







Future Transport Fuels for Sustainability: A Step by IOCL towards Net Zero Goals



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Contents

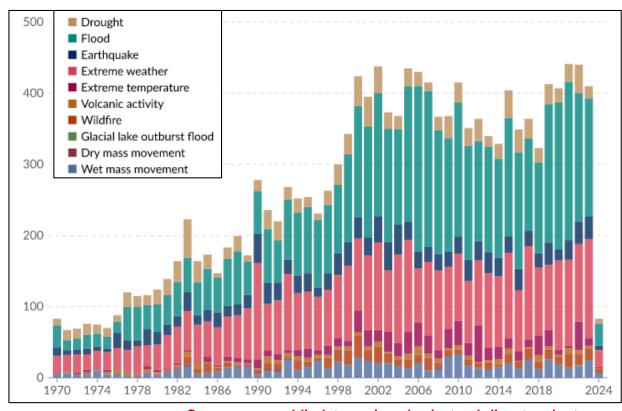
- Natural Disasters & Losses: World towards Transition
- Net Zero Carbon Emission Target: Global & India
- Scope of Emissions
- Energy Mix:
 - Global
 - India
- Clean and Sustainable Transport Fuel
 - 2. Futuristic Fuel Demand
 - 3. Future Fuels
 - Differentiated Fuel(s) IndianOil™ Initiative
 - Alcohol blended fuel- Ethanol, Methanol
 - CBG
 - HCNG





Natural Disasters & Losses

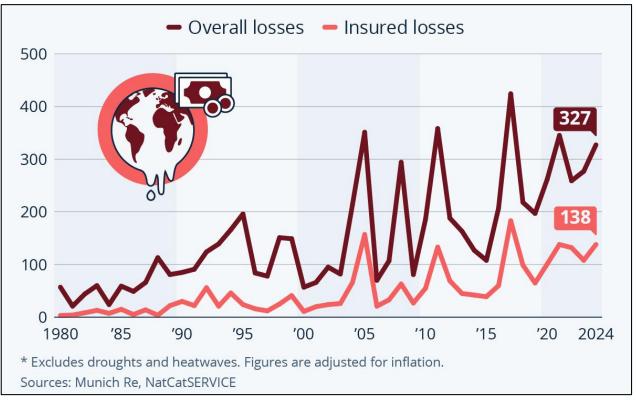
Global Reported Natural Disasters since 1970 onwards



Source: ourworldindata.org/grapher/natural-disasters-by-type

Monetary Loss due to natural disasters

In Billion USD



Source: First Climate; Source: Greenhouse Gas Protocol

Time to act to reset and preserve mother earth & move towards Sustainable Energy sources





A World towards Transition

- Global Clean Energy Investment Jumps 17%, Hits \$1.8 Trillion in 2023
- RE, EV vehicles, hydrogen and CCUS drive investment growth yearon-year

Record Global Clean

Hottest Year on record



- 2023 was the world's warmest year on record, by far
- Antarctic sea ice coverage hit record low

COP28, setting new direction



- Energy Investment

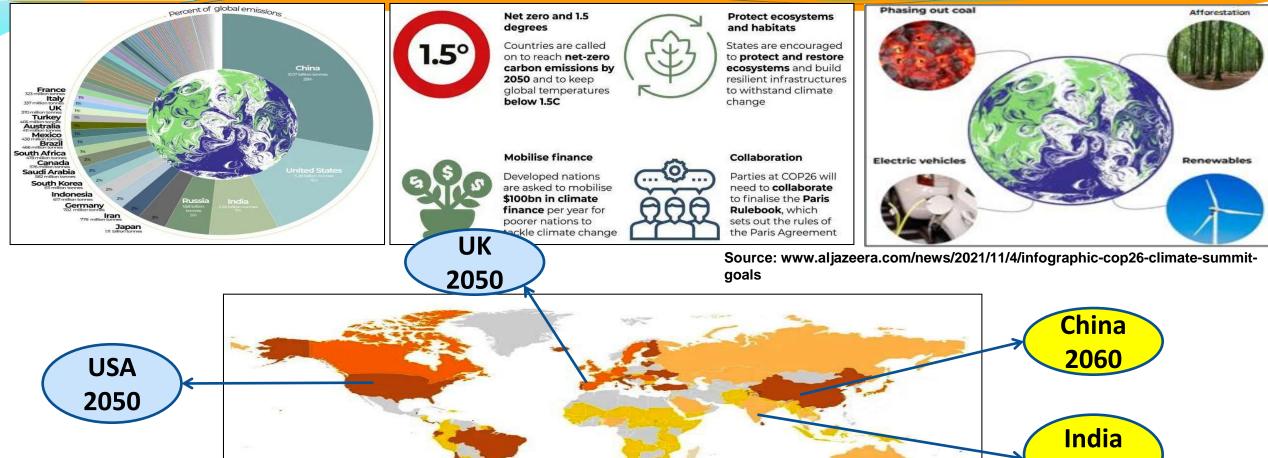
 First ever Global Stocktake
 - To triple global RE capacity to at least 11 TW and double energy efficiency improvement rates
 - For the 1st time ever, COP agreement called for transitioning away from fossil fuels in energy systems, in a just, orderly, and equitable manner
 - 50 global oil and gas companies signed the "Oil and Gas Decarbonization Charter" (OGDC)
 - Loss and Damage Fund

Strengthening Resilience through Energy Security





Net Zero Carbon Emission: Global Perspective



Source: Energy and Climate Change unit, Aljazeera

Declaration/Pledge

2070

In policy document

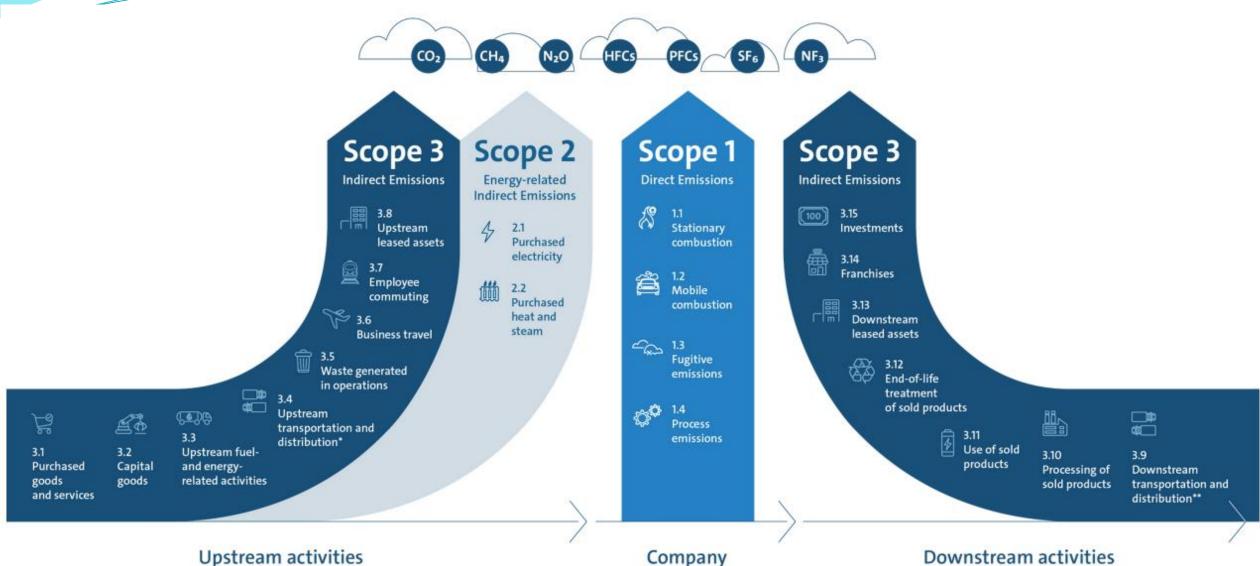
No committment

Proposed/In discussion





A SCOPE of EMISSIONS



Company

Downstream activities

Source: First Climate; Source: Greenhouse Gas Protocol





India: Energy Scenario



World's 3rd biggest energy consumer (6.3% share)



Energy consumption grew 3 folds since 1990, and @4.2% per annum in last decade driven by rising incomes & improving standards of living



Over 80% of energy demand still being met by coal, oil & solid biomass



3rd Biggest Oil Consumer & Importer



4th Biggest Solar & Wind Capacity



On a per capita basis, India's energy use is 1/3rd of the world average



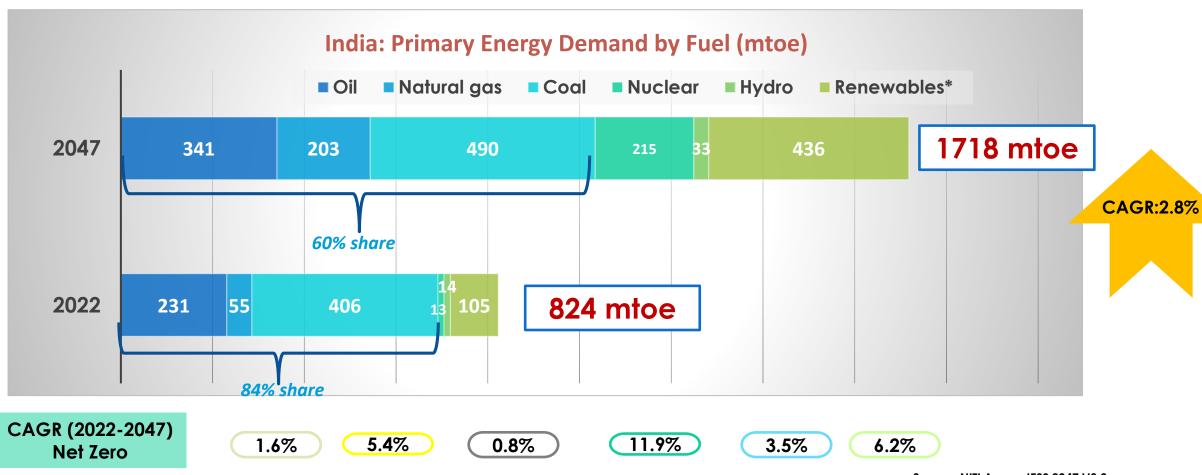








Long Term Energy Mix (compliant with Net Zero 2070 Target)

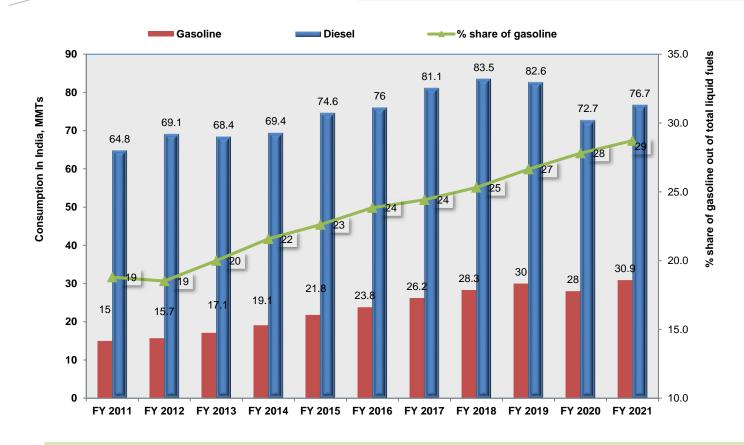


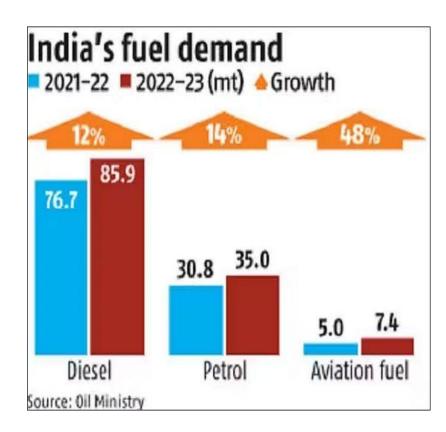
Source: NITI Aayog IESS 2047 V3.0



Petroleum Fuels - Gasoline & Diesel

Consumption of Liquid Fuels - India



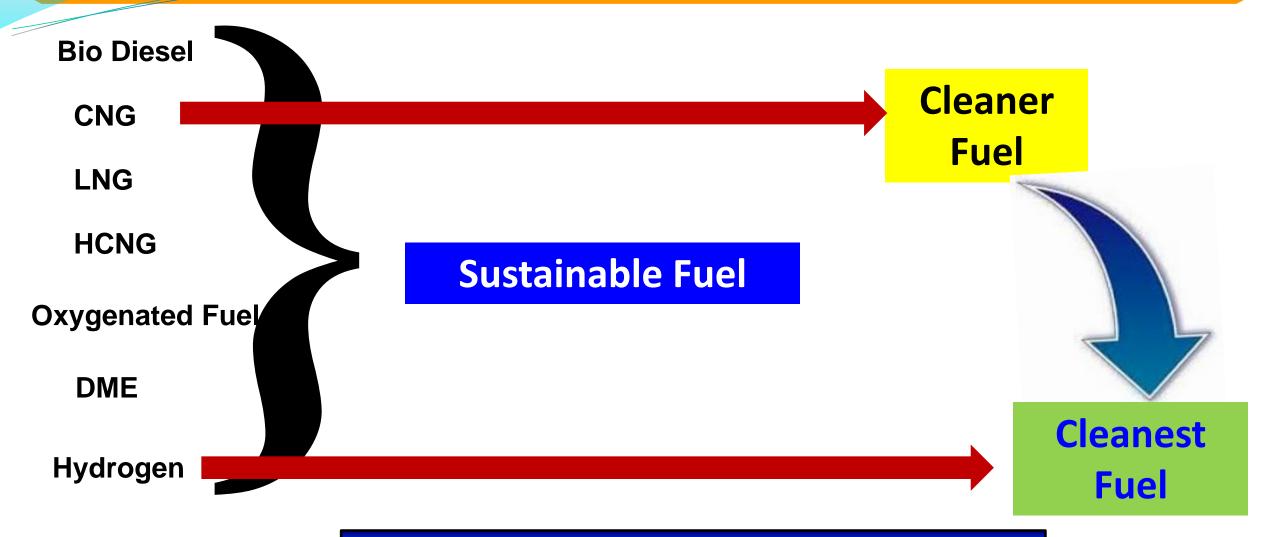


The consumption growth of gasoline is at a faster rate than diesel Transport sector consumes almost 100% gasoline & 80% of Diesel shown above Penetration of CNG in heavy duty segment affects the diesel consumption Decarbonization of transport sector is essential to meet the net Zero Target





Clean and Sustainable Transport Fuel



Renewable / Green Hydrogen
Ultimate Solution to Sustainable Energy





IndianOil Sustainable Energy Solution to the Nation





Alternative & Renewable Energy



1st, 2nd & 3rd Gen Biofuels



Bio-methane Technology



HCNG / H2



Batteries / Fuel Cells



Solar Energy



CO2 Capture & Utilization



Gasification-Coal/Petcoke/ Biomass

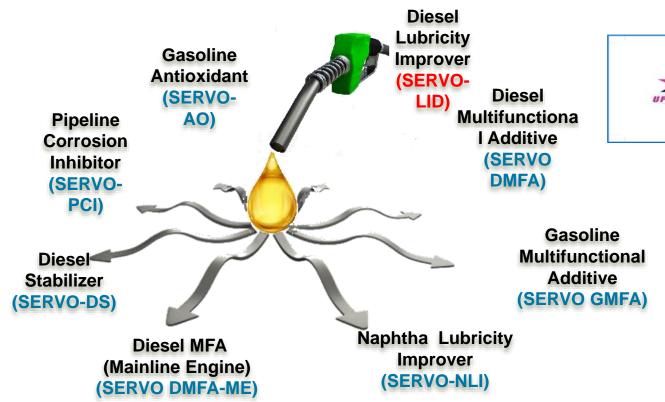


Towards Energy Independence and Sustainable Ecosystem





Fuels & Fuel Additives













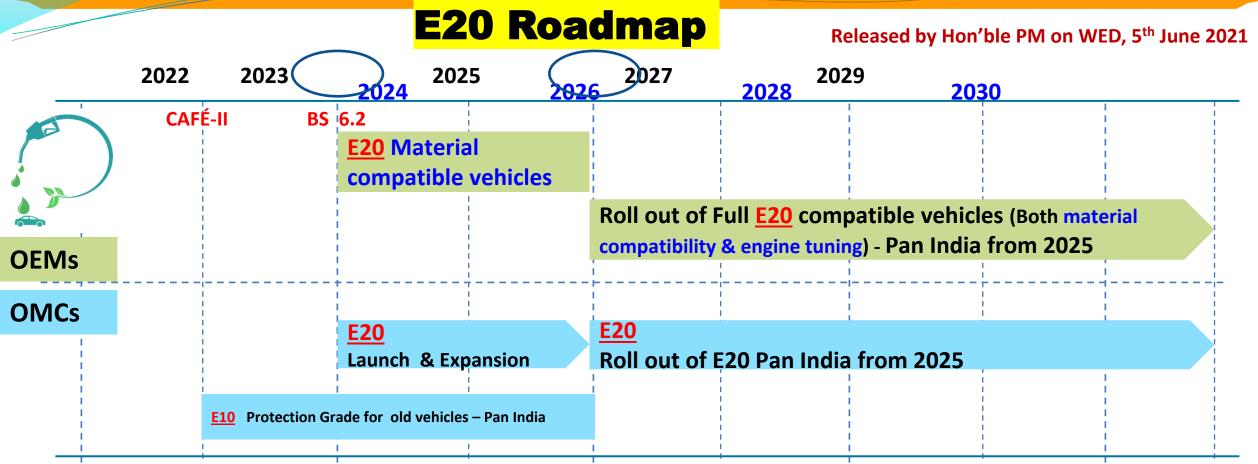




- Premium Fuels Gasoline: XP95, XP100 (Gasoline), XtraGreen diesel
- Special fuels for Defense forces
- High Flash High Speed Diesel (HFHSD) superior hygiene & rheological requirement for Navy
- Solutions for Marpol 2020 compliant FO
- Stabilizer for E20 pipeline transportation to get octane benefit at refinery end
- Methanol Stabilized M15 blends; pilot launch



Oxygenated Fuels



Key Recommendations

- E10 Pan India by April 2022 & will remain as protection grade fuel till April 2025.
- E20 dispensing to start from April 2023
- E20 Pan India by April 2025

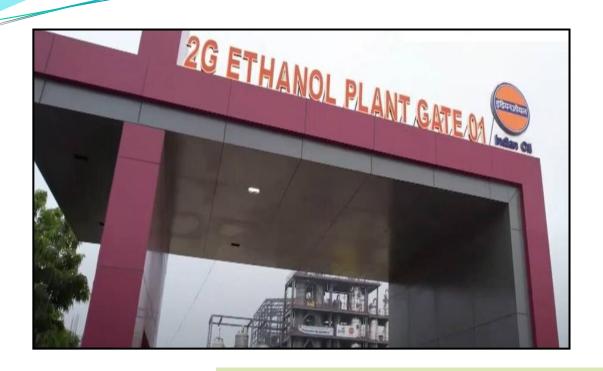
India would require about 1000 Cr Litres of ethanol for E20 by 2025

Confidential





IOCL 2G Ethanol - Panipat, Haryana





- Capacity (Ethanol Production): 100 KL/day
- Feedstock : Paddy straw
- Feedstock Requirement: 2.14 lakh Ton/Annum
- Licensor: Praj Industries

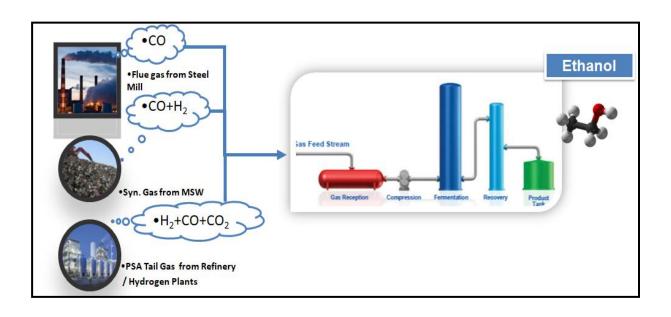
Hon'ble Prime Minister dedicated to the nation India's first 2G ethanol plant on 10th August 2022 on World Biofuel day

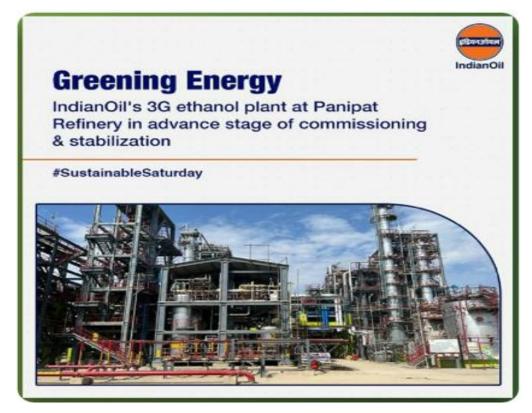




IOCL 3G Ethanol - Panipat, Haryana

Off-gases to Ethanol Production





- IndianOil's 3G ethanol plant at Panipat Refinery, is the first refinery off-gas based ethanol plant in the world. Fixes CO2 apart from ethanol production >60% GHG reduction
- Capacity: 33000 t/annum
- The Plant expected to mitigate 180 TMTPA CO2 equivalent emissions.
- Low Capex and opex compared to cellulosic 2G Ethanol. Low Water foot print per ton of ethanol





Oxygenated Diesel (ED5/MD15) Activities at IndianOil

Negligible torque & power drop, 2-3% BSFC improvement

20 K km in 20 buses



Endurance Test on a HD Engine in progress with ED5 Fuel (MoU with M/s Ashok Leyland)



MD15 Pilot Project launched in 20 buses of Bangalore Metropolitan Transport Corporation (BMTC)



Demo-run of an inland water vessel with IOC R&D Developed MD15 Fuel by Numaligarh Refinery Limited

 IndianOil is in discussion with leading tractor and CEV manufacturers for evaluation of ED5/MD15 Fuel and development of compatible lubricants





High Octane Premium Fuels





XP95 gives:

- Increases power by 4%,
- Ability to accelerate by 20.15%.
- Additional 3.95% fuel economy,
- Reduces CO emissions by up to 44%
- Hydrocarbon emissions by up to 13%,
- XP95 keeps engines clean and makes more corrosion resistant

XP100 gives:

- Suitable for higher compression ratio vehicles
- superior antiknock properties improves engine power with faster acceleration,
- Enhances fuel economy
- Better drivability with increased engine life.
- Reduced carbon emissions.

Improved performance in 2 wheelers and passenger car segment





High Octane Fuel - IOCL

XP-100 and XP-95 gasoline having octane of 100 and 95 respectively launched by IndianOil provides

- Faster acceleration
- Smoother drivability
- Enhanced fuel economy
- Lower engine deposits
- Significant reduction in emissions

Enhanced Fuel Economy

FE Enhancement: 3-5%

Enhanced Performance
Faster Acceleration
Reduction in acceleration time by 11.61% to 20.15%

Better Drivability & Engine Life

Reduction in Emissions in BSVI vehicle (-) 4.78% CO (-) 6.07% HC

All results certified by accredited labs







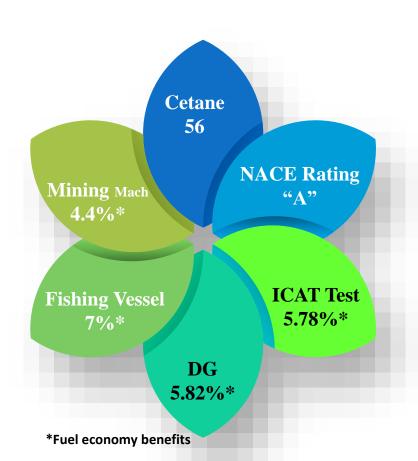
XP95 and XP100 fuels based on in-house technologies provides variable options to our customers in MS





XtraGreen Diesel

- ☐ Product based on Indigenous technology launched by IOCL in 2021
- ☐ Product available commercially Confidential



Lab Evaluations

CFR Test ASTM D 613/IS 1448: P9 Method for Cetane No. Corrosion Test NACE TM-0172 Method for Corrosion

Accredited Testing Centre

International Centre for Automotive Technology IS:11921 Based Test on On-road Heavy Duty In-Use Vehicle International Centre for Automotive Technology Tests on Off-highway and Stationary Engine by 3rd Party

Field Performances - Govt, Lab / Customer's End

Central Institute for Fisheries Technology Field Evaluation on Fishing Vessel in Sea with Voyage & Fishing

Mining Machinery
Tests on Komatsu Dumpers at
TATA Steel Iron Mines

Complete chain of performance evaluation from laboratory to certified 3rd party lab to field performance done





Reduction in Carbon Footprint on using XtraGreen diesel fuel

Normal Diesel



Combustio

2640 Kg CO₂ per KL of Diesel Fuel

XtraGreen Diesel



2508 Kg CO₂ per 0.95 KL of Diesel Fuel 5% fuel economy

0.13 MT of CO₂ per

Equivalent to ~12 MMTPA of CO_2 under Scope-3 emission considering sale of 9217 cr litre of diesel~76.5 MMTPA(2021-22)



- √ 5.29% Carbon Monoxide (CO)
- √ 4.99% Oxides of Nitrogen (NOx)
- \checkmark 0.13 0.15 MT of CO2 per KL of diesel







XtraGreen Diesel and Green Combo Lubricants



Green Combo Lubricants:

- Engine Oil
- Axle Oil
- Transmission Oil

XtraGreen Diesel and Green Combo.

- **♦ (+) 9.26 %** on BS4 Truck
- **♦ (+) 9.01%** on BS4 Bus
- **♦ (+) 5.82 %** on DG Set
- **♦ (+) 5.81 %** on Loader 3DX
- **❖ (+) 4.30%** on Dumper

Reduction in emissions

- ✓ <mark>5.29%</mark> Carbon Monoxide (CO)
- √ 4.99% Oxides of Nitrogen (NOx)
- ✓ 0.13 0 .15 MT of CO2 per KL of diesel
- ✓ Environmentally greener fuel with low carbon footprint

Superior Injector Cleanliness & Lubricity

✓ Longer injector life

Smoother drivability

✓ Reduction in noise by ~ 5%



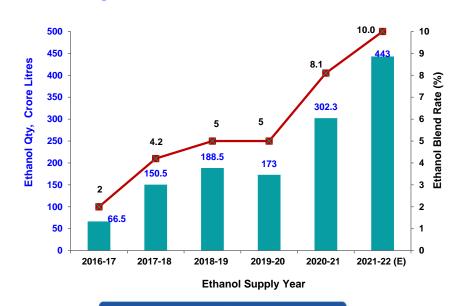
Product is Commercially Available





Ethanol as a fuel

Present Scenario



All-India Average Ethanol Blending

Ethanol blending with petrol (EBP) = 19.6% 2025

Forecast

Capacity Augmentation (in Crore Litres)					
	Plant Capacity				
Year		Sugar		d for blendin	
	Grain	based	Total	g	
2021-22	300	519	819	443	
2022-23	350	625	975	542	
2023-24	450	725	1175	698	
2024-25	700	730	1430	988	
2025-26	740	760	1500 not Blending Ro	1016	

E20 Roll out from April 2023

Feedstock Options: Sugar cane juice, Sugar, Sugar Syrup, B & C molasses, damaged food grains, FCI Rice, Maize 50:50 mix of grain and sugar based feedstock by 2025-26 can help sustainable supply of ethanol balancing lean & rich sugar seasons

Benefits

- · Low-hanging fruit, Eco-system exist for fuel ethanol
- Automotive technology for E20 & FFVs are available
- 2G & 3G ethanol plants can support availability to some extent

Challenges & Opportunities

- Surplus ethanol to be used for blending with diesel (ED5)-Research work started, Trials for use of ethanol in SAF route to begin.
- If ethanol become deficit due to natural calamities like extreme drought, then E10 fuel with 95 RON can suffice automotive use





Joint Projects by IOCL with ARAI and SIAM

Fuel Chemistry:

- Development and optimization of additives
- Improving anti-corrosion and ant-oxidant characteristics
- Improving the fuel stability

E10 Studies at IndianOil R&D:

- Joint project undertaken with SIAM and ARAI, in 2010
- Extensive testing on two-wheelers, three-wheelers and passenger cars were undertaken at ARAI and IOCL
- Detailed material compatibility studies were also undertaken
- Durability of vehicles were ascertained over mileage accumulation in chassis dynamometer

Ethanol-Gasoline Blends (E10, E20)

E20 Studies at IndianOil R&D:

Under the aegis of Department of Heavy Industries,
Gol

- Joint project of IOCL-ARAI-IIP in the year 2015-16
- Detailed physicochemical characteristics of E20 fuel
- Startability and Drivability testing of 2-wheelers and passenger cars with E10 and E20 fuels
- Vehicles tested at both cold (-5°C) and hot (+45°C) conditions

Impact of E20 on E10 compatible vehicles: Under the aegis of MoP&NG, Govt. of India

- Joint project of IOCL-ARAI-SIAM (Testing under progress)
- Mattel compatibility tests completed at IOC R&D
- Staratbility and Drivability testing of passenger cars at cold (-20°C) and hot (+45°C) are under progress

Indian Oil R&D Played a key role in framing BIS specification & drafting the Ethanol Blending Roadmap for India

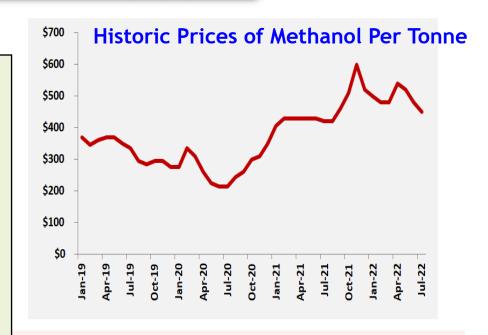




Methanol as a fuel

Methanol Scenario

- Estimated current demand: ~ 2.4 MMTPA
- Domestic production capacity: ~ 0.47
 MMTPA
- Domestic methanol production ~0.272
 MMTPA
- Methanol import: 2.16 MMTPA
- Cost of Methanol \$500/ton
- Cost is the main factor triggering methanol imports



Feedstock Options: Natural Gas, Coal (Indian High Ash Coal), Bio-mass, Municipal Solid waste and CO2.

Setting up of New Indian coal-based methanol plants is essential. Technology demonstrated.

Benefits

- 15% substitution of gasoline can save the crude import bill
- Methanol blending can significantly decrease the Particulate matter (PM) emissions

Challenges

- The large-scale availability of methanol for fuel purpose is a major hurdle in embarking methanol economy
- Substitution of gasoline by 15% would require ~4.5 MMT of methanol

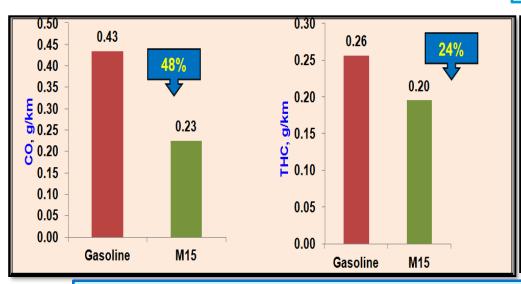


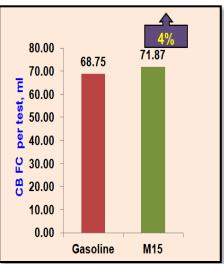


15% Methanol- Gasoline Blend (MG15)

Evaluation of Motorcycle with M15 at IOC R&D

Test Vehicle: BS-III, 150 cc motorcycle





CO decreases by 48%; THC decreases by 24%; NOx is comparable;
Fuel Consumption increases by ~4%

Performance and Emission Study in a fleet of vehicles at ARAI, Pune

- Emission trials using M15 on new vehicles (2-wheeler, 3-wheeler & passenger cars) were carried out.
- M15 exhibited emission benefits for CO & HC as compared to normal gasoline.
- NOx emissions for M15 are more or less constant & do not show any reduction as compared to gasoline.





CNG/LNG



Benefits

- Cleaner low-carbon fuels
- Vehicle technology exist and vehicle park will ramp up as the availability increases
- Viable alternative for LPG (domestic) and Diesel (automotive)

NG Demand for Transport: 6 MMT (Now), 13.57 MMT (2030) and 17.85 MMT (2040)

Challenges

- Infrastructure requirement is huge & require capital intensive equipment for handling.
- Domestic Production of NG is 23 MMTPA which is 53% of total consumption

LNG Terminal	Capacity	Capacity (MMTPA) 2025			
Dahej	17.5	17.5			
Hazira	5	5			
Dabhol	5	5			
Kochi	5	5			
Ennore	5	5			
Mundra	5	5			
Dhamra	-	5			
Jafrabad	-	5			
Jaigarh	-	4			
Chhara	-	5			
Kakinada	-	4			
Kukrahati	-	3			
Krishnapatnam	-	1			
Gopalpur	-	1			
Karaikal	-	1			
Total Capacity (MMTPA)	42.5	71.5			





CBG or Bio-CNG

SATAT Scheme

Initiative by Government - Rolled out in 2018



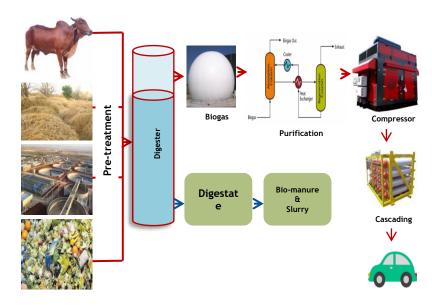




5000 CBG Plants

15 MMT of CBG

50 MMT of Bio-Manure



Feedstock Options: Organic waste / bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, municipal solid waste and sewage treatment plant waste, etc.

Benefits

- Total CBG Potential: 120 MMT
- Production technology is matured and available
- Guaranteed off-take by OMCs and Eco-system exist
- No change in vehicle technology required

Challenges

Aggregating the feedstock, as used for multiple purposes





Major Hydrogen Initiatives



- Development of PEM Fuel Cell buses (manufactured in India)
- Indigenous fuel cell stack technology
- Indigenous hydrogen production pathways
- · Achieving TCO at par with diesel buses
- Multiple pathways giving flexibility in hydrogen production

HCNG -India's 1st tryst with Hydrogen Economy



Biomass gasifier - 10 Kg/hr



Solar Electrolyser - 10 Kg/hr



NG Reformer - 10 Kg/hr



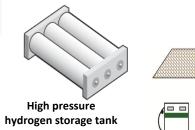
Biomethanation - 10 Kg/hr



Low pressure buffer Storage

Fuel cell Stack
Designed / Manufactured /
Fabricated / Integrated in India





H₂ Dispenser



cylinder with IIT-Kharagpur

1st Indigenous Type 3 hydrogen





Hydrogen / HCNG Activities at IndianOil R&D Centre











1st HCNG/hydrogen dispensing station in India



Funded by HCF : HCNG blends in Heavy Duty Vehicles :TATA Motors & AL



H2 ICE Buses: Mahindra & Mahindra

as Fuel Blended with CNG in Light Duty Vehicles

MoU with SIAM & MNRE: Use of Hydrogen (up to 30%)



H2 Genset: IIT Delhi & KOEL



H2 Fuel Cell testing

Honorable Supreme Court Monitored Project "Demonstration of HCNG fuel mixture in 50 Delhi Public Buses"











HCNG Plant at Rajghat, Delhi; Inauguration of plant

HCNG Dispensing Station HCNG field Trial Inauguration

Testing at ICAT





Conclusion

- Energy transition (India 2040) Share of global energy demand 9.2%
 - Key driver for energy demand shall be the Urbanization
- Energy Demand is increasing
 - ❖ Against 940 MTOE (Present) India may require ~1500 MTOE by 2040
- Energy Hungry India
- https://www.eria.org/uploads/media/Books/2023-Energy-Outlook/12_Ch.6-India.pdf
- Population surpassed China
- GDP Growth
- Make in India thrust
- Major role is of conventional fuel
 - Existing Infrastructure
 - Vehicle Compatibility
 - Cost Economics
- Alternate Fuel Resources
 - Scalable
 - Sustainable
 - Low cost

Till the time Alternate / Renewable Energy Technologies mature the Differentiated Fuel options may be well adopted by fuel end-users to reach the short term goals of Net Zero







THANK YOU