“Regulatory Framework for NGVs in India and Advanced LNG Dual-Fuel Retrofit Technologies for Mining Dumpers”

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पी एन जी आर बी PNGRB | MNGL

Conference on

Leverage Global Innovations to Fuel CGD Growth in India

Organised by

PETROLEUM AND NATURAL GAS REGULATORY BOARD (PNGRB)

In Association with

MAHARASHTRA NATURAL GAS LIMITED

(A Joint Venture of GAIL and BPCL)

Sustainable Mobility is the need of the hour

1

Energy Security

In FY25 **$134 Bn** oil imports which accounts for **>85%** import dependency

2

Global Commitment

Reduction of **45%** carbon intensity & **1 bn** tonne of CO_2 by 2030

3

Pollution Mitigation

22/30 most polluted cities in the world are in India

Indian Automotive Industry is aligned with the Government of India's vision & priorities towards sustainability

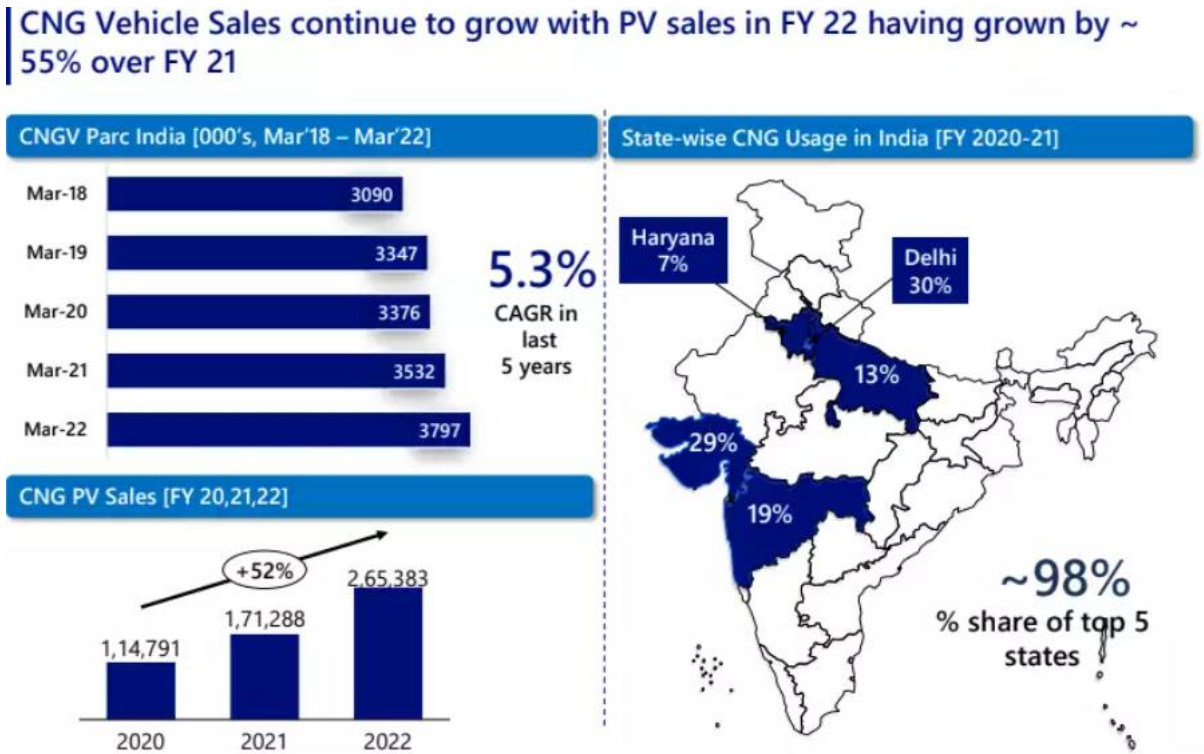
Alternative Fuels – Notifications

Bio-CNG / Bio-Methane	Biodiesel (B–20 and B-100)	Compressed Natural Gas (CNG)	Di-Methyl Ether (DME)	Dual fuel – Diesel/CNG/ Bio-CNG/LNG	Ethanol (E–20)
GSR 498 (E) dated 16th June 2015	GSR 412 (E) dated 11th April 2016	GSR 889 (E) Notified for BS VI	GSR 37 (E) dated 17th January 2020	GSR 1151 (E) dated 29th November 2018	GSR 156 (E) dated 8th March 2021

Ethanol (E-85, ED-95, E-100)	Hydrogen	Hydrogen – CNG (HCNG)	Liquified Petroleum Gas (Auto LPG)	Liquefied Natural Gas (LNG)	Methanol M-15/ M100 & Methanol MD95
GSR 682 (E) dated 19th May 2015	GSR 889 (E) Notified for BS VI	GSR 585 (E) dated 25th Sept 2020	GSR 889 (E) Notified for BS VI	GSR 643 (E) dated 27th June 2017	GSR 490 (E) dated 24th May 2018

Increasing NGV Penetration in India

Region / Country	CNG Vehicle Count	Remark
India	~10 million	Rapidly growing; major infrastructure expansion from 1,081 stations in FY16 to ~8,400+ by FY25.
Global Trend	15 millions (aggregate estimate)**	Led by Argentina, Iran, Pakistan, Brazil, China — all with millions of CNG vehicles each.



Source: PPAC, IGL and MGL Investor Presentations

Increasing NGV Penetration in India

NGV Sales Penetration by 2030

50%

CNG Stations

~10,000 Stations

1,000 LNG retail outlets, entailing an investment of Rs 10,000 cr., in the next 3 years

INR 11 Lakh Crore
Crude Oil Import Savings

Target Segments for CNG

Cars, 3W, LCVs and Buses

Target Segments for LNG

Trucks

Crude Oil Import Savings
10%
Of the Central Budget Expenditure on Welfare Schemes

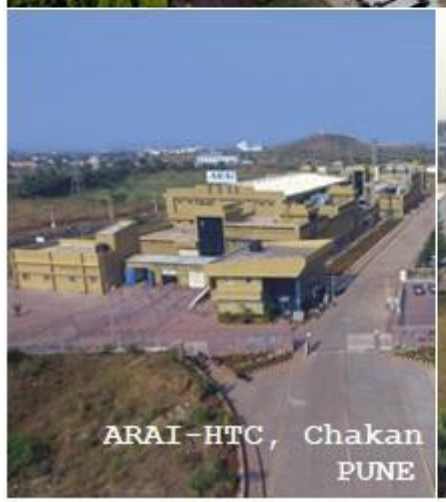
Growth in the income of 3W and LCV drivers

Up to INR 5000 to 8000 per month

Employment Generation

4 Lakh new jobs

ARAI ROLE IN ALTERNATIVE FUELS



01 R&D PROJECTS ON ALTERNATIVE FUELS

02 REGULATION FORMATION IN CMVR & BIS STANDARDS

03 CMVR CERTIFICATION OF GENSETS & VEHICLES ON ALTERNATIVE FUELS

04 TRAINING ON ALTERNATIVE FUELS

05 IPR GENERATION IN ALTERNATIVE FUELS

06 CONSULTANCY TO INDUSTRY

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Progress through Research

Alternate Fuel Centre at ARAI

“All Solutions to alternate fuels under one roof”

Various Fuels handled by Alternate Fuel Centre

Flex Fuel
- E85
- M85

Dual Fuel
- Diesel + CNG
- Diesel + LNG
- Diesel + Bio-CNG

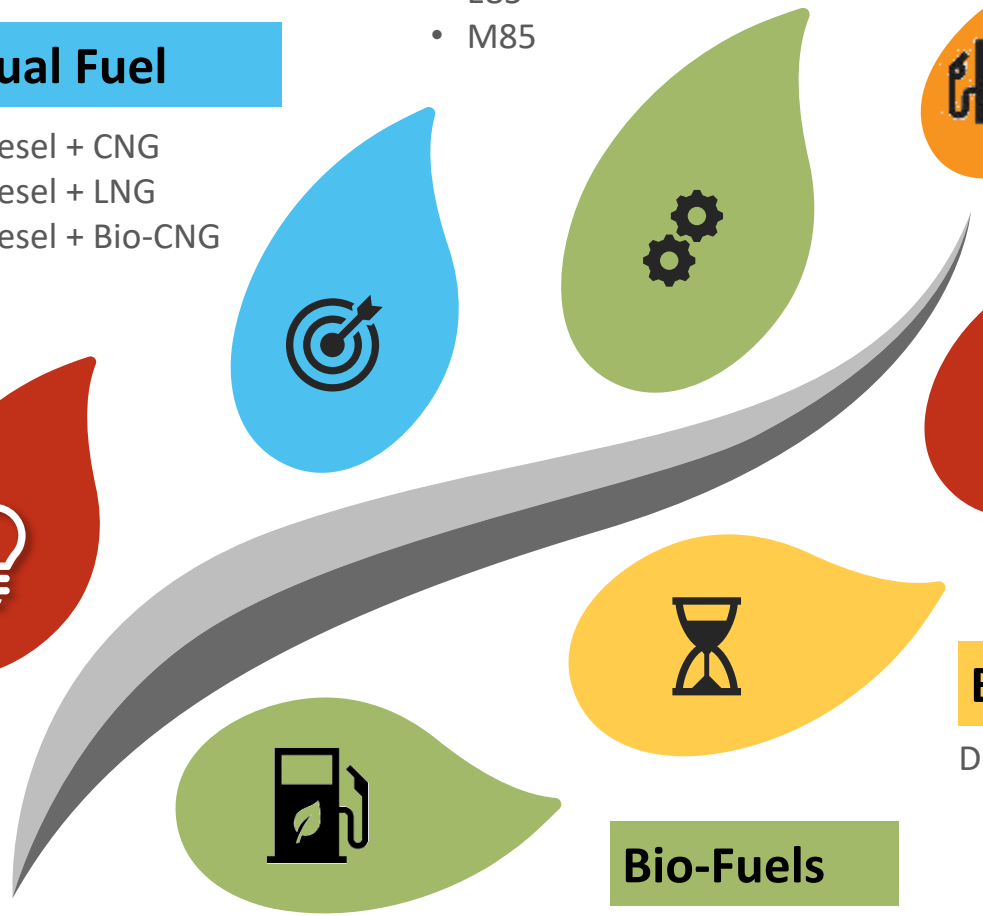
Hydrogen
- H2 ICE
- HCNG

Gaseous Fuels
- Compressed Natural Gas (CNG)
- Liquefied Natural Gas (LNG)
- Bio-CNG
- Liquefied Petroleum Gas (LPG)

Synthetic Fuels
- DME
- DME+LPG

Blended Fuel
Diesel - Ethanol

Bio-Fuels
- E10, E20, E100
- M15 M100
- ED95 MD95



ARAI Completed Alternate Fuel Projects

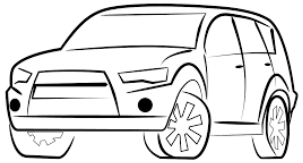
No of Projects completed – 60 Nos

2 Wheeler	8	0.15 engine	BS 3 BS 4 BS 6

3 Wheeler	9	0.1 – 0.6 L engines	BS 2 BS 3 BS 4

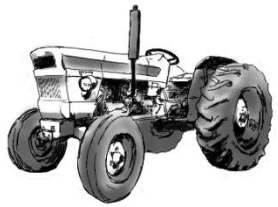
Passenger Car	6	1 – 1.4 L engines	BS 2 BS 3 BS 4

LCV	5	2.5 – 4 L engines	BS 3 BS 4 EURO 5



SUV	5	2.5 – 4 L engines	BS 3 BS 4 BS 6

SCV	1	1.5 L engine	BS 4



HCV	9	3 – 6 L engines	BS 3 BS 4 BS 6

Off-Road / Genset	9	3 – 6 L engines	Trem – III A CPCB I & II
	1	LPG engine for Marine Application	

ARAI has worked on various Alternate fuels like CNG, LPG, HCNG, Methanol (M15), Ethanol (Diesel Ethanol), Dual Fuel, CBG etc.

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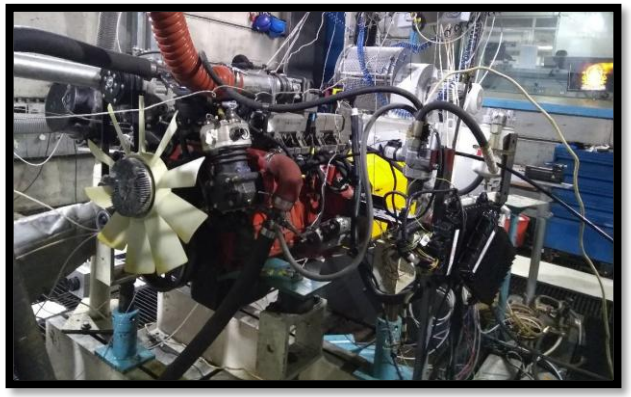
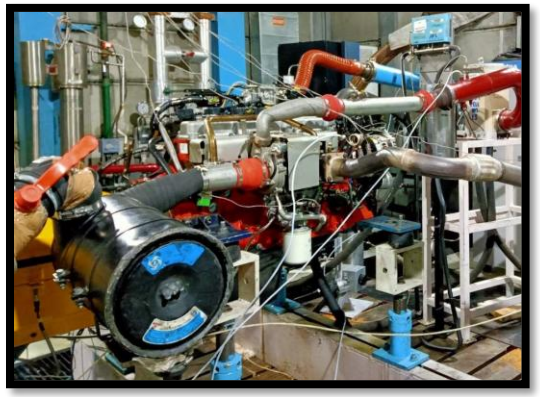
Progress through Research

Completed BS-VI NG Engine Development

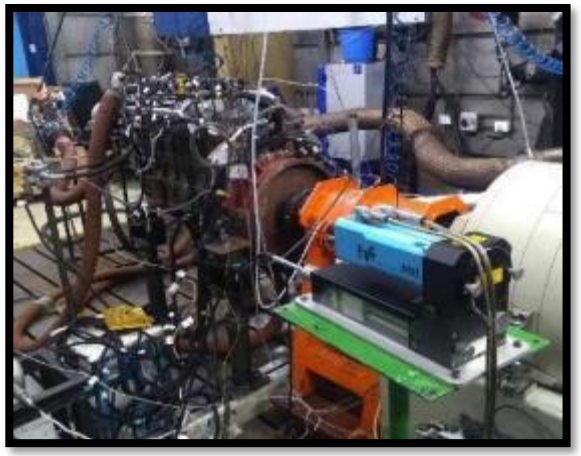
Development of BS-VI compliant 6-Cylinder NA NG Engine



Development of BS-VI compliant 4-Cylinder TCIC NG Engine



Development of BS-VI compliant 6-Cylinder TCIC NG Engine



Demonstrative up-gradation of existing BS-IV NG HCV Engine to meet BS-VI emissions

Highlights:

- All the projects are commercialized and vehicles launched
- Development done with only one after-treatment system (3-way cat-con)
- Mechanical piped EGR used for TCIC version & **no use of GPF for PN control**
- Robust Calibration for control of NH3 and PN
- Certifed OE & Retrofitted LNG vehicles
- Established LNG storage and engine testing/certification facility at ARAI

एआरएआई ARAI Progress through Research

India’s Energy Landscape & Role of Innovation

India’s Energy Transition Landscape

India is targeting a **shift toward** cleaner**, low-carbon mobility** across heavy-duty sectors.

The **CGD network is becoming a key enabler** for supplying cleaner fuels like LNG/CNG.

Need for Cleaner Heavy-Duty Mobility

Mining dumpers are major diesel consumers and contributors to emissions.

LNG-based solutions reduce emissions and operational costs significantly.

Role of Innovation

Dual-fuel LNG retrofits and digital monitoring enable heavy mobility decarbonization.

These **innovations support the strengthening of the CGD ecosystem.**

LIQUEFIED NATURAL GAS (LNG)

LNG

- **Low Carbon Fuel** — Mostly contains methane (CH4). Hence less contribution to CO and HC emissions
- **Lower Particulates** — Particulate Matter and smoke is almost negligible from LNG emissions
- **Renewable Fuel** — Bio-LNG is a renewable source of energy which is obtained from decomposed biological sources like animal waste, dry leaves, etc.
- **Cost Effective** — LNG will be cheaper than the fossil fuels and will be more affordable however recent hike of prices of LNG may affect market.

Emission Benefits from LNG trucks

Tailple CO_2 Emissions Reduction

- Lifecycle benefits are impacted by methane slip, but are cleaner overall for long haul

NOx & Particulate Matter Reduction

Nox

-59%

Particulate Matter

-91-98%

Regulatory Requirements for LNG vehicles as per CMVR 115B

OE Dedicated Dual Fuel LNG Vehicle

G.S.R. 1151 (E)

Replacement of Existing Diesel Engines with LNG Dual Fuel System

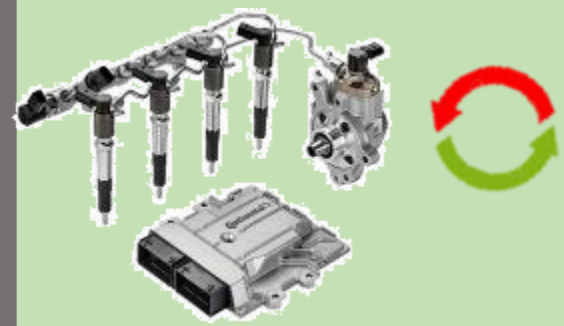
G.S.R. 1151 (E)

Diesel

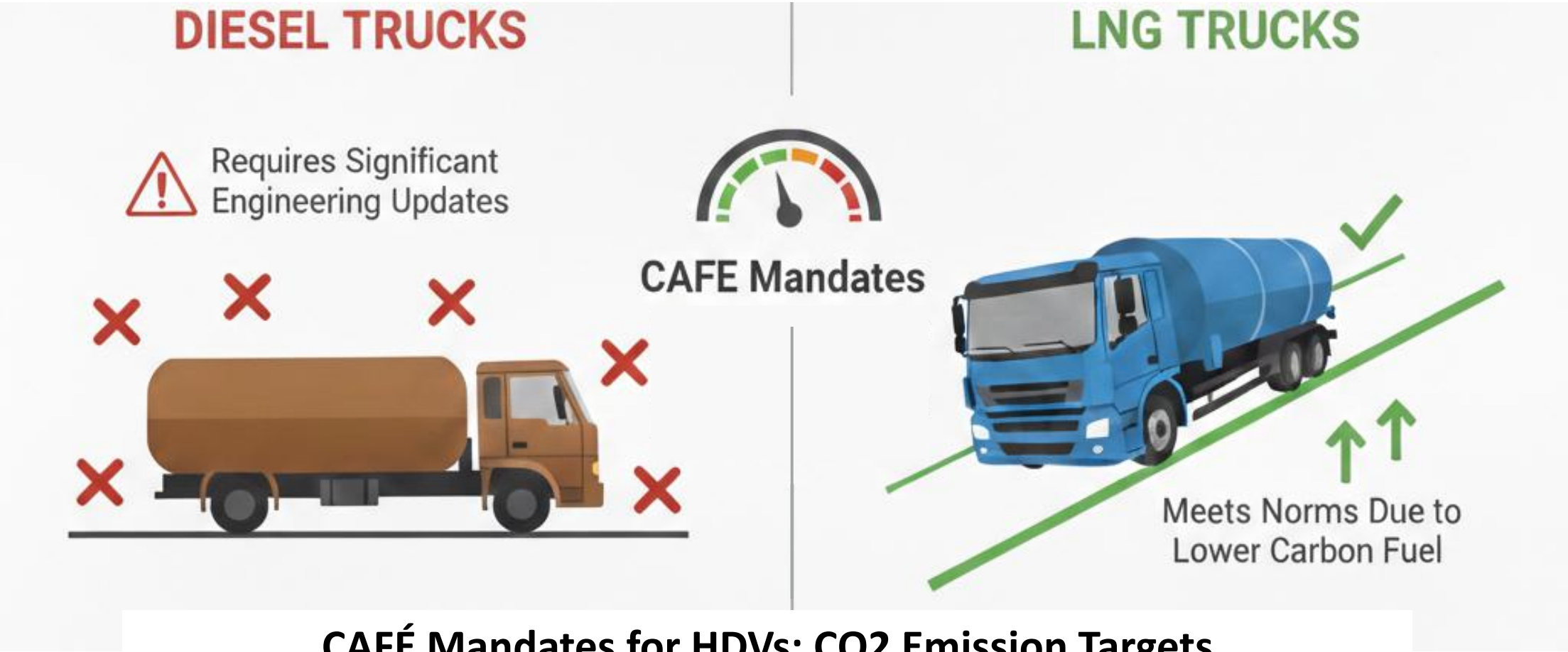
LNG

Retro-fitment of Existing Diesel Engines with LNG Dual Fuel System

G.S.R. 1151 (E)



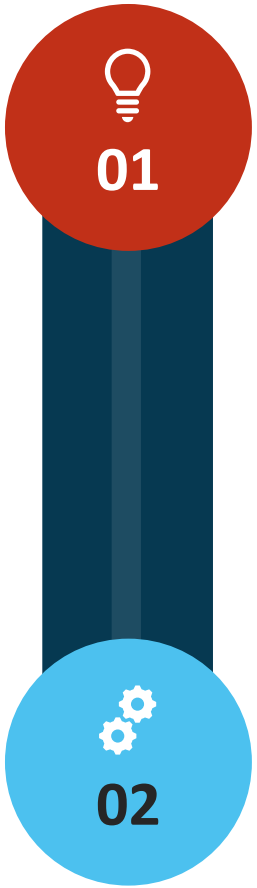
Future Challenges for Heavy-Duty Vehicles



CAFÉ Mandates for HDVs: CO2 Emission Targets

- FY2027: 110 g/ton-km -FY2030: 90g/ton-km

LNG/Diesel-LNG (Dual Fuel) – Notifications and Standards



01

GSR 1151 (E)

Notification for Diesel-LNG to be used as Automotive fuel

02

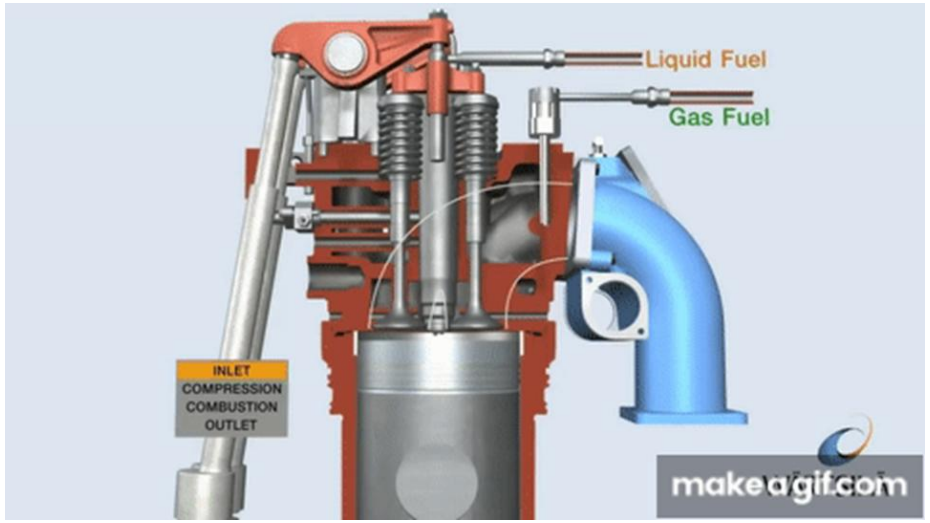
Safety Standards

AIS 024-028 – applicable for CNG / Bio-CNG / LNG
Safety check on LNG Vehicle
Component testing requirement

What is LNG Dual-Fuel Retrofit?

An LNG Dual-Fuel Retrofit is a modification to an existing diesel engine that enables it to run on both diesel and LNG (Liquefied Natural Gas) simultaneously.

Diesel + **LNG together** → **Dual-Fuel engine**



What "Retrofit" means?

Retrofit = upgrading an **already-in-use diesel engine** (truck) **without replacing the engine**.

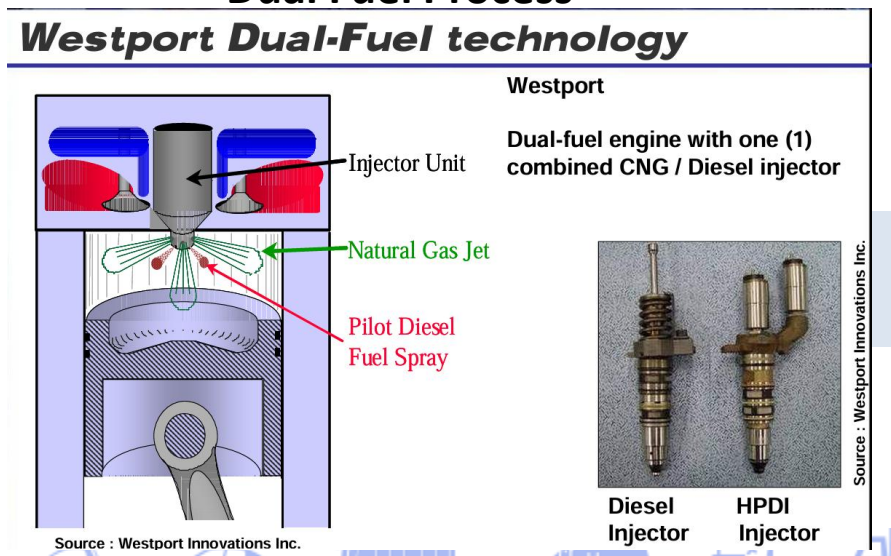
So instead of buying a new gas engine, you:

- Keep the diesel engine
- Add LNG-related components
- Enable dual-fuel operation

How It Works:

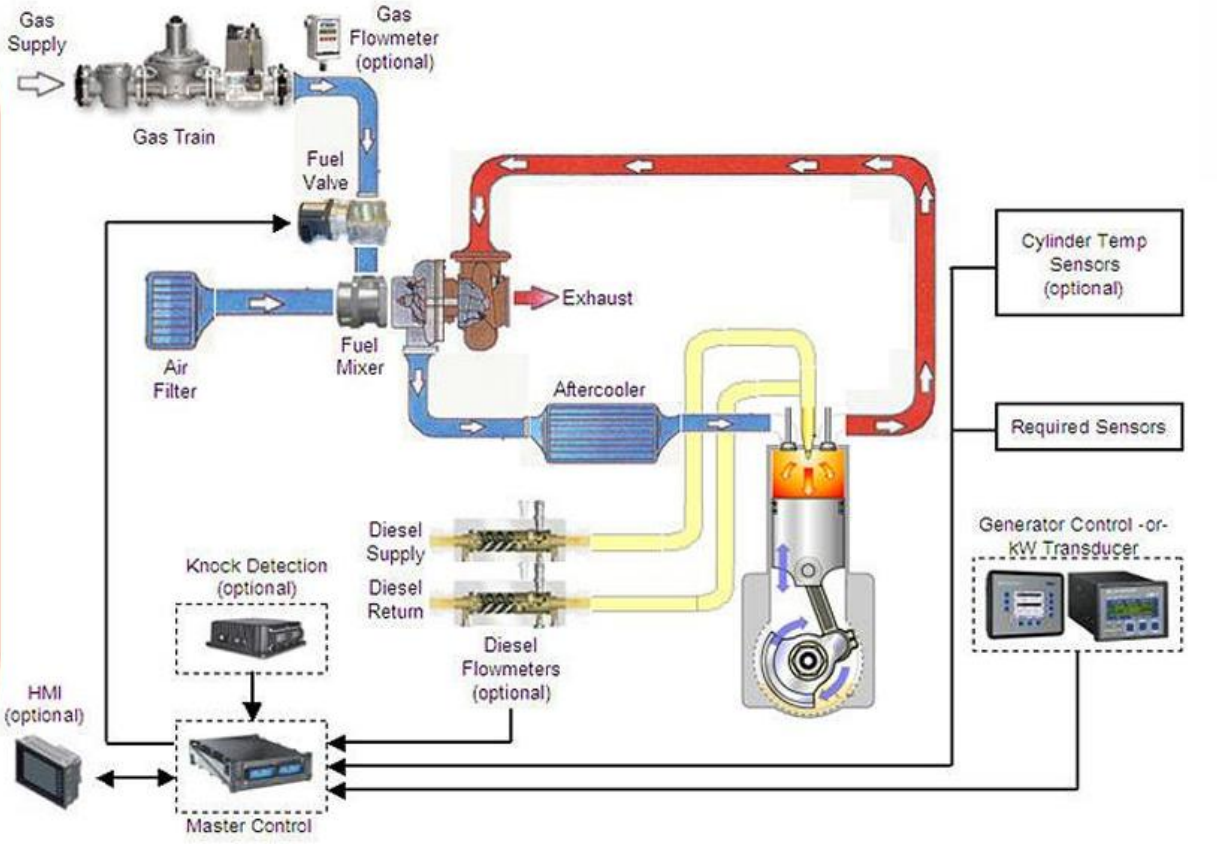
- LNG is **introduced into the intake air**
- Diesel continues as **pilot fuel for ignition**
- Engine operates in **dual-fuel mode automatically**

Dual Fuel Process



Schematic for Dual Fuel Engine

- Simultaneous Combustion of Two fuels
- Gas inducted into diesel engine inlet manifold
- With Controlled Systems
- Diesel Engine runs with Gas + Diesel
- Replacing usage of diesel Approx 50% to 70%
- When No gas the engine can operate on Diesel



Key Inputs for Operation

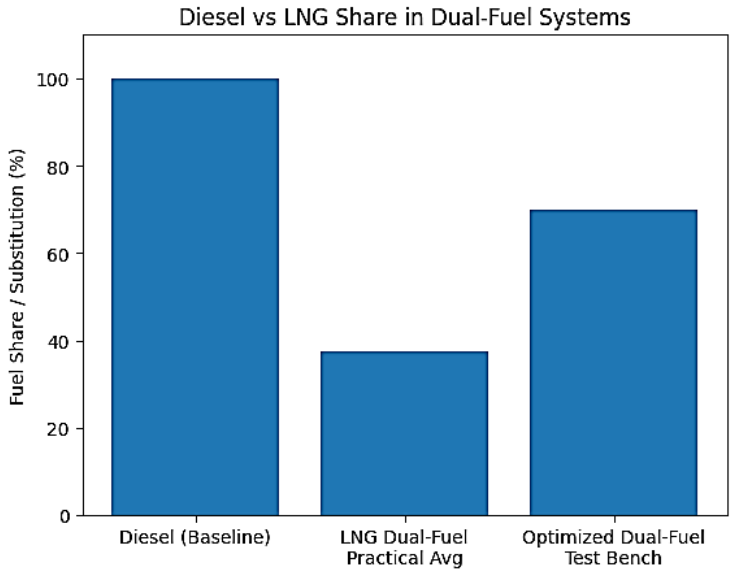
- ✓ Inlet Air Sensing - Pressure & Temperature
- ✓ Exhaust Sensing - Temperature
- ✓ Vibration Sensing - Crank Case

https://www.researchgate.net/figure/Figure-1-9-illustrate-the-principle-design-of-a-CNGDiesel-dual-fuel-engine-which-is_fig1_308867209

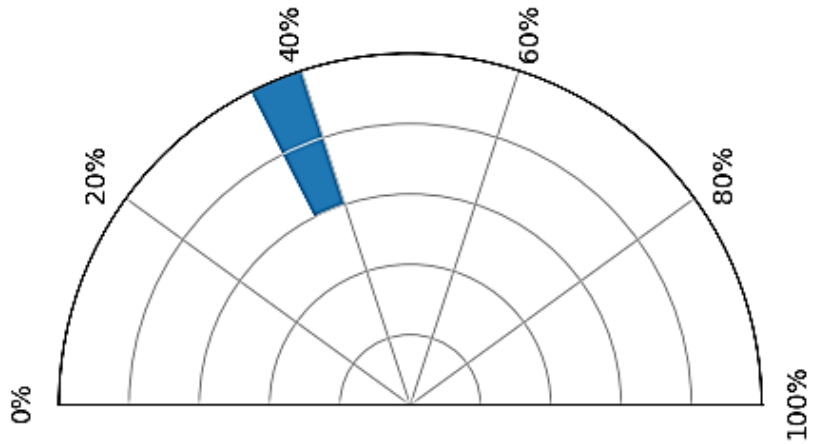
Diesel Substitution Potential

Field & Industry Observations:

- Typical average substitution in practical retrofit applications is ~35–40% of diesel by LNG, depending on load cycles and duty profile.
- Heavy-duty mining or industrial cycle engines usually operate in the range where LNG replaces ~30–40% of diesel energy without hardware changes.



Comparison of diesel baseline operation with practical and optimized LNG dual-fuel substitution levels



Typical LNG Substitution Zone (35–40%)

Safety & Reliability Features

- Fail-safe system design ensures immediate reversion to conventional diesel operation under any abnormal condition.

Cryogenic LNG Storage Tank

Designed for **–162°C LNG storage**

Double-walled, vacuum-insulated construction

Certified pressure relief & thermal safety valves

Mechanically protected for **harsh mining environments**

LNG Vaporiser, Pressure Regulation and injection

Converts LNG to gaseous natural gas in a **controlled manner**

Maintains stable gas pressure across load variations

Integrated **over-pressure and temperature protection**

Electronic Control Unit (ECU)

Real-time monitoring of:

- Engine load
- Gas flow
- Temperature & pressure

Automatically adjusts **LNG–diesel ratio**

Reverts to **100% diesel mode** in fault conditions

Leak Detection & Emergency Shutdown

Continuous gas leak detection sensors

Automatic isolation valves on LNG lines

Emergency shutdown activated during:

- Leak detection
- Over-pressure

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Progress through Research

ARAI Developed Dual Fuel vehicles for Indian OEM's

- Development of a dual fuel diesel-CNG engine for Heavy duty application
- Development of a dual fuel system (Indigenous including ECU) for SUV engine
- Development of a dual fuel diesel-CNG engine for Tractor application
- Development of a dual fuel diesel-CNG engine for Off highway application

India’s First dual fuel (Diesel + CNG) operated Construction Equipment

Vehicle Conceptualised and Developed by ARAI

Key Highlights:

- Vehicle market launch at the hands of Hon’ble Minister (MoRRH) Shri. Nitin Gadkariji
- Dual fuel CEV meeting Trem-III A norms
- Diesel replacement approx. 70% by CNG.
- It meets stringent field duty cycles such as excavation, re-handling and roading
- Unique CNG fuel system along with CNG cylinder packaging

From Automotive LNG Adoption → Mining Sector Decarbonization

Ground Scenario

- LNG/CNG momentum is growing in transport, supported by CGD expansion.
- **Heavy-duty mobility faces rising pressure to cut local pollutants & GHG intensity.**
- Upcoming CAFÉ & Euro 7 signals stricter heavy-duty pollutant limits, real-driving compliance and durability.

Why now move to Mining?

- Mining fleets operate high-utilization duty cycles with very high diesel consumption.
- Net-Zero pathways require decarbonization beyond on-road—off-road must contribute.

Tightening Emission Norms for CEV/Mining engines

- Stage V emissions norms are stricter above 560kW with the introduction of PM
- Global norms influence supply chains and future regulatory expectations.
- Mining dumpers operate 24×7 under heavy load. Diesel accounts for 30–40% of operating cost. High exposure to fuel price volatility.

On-road LNG momentum
HD trucks / corridors

↓

Off-road mining deployment
Dumpers / haul trucks

↓

CGD ecosystem scale-up
Demand + infra + standards

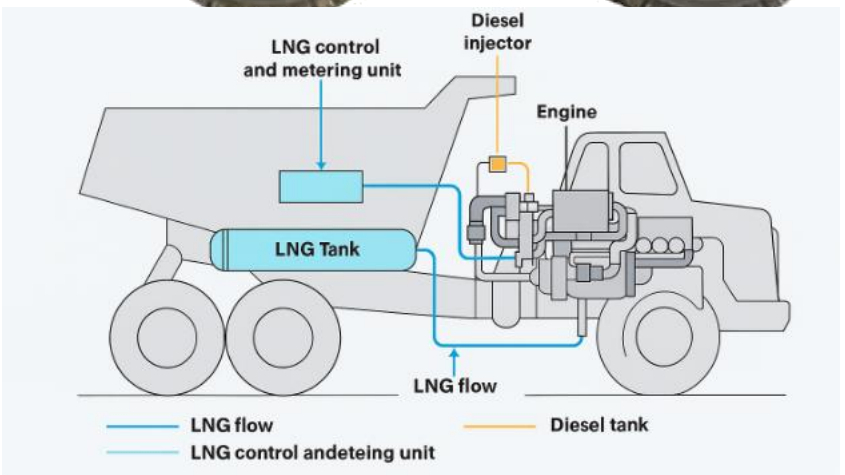
Transition: LNG is proven in mobility—mining offers the next high-impact, scalable decarbonization lever.

Mining Dumpers

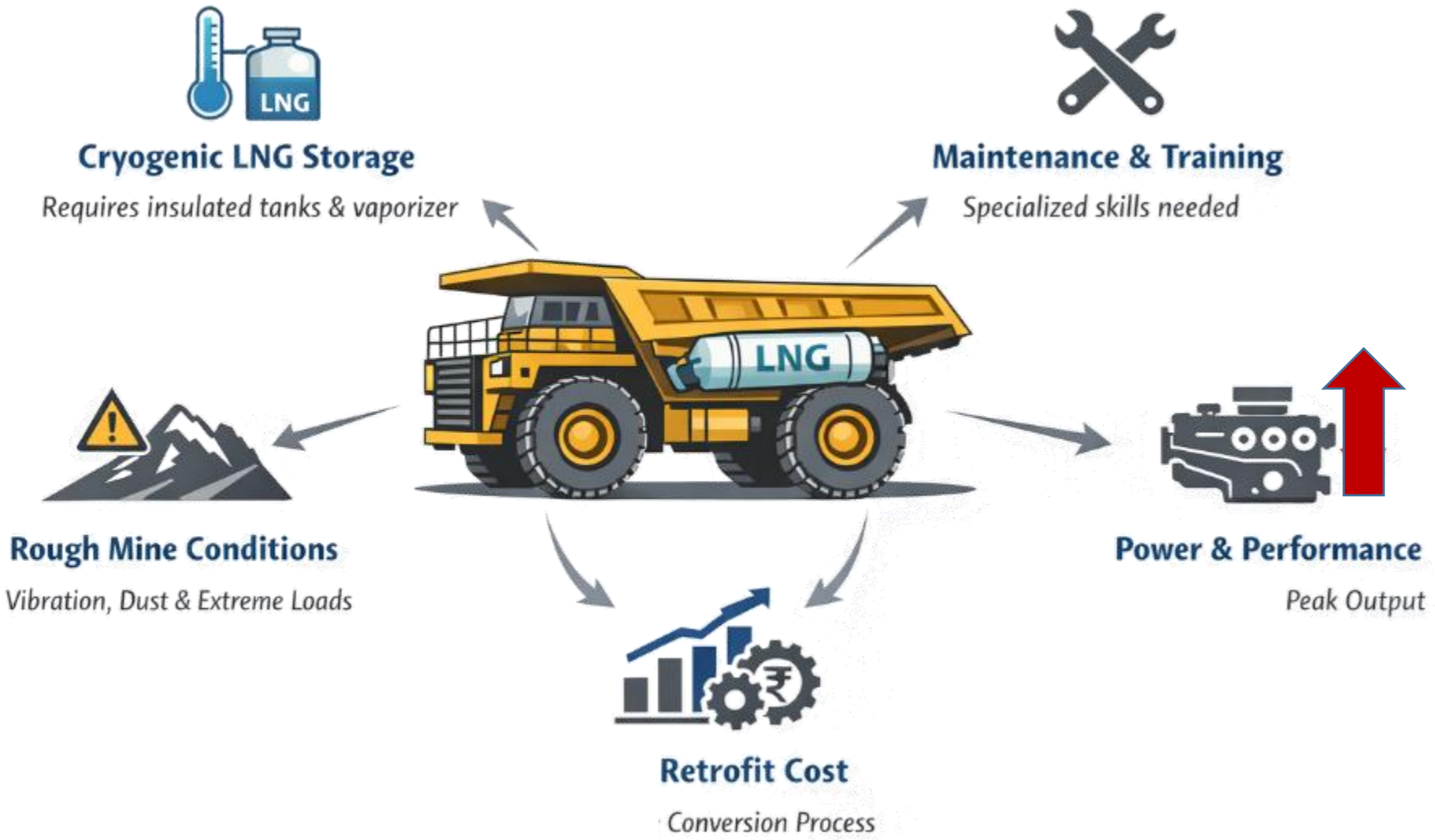
Mining dumpers—especially 60T, 100T, 150T and ultra-class 240T/320T haul trucks—operate in continuous duty cycles, often 24 hours a day, 7 days a week, to maintain mine productivity targets.

Engine Specifications Table

Parameter	Caterpillar 777G (Cat C32B)	Qingong 100T Mining Dumper (Cummins Z14-C540)
Engine Model	Cat C32B	Cummins Z14-C540
Type	V12 Diesel, Turbocharged & Aftercooled	Inline 6 Diesel, Turbocharged
Displacement	32.1 L	(Derived from 397 kW = ~540 hp class)
Rated Power	~711 kW (≈953 hp net)	~397 kW (≈540 hp)
Rated Speed	1750–1800 rpm	~Unknown exact rpm
Net Torque	~5130 Nm	~2400 Nm
Cylinders	12	6
Emission Standard	EPA Tier 2 / Stage IIIA equivalent	Euro II/III

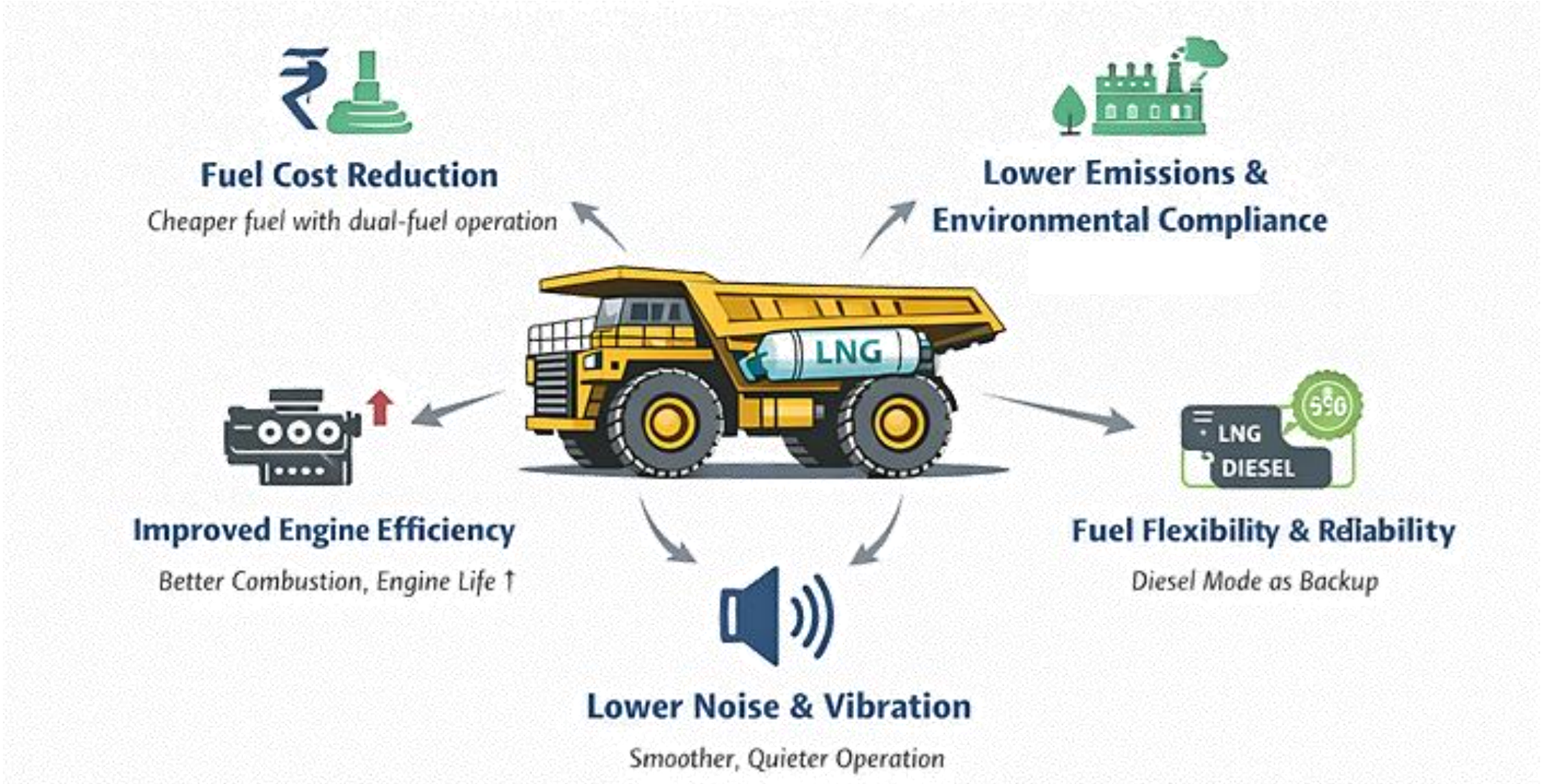


Challenges in Converting Diesel Dumpers to LNG (Dual Fuel)



Directorate General of Mines Safety (DGMS) shall notify LNG conversion for dumpers

Benefits in Converting Diesel Dumpers to LNG (Dual Fuel)



Supported by the Alternate Fuel Centre at ARAI (For LNG dumper conversion)

Engine Level – Calibration Support

- Alternate **fuel engine calibration** for emission/power/BSFC
- Alternate fuel engine durability
- Alternate fuel **engine development**, testing and **validation**
- Alternate fuel engine **combustion and simulation**
- Alternate fuel engine/Kit **component evaluation**
- Upgradation of the engine for specific fuel
- Genset Certification and Consultancy

Vehicle Level - Support

- Safety layout design and review as per AIS
- Vehicle trials

Other Support Services

- **Fuel Characterisation**
- Preparation of additive / oil / catalyst and its evaluation
- Material compatibility as per ASTM standards
- **Training on alternate fuel engine, vehicle, rules and regulations** to RTO & other govt officials, Fuel suppliers, STU's, Academician, Industry personnel, Graduate trainees, etc.
- Consultancy on need basis for specific project / technical support
- OBD demonstration Consultancy
- De-coding of regulation and consultancy
- System verification, review and readiness for any specified notification
- Assistance in new standard development
- Evaluation of additive/ efficiency improvement devices
- Third party inspection

AWARDS & RECOGNITION

BEST PAPER AWARD
FIRST PRIZE
2011-26-0002

Development of CNG Injection Engine to meet Future Euro Emission Norms for LCV Applications

BEST INDIAN PAPER
ENVIRONMENTAL POLLUTION
2009-26-031

Development of a Six Cylinder HCNG Engine using an optimized Lean Burn Concept

INTERNATIONAL AWARDS

US SAE International Award – First Prize –Clean City Delhi

Barcelona Award – Pumpless Lubrication system

BEST TECHNICAL PAPER
FIRST PRIZE
2019-26-0089

Development of Diesel-Ethanol Engine for HCV

BEST INDIAN PAPER
ENVIRONMENTAL POLLUTION
2021-26-0117

Experimental Analysis of Heavy Duty CNG Engine based on its Aspiration & Fuel System

BEST PAPER AWARD
THIRD PRIZE
2013-26-0009

Development of Three Cylinder CNG Engine for LCV

BEST PAPER AWARD
FIRST PRIZE
2007-26-029

Development of a CNG Injection Engine Compliant to Euro –IV Norms and Development Strategy for HCNG Operation

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THANK YOU