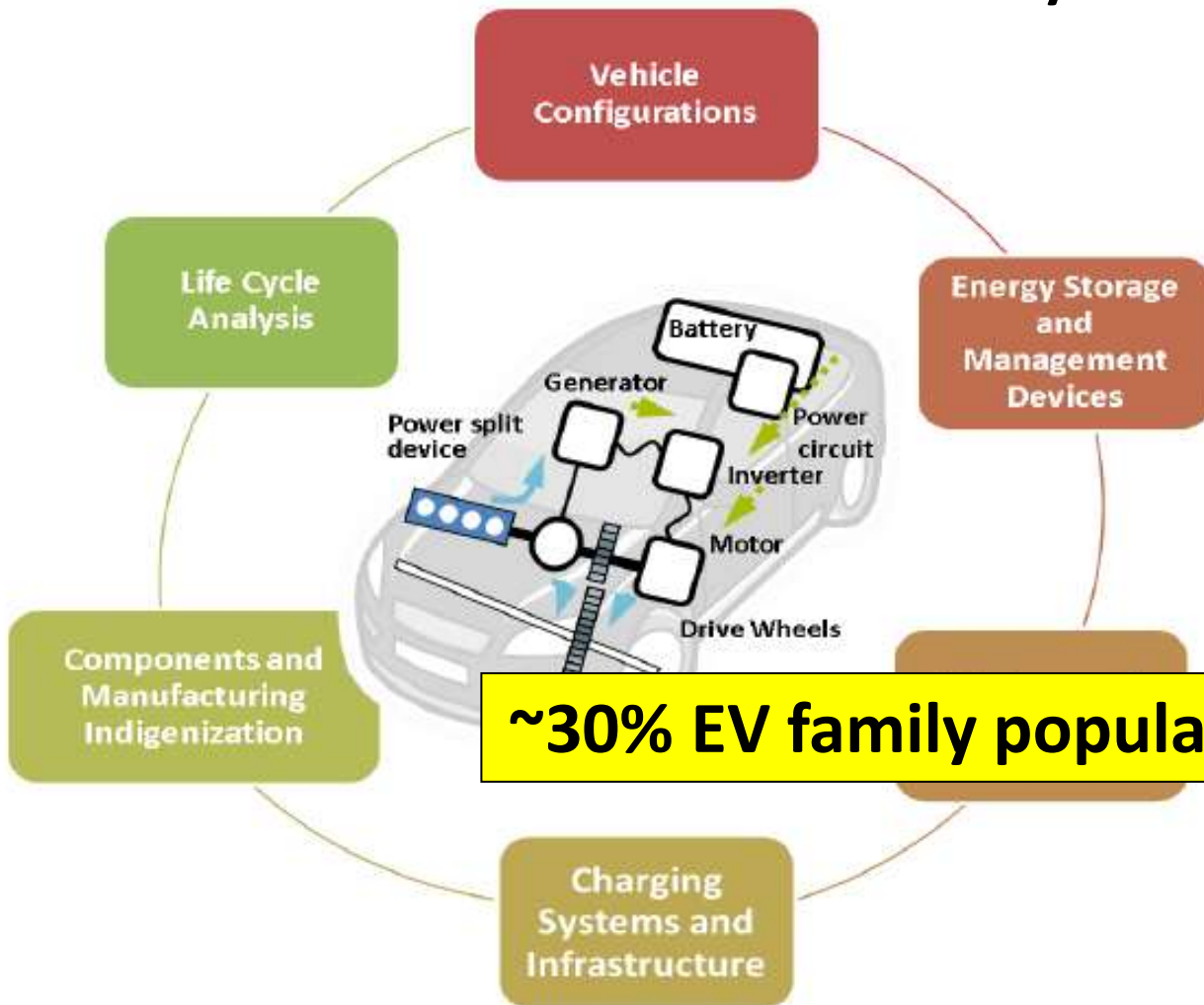
On-board charging when vehicle is moving

Action plans required :

- **Promoting e-mobility**
- Scientific measurement and control of in-use vehicles
- Developing fuel efficient vehicles
- Focused development of mass transportation
- Fostering joint research in green technologies

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Action plans required:

~30% EV family population is expected by 2035

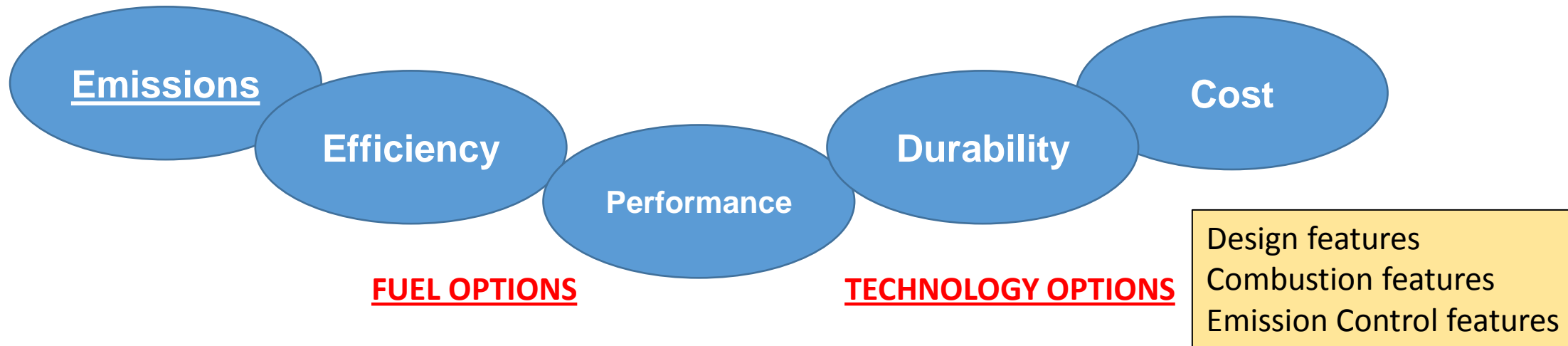
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What is rest ?

Internal Combustion Engines will continue to exist for about 3 decades

Dedicated ICE and ICE in hybrids



Regulated pollutants from ICE include –

- Nitrogen oxides (NOX)
- Particles (mass) (PM)
- Hydrocarbons (HC)
- Carbon monoxide (CO)

Additionally, there are some regulations on *smoke* emissions and *ammonia slip* emissions.

Further developments in ICE will be necessary

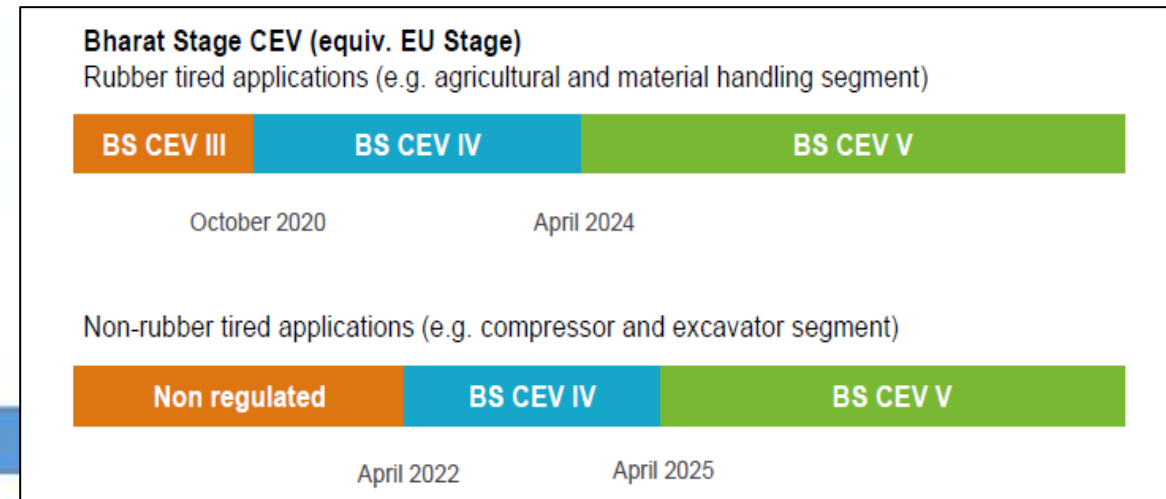
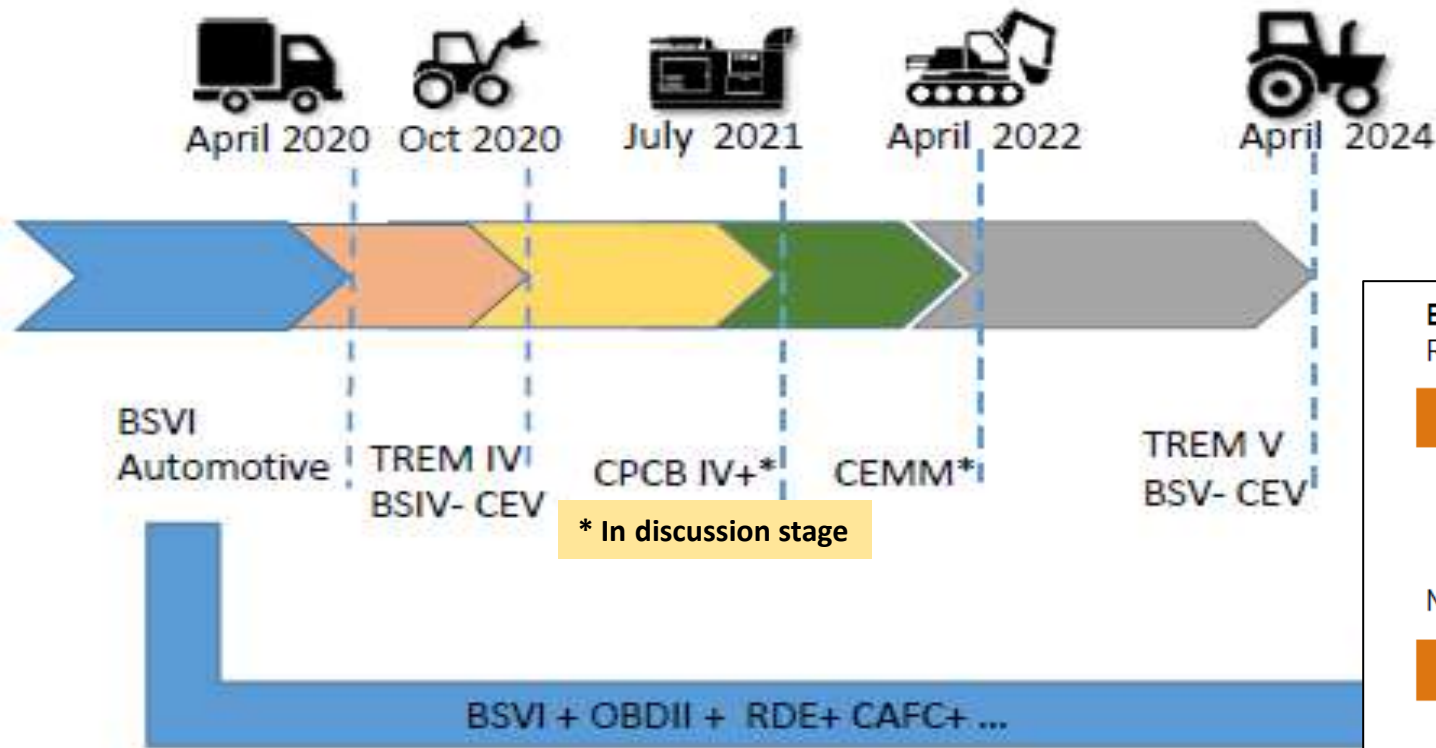
↓ **Tail pipe emissions – health and ecology considerations**

↓ **CO2 emissions – global warming controls**

↑ **Fuel economy – fossil fuel conservation / FE burden**

Road map of Emission Regulations in India

On-road vehicle engines
 Off-road / non-road vehicle engines
 Stationary application engines



Legend:

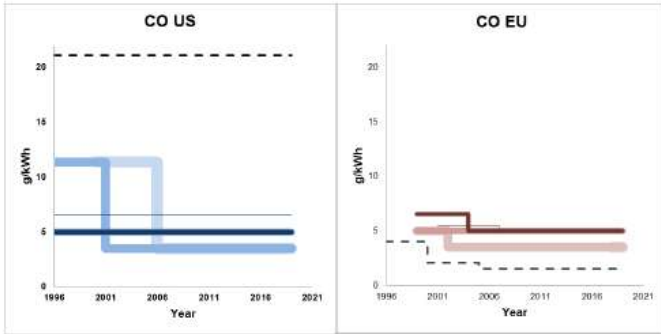
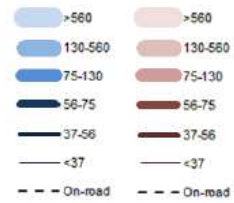


Figure 2. Progression of CO emission standards for on-road HD diesel engines and non-road mobile machinery in the two regions (US and EU).

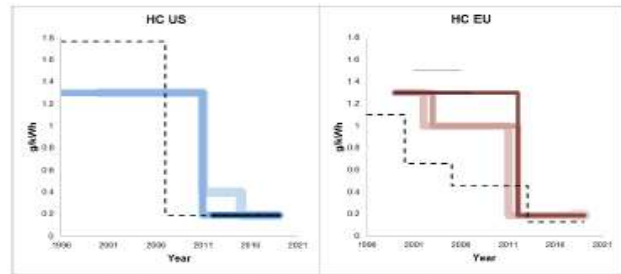


Figure 4. Progression of HC emission standards for on-road HD diesel engines and non-road mobile machinery in the two regions (US and EU).

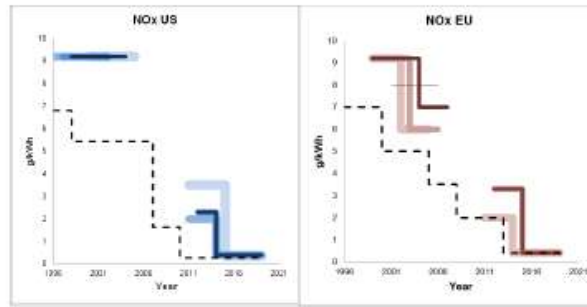


Figure 3. Progression of NO_x emission standards for on-road HD diesel engines and non-road mobile machinery in the two regions (US and EU).

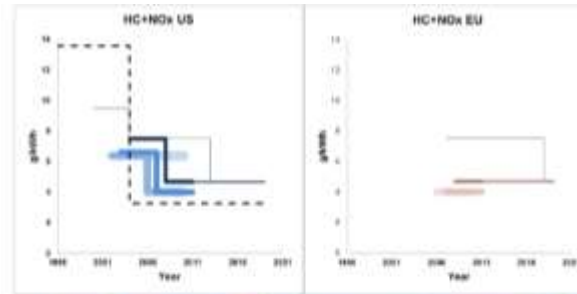


Figure 5. Progression of HC+NO_x emission standards for on-road HD diesel engines and non-road mobile machinery in the two regions (US and EU).

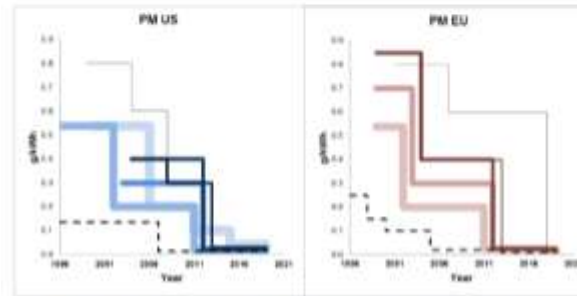
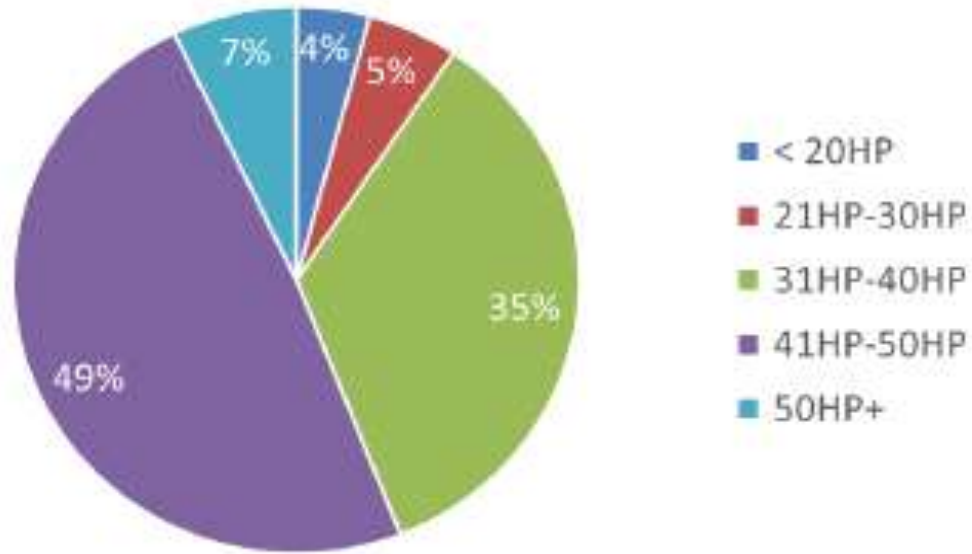


Figure 6. Progression of PM emission standards for on-road HD diesel engines and non-road mobile machinery in the two regions (US and EU).

- Engines sold today are required to meet PM and NOX emission limits that are approximately 95% lower than Tier 1/Stage I limits.
- With the implementation of BS6 on-road and BS4/5 off-road emission standards, in-cylinder controls are, in general, no longer sufficient to meet emission targets.
- Exhaust after-treatment devices have become almost mandatory requirement.

Off-road market status in India – impact of forthcoming emission regulations

FY'2017-18



Source: ICRA Research

- Based on today market, only 7% of tractors will require an After Treatment System from October 2020
- Most probably the 50HP+ market will even drop because of TREM IV introduction
- In April 2024, with the introduction of TREM V, more than 90% of the tractor market will be equipped with an ATS system

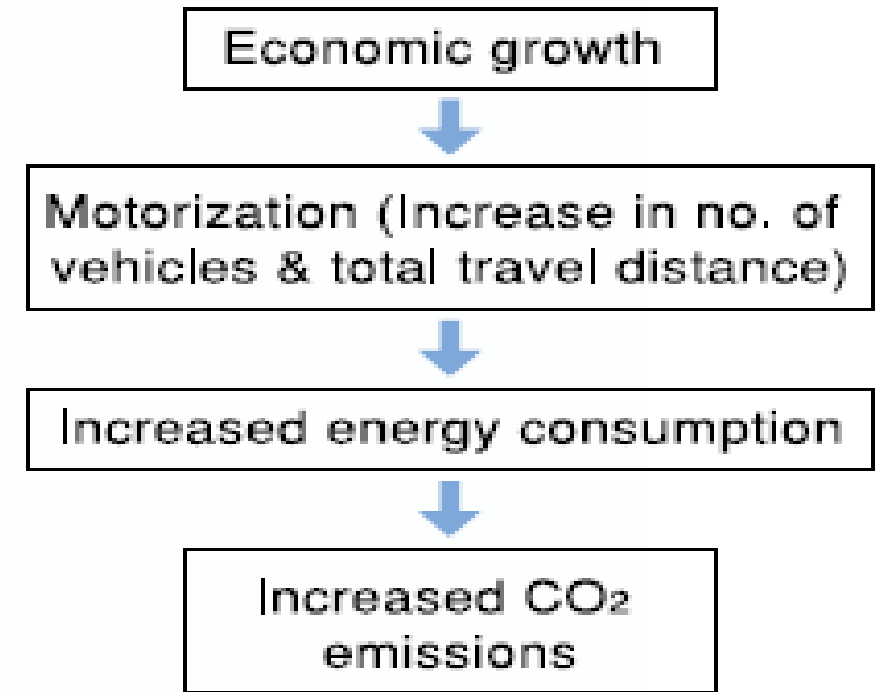
- Although there is a good experience from US and Europe is available in the background about EAT technology, however, there are severe challenges in Indian scenario because of different working conditions / working temperatures.
- Therefore, specific indigenous development efforts will be required to ensure controlled real-field emissions

EAT in general

- SCR has strong effect on NOX-emission reduction and is mandatory for achieving the BS IV / V NOX-emission regulation in 56 kW to 560 kW category off-road engines. EGR has now limited effect on NOX emissions.
- DPF is the most effective way to reduce particle mass emissions and will be necessary to comply with regulations of particle number as well.
- DOC has a strong reduction effect on HC and CO emissions.

India – Facts of Life

- Traffic Congestion
- Bad maintenance of vehicles
- Fuel quality controls
- Bad and unsafe road conditions
- Poor road signal synchronisation
- Poorly supported public transportation
- Co-existence of old and new technology
- Rough and hard driving habits
- Safety on the roads
- Social culture – alignment with advances



**GOOD SPEC
+ GOOD DRIVING
= GREAT FUEL ECONOMY**

High Congestion



Cities	Average Traffic Speed (Km/hr)	
	2016	2017
Hyderabad	27.1	18.5
Bangalore	20.4	17.2
Delhi	26.5	25
Mumbai	21.6	20.7
Pune	21.9	19.4
Kolkata	20.2	19.2

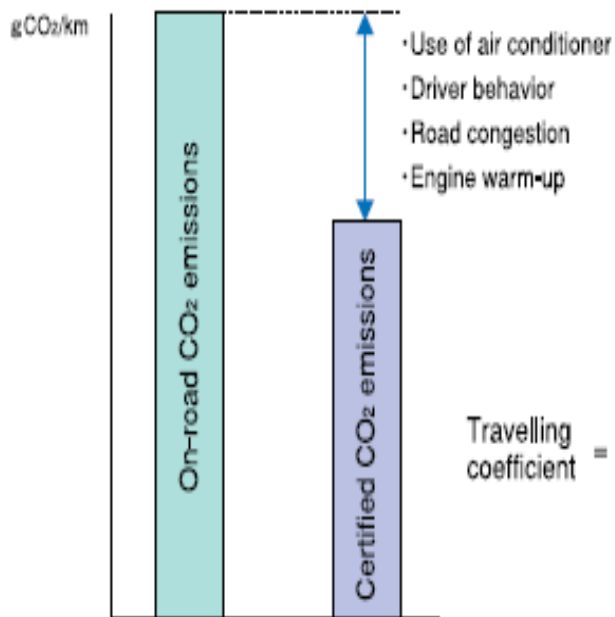
IMPACT OF VEHICLE SPEED ON CO2 EMISSIONS

CO₂ emissions



Source: Japan Automobile Research Institute

High Congestion → Reducing Speed → Rising Emission



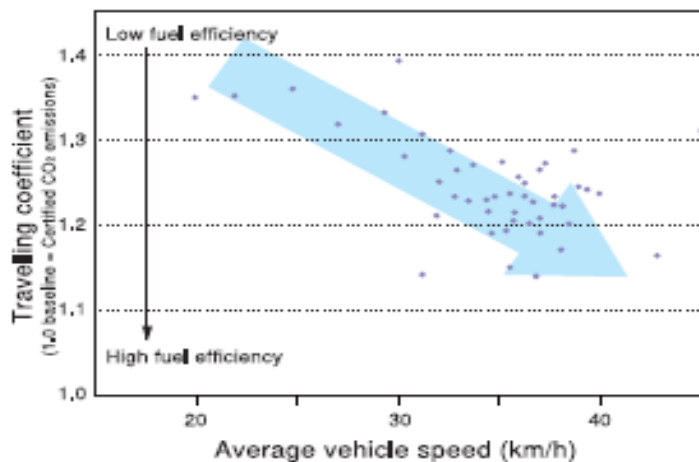
$$\text{Travelling coefficient} = \frac{\text{On-road CO}_2 \text{ emissions}}{\text{Certified CO}_2 \text{ emissions}}$$

On-road CO₂ emissions are usually higher than certified CO₂ emissions due to number of factors –

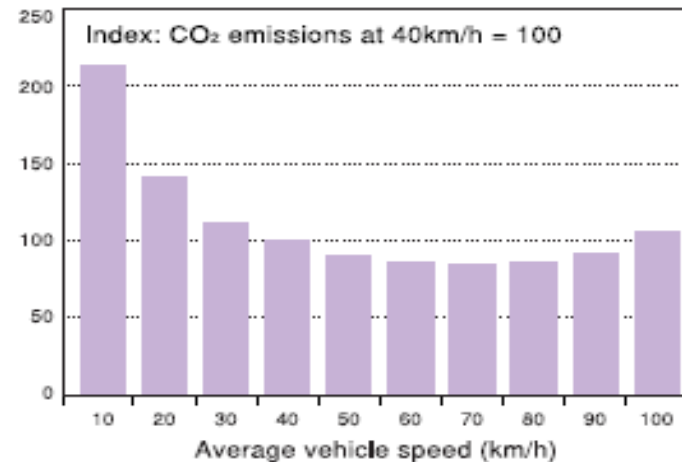
- Engine warm-up
- Use of air conditioner
- Road conditions
- Driver behaviour – abrupt acceleration, sudden braking, poor gear selection

Aim is to reduce CO₂ Travelling Coefficient by way of reducing discrepancy between lab and real life operations

Travelling Coefficient Values in Congested Traffic (Japan Case Study)



Impact of Vehicle Speed on CO₂ Emissions

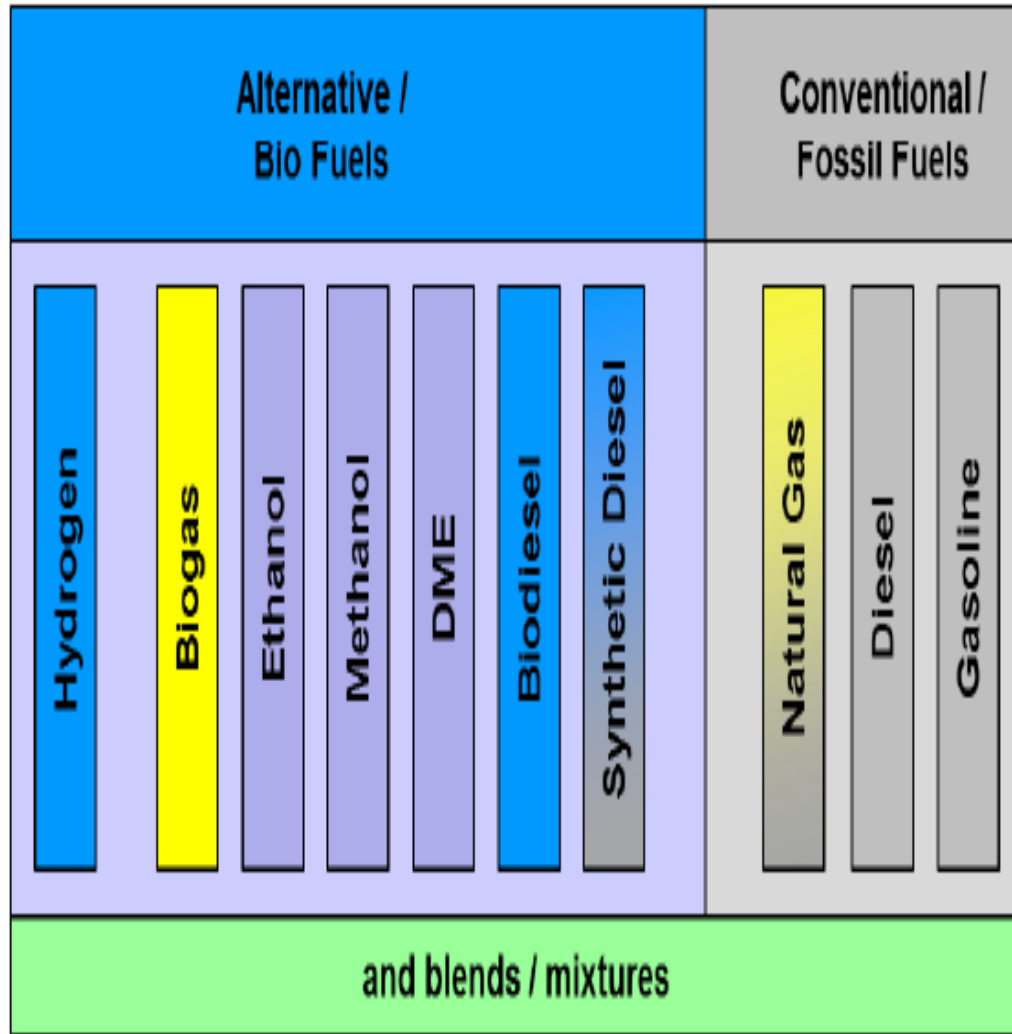


Improved traffic flow increases the vehicle speed – increased fuel efficiency, reduced CO₂ emissions

Improved traffic flow –

- Upgrading roads and road infrastructure
 - avoiding frequent start stops,
 - less road cutting
- Signal controls and synchronisation

The role of alternative fuels



On the Heavy Duty application side, CNG is already widely used for short range journeys like those conducted by urban buses and delivery trucks and has huge potential for extension of use to long haulage applications.

Development and dissemination of LNG technologies in long haulage application has a future providing an alternative and cost competitive solution to Diesel, thanks to a lower fuel operating cost, a better environmental footprint and a simpler after-treatment system (3 way catalysts in case of lambda = 1 approach versus DPF+SCR system).

For Diesel-like efficiency and taking advantage of the CNG's improved hydrogen to carbon ratio in comparison to Diesel, a lean diffusive combustion concept needs to be developed in conjunction with an appropriate exhaust gas aftertreatment system.

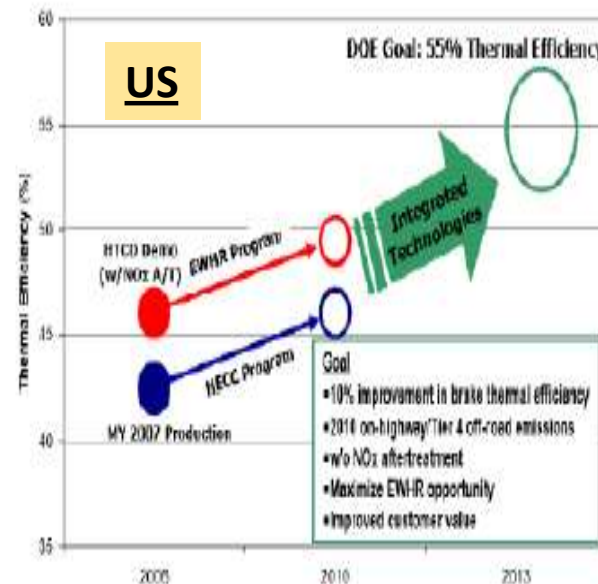
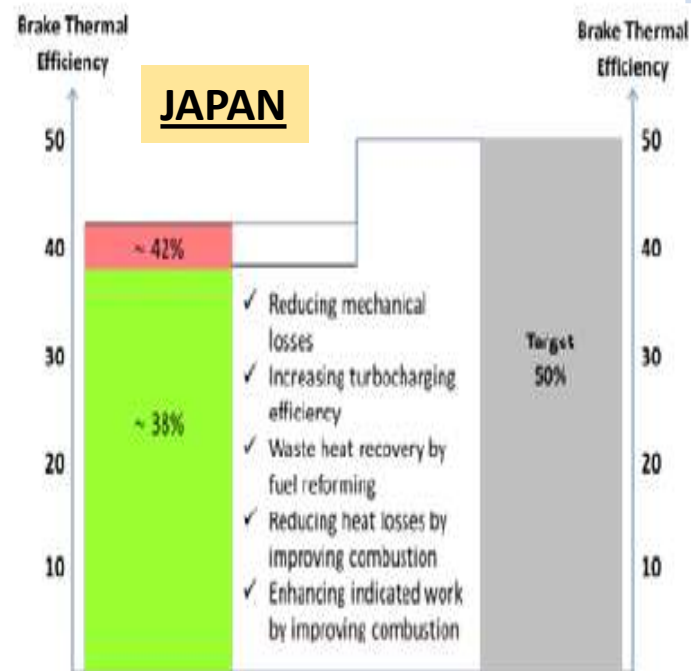
The CO₂ benefit potential of such a Natural Gas concept with respect to Diesel combustion could be as high as 20%.

Thermal efficiency targets

Japan R&D Program ----- 50%

US SuperTruck Program -55%

Config	Thermal Eff	Fuel Cons
Gasoline	38%	226 g/kWh
Diesel	42%	205 g/kWh
Diesel	50%	172 g/kWh

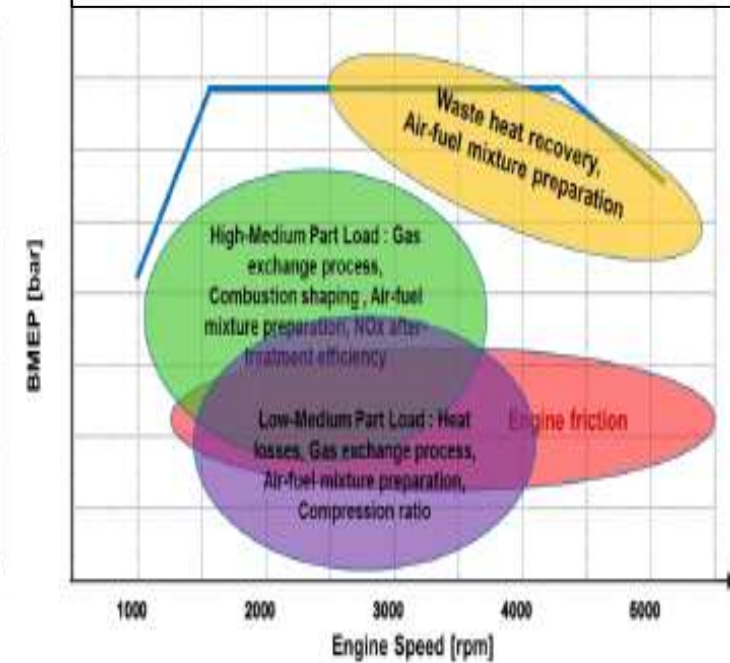


- Friction reduction
- Reduction of throttling losses from SI engines
- Cylinder de-activation
- Surface coatings
- low viscosity lubricants
- Atkinson/Miller cycles
- Variable compression ratio
- Advanced variable valve actuating systems

Enhancing overall thermal efficiency

It is important for the ICE to increase the thermal efficiency in the entire engine operating range

- Gas Exchange Process
- Boosting
 - EGR network
 - Port Flow capabilities
 - After cooling



- Thermodynamic engine process
- Heat loss reduction
 - Combustion shaping
 - Compression ratio
 - Air-fuel mixture preparation
 - Waste-heat recovery
 - NOx after-treatment efficiency

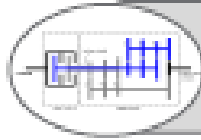
- Engine mechanics
- Downsizing and Downspeeding
 - Piston and rings
 - Low viscosity oils
 - Reduced peak firing pressure
 - electrified ancillaries
 - Thermal management

- 50% brake thermal efficiency can be reached only with radically different ICE technologies.
- It is necessary to have electrification of the powertrain i.e. for hybridisation.
- Higher efficiencies can be realised with an electrified ICE powertrain (ICE + Electric support).

FE Improvement Technologies



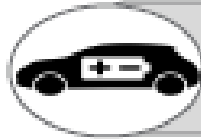
Engine Measures



Transmission Measures



Hybridization



Electric Vehicles

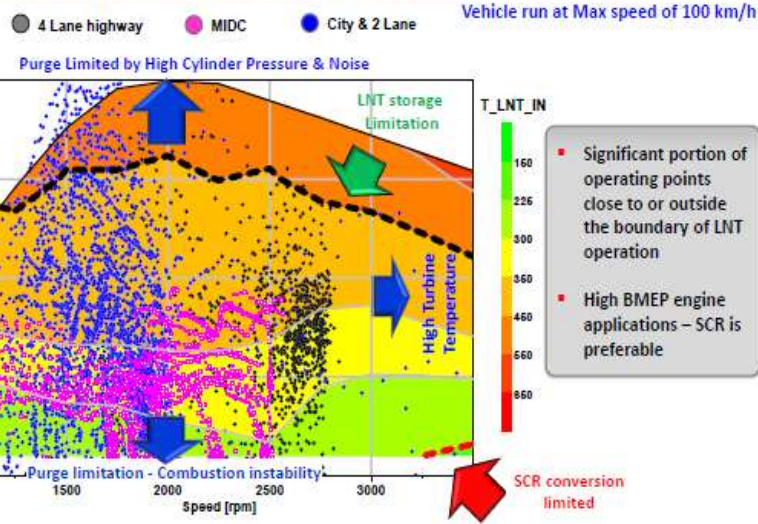


Vehicle Improvements – Weight, Coast Down, DTL

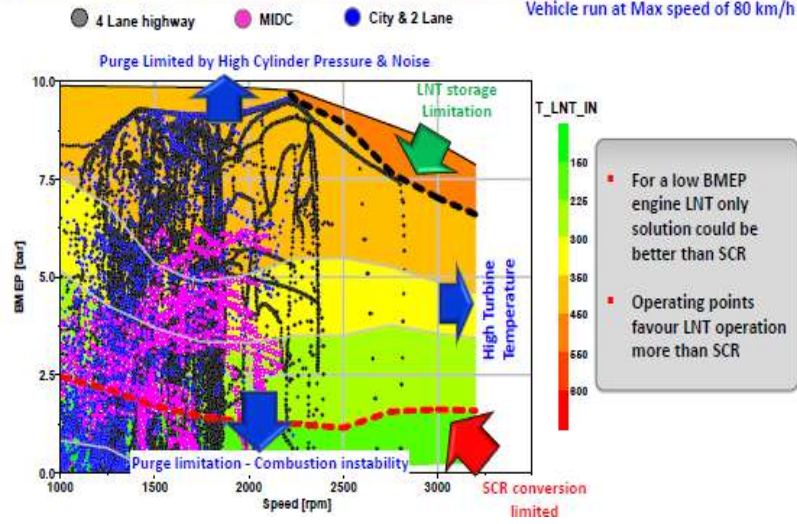
EAT development considerations

- **Cost.** Especially for smaller-sized engines, the cost of advanced emission control technologies relative to the cost of the engine can be prohibitive. For large power classes, costs associated with engine development must be recovered on a relatively low sales volume.
- **Packaging constraints.** Non-road engines must fit in a variety of equipment envelopes. Power class and shape changes resulting from the adoption of emission control technologies can affect sales and suitability of engines for specific equipment types.
- **Operating environment.** Non-road equipment is often used in more challenging environments than those encountered by on-road vehicles, leading to higher vibration and mechanical stress and increased exposure to dust. Also, the velocity of non-road equipment cannot be relied upon to cool the engine, resulting in thermal management challenges.
- **Duty cycles.** Engine operating modes tend to be different from on-road duty cycles. Key parameters for effective emission control design may differ (such as exhaust temperature), and work cycles over which control equipment must be effective, vary considerably.

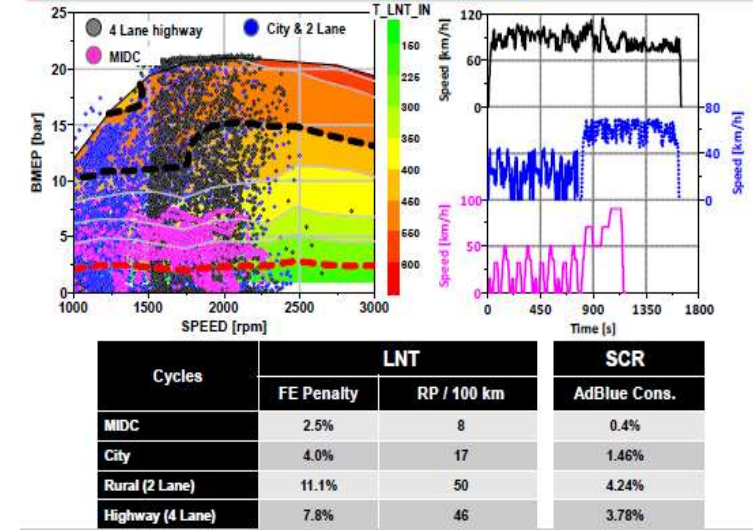
Lean Operation – High BMEP / without Speed Limitation



Lean Operation – Low BMEP / with Speed Limitation



LNT Vs SCR : High BMEP Engine



- Lab emissions
- Real-Life emissions

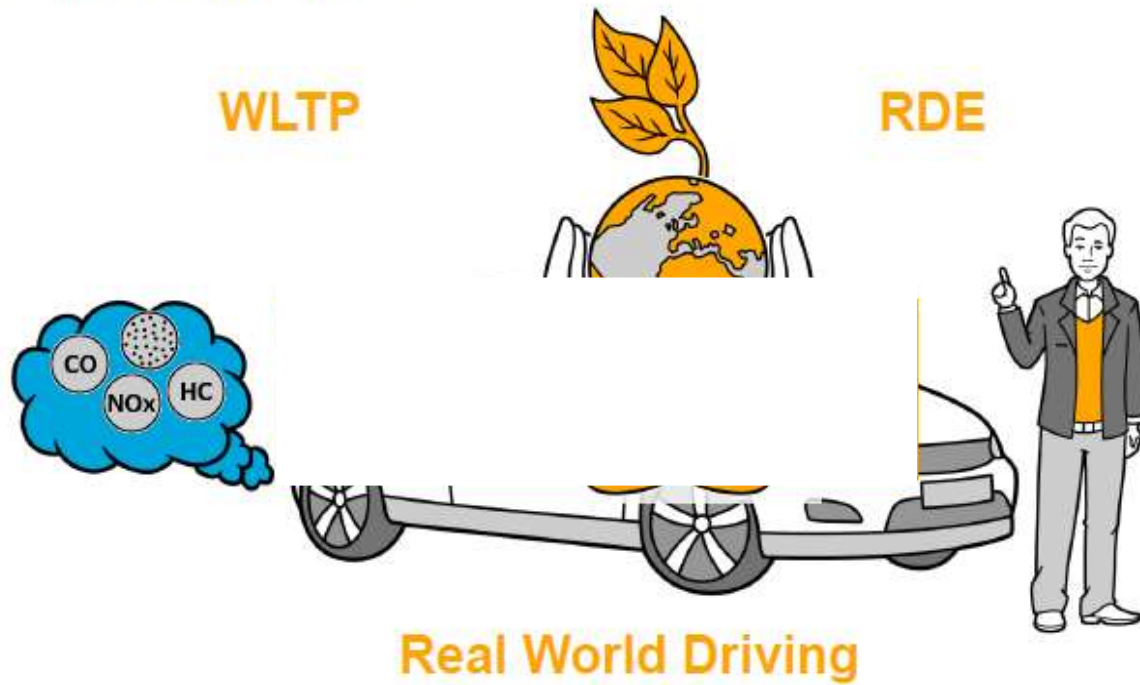


Factor of Real-life to Lab emissions is desired to be as close as possible to unity

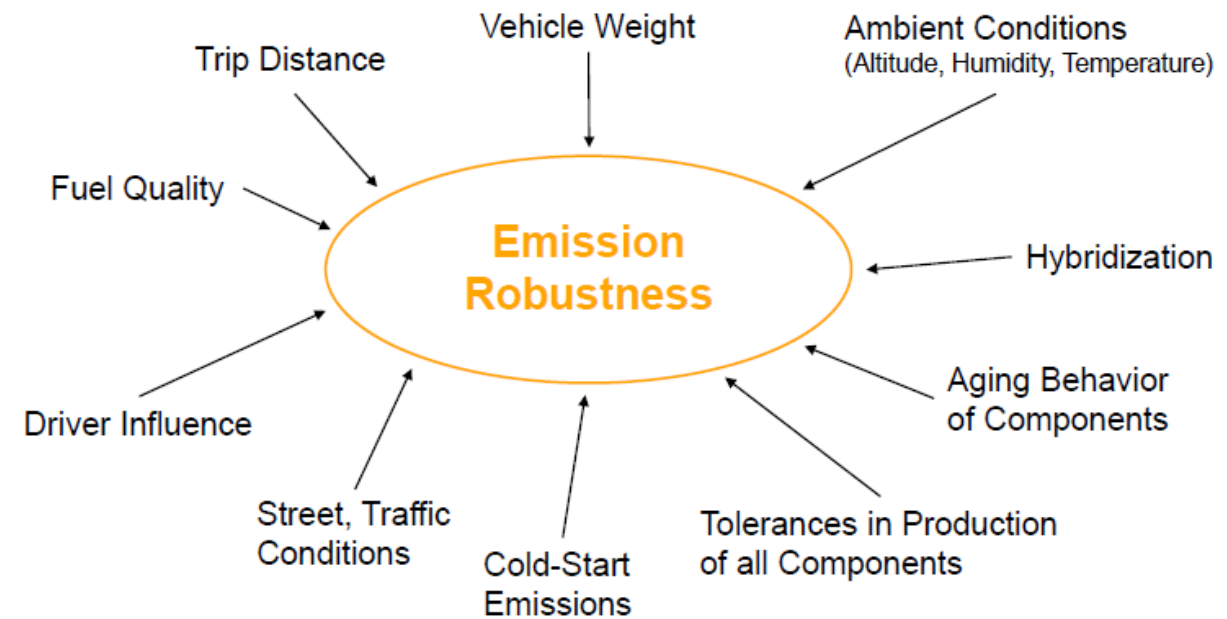
Robustness in emission performance

Challenges for the Powertrain Development

Emission Robustness



Key Challenge: Emission Robustness



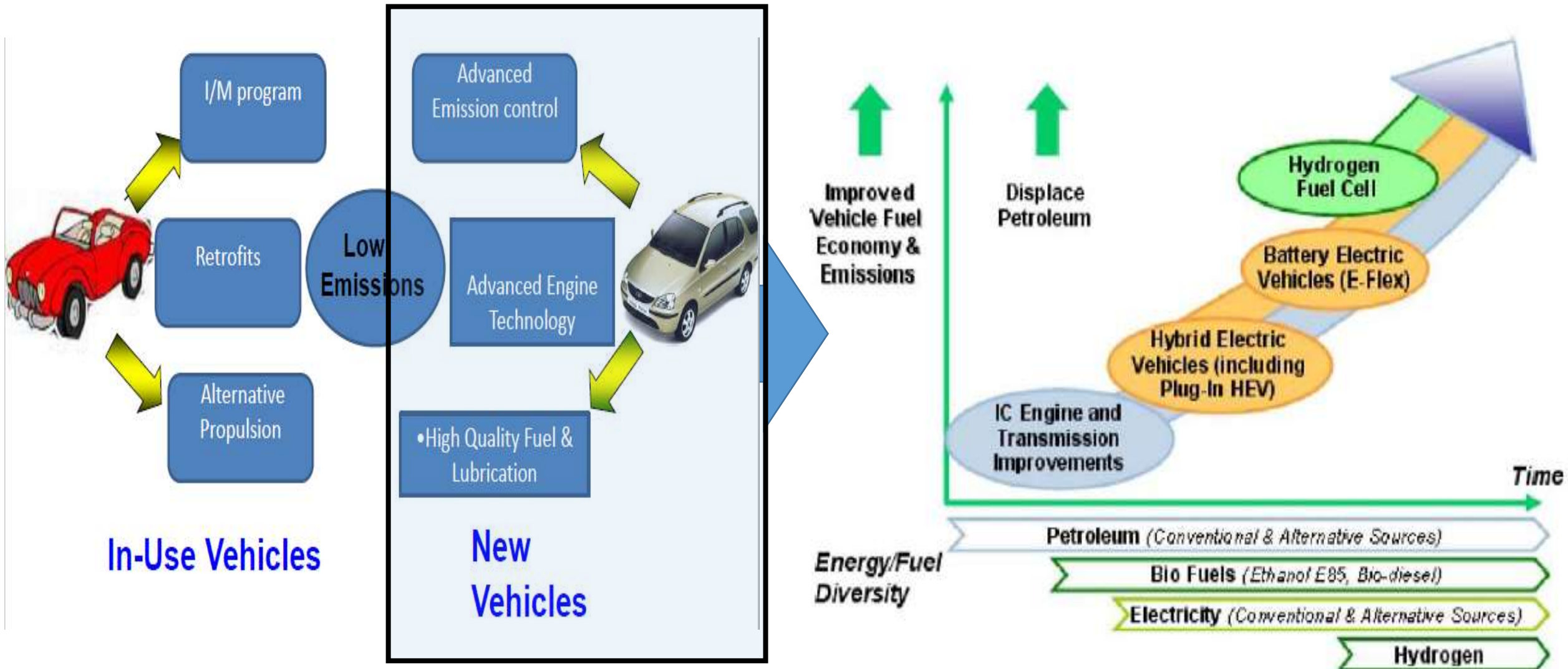
Special approach is required for EAT R&D in India :

- Exhaust After-treatment development for lower exhaust temperature operations
- Deposition control at lower temperatures
- High efficiency at lower packaging volume
- Cost of development
- Cost of EAT system
- Highest conversion efficiencies within Packaging volume constraints
- Pre-cylinder treatments to change boundaries of nitrogen and oxygen reaction temperatures
- Particle number control technology other than DPF
- All-in-all; Right Technology at affordable cost

Strategy for Old and New Vehicles

CO-EXISTANCE

Alternative Propulsion Systems



Closing Remarks

Way Ahead

- Further improvements in combustion systems - e.g. LTC
- Incorporation of advanced engine design features for improving the efficiency – e.g. VVA, VCR, Miller cycle, etc
- Alignment of Exhaust After-treatment control devices with real field operating conditions
- Promotion of alternative fuels with a clear road-map
- Improved drive line systems with reduced losses and efficient power flow at wheels
- Advanced design features for vehicle systems
- Adequate considerations for Emission control, Economy enhancement and Safety aspects
- Strict implementation of I & M for all categories
- Road map for Retro-fitment
- Scrapping / Disposal policy implementation of old and tempered vehicles
- Clear and phase-wise achievable Road map for new powertrains – Hybrids, BEVs, FCEVs, etc

- **Diesel remains the most efficient technology for transporting goods. Advance combustion systems and exhaust after treatment strategies makes diesel shows promising future. Relevance further increases with Euro VI in particular being a step-change for very low emission values and potential closeness to real-world emissions. Diesel will continue to be preference for commercial, offroad, and heavy duty applications. Interest for hybrids may grow subject to clarity and support through policies.**
- **GDI is growing interest with further improved specific power, better thermal efficiency, fuel economy competing with diesel. Small vehicles, cars, light goods carriers could employ GDI singly and in hybrid configuration.**

- **New fuel options such as CNG, LNG, Ethanol, Biofuels.**
- **Government pushing electrification.**
- **Small vehicles and city buses best immediate candidates for E-mobility.**
- **There is some confusion about hybrids. Hybrids shall be promoted as an intermediate solution for medium and heavy duty segment.**

INDIAN SCENARIO

- **Future is unclear. Several Options. Simultaneous technologies.**
- **No single technology or strategy a final answer.**
- **Many options will coexist.**
- **Political and public pressure may drive an earlier end to the diesel engine than the industry demands.**
- **Maturity of EV charging infrastructure and viability will decide the uprooting of diesel.**
- **Transition through Hybrids would be practical.**
- **Hydrogen and FUEL Cell based mobility will be the final destination after 15 years.**

**Supporting Infrastructure should be in place and well matured,
aligning with the implementation plan of any technology.**

Advancements in Mobility to align the changing life style and social needs

- **Electrification**
- **Autonomous** (driverless)
- **ITS**
- **Shared**
- **Connected**

Indian Scenario

Emissions



Efficiency



Safety



Luxury



**Because of changes in life style,
Mobility is going through a Transformation in India also**

- **There are several technological solutions**
- **There are several combinations**
- **There are several driving forces**
- **There are several customer perceptions**
- **There are several local real-field aspects to be considered**

Quote of the day!

Any Technology is, of course, a double edged sword.

Fire can cook our food. Fire can also burn us.

(Jason Silva)

What do we do then !!!!

Choose the right solutions.

“ The Right Technology Matters “

..... for a sustainable ICE Mobility of FUTURE



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**Thank
you**

