Clean & Sustainable Mobility for All

Next Generation Clean Fuel Challenges for Indian Refineries

By

B.D.Ghosh

Centre for High Technology

Ministry of Petroleum & Natural Gas

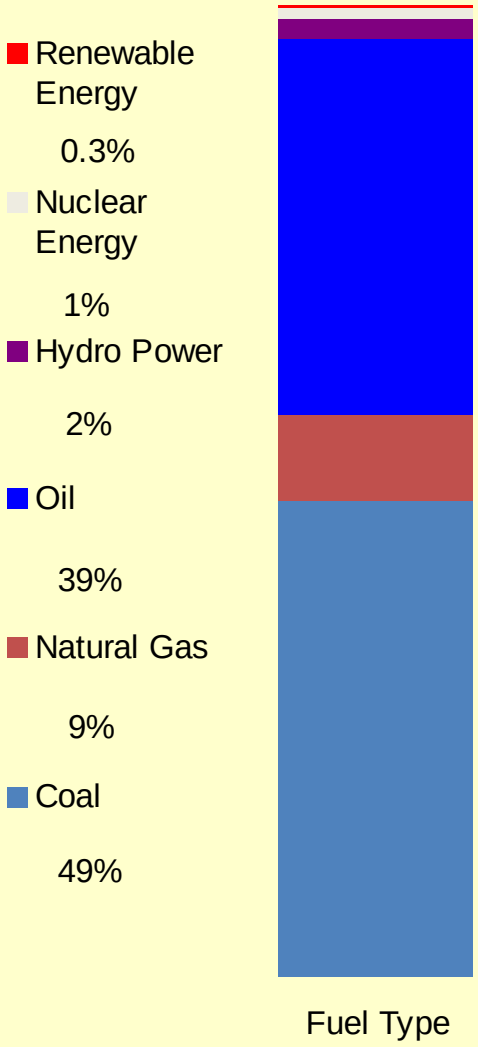
on

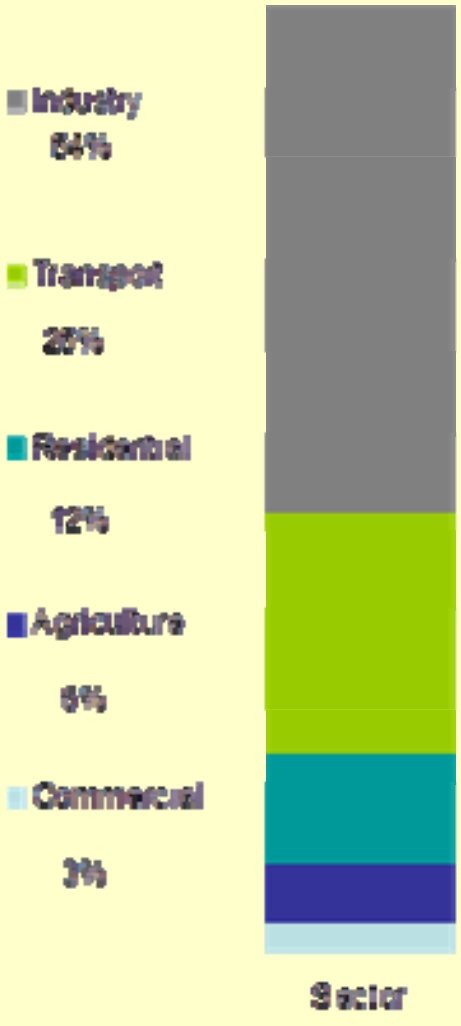
29.09.2011

Energy Outlook

- The global oil demand estimates growth rate of 0.8% between 2007-2030,
- Whereas, the global energy demand during this period is estimated at 1.5%.
- Gas, hydro, biomass and renewable have been projected to grow in the range of 1.5% to 7.4%.
- The fossil fuel in the Energy mix in India would continue to remain more than 90% even in 2030.
- Nuclear and Hydro energy will grow along with gas. Oil will reduce while coal will remain same in 2030.

Energy Consumption in India





Oil Refining in India

- Refining capacity of 193.4 MMTPA in 2011 to become 232.3 MMTPA in 2012 and 311 MMTPA by 2017
- Petroleum consumption may triple by 2030 from its level in 2005 (130 MMTPA). 2010-11 fig 141.7 MMTPA
- LPG, Diesel and Petrol consumption during last 5 years, has grown at 9-10%
- Petroleum products increased from 113.2 MMT in 2005-06 to 138.2 MMT in 2009-10 (4.85% growth)
- Petroleum products is likely to grow by about 3.5 to 4 % next 10-15 years to meet largely the demand of transport and domestic fuel (LPG) sector

Crude Oil & Refining Projections

Sl	Items	2005-06	2007-08	2008-09	2009-10	2010-11	2011-12	2017-18	2020-21
1	Crude Oil Production (MMT)	32.19	34.13	33.51	35.95	40.40	42.88	40.40	42.88
2	Refining Capacity (MMT)	118.75	144.93	150.00	182.00	205.00	240.00	302.00	342.00
3	Demand of Petroleum products (MMT)	113.21	128.94	133.40	136.61	143.44*	150.61*	185.14*	212.45*

* Assumed 5% growth over the consumption level of 2009-10.

Petrol & Diesel Consumption Ratio

- Worldwide consumption of light and middle distillates may give an idea about the ratio of petrol and diesel. Volumetric consumption ratio (BP Statistical data) in respect of petrol: diesel is given below for comparison:
  - World 1: 1.15
  - USA 1: 0.65
  - EU 1: 2.15
  - Asia Pacific 1: 1.3
  - Japan 1: 0.96
  - China 1: 1.42
  - India 1: 4.1

Crude Oil & Products

- Type of Crude oil and its composition affect the yield of these products. Lighter crude oils have higher amount of distillates, i.e petrol and diesel as compared to heavier crude oils.
- Straight run products obtained from distillation of crude oil may not entirely & directly meet the requisite quality of petrol and diesel for which additional secondary processing and treatments would be required.

Crude Oil & Products

- Various secondary and conversion processes are put up in refineries to improve distillate yield and quality of these streams for upgradation to petrol & diesel.
- The Fluidized Catalytic Cracking, Hydrocracking, Delayed Coker, Visbreaker improves the yield through processing of heavier gas oil & residues
- Catalytic Reformer, Isomerization, Alkylation, Hydrotreaters improve the quality selectively, i.e. octane number, olefin/aromatics, sulphur etc.

Typical Yield of Products

	Crude oil					
Yield, % wt	S Gujarat	N Gujarat	Assam	Mumbai High	Imported (HS)	Imported (LS)
Gas	0.7	0.2	-	0.3	0.2	0.2
LPG	2.3	0.2	0.9	1.3	1.3	1.3
Naphtha/ Petrol	26.0	5.0	14.5	17.0	12.0	13.0
SKO/ATF	22.0	10.5	14.9	21.0	17.5	19.0
Gas Oil/Diesel	19.0	12.5	29.1	24.5	19.0	31.0
RCO (AR)	29.0	70.0	40.5	34.0	48.5	34.0

Refinery Configuration & Yield

	International Refineries				Indian average
Yield, % wt	Hydroskimming	Gasoline Maximum	Gasoline-Distillate	Hydro-cracking	Typical
LPG	1.8	2.0	1.8	1.9	4.3
Naphtha/ Petrol	30.0	56.0	45.0	30.3	21.5
SKO/ATF/ Diesel	27.5	28.6	32.6	45.0	49.4
Total Distillate	59.3	86.6	79.4	77.2	75.2*
Gas Oil/					*incl lube

Typical Yield of Process Units

Yield, % wt	Fluidized Cat Cracking (FCC)	Hydrocracking	Delayed Coker		Visbreaker
			LS	HS	
Gas	3.5	2.2	8.3	3.7	2.0
LPG	12.0	3.0	3.6	3.1	
Naphtha/ Petrol	32.5	11.5/-	6.6	11.9	3.5
SKO/ATF	-	30.0	18.5	48.8	11.2 (Gas oil) +13.2 (VGO)
Gas Oil/Diesel	37.0	50.0	28.3		
Fuel Oil/LSHS	10.0	-	4.3	1.2	70.0
Residue/Coke	4.5	5.0	30.4	31.3	

Additional petrol and diesel components are available from these secondary units.

Petrol Quality Specifications prior to Auto Fuel Policy

- The BIS specification (IS 2796) for Petrol was first published in 1964 and the first revision of this standard was done in June, 1971.
- The first major change that took place was in Nov, 1984 when octane number (RON) of regular petrol was amended from 83 to 87
- The standard was amended in 1992 to facilitate blending of methanol in petrol.
- The second revision of BIS standard was done in 1995 particularly for low lead and unleaded petrol
- Major changes in petrol specification based on emission considerations were brought out in the third revision of BIS standard in 2000

Petrol Quality Improvements prior to Auto Fuel Policy

- Total lead phasing out in petrol in 5 years (1996 to 2001). From 1.2.2000, only unleaded petrol is produced and sold in the entire country
- Increase in RON has been done from 87 to 88 and AKI of 84 with effect from 1.4.2000.
- Sulphur content in petrol has been reduced from 0.20% max. to 0.1% max. in the entire country from 1.4.2000. Whereas, the 4 metro towns were supplied with petrol of 0.05% max. sulphur content
- From 1.4.2000, benzene content limit is 3% vol. max. for the metros and 5% vol. max for the entire country. NCT/NCR and Greater Mumbai benzene already has benzene limit of 1% vol. max

Diesel Quality Specifications prior to Auto Fuel Policy

- The BIS specification (IS 1460) for HSD was first published in 1959 and revised in 1968 and amended in 1971
- The second revision was done in 1974 and amended in 1981.
- The third revision of BIS specification of HSD was done in 1995
- Major changes in HSD specification based on emission considerations were brought out in the fourth revision of BIS standard in 2000

Diesel Quality Improvements prior to Auto Fuel Policy

- Sulphur content in diesel has been reduced from 1.0% max. to 0.25% max. in the entire country in a period of four years from 1.4.1996 to 1.1.2000. Whereas the 4 metro towns were supplied with petrol of 0.05% max. sulphur content
- The cetane number has been increased from 45 to 48 from 1.4.2000
- The density specification was revised from 820 – 880 to 820 – 860 kg/m^3 and the 90 % vol. distillation recovery at 366^0 C max. to 85 & 95 % vol. min. recovery at 350^0 C and 370^0 C respectively

Auto Fuel Policy and Road Map for implementation

- Bharat Stage-II norms which are in place in the 4 mega cities of Delhi, Mumbai, Kolkata & Chennai should be introduced in the other seven mega cities of Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra from April, 2003.
- Bharat Stage-II norms should be introduced in the entire country from 1st April, 2005.
- Euro-III equivalent emission norms for all categories of vehicles (excluding two and three wheelers), should be introduced in eleven mega cities from 1st April, 2005.

Auto Fuel Policy and Road Map for implementation

- Euro-III equivalent emission norms for all categories of vehicles (excluding two and three wheelers) should be extended to other parts of the country from 2010.
- Euro-IV equivalent emission norms for all categories of vehicles (excluding two and three wheelers), should be introduced in thirteen mega cities from 1st April, 2010.
- To meet Bharat Stage II, Euro III and Euro IV equivalent vehicular emission norms, matching quality of petrol and diesel, detailed by the Committee, should be simultaneously made available.

Fuel Quality Improvements as per Road Map

- Prior to Auto Fuel Policy, ` 10,000 crore invested by the refineries to achieve desired quality of fuels
- Investment of ` 18,000 crore and ` 12,000 crore estimated by the refineries to meet the quality targets envisaged in 2005 and 2010
- Besides the high investments, the production cost of improved quality of auto fuels is substantial due to high requirements of energy, fuel, hydrogen and higher generation of low priced byproducts
- Some refineries are able to produce two different qualities of petrol and diesel to meet Bharat Stage III & IV norms, whereas for others improvement is not viable

Issues for Fuel Quality Improvements as per Road Map

- Reasonable lead time for construction and commissioning of requisite facilities for desired quality improvement would be required
- In deregulated, free competitive market scenario from the year 2002, refineries are forced to charge price for the higher spec. petrol or diesel based on domestic competitors or an importer of product.
- Only a few of the refineries would be able to recover investments for meeting Euro III/IV equivalent quality fuels
- Investments in refineries for upgrading auto fuels are not self-repaying. Non availability of sufficient funds require Government support/subsidy

Implementation of Fuel Quality Road Map

- Fuel quality improved as per the Auto Fuel Policy to introduce the Euro-IV Gasoline and Diesel in 13 major cities in the country from 1st April 2010. The quality of Gasoline and Diesel in the rest of the country is upgraded to Euro III.
- These low sulphur fuels will not only reduced SOx but bring down emission of CO, HC, NOx and PM substantially. New Euro-IV vehicles compared to Euro-II vehicles with the use of improved quality fuel will bring down emissions in respect of CO, HC and NOx by about 50%.
- All the refineries have completed the fuel quality up gradation program to improve the fuel quality for Euro III/Euro IV at an estimated cost of US $ 7-8 Billion.

Gap in Fuel Quality

- Comparison of Auto fuel specifications with various countries such as Asia- Pacific region, European Union(EU), USA, indicate the following:
  - Indian specifications are better / at par with most Asian countries.
  - Gap between Indian specifications and that of USA, EU, Japan, is reducing.
  - Some of fuel parameters are superior than USA, Japan

Emission related Fuel Characteristics

- **Petrol**

  Sulphur, Benzene, Aromatics, Olefins, Oxygenates, Distillation recovery, RVP

- **Diesel**

  Sulphur, Cetane number, Poly Aromatics (PAH), Density, Distillation recovery

Clean Fuel Challenges

- Sulfur Content reduction
- Increase Oxygen Content
- Reduction of PAH
- Lower limit of Aromatics/Olefins
- Reduced CO2 emissions

Options available to Oil Industry to meet future Indian Gasoline Quality

S.No.	Quality Requirement	Options Available
1	Octane Number increase	Catalytic cracking and refining to be used to produce highly aromatic and branched chain hydrocarbons and use of oxygenates to achieve increase in octane number for low lead gasoline
2	Sulphur reduction	Hydrotreatment of FCC gasoline
3	RVP reduction	Reduction of butanes content
4	Benzene reduction	Higher initial boiling point for reformer feed and reformate fractionation and alkylation
5	Aromatics and Olefins reduction	Modification of the gasoline pool including elimination of pyrolysis gasoline, reduction of reformate increase in alkylate and MTBE

Technology options for Benzene Reduction

Prefractionation option:

Naphtha is being prefractionated into light naphtha containing Benzene and its precursors and heavy Naphtha. Heavy Naphtha is converted in a CCR or SR reforming unit to gasoline with octane above 98. The prefractionated light Naphtha is isomerised to improve octane and Benzene fraction is saturated.

The other option is Benzene and its precursors are fractionated after reforming to obtain the light Naphtha. The light Naphtha is isomerised and / or Saturated or extracted to remove benzene

Sulphur reduction in Gasoline

- Main contributor of sulphur is FCC gasoline
- FCC gasoline in India comprises 50-70 volume percent of gasoline pool
- Gasoline Sulphur reduction strategy is mainly for FCC gasoline which has 300-600 ppm of sulphur through:
  - Pretreatment (Hydrotreating) of FCC feed
  - Post treatment (HDS + Isomerisation) of FCC Naphtha

Options for FCC Gasoline Desulphurisation

Pre - treatment

- Improves FCC yields
- Positive economic return
- Also addresses distillate sulphur reduction issue
- High hydrogen usage
- May need to undercut gasoline for 30 ppm
- High capital investment for FCC pre-treating option (30,000 BPD) is ` 500 Crores

Options for FCC Gasoline Desulphurisation

Post - treatment

- Only addresses gasoline sulphur reduction issue
- Increases operating cost
- Need to manage sulphur and Olefin in the FCC gasoline to minimise loss of Octane number
- Will meet regulations
- ISBL estimated cost for 10,000 BPSD unit ` 50 Crores

Options for meeting future Diesel specifications

Product quality issues

- Density
- Poly Aromatics Hydrocarbons
- Cetane Index
- Back End Distillation

Sulphur & Aromatics Reduction

- Additional Reactor for reduction of current ‘S’
- Further reduction to 50 ppm at current catalyst activity levels will reduce thruput by 50%
- New catalyst developments will enable refiners to reach 50 ppm with existing units for 500 ppm
- Options such as Bio-desulphurisation of diesel are yet to reach commercially viability
- For PAH 6 wt % and above, existing units for 50 ppm “S” limit will meet the requirements

Cetane Number

Cetane Number

Two stage Hydrotreating

- May require additional hydrotreating reactor for meeting PAH content DS/HAD for Aromatics saturation will also meet Cetane number requirement
- Refiners may also be required to use additives to Meet the Cetane Index

Reduction of 95% distillation by 20 C

Reduction of end point will lead to

- Density reduction
- Most refractive sulphur compounds will be eliminated
- PAH reduction
- However there will be a cut back of diesel production by 10-15 wt%

Next Generation Clean Fuel Challenge

- Bio Fuel Program (ETHANOL & BIODIESEL)
- Present gasoline ethanol level of 5% to increase to 10%. Target of 20 % across the country by 2017

- **Bio Diesel:** National Mission of Planning Commission on Bio-diesel is for production of oil from Jatropha and reaching 20 % blend (B20). Action has been initiated for adequate plantation, extraction of oil and trans-esterification of oil for blending in diesel.

- The Government has also announced the purchase policy for bio diesel. Also BIS specification for Bio diesel has been formulated.

Next Generation Clean Fuel Challenge

- **Emission Reduction through product substitution by Gas**

- Initiatives are being taken to introduce the Natural Gas as a clean fuel for various user sectors including domestic, industrial, commercial, power and transport sector.

- Ministry of petroleum to introduce city gas distribution system in 200 cities covering transport, domestic and commercial sectors by 2015

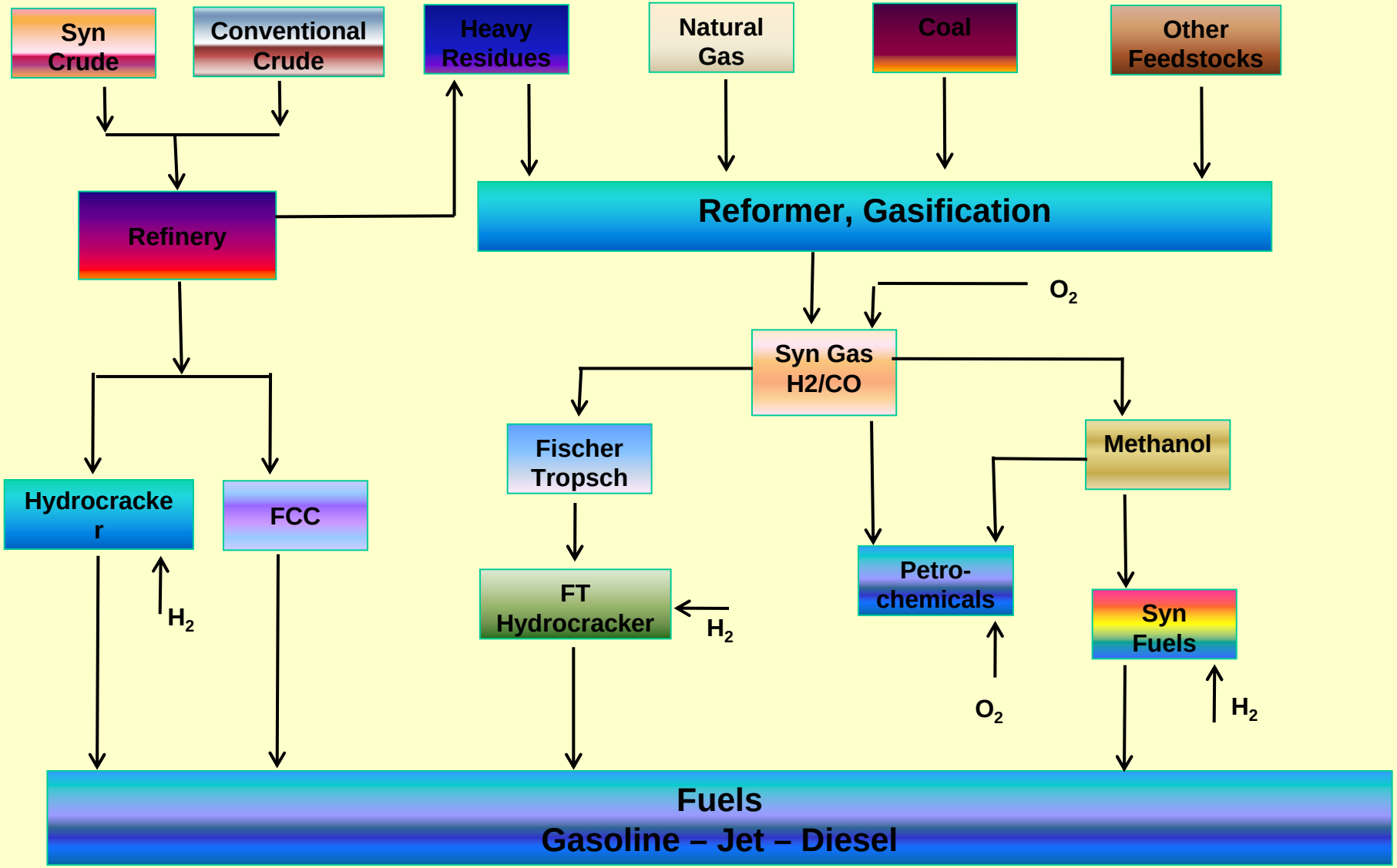
- More Gas for domestic, industrial, commercial, power and transport sector. 20% replacement of FO, Naphtha, Diesel, Gasoline and LPG. Emission reduction of 18 MMT of CO_2 by 2021 has been estimated under 8% oil substitution of gas.

Next Generation Clean Fuel Challenge

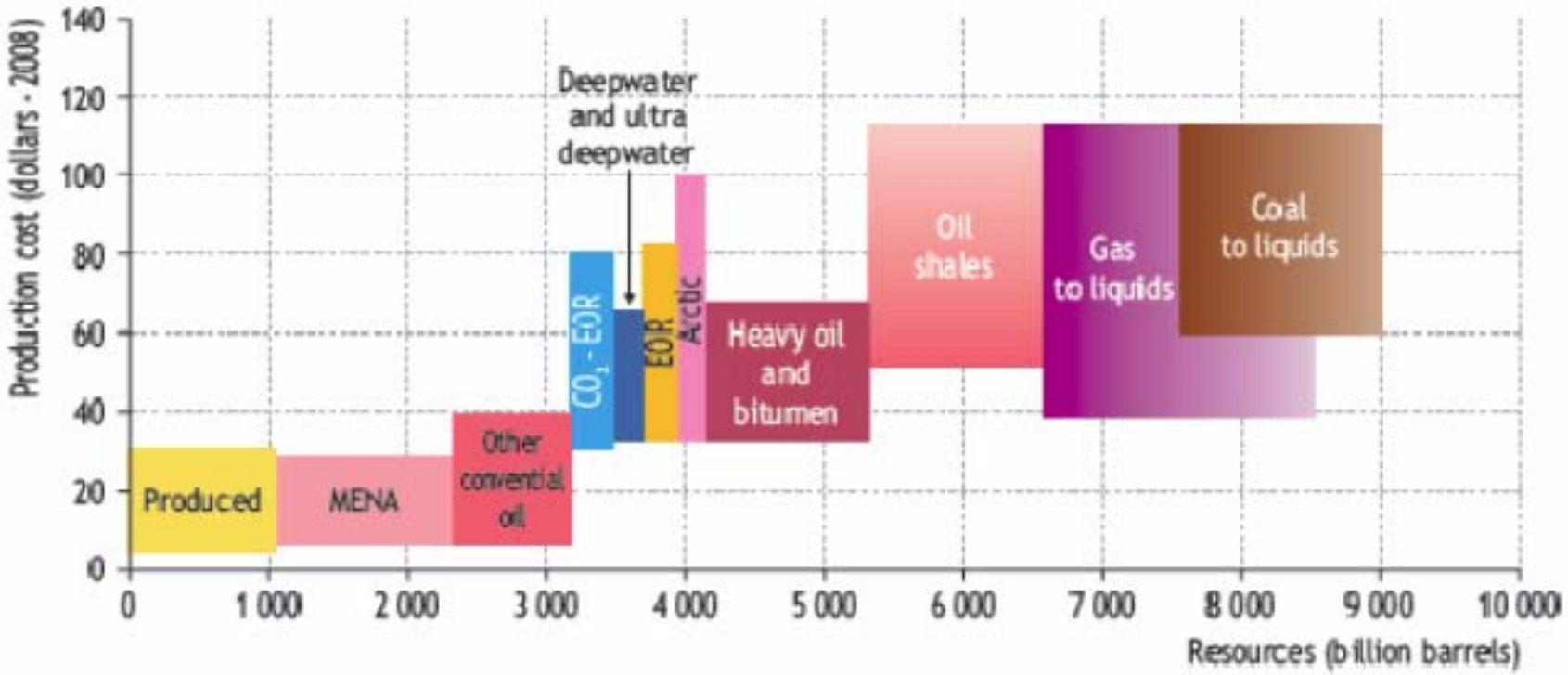
Other Areas for development of fuels are:

- Bio process for De-sulphurization of gasoline and diesel
- Suitable process for reduction of sulphur, benzene, aromatics, olefins while sustaining octane number and volume
- Suitable and viable technology for Fuel Cells, DME, Hybrid Energy Systems
- Hydrogen Technologies, bio/renewable source based H2 generation (i.e. production from bio mass/alg renewable sources)
- Membrane processes for CO2 absorption
- Substitution of high energy emission sources

Routes To Liquid Fuels



Long Term Oil Supply Cost Curve



Note: The curve shows the availability of oil resources as a function of the estimated production cost. Cost associated with CO_2 emissions is not included. There is also a significant uncertainty on oil shales production cost as the technology is not yet commercial. MENA is the Middle East and North Africa. The shading and overlapping of the gas-to-liquids and coal-to-liquids segments indicates the range of uncertainty surrounding the size of these resources, with 2.4 trillion shown as a best estimate of the likely total potential for the two combined.

Future Action Plan

- In line with the recommendations of the Auto Fuel Policy of Government of India, oil industry has already introduced BS-IV grade petrol and diesel in the 13 notified cities and BS-III grade petrol and diesel in rest of the country in 2010.
- To meet this commitment, major quality upgradation projects have been put up recently at all refineries with a total investment of around ` 35,000 crore.
- Supply of BS-IV grade petrol/diesel in the entire country would require similar investment in all the refineries.

Future Action Plan

- Further upgradation in fuel quality will call for very huge investment and increased operating cost.
- Preliminary estimates indicate that the investment required for supply of BS-V grade fuel would of the order of Rs 40,000 crore for IOCL refineries alone.
- The Auto Fuel Policy had also recommended for following initiatives for reduction of pollution from in-use/new vehicles :
  - introduction of Inspection and Maintenance (I&M) System initially in the notified cities on urgent basis and extending the same in rest of the country
  - OBD system for new vehicles in lieu of I&M systems
  - Mandatory performance checking of catalytic converters and conversion kits already installed in vehicles
  - Checking of emission warranty for new vehicles etc

Future Action Plan

- While the oil industry has met its commitment towards Auto Fuel Policy recommendations, it is believed that not much progress has been made with regard to the other initiatives.
- There are many sources other than transport sector, viz., road dust, construction, domestic combustion, DG sets, bio-mass/garbage burning etc. which significantly contribute to the overall emission load particularly w.r.t. PM emission.
- This vindicates the view of oil industry that the vehicular emissions are not the major contributor to the overall pollution and there is further significant improvement with changes in vehicle technology and fuel quality.
- The actual progress made on this front and the resulting impact on the emissions needs to be captured.

Thank You