Engine Development Trends and the Implications for Transport Fuels

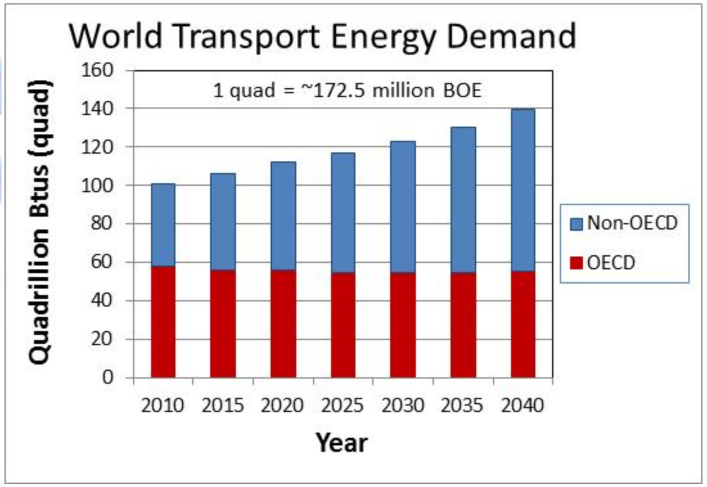
Gautam Kalghatgi

Structure of the Talk

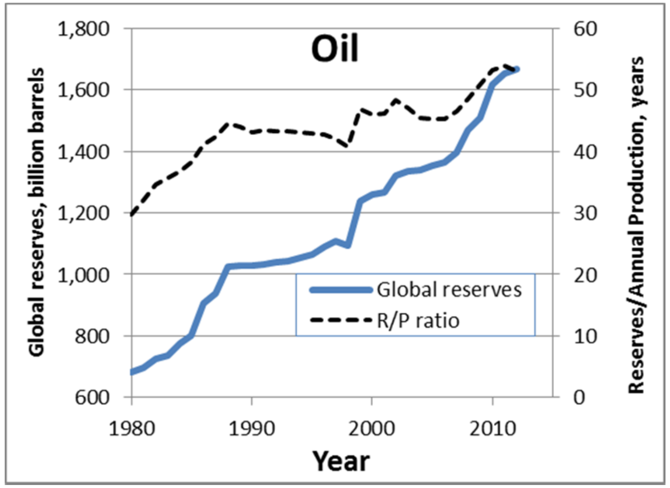
- Demand /Supply Outlook for Transport Energy
- Current engines and fuels
- Engine development trends and the implications for fuels for
  - SI Engines
  - CI Engines
- A possible future scenario for transport fuels

World Transport Energy

- Transport is essentially driven by liquid fuels – high energy density, ease of transport and storage, extensive infrastructure
- ~95% of transport energy supplied by petroleum
- Demand is increasing – mostly because of growth in non-OECD countries



U.S. EIA (Energy Information Admin.)



Source: BP Statistical Review of World Energy 2013

Plenty of oil will be available

Even in 2040, ~90% of transport energy from petroleum - alternatives cannot grow fast enough

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Current IC Engines

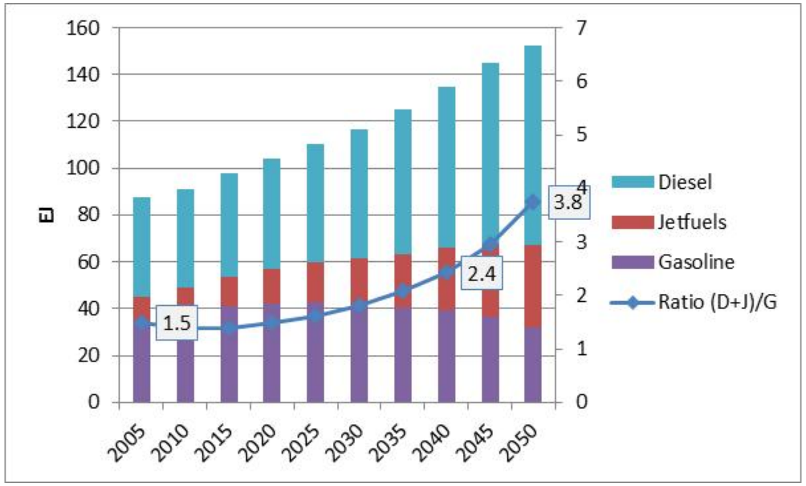
- Spark Ignition (SI) – fuel/air are mixed and compressed, heat release via expanding flame.
  - Uses gasoline.
  - Light duty.
- Compression Ignition (CI) – air is compressed, heat release via autoignition of fuel as it mixes with air.
  - Uses diesel fuel.
  - Mostly heavy duty.
- CI engines more efficient but more expensive

Current Fuels for IC Engines

- Gasoline and diesel complex mixtures of hydrocarbons
- Primary fuel property is the autoignition quality –
- Gasolines are resistant to autoignition to avoid knock (measured by octane numbers, RON and MON) – used in SI engines
- Diesel fuels are prone to autoignition (measured by Cetane Number) – used in diesel engines
- Diesels are also less volatile, heavier. (Jet fuel is like a lighter diesel)

Transport Energy Demand Increase Skewed Heavily Towards Commercial Sector

- Passenger Car Sector – a) future average car will be smaller/lighter and drive fewer miles compared to today b) larger scope for efficiency improvements e.g. hybridisation



WEC, World Energy Council. Freeway Scenario.

- Very significant investments (100s of billions of dollars) in refineries will be needed to change the global demand slate
- Significant number of future CI engines (especially heavy duty) will have to move from conventional diesel fuel to alternatives such as natural gas, light fuels

Engine Development Trends

High efficiency, low emissions and affordable

SI Engines : Improve fuel economy – downsizing and turbocharging.

- Knock and fuel anti-knock quality become important
- Cost increase if high performance is to be maintained

CI Engines: Reduce soot and NOx.

- High engine/after-treatment cost with existing diesel fuel
- Efficiency might be compromised

Hybridization:

- Cost increase
- More benefit in low-duty urban cycles.
- Easier to implement on light-duty vehicles

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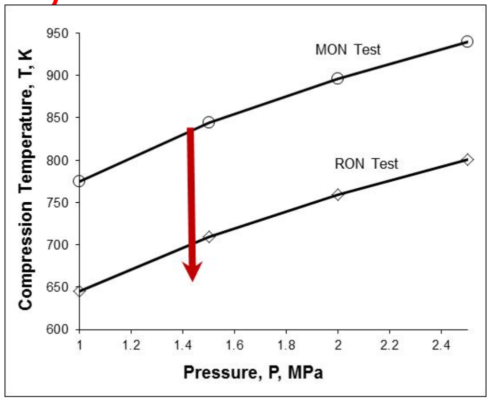
Fuel Requirements of Future SI Engines -1

• Higher efficiency requires higher anti-knock quality (measured by RON and MON) fuels.

• For a given RON, lower MON has higher anti-knock quality.

This is because, a) they will run at higher pressures for a given temperature – thermodynamics.



AND b)for a given temperature, if pressure is increased, real fuels become more resistant to knock compared to PRF used for the Octane Scale – chemical kinetics

MON has been losing importance through the last 80 years as engine efficiency has improved

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SI Fuel Implications

- Current specifications and other fuel initiatives are often not consistent with this requirement

Minimum MON of 85 in Europe

Anti-knock quality specified by(RON+MON)/2 in the U.S.....

Result - **harder-to-make and less suitable fuels for current and future engines.**

- Rational specifications needed. Some are necessary e.g. low sulphur and benzene but others?

Introducing MON specifications where there are none is a retrogressive step

- Preignition and superknock in downsized, turbocharged engines. Higher anti-knock quality helps mitigate superknock

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Low NOx/low soot in CI engines

- Conventional CI (diesel) engines have high efficiency but high particulate and NOx emissions
- Regulations to control these pollutants are getting tighter.
- Promoting mixing of fuel and air before combustion reduces smoke
- Low-temperature combustion reduces NOx – lean mixtures + EGR (exhaust gas recirculation)
- Diesel fuel ignites too quickly before fuel can mix with oxygen– low NOx/low smoke is very difficult.
- Technology which makes CI engines expensive and complicated is aimed at overcoming this difficulty – high injection pressures, expensive after-treatment

Gasoline Compression Ignition (GCI)

- Inject "gasoline" earlier than you would with diesel fuel
- High ignition delay makes pre-mixed, low NOx/low soot CI combustion very much easier
- Great scope for simplifying the future CI (diesel) engine by running it on gasoline-like fuels –
  - lower injection pressure
  - HC and CO rather than NOx after-treatment
  - very high efficiency, scope for "downsizing", exploiting low noise at low load to improve efficiency…..
- Needs low octane gasoline - 70 to 85 RON but could be much less volatile than current gasolines. **Save energy / CO2 also in the refinery**

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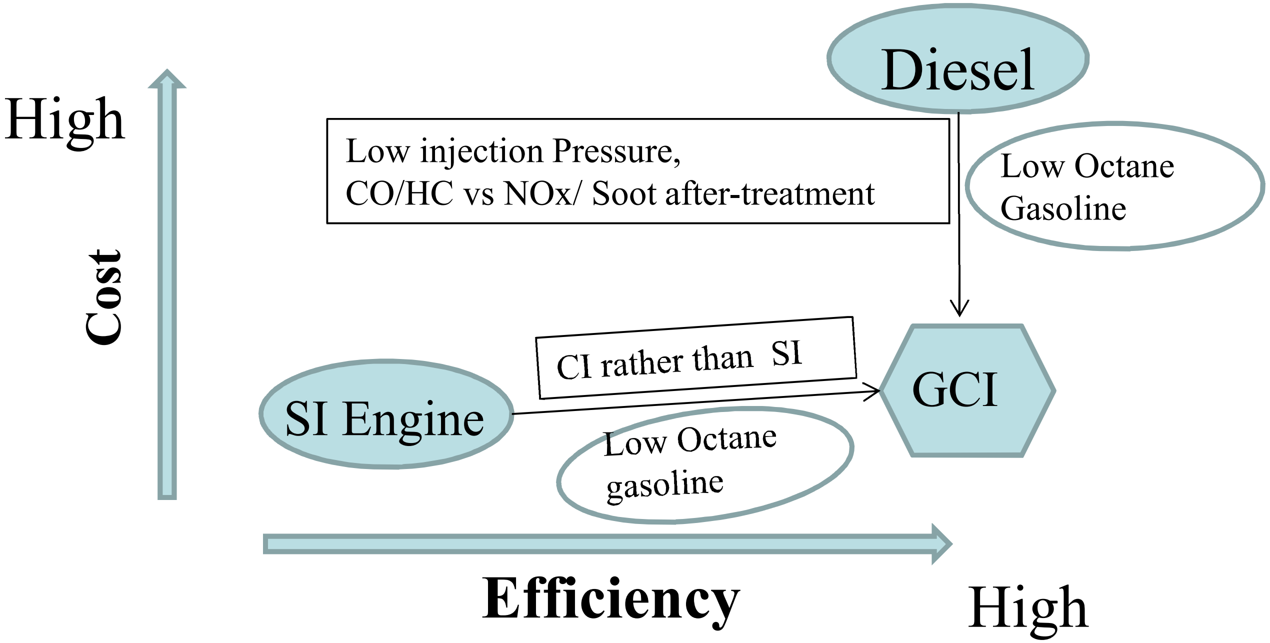
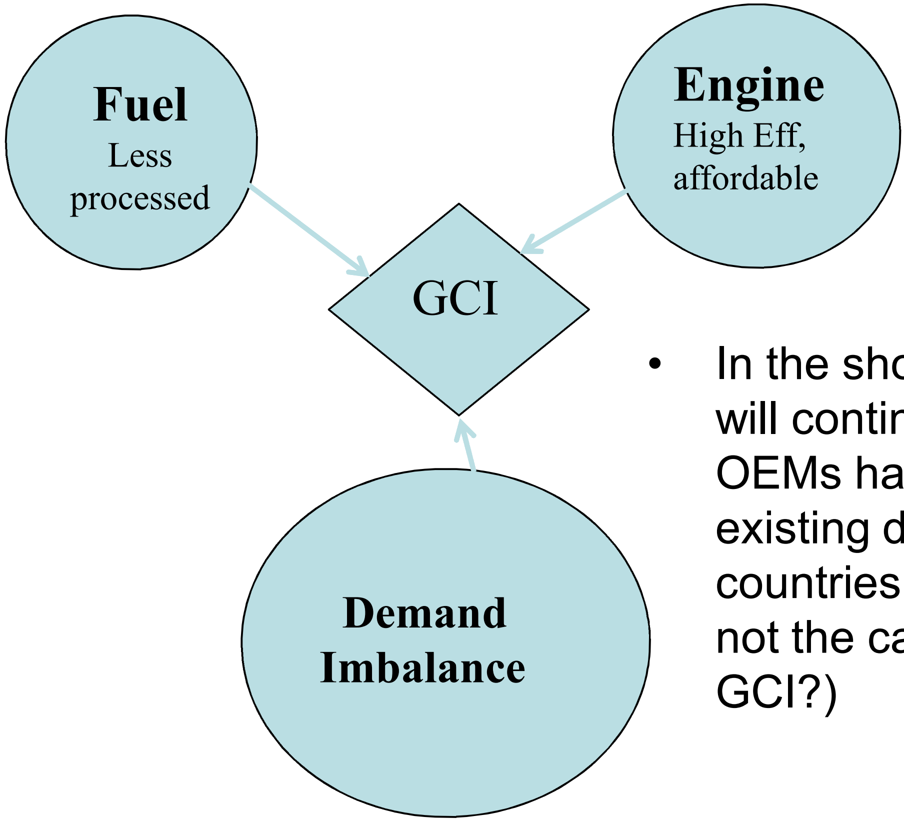
Develop Fuel/Engine Systems – e.g., run CI engines on gasoline-like fuels



Low octane Gasoline – RON between 70 and 85, no strict volatility requirement

Future CI engines should move away from using conventional diesel fuel



- In the short term diesel engines will continue to use diesel fuels – OEMs have too much invested in existing diesel technology (Could countries like China where this is not the case be more receptive to GCI?)

- Development work needed – starting, optimisation of injectors and injector strategy, transients, sufficient boost pressures at high EGR levels, lower temperature oxidation catalysts …

A Possible Long-term Fuels Scenario

~ 40% high efficiency SI engines – need high RON and low MON fuels. Gasoline specifications to be revised. Ethanol will play a role (May be methanol even?)

- ~ 60% GCI engines running on 70-85 RON, wide volatility range fuel. Heavier oil fractions need to be cracked to bring them in the diesel boiling range with much less upgrading required in terms of octane.
- Common fuel components for both SI and CI engines – fuel blending becomes more flexible
- Current bio-diesels with cetane in the 50s will have little relevance
- Very high cetane of gas-to-liquids (GTL) diesel has no advantage
- During the transition, GCI will have to run with existing gasoline and diesel fuels e.g. 10% diesel blends.

THANK YOU

Details in

Fuel / Engine Interactions

SAE International

http://books.sae.org/r-409/

Additional Slides

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What about alternatives?

- Annual global demand for transport fuels is very large – around 23 MBOED for gasoline, 26 MBOED for diesel (1.6 trillion litres each per year).
- Alternatives like biofuels are growing but cannot displace conventional fuels
- Biofuels – in 2012 supplied just under 4% of global transport energy
  - Food vs Fuel
  - No immediate prospect for 2nd generation biofuels or algal fuel
  - Increasing environmental concerns
  - Costlier
- Gas-to-liquids (GTL) – even by 2015, < 0.2% of total demand but cheap shale gas could have an impact
- Hydrogen – problems with production, transport and storage make its use for transport very unlikely
- CNG, LNG – renewed interest because of cheap shale gas but infrastructure limitations
- LPG – niche fuel

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Electric Vehicles

Different levels of electrification – hybridization to improve efficiency, full electric vehicles (FEV), plug-in EVs (PEV)

- Only FEVs get their energy from the grid rather than liquid fuels

Issues with FEVs –

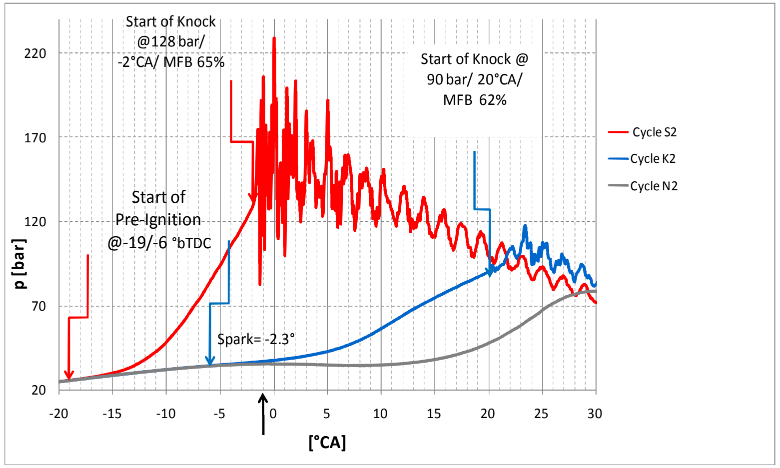
- CO_2 and overall energy impact depends on how electricity is generated
- Cost
- Driving range
- Charging time, convenience, infrastructure
- Scope limited to small vehicles working in urban cycles

Hybrid Electric Vehicles (HEVs) are expected to become wide-spread

Fuel demand from the personal transportation sector is expected to be significantly reduced by the spread of HEVs but not from FEVs or PEVs

Fuel Requirements of Future SI Engines -2

"Preignition" leading to "Superknock"



Three links in the chain of probability leading to Superknock

- Initial ignition – in DISI engines from the ignition of oil droplets. NOT RELATED TO FUEL OCTANE QUALITY
- Flame initiation – More likely the higher the laminar burning velocity
- Developing Detonation – because of autoignition at high pressure and temperature. Leads to high knock intensity. Less likely if fuel anti-knock quality is high

Thus ethanol more likely to cause preignition but less likely to lead to superknock.

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