Kingdom of the Netherlands

NITI Aayog

LNG as a Transportation Fuel in Medium & Heavy Commercial Vehicle Segment

Report
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ICF

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Foreword

NITI Aayog and the Embassy of Netherlands are engaged in bilateral cooperation through a Statement of Intent (SOI) on projects related to the energy transition. The objective of this bilateral engagement is to promote effective, timely and coordinated policy development in areas of mutual interest such as energy access, sustainability, ease of doing business, and improved energy infrastructure for enabling an orderly transition. The SOI is focused on bringing together industry bodies, private enterprise and sector experts for garnering actionable policy inputs.

The report, 'LNG as a Transportation Fuel in Medium & Heavy Commercial Vehicle Segment' is one outcome of this partnership. It seeks to leverage the use of LNG as a fuel in order to lower CO2 emissions and contribute towards the national goal of a gas-based economy by increasing the share of natural gas in the primary energy mix to 15% by 2030.

The Government of India has played a proactive role in the global conversation on sustainability and the energy transition. The forward-looking 'Panchamrit' commitments and the updated Nationally Determined Contributions (NDCs) underscore the fact that India is a critical part of the global solution. For mitigating greenhouse gas emissions, we are also driving the global agenda through bold commitments such as achieving Net Zero by 2070 and away for a 45% reduction in the emissions intensity of GDP by 2030, when compared to 2005 levels. India's rapidly expanding trucking market, which is expected to more than quadruple, from 4 million trucks in 2022 to roughly 17 million trucks by 2050, offers immense scope for lowering emissions and encouraging investments for growth. Therefore, the role of transition fuels as part of a diversified basket of energy source has been emphasised in the report.

The report has identified opportunities in the transport sector and suggested a roadmap for LNG adoption based on extensive stakeholder interactions, a review of successful global models and in-depth financial analysis. I am sure that this report will serve as a valuable resource for policymakers, researchers, industry professionals and other stakeholders dealing with the energy transition in the transportation sector.

(Suman Bery)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Kingdom of the Netherlands

Foreword

Climate Change is a global concern. Reports of the IPCC show alarming trends of the increase of warming of our earth and urges governments to accelerate the energy transition. The challenge the world encounters is to decarbonize future economic growth.

India and the Netherlands are both vulnerable to the impacts of climate change, such as erratic rainfall, floods and prolonged droughts, often threatening the livelihood of large parts of the population. Both our countries are committed to fight climate change and have set ambitious targets for decarbonization and development of renewable energy. In our bilateral cooperation there is a strong focus on energy & climate.

The Government of the Netherlands and NITI Aayog have joined forces and signed a Statement of Intent (SoI). Under the SoI studies are being prepared jointly with the support of SHELL. The reports aim to inform stakeholders, stimulate dialogues and support impactful policy development.

I am very pleased to see our first joint report launched at the India Energy Week 2024: 'LNG as a Transportation Fuel in Medium & Heavy Commercial Vehicle Segment'.

This report presents an analysis of benefits, challenges and future prospects of LNG for the Medium and Heavy vehicle segment in India. LNG is a transition fuel and as such a first step in decarbonization of transport and logistics sector.

Connected to our efforts to decarbonize the transport sector, I would like to mention that The Netherlands is co-leading a Global MoU on Zero Emission – Medium and Heavy Duty Vehicles (ZE – MHDVs).

I would like to thank NITI Aayog for the close cooperation we enjoyed. We are looking forward to continuing our collaboration and taking our partnership to the next phase.

H.E. Marisa Gerards,
Ambassador, Embassy of the Kingdom of the Netherlands in India, Nepal and Bhutan

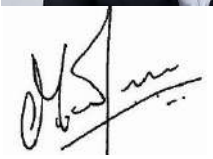
Preface

Embassy of the Kingdom of the Netherlands signed a Statement of Intent (SoI) with NITI Aayog in September 2020 to collaboratively work on energy transition and decarbonization agenda. The objective for this collaboration was to accelerate induction of cleaner and more energy in delivering economic and sustainability goals of the nation.

Today, we stand at the crossroads of environmental responsibility and economic development, where world continues to grapple with increasing air quality challenge and Green House Gas (GHG) emissions from various sectors like heavy-duty vehicles. The report, titled "LNG as a Transportation Fuel in Medium & Heavy Commercial Vehicle (M&HCV) Segment," developed in consultation with sector experts, navigates the complexities of this challenge, exploring the transformative solution of LNG as a resilient and transition fuel for M&HCV.
While the growing use of compressed natural gas (CNG) in urban transport has helped in combatting high levels of pollution in the last 10 years, the conversion of HDVs to CNG poses an arduous challenge. In this context, our report takes a closer look at LNG, exploring how it can work as an alternative fuel for diesel, for HDVs to address air pollution and at the same time, aligns with India's vision of a gas-based economy. The draft LNG policy offers a guiding framework, providing actionable insights and a detailed roadmap to increase the adoption of LNG as a transport fuel, in the HDV sector.

In this report, we not only unveil a strategy but also emphasise on importance of collective action. Aligned with our steadfast commitment to sustainable energy solutions, we propose a roadmap for early adoption of LNG by the transport sector, propelling India towards economic growth, environmental resilience and a bright energy future.

The report presents key insights from interactions with important stakeholders in the value chain of LNG transport for M&HCV. This includes approximately 40 different stakeholders covering LNG suppliers, transporters, fleet operators, end users, LNG retailers, regulators, OEMs, financiers, and government departments and relevant ministries. We collaboratively reviewed existing policies and regulations in place for adoption of LNG and summarized key learnings from international experiences like China and European Union in adopting LNG as a transport fuel. Report also presents the environmental and economic benefits for India in adopting LNG in this segment. Finally, it illustrates potential business models for different stakeholders, key recommendations for supporting adoption and a roadmap for LNG in M&HCV, identifying a priority order for implementing possible solutions based on the impact and readiness of the market.



Mansi Madan Tripathy
Chairman Shell Group of Companies, India &
Vice President – Lubricants, Asia Pacific

Gurpreet Chugh
Managing Director, India
ICF

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1 Executive Summary

The push for emissions reduction has gained significant momentum in the recent years and India has shown strong climate leadership at global forums to support sustainable initiatives while balancing it with its key goals of economic development. In addition to reducing greenhouse gas (GHG) emission Indian cities also need to act on reducing local air pollution which is a big concern in many Indian cities today. The levels of air pollutants in many cities, including particulate matter (PM), sulphur dioxide, nitrogen oxides, carbon monoxides and ozone today exceed the National Ambient Air Quality Standards (NAAQS) by a large margin. According to the World Air Quality Report, 2021, several cities in India rank among the top 30 cities with the highest air pollution levels. Transportation has been identified as a major contributor to PM2.5 emissions in cities like Delhi, accounting for almost 40% of the total emissions. Studies have shown that the heavy-duty vehicle (HDV) segment is the most significant contributor to air pollution and the largest consumer of fossil fuels. Nationally, the HDV sector contributes up to 66 per cent[1] of the particulate matter from on road transport sector.

The growing use of compressed natural gas (CNG) in urban transportation has helped in combatting high levels of pollution in the last 10 years, based on conversion of cars, buses, and auto rickshaws to CNG. However, the conversion of heavy-duty vehicles (HDVs) to CNG is challenging, not the least due to the heavy payloads involved and the requirements of long travel time without having to stop for frequent refueling. In this context LNG can work as an alternative fuel for diesel, for HDVs in India. Natural Gas is a well-tested transportation fuel in India and the technology for gas engines has already reached a matured stage thereby limiting any technology risks for use of LNG by HDVs.

India's aim to develop a gas-based economy

India has defined a vision for increasing the natural gas share in the primary energy mix to 15 per cent. For this, significant impetus has been given towards development of natural gas infrastructure via authorizing multiple city gas distribution licenses across the country. While an aim is to develop the natural gas market in new areas with infrastructure creation, the focus has been also on finding new areas of application, where natural gas can play a role. The draft LNG policy2 issued by Ministry of Petroleum and Natural Gas focuses on the strategies to increase LNG as a transport fuel. To implement the same, foundation for India's first 50 LNG fuel stations were laid along the Golden Quadrilateral. Such steps settled the debate on whether infrastructure should come first, or if demand must be established. While infrastructure is being developed now, the key focus is to understand the demand side measures, for which stakeholders' discussions were carried out.

Draft LNG Policy

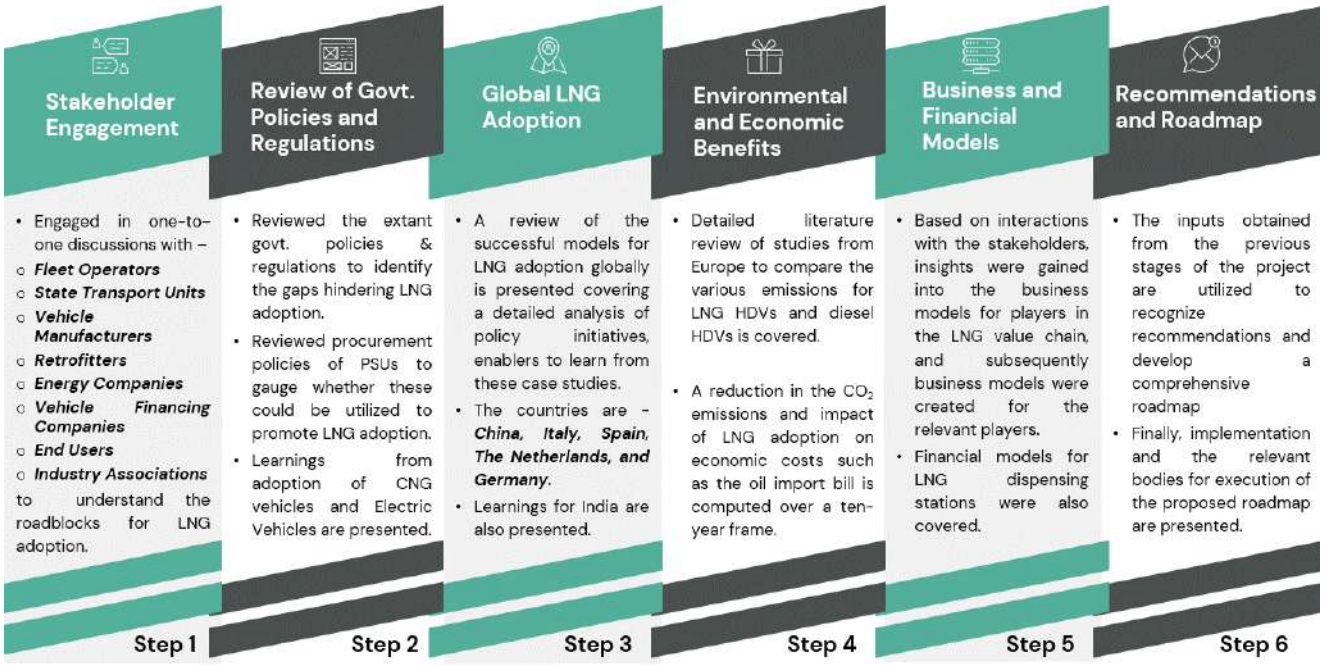
The government of India has released a draft LNG policy to increase LNG usage as transport fuel and in the mining sector among other objectives as described below:

fuel. The current project addresses this gap to build a detailed roadmap to kickstart and sustain the adoption of LNG as a fuel.

Approach & Methodology

In this report, ICF reviews the details of current scenario for LNG and how LNG adoption in HDVs can be brought on with the right policy incentives and market conditions. We delve into the specificities of the roadblocks creating obstacles in the development of the LNG market, and how these can be removed.

The figure below illustrates approach and methodology to arrive at the recommendations and roadmap for this report.



Stakeholder Consultation

Engaging with key stakeholders across the value chain is an essential step in understanding the barriers and opportunities for the large-scale adoption of LNG as a transportation fuel in India. Drawing from the experiences of countries like China and parts of Europe, where a robust LNG value chain exists, can provide valuable insights and lessons for India. Consensus building among stakeholders is crucial to address the challenges and roadblocks hindering the widespread use of LNG in transportation. We engaged with key stakeholders across the value chain to capture their diverse perspectives, identify roadblocks and to understand opportunities towards devising a robust approach. On a practical level, stakeholder engagement identified areas of agreement as well as disagreement, and provided a unique opportunity to understand with complete clarity what might be the driving factors.

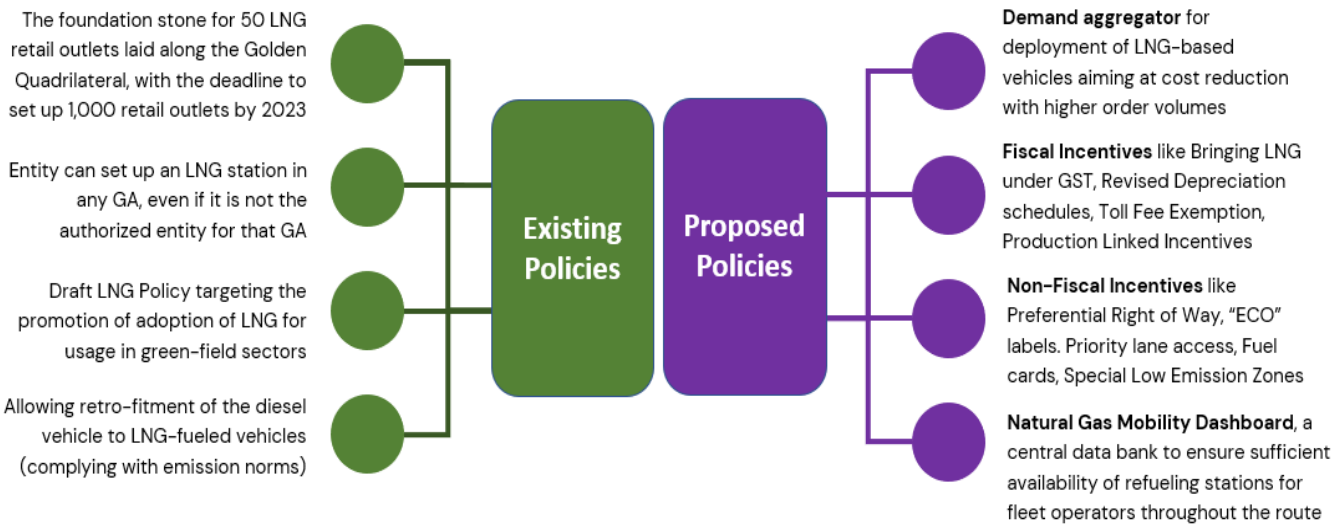
We engaged with multiple stakeholders, such as fleet operators, state transport utilities, vehicle manufacturers, retrofitters, energy companies, vehicle financing companies, end-users, and industry associations for this study. We gathered the key concerns and issues that each stakeholder valued.

Some of the common themes and insights across stakeholder set were:

- Delivered LNG price should be 20-30% cheaper than alternate fuel price for commercial viability.
- Fuel availability is critical, and thus, fueling infrastructure needs to be well-developed.
- Both fleet operators and financing companies prefer new LNG HDVs over retrofitted vehicles.
- Demand aggregation is important, as minimum LNG sales volume is required to justify the economies of scale for infrastructure roll out. Both original equipment manufacturers (OEMs) and retrofitters require firm orders to amortise cost of changes in assembly lines.

Policy & Regulatory Review

We reviewed the key policies and regulations that have been issued from time to time by the various ministries, and accordingly laid the basis for LNG ecosystem in India. Then, we discussed key issue with stakeholders operating across the value chain of LNG in the transportation sector. Based on these discussions and a thorough review of global polices, we propose a number of policy asks that may help the adoption of LNG even further.

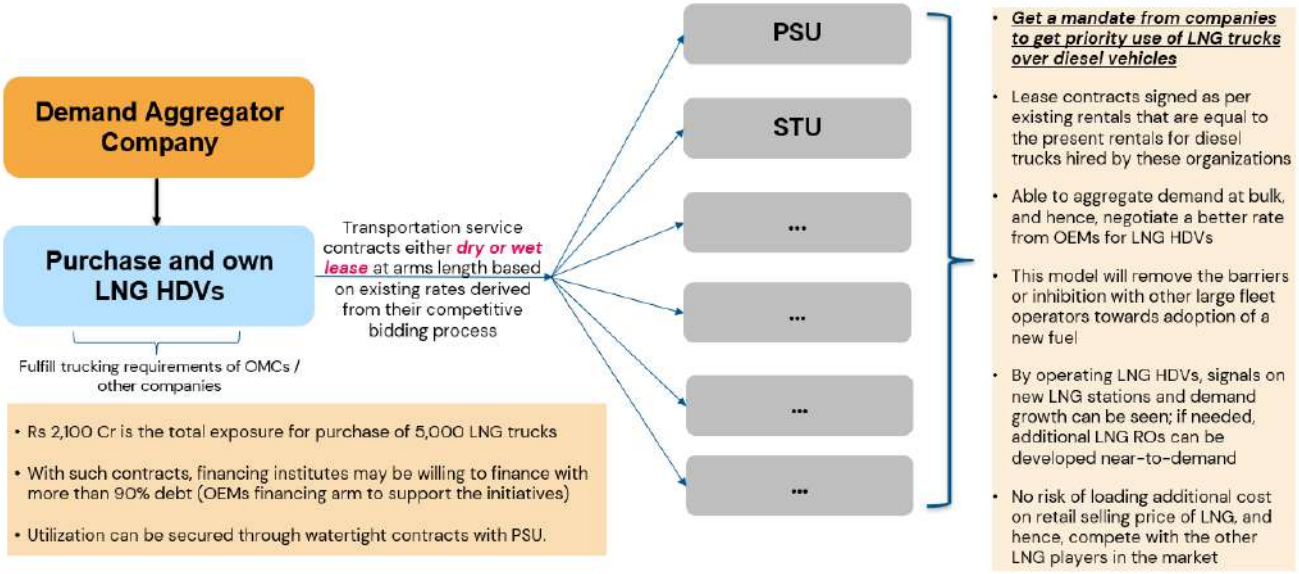


Some key learnings from adoption of electric vehicles in India could be utilized in the case of LNG in HDVs, too. Even in case of EVs, certain incentives and policies along with government orders have helped in their market development. We saw how Energy Efficiency Services Limited (EESL) acted as a demand aggregator for EVs leading to larger order volumes and cost optimization.

The EESL model of demand aggregation can be adopted for LNG HDVs:

- **Clear signal to manufacturers:** Demand creation and aggregation to give clear signals to manufacturers for consistent future demands to launch LNG HDV models.
- **Cost optimisation:** This can be achieved through bulk procurement.
- **Optimising utilisation of LNG HDVs:** Any LNG HDV that remains underutilised could be leased out to another entity where it is needed. It also optimises the utilisation of LNG HDVs across the different end-user sectors.
- **Better financing terms:** With high order volumes, it is possible to obtain better financing terms.
- **LNG retail developments:** With clear signs of such demand, it would also promote development of LNG retail outlets, and private players could start coming into the fold.

The role of demand aggregator is critical for the market development of LNG and a proposed model for demand aggregation based on our key learnings from EESL and stakeholder interactions is given below:



Adoption of LNG vehicles In India: Role that can be played by a demand aggregator.

Challenges in the adoption of LNG

The high initial cost of LNG-based vehicles compared to traditional diesel trucks is a significant challenge for the adoption of LNG in the HDV segment. While operational cost savings can be achieved using LNG as a fuel, the estimated price difference of around Rs 11-12 lakh poses a barrier for fleet operators. However, this analysis under the project reveals that the additional cost of an LNG truck can be recovered over time if the fleet operator is willing to make the investment.

In addition to the cost challenge, several other challenges and observations were discussed during our interactions with stakeholders. These include:

a. **Availability of LNG vehicles and plans of OEMs:** Availability of LNG vehicles is a crucial factor in the adoption of LNG as a transportation fuel. To bridge the gap between infrastructure development and vehicle scarcity, State Transport Undertakings (STUs) can play a significant role in ensuring the initial demand for alternative fuel vehicles, including LNG.

b. **Availability of LNG retail outlets**: The establishment of LNG refueling infrastructure is crucial for the successful adoption of LNG as a transportation fuel. While plans are in place for 50 LNG retail outlets along the Golden Quadrilateral, the progress in implementing these outlets and their geographical distribution has been slower than anticipated.

c. **Retro-fitment of LNG trucks:** There is limited interest on financing of retro-fitment kits, as it can lead to multiple hypothecations of the truck, and thus, create legal issues. In addition, most HDVs stop plying on long distance routes and go to the secondary market once they are more than six years old. Thus, conversion/retro-fitment of trucks does not seem to be a long-term solution for this project.

d. **Financing of LNG trucks and risks:** The discussions with financing companies have revealed different risk perceptions regarding the financing of LNG-based HDVs. Financing entities, particularly those

affiliated with OEMs (original equipment manufacturers), are often in a better position to extend credit and provide financing solutions for fleet operators. The same is not the case with financing banks, and they would like to put majority of the risks with the proponents of the scheme i.e., MSPs (Market Service Providers) in case the scheme fails to take off as intended.

Total Cost of Ownership (TCO)

Both diesel and LNG HDVs have similar TCO, while that for EV (Electric Vehicle) HDVs and FCEV (Fuel Cell Electric Vehicle) HDVs are significantly higher. The TCO of a diesel truck is approximately 2 per cent higher than that of an LNG truck. This difference between the two can be increased further to drive the adoption towards LNG by lowering or exempting toll charges as has been done in certain regions in Europe. The TCO of all fuel technologies are expected to reduce further due to improvement in energy efficiency and scale of production (for LNG, EV and FCEV).

The total cost of ownership of a vehicle is dependent on the following applicable costs:

- Capital cost
- Rate and term of financing
- Fuel cost
- Salary of drivers and staff
- Toll charges
- Annual maintenance & replacement costs

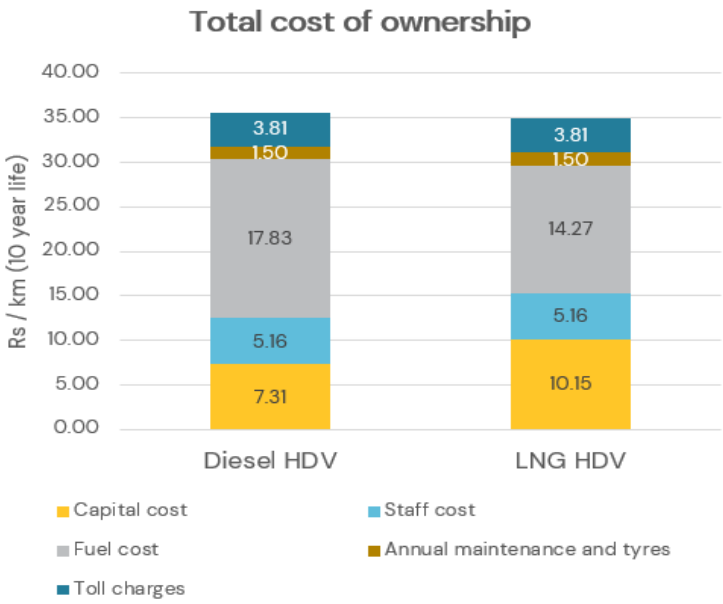


Figure 1-1: Total cost of ownership comparison between diesel and LNG HDV

Based on the assumptions considered in this study, we calculated average TCO, and the results show that the TCO of a diesel truck comes out to be approximately 2 per cent higher than that of an LNG HDV.

Review of Successful Global Models

The adoption of any alternative fuel always brings challenges in the initial stages. These challenges range from the classical 'chicken and egg' problem related to infrastructure and vehicle manufacturing, as well as

to doubts and hesitancy in the market regarding the newer technologies. In these circumstances, the role of the government becomes critical to assuage the concerns of the stakeholders involved. Hence, in these initial stages, the mix of right policy support and swift modifications of existing regulations can make or break the nascent alternative fuel market. We further observed this in the case of CNG and EVs, which will be discussed in the subsequent sections in detail. In the case of LNG as well, it is of utmost importance that during these initial years of adoption, necessary policy support and regulations are present, for such continuous engagement by the government in the sector would lead to increased confidence among the remaining stakeholders to do their part and take decisive action.

From the review of successful models adopted globally in countries, such as **China, Italy, Spain, the Netherlands, and Germany**, it is evident that government support through policy initiatives is one of the first enablers for the adoption of any alternative fuel vehicle. Strong support from the government also sends signals to the private players, thus giving them the confidence to enter a nascent market and invest in its technologies, which leads to further development of the market. A summary of the various policy initiatives and drivers for LNG adoption present in countries around the world that were reviewed as part of our study are shown in the following table.

Table 1-1: How LNG policies are adopted globally

#	Incentives	China	Italy	Spain	Netherlands	Germany
1	Subsidy on purchase of new LNG HDV	✓	✓	✓	✓	✓
2	Monetary benefit for scrapping old diesel HDV	✓	.	.	.	.
3	Lower tax on LNG vs Diesel	✓	✓	.	✓	✓
4	Toll fee exemption for LNG HDV	.	.	.	.	✓
5	Procurement policy to promote LNG HDV	.	✓	.	.	.
6	Ban on diesel HDV in select regions, where LNG HDV allowed	✓	.	✓	✓	.
7	Fuel efficiency and/or emission targets for HDVs	✓	✓	✓	✓	✓
8	National targets on LNG HDV and associated infrastructure	✓	✓	✓	✓	.

The key conclusion from the data presented in the table above is that to promote LNG as a transportation fuel, each country has provided certain fiscal and/or non-fiscal incentives which has led to successful adoption of LNG-fueled vehicles and development of corresponding infrastructure.

Benefits to Nation - Environmental and Economic Benefits

The utilisation of LNG in HDV has its benefits for the environment and even in the realm of economics. Studies reviewed from Europe show that the utilisation of LNG in HDV offers emission reduction in the long term. It would also tackle the issue of high oil import bill for India. According to calculations, the switch from diesel to LNG for the base case scenario (10 per cent of new diesel vehicles switched to LNG by 2032) could offer a cumulative reduction in oil import bill by $1.5 billion (nominal) by the year 2032. The reduction in tank-to-wheel emissions, as found during our review of European studies, is shown in the following chart.

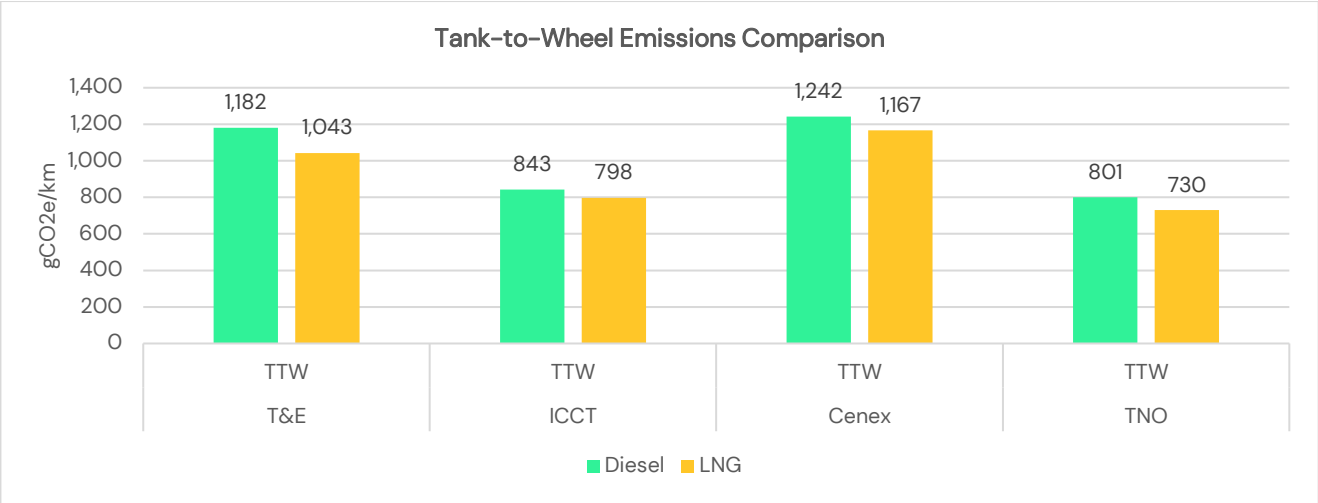


Figure 1-2: Tank-to-Wheel Emissions Comparison between diesel and LNG HDV

The success of any alternative fuel ultimately boils down to the question whether it is economical for the consumers to adopt or not. In the case of LNG, it is essential that government believes that the adoption of this fuel would align with its long-term targets. In India, the government has set aggressive targets to reduce dependence on crude oil imports and to increase share of natural gas in energy mix. Adoption of LNG in HDVs will help meet both these objectives.

The results show that even under the base case, which assumes linear growth in percentage of LNG HDV in total HDV sales per annum and reaches 10 per cent by 2032, it could achieve an import bill reduction of $1.5 billion (nominal) by 2032.

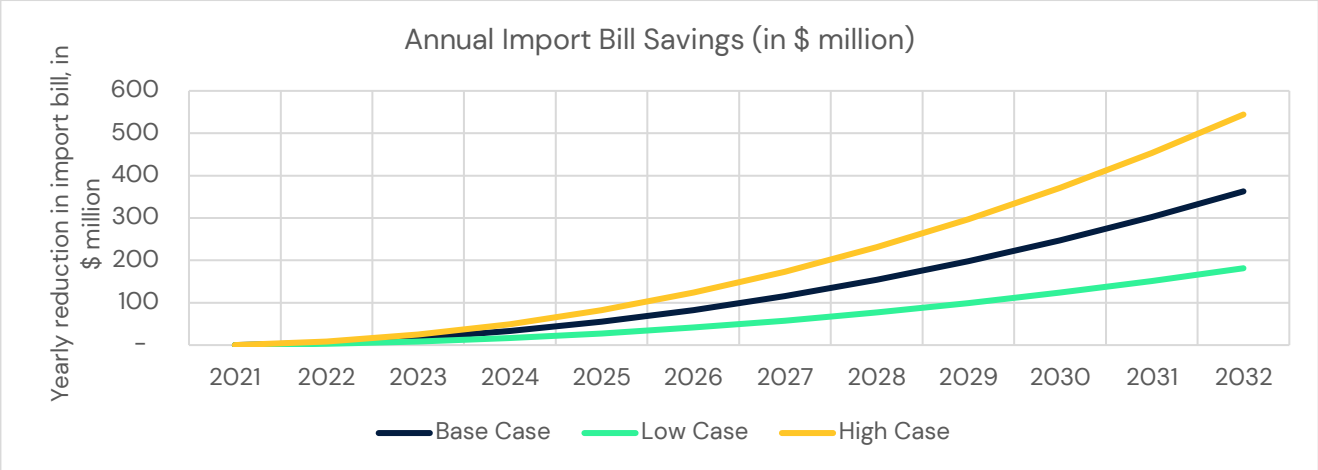


Figure 1-3: Projected Annual Import Bill Savings (in $ Million) by Switching to LNG

We have created business models and financial models for LNG HDV segment to understand the impact of various suggested policy asks in the coming years.

Financial Analysis – OEMs

The OEM business is very well-integrated, wherein the existing OEMs bank upon their current capability and existing infrastructure to develop new vehicles. So, to understand if the OEMs would be able to invest in new assembly line for LNG vehicles, it is important to compute the volume foreseen by these companies going forward. As per discussions with one of largest OEMs, we realised that they might be looking at an order book of 3,000-5,000 LNG HDVs annually, to help recover the associated capex.

While it might be a bit difficult to analyse the margins associated with LNG HDVs on a standalone basis, but the gross margin per vehicle currently earned by these companies might be helpful to understand the overall revenue share/ margin share they would like to achieve from LNG. We analysed two of the major players in the country in the medium and heavy commercial vehicles (MHCVs) segment on margin and revenue.

Our analysis showed that the gross margin (vehicle sales – procurement cost) for such companies averaged out to be in the range of 26-27 per cent[2] (Refer to Section 7.5 for details). This refers to the margin expected by these companies on each vehicle if they are to go ahead with a new investment.

As we found during our discussions with the fleet operators, they anticipate the total sales price for an LNG truck in the range of ~ Rs. 42.4 lakh. Considering factors like dealer margin, Goods and Services Tax (GST) and other costs, the sales price charged by OEMs for an LNG truck is around ~ Rs. 32.5 lakh *(Refer Annexure for detailed computation).* Considering the cost margin as computed above and the minimum order book of approximately 3,000 vehicles anticipated, the **OEMs might be looking at a margin of Rs. 8.5 lakh from the sale of a single LNG truck and ~ Rs. 260 crore from the sales of their expected order book.**

The following table summarises the level of margin that OEMs would like to ensure for capex recovery if they go ahead with investing in LNG trucks.

[2] Excluding any outliers in the analysis. Refer Annexure for detailed computation

Table 1-2: Details for margin that OEMs would like to ensure for capex recovery

Particulars	Value
Cost of LNG truck *(as per market information)*	INR 42.4 lakh
Sale price of LNG truck for OEM *(Refer Annexure for detailed computation)*	INR 32.5 lakh
Expected cost margin	26%-27%
Expected margin from sale of single LNG truck	INR ~8.5 lakh
Expected orderbook of LNG trucks	3,000–5,000
Minimum expected margin from sale of expected orderbook	INR ~260 crore

Financial Analysis – LNG Retail Outlets

We prepared a financial model for an LNG/LCNG dispensing station on a per station basis to showcase the circumstances under which a business model would be feasible. Some key assumptions have been taken in the model to ***understand what values of truck traffic, LNG prices, and LNG discount percentage would lead to the LNG station's viability in the long run***.

Table 1-3: Key assumptions for LNG retail stations financial analysis

Assumptions (per station)	Unit	LNG station	L-CNG station
Capex	INR cr	7.15	9.98
Opex	INR cr	0.68	
Truck Traffic (Base Year)	#	50	
LNG Volume (Base Year)	tons/year	1310	

We evaluated the LNG station's profitability at base scenario of crude price at $80/bbl for both LNG and LCNG station. Other scenarios at different LNG prices are mentioned in Section 7.6.

Outcomes from the financial analysis of an LNG and L-CNG station

Listed below are some key project outputs achieved from financial analysis carried out for one LNG/ L-CNG station, under different scenarios:

Table 1-4: Model Outputs for different scenarios of running LNG/LCNG Station

Parameters		LNG station: Crude @$80/bbl	L-CNG station: Crude @$80/bbl
Rate of Return	**Project IRR**	12.89 %	15.48 %
	Equity IRR	17.63 %	22.30 %
Coverage Ratio	**Average DSCR**	0.82	0.99
Payback	**Payback Period**	104 months	88 months
Net Present Value (NPV)	**Project NPV**	Rs. 2.11 cr	Rs. 5.43 cr
	Equity NPV	Rs. 0.29 cr	Rs. 1.68 cr
EBITDA Margin	**Avg. Operating Profit**	Rs. 1.3 cr	Rs. 2.4 cr
	Avg. Revenue from Operations	Rs. 16.6 cr	Rs. 26.8 cr

As can be seen from the above tables, the financial analysis shows that the business model of operating an LNG or L-CNG station could be viable in most scenarios. However, to make sure that it is a sustainable model, there are some key parameters on demand and pricing which need to be ensured:

1. **Number of trucks** – About 2,500 trucks are required initially for 50 LNG/L-CNG stations. This figure would go up to 5,000 trucks in the long term. This number is bound to grow further if the number of stations go up eventually. However, if the LNG infrastructure isn't set up on time, then it would impact the expected demand of LNG. This shows that ***maintaining truck traffic, and hence, the demand is very critical to achieve the above expected results.***

2. **Prices of crude oil and LNG –** LNG spot prices can go very low/high amid high volatility in crude prices. So, **if the LNG cost price goes high**, the margin for any energy company might reduce, since it is bound to sell LNG at a certain discount to diesel retail selling price (RSP). If the company chooses to reduce the discount offered on diesel RSP, it would not be able to convert many existing customers of diesel to LNG.

Thus, demand and pricing consistency are the key elements for ensuring success of this business model in the long term, without which the viability might take a hit.

Recommendations

India's vision of economic growth underpinned by clean energy development based on collective approach, innovation, and learning from global best practices can set India on a transformative path to a new future driven by LNG.

Demand Aggregation model

As many energy companies are developing LNG retail stations, there is a need to ensure that adequate demand measures are taken so that the assets are optimally utilised. Demand aggregation suggestion came out as a common theme across all stakeholders in the LNG value chain, including energy companies, OEMs, retrofitters, fleet operators and financial companies. This would include:

- **Demand Aggregation:** This would involve an **"Aggregator",** i.e., a demand aggregator company for buying LNG trucks. Demand aggregation model, similar to EESL in the EV sector, can generate initial demand of the LNG project and provide sustainability to the retail outlets. Ownership of such aggregated vehicles could be undertaken by an entity like CESL, a subsidiary of the state-owned EESL, which is already working towards creating demand for EVs aggregated across the country.

- **Business Model:** The Aggregator would purchase the LNG HDVs in the as bulk procurement in order to achieve cost optimisation. On lines of the model adopted by CESL, the LNG HDVs could be offered to STUs (for buses), PSUs, and other logistics companies (for trucks) on sale or service model with an assurance of recovery, which can be developed by creating a payment security mechanism.

- **Financing of vehicles:** Aggregation of demand at bulk would help in negotiating better rates from the OEMs. This would provide a case for financing companies, which have been skeptical towards LNG HDVs due to their higher cost price. The financing arms of OMCs can play an important role in enabling this ecosystem.
- **Purchase of LNG-based HDVs:** The aggregator could set well-defined targets to replace a specific number of vehicles every year to ensure optimum utilisation of the initial 50 LNG retail outlets.
- **Private Player Participation:** Once the cost of LNG HDVs is reduced through aggregator model and ecosystem is established, private sector participation can come in all elements of the business model.

As seen from our review of EV policies and initiatives in Section 4.4, we conclude that the role of a demand aggregator is important, and such a role in the case of LNG adoption could help remove some existing roadblocks in LNG adoption.

Non-Fiscal Incentives

Looking at the unique solutions in the form of non-fiscal incentives in China, Spain, the Netherland and Italy, as described in Chapter 5, it is seen that across a diverse group of countries, the governments provided incentives to change or adapt the mindset of the industry towards alternative fuel vehicles. Hence certain non-fiscal incentives can play a key role in developing a sustainable mindset in the market for India. Some of these incentives are suggested below:

- **Targeting high pollution cities/zones:** Such zones could be identified across India and categorized into red, orange, and green areas. Special **Low Emission Zones** can be created in these cities, starting with the red category. Alternative fuels should be allowed unrestricted movements in these zones, while diesel vehicles can be heavily restricted in these zones.
- **Preferential Right of Way:** Heavy duty trucks running on LNG can be allowed to enter cities to incentivise alternative fuel adoptions, while diesel trucks can be banned and/or levied with entry charges as has been done in Delhi by implementing the environmental compensation charge (ECC) for all diesel heavy duty trucks.
- **"ECO" labels differentiating alternative fuel vehicles from fossil fuel vehicles** can be introduced too. Coloured license plates can also be used to clearly indicate which vehicles are running on alternative fuels.
- **Priority lane access**, for LNG vehicles can be provided as non-fiscal incentives to promote LNG. Major cities and roadways need to be recognised, and such priority lane access can be tested first in major cities and roads.
- **Fuel cards** can be introduced to ensure easier refuelling of LNG for fleet operators. Such cards would enable certain offers for the trucks and help obtain (potentially) significant savings both on the current price of fuel and on administrative costs. The fleet operator would receive a single weekly invoice, and hence any hassle associated with payments could be avoided.
- **The life of LNG retrofitted trucks could be extended by 5 years.** Diesel trucks are required to be scrapped after completing 15 years. With an extension of 5 years life in case they are retrofitted to ply on LNG, the truck owner would be able to get services for additional 5 years.

Allocation of domestic gas to LNG HDVs for initial 3-5 years

At present, CNG is allocated domestic gas on a priority basis while LNG in HDV sector is based on market pricing. MoPNG may allocate domestic gas to LNG fuel retailers for use of LNG in HDV sector for an initial 3-5 years. This may be implemented by swapping mechanism where swapping arrangements may be agreed between domestic gas producers and LNG retailers. This will allow market seeding of LNG in HDV sector and support LNG in HDV till it becomes self-sufficient.

Natural Gas Mobility Dashboard

HDVs ply on long distance routes, and thus, if they are operating on LNG, they need to ensure sufficient availability of refueling stations throughout the route. However, apart from availability, they also need to be aware of the locations of such stations. The national level dashboard with GIS mapping would act as a central data bank to provide location and real time wait time for refuelling.

This information would help fleet operators towards decision making in planning, procurement and effective deployment of their LNG HDVs. This information could be publicised widely to increase awareness among the different stakeholders. This dashboard can further be extended to include CNG retail outlets in the future.

Fiscal Incentives

Bringing Natural Gas and LNG under GST

State governments control Value Added Tax (VAT). By reducing the VAT on sale of LNG to HDV to 5 per cent and by bringing the retail LNG price under the ambit of the 5 per cent GST bracket, it will be possible to achieve the required tax rate harmonisation across states, thus effectively bringing down the LNG HDV operating costs.

LNG HDV Vehicles and LNG equipment under 5% GST

To give an impetus to the LNG vehicle adoption and to bring the cost differential to a reasonable range, GST on LNG trucks can be reduced to 5 per cent in line with EVs. This scheme for GST reduction can be limited to the first 5,000 LNG trucks sold, and can be further reviewed based on the capex reduction achieved.

Revised Depreciation schedules for LNG vehicles and RO developers

Accelerated depreciation could be provided to LNG vehicles and the LNG storage and/or dispensing equipment. This would help to shift the tax burden from the initial years to the later stages of the project, when the stakeholder starts getting enough cash inflows from the LNG business.

Toll Fee Exemption

Toll charges form more than 10 per cent of the total cost of ownership as detailed out in Section 7.2; while this manifests the importance of exemption of toll fee for LNG HDVs for their rapid adoption over diesel-based vehicles, the market readiness of this solution is a bit low, since it needs to be implemented at more than 500 toll plazas across the country.

Production Linked Incentive

The Production Linked Incentive (PLI) Scheme for Automobile and Auto Component Industry had been notified in the Gazette of India dated 23rd September, 2021[3]. Under the scheme, OEMs or even new non-automotive investor companies are supposed to get benefits based on their determined sales value, subject to meeting a 10 per cent year-on-year (y-o-y) criteria for growth. The ***overall development of LNG vehicles is not covered for OEMs under this scheme*** unlike that for battery vehicles and hydrogen fuel cell vehicles. Thus, there is a need to include the LNG-fueled vehicles in the list of AAT (advanced automotive technology) vehicles eligible for PLI Scheme, thereby providing a major boost to OEMs to manufacture and produce additional LNG vehicles.

Defining Corporate Level Fuel Efficiency Standards for HDVs

The government can bring in the necessary revisions to the existing HDV fuel consumption norms to make it similar to the norms notified for passenger cars. The government can also conduct a review of the impact of fuel efficiency norms in promoting alternative fuel vehicles, and through feedback, further improve the methodology to bring one for HDVs as well. The government can also create a credit system for manufacturers who achieve significantly lower fuel consumption benchmark than the one notified.

[3] vide S.O. no. 3946(E)

Proposed roadmap

While the recommendations listed in the previous sections form a basis for actionable solutions, there is a need to clarify the implementation approach and provide a framework for the same. Sequencing these solutions provides a prioritized timeline, which is dependent on the readiness of systemic change and the order of operations. This requires setting up an order of priority for these solutions, based on the level of impact they are expected to make on LNG demand, and readiness of the market (including various stakeholders) in accepting those changes.

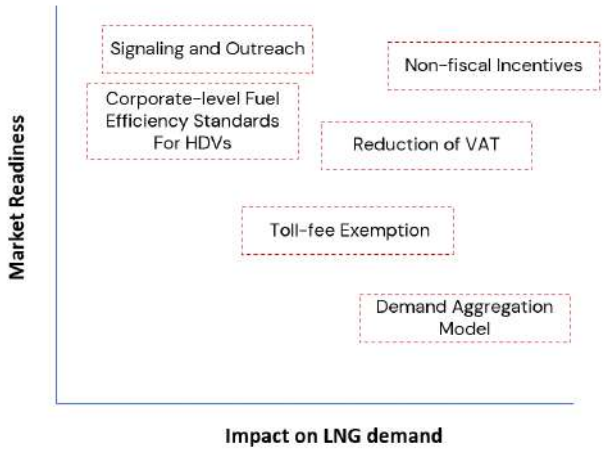
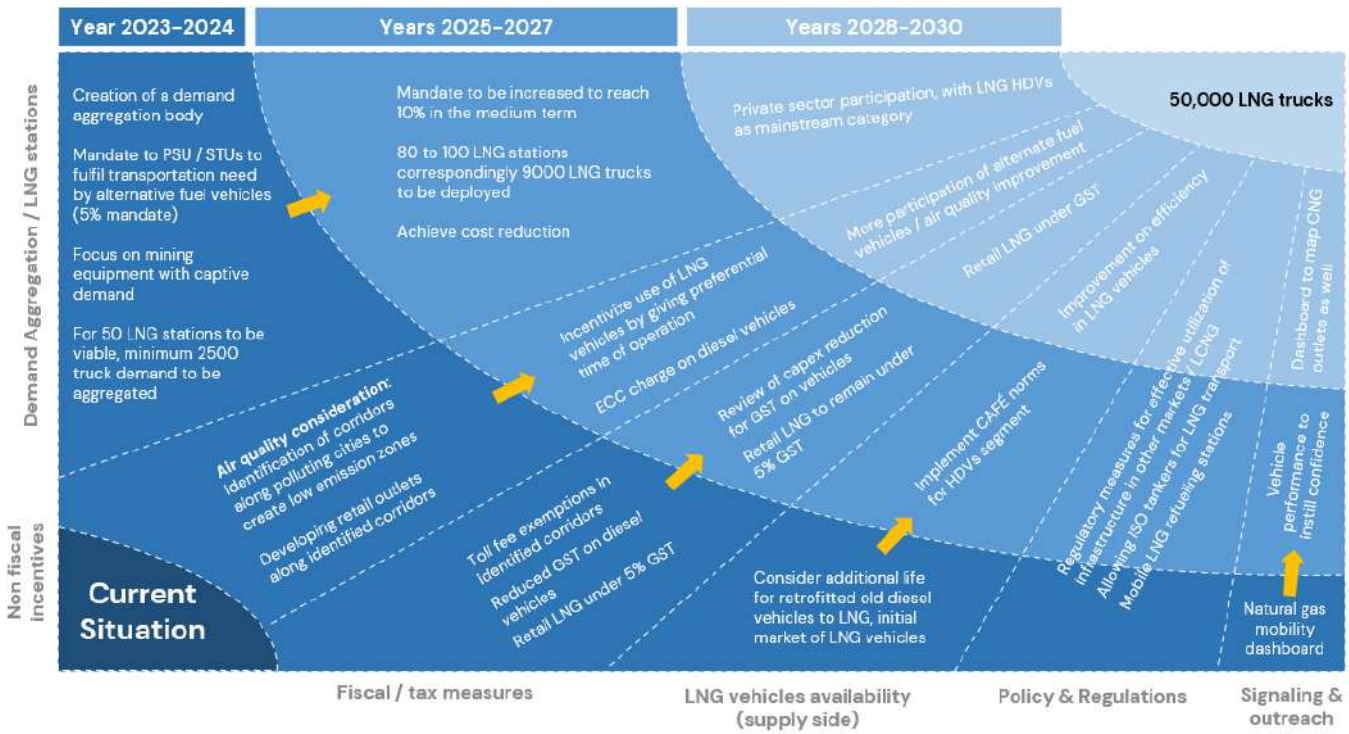


Figure 1-5: Market Readiness and impact on LNG demand for proposed solutions

Over next two years (till 2024), the focus should be on demand creation and market seeding. Some of the key near term initiatives may include creation of demand aggregation body, mandating STUs to purchase alternative fuel vehicle (5% mandate). High impact recommendations may be implemented by 2030 such as private participation, implementation of GST etc.

Roadmap for LNG adoption



2 Introduction

Air pollution is a cause for concern in many Indian cities, with the levels of air pollutants, including particulate matter (PM), sulphur dioxide, nitrogen oxides, carbon monoxides and ozone exceeding the National Ambient Air Quality Standards (NAAQS). According to the World Air Quality Report, 2021, by Swiss organization IQAir, 21 cities from India feature in the top-30 cities with the highest air pollution. In one of the studies, named "Identify source apportionment of PM2.5 and PM10 concentrations of Delhi NCR for identification of major sources", it was concluded that major contributor for PM2.5 emission in cities like Delhi is from transportation, which contributes to 39 per cent of the total emission.

The growing use of compressed natural gas (CNG) in urban transportation in various urban centers in India has helped in combatting high levels of urban pollution in the last 10 years, based on conversion of cars, buses, and auto rickshaws to CNG. However, the conversion of heavy duty vehicles (HDVs) to CNG is challenging, not the least due to the heavy payloads involved and the requirements of long travel time without refueling. Since electrification of HDVs might take time owning to technology maturity, reduction in weight of the battery and seamless access to fast charging stations which will be needed to charge the heavy capacity battery needed to carry load and long run. A solution around introducing liquefied natural gas (LNG) can work as an alternative for diesel, at least for in trucks in India. Natural Gas in the form of CNG is a tested fuel in India and technology for gas engines has already reached a matured stage. It is also expected that viability from LNG will be better for those vehicles which run more kms per year. Hence the use of LNG as a fuel in HDVs is more viable as compared to light duty vehicles.

To adopt LNG for transport application, the Government of India also modified the Central Motor Vehicles Rules, 1989 in 2017, to include LNG as transport fuel. In 2018, amendments and codes were finalized to facilitate the setting up of LNG stations. The clarification from Petroleum and Natural Gas Regulatory Board (PNGRB) further stated that any entity can set up an LNG station in any geographical area irrespective of City Gas Distribution (CGD) authorization, has been a key step towards avoiding conflicts from the regulatory provisions. Such steps are expected to facilitate the development of LNG dispensing infrastructure across the country.

In November 2020, the foundation stone was laid for the first 50 LNG fuel stations[4]. Planned along the National Highways and the Golden Quadrilateral, these stations are intended to be set up by public sector firms IOCL, BPCL, HPCL, GAIL, PLL, Gujarat Gas and their joint venture companies and subsidiaries. The government also announced an investment of Rs 10,000 crore to set up 1,000 LNG stations in the near future, through investments from both private and public sector companies.

The total diesel consumption in India has grown at a compounded annualized growth rate (CAGR) of 5.2 per cent between FY2008 and FY2019 reaching 83.52 MMT, just before the COVID-19 pandemic hit the economy. Out of this, approximately 34.25 MMT diesel, or 41 per cent of the total consumption, was met by medium and heavy commercial vehicle (M&HCV) segment alone; this is equivalent to 41.27 MMT LNG. With such high demand of diesel in M&HCV segment, LNG could become an alternative fuel for this sector.

It's understood that the Government of India intends to reduce its oil import bill as part of its long-term strategy. LNG can play a key role in achieving this objective. As it is estimated that 41 per cent of total diesel

[4] https://pib.gov.in/Pressreleaseshare.aspx?PRID=1673998

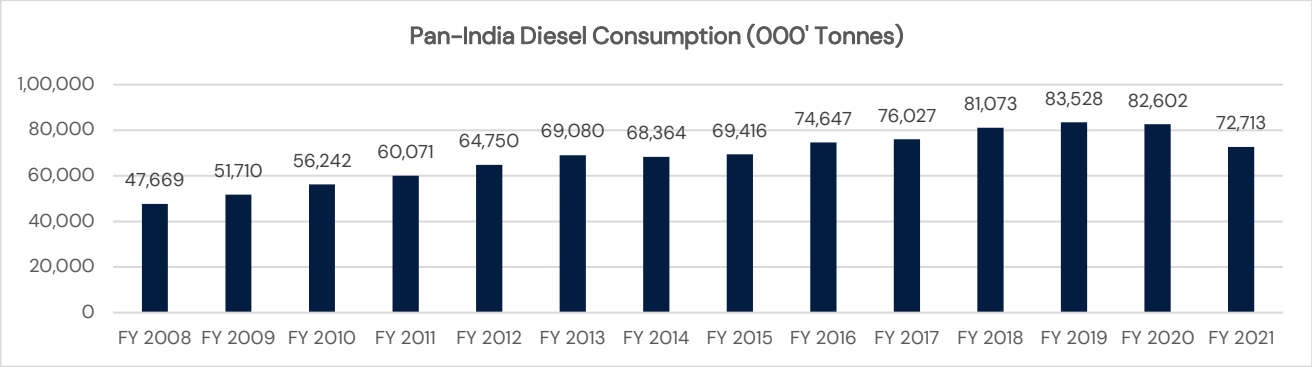


Figure 2-1: PAN-India Diesel Consumption in 000' tonnes from FY 2008 to FY 2021

consumption is done by M&HCV segment, the adoption of LNG in this segment can go a long way in reducing India's oil import bill. Calculations for the same are shown in the following chapters.

2.1. Objective

Embassy of the Kingdom of the Netherlands signed a Statement of Intent (SoI) with NITI Aayog, India's premier policy think tank last year to support the decarbonisation and energy transition agenda to accommodate cleaner and more energy to deliver its economic and sustainability agenda. Through this collaboration, NITI Aayog and Embassy of the Netherlands seek for a strategic partnership to create a platform that enables a comprehensive collaboration among the stakeholders and influencers which includes policy makers, industry bodies, OEMs, Private enterprises and sector experts.

The Government of India has identified LNG as a transport fuel considering the potential of manifold benefits in reducing vehicular pollution, import bill savings and wide-ranging benefits that may accrue to fleet operators, vehicle manufacturers and other entities. LNG is notified as a transport fuel in 2017 and identified as a new generation green fuel under the new fuel retailing policy 2019. LNG vehicles' adoption in India is limited to only pilot projects in both new and retrofitting modes.

The adoption of any new fuel is driven by attractive and sustainable economic case for all stakeholders along the value chain. While the availability of refueling infrastructure and a robust economic case are the prerequisites for adopting a new fuel like LNG, the availability of vehicles, vehicle financing and after-sales support are equally important to instill confidence among buyers. The upfront capex is a key barrier to the switchover decision. The vehicle owners' preference to assume this exposure is dependent on the presence of suitable ecosystem, assuring a lower payback period. Similarly, suitable business models need to be developed for key stakeholders, considering their expectations and risk appetite. Finally, a comprehensive review of successful models adopted globally (for LNG HDV) and within India (for EV) needs to be undertaken to draw lessons, which may be adopted, especially on the policy front.

A key step for the adoption of LNG has been the release of the Draft LNG policy to increase LNG usage as transport fuel and in the mining sector among other objectives

Draft LNG Policy

India being the 3rd largest energy consumer in the world, also comes in the top 13 countries for quantity of gas consumption. Hence, this also offers an opportunity for India, to reduce its CO2 emissions and foreign exchange by substituting polluting liquid fuels with LNG or natural gas. The government of India has

recognized these points of notice, and thereafter, has released a draft LNG policy to increase LNG usage as transport fuel and in the mining sector among other objectives.

The policy lists the key aims and objectives as follows:

i. Frame an integrated approach towards procurement, storage, transportation, and use of LNG, including its by-products such as boil offs.
ii. Ensure equitable distribution and adequate availability of LNG for all technologically feasible sectors
iii. Promote increased use of LNG in various sectors including in transportation and in mining sectors.
iv. Ensure stable, transparent, and enabling framework for activities related to LNG.
v. Promotion of new technologies related to LNG.
vi. Promotion of adoption of LNG for usage in green-field sectors, i.e., where LNG is not being used in any manner currently.

The policy explains the strategy that will be employed to meet the objectives set by the government and explains the approach for different sectors such as – upstream, midstream, and downstream.

For the upstream, it focuses on creation of LNG terminals and regassification facility to deal with the import needs. LNG terminals with capacity more than 100 MMTPA are needed to achieve the vision of 15% share of natural gas in the primary energy mix by 2030. The policy sets out an aim for creating regasification capacity of 70 MMTPA by 2030 and 100 MMTPA by 2040. It also looks to create virtual pipelines and enabling infrastructure for transportation of LNG to all areas of consumption.

For the midstream, focus is shifted to dedicated highways having extensive LNG infrastructure to promote LNG trucking and its use as transport fuel. High volume closed loop truck circuits will also be developed in sectors such as mining, refining, to enhance penetration of LNG as fuel. To achieve a target that 10 per cent of all heavy-duty trucks and similar automotive be based on LNG, conversion of trucks will be promoted and automotive companies shall be encouraged to bring new models based on LNG. The policy also is looking to promote regulatory environment for mobile dispensing of LNG as it could alleviate key concerns and lead to faster adoption of LNG. Creation of enabling regulatory environment with respect to safety and technical requirements for storage, transport and usage of LNG are also mentioned. Domestic manufacturing of LNG storage tanks, vehicles etc. shall be promoted along with the sale and marketing of LNG at gas exchange to develop spot and other possible markets for LNG.

In the downstream, a target of 1000 LNG stations is set to ensure availability of LNG for long-haul, heavy-duty trucks. Marketing and sale of LNG as a vehicular fuel shall be a free activity and will not have any restriction as to the quantity, area or any other parameter except the safety and technical parameters. Use of LNG as a fuel in heavy duty trucks and other vehicles will be promoted by incentivizing the development of new LNG models or other incentives.

The policy strives to promote research and development institutions to explore new technologies for establishing the LNG value chain and also ensures that effort will be taken to involve start-ups for the creation of an ecosystem.

The policy provides an overview of the steps that are required to promote the adoption of LNG as a fuel. But, it does not present a comprehensive roadmap with specific goals that could lead to successful adoption of LNG as a fuel. This is where, the current project comes in, as we utilize the necessary approach and methodology to build a detailed roadmap to kickstart the adoption of LNG and ensure that a sustainable value chain for LNG is created.

With the above policy in place, and focus on infrastructure creation, there is limited impetus on the demand creation. Hence the overall objective of this study is to develop a clear roadmap to support the LNG adoption in M&HCV segment in the near term, and accelerated growth in the mid- to long term.

2.2. Approach & Methodology

The report goes through the details of current scenario for LNG and how LNG adoption in HDVs can be brought on with the right policy incentives and market conditions. We delve into the specificities of the LNG market roadblocks, and how these can be removed. The approach and methodology followed for the report is detailed chapter wise as follows.

Stakeholder engagement: During this study ICF team has covered the perspective of all the important stakeholders namely – Fleet Operators, State Transport Units, Vehicle Manufacturers, Retrofitters, Energy Companies, Vehicle Financing Companies, End Users, and Industry Associations. The team engaged in one to one discussions with all stakeholders to understand the hindrances for switching over to LNG and their expectations, fiscal/non-fiscal enablers for faster adoption of LNG. Questionnaires were drafted for each stakeholder beforehand to ensure a structured approach is followed during the discussions. The details of the discussions and summary for the same are presented in the report for each stakeholder.

Review of government policies and regulations: The team has also reviewed the extant Government policies and regulations to identify the gaps to be addressed for promoting LNG as a transport fuel. A review of the procurement policies of PSUs is conducted to gauge whether these procurement policies can be engineered to promote LNG adoption. It also covers learnings from other alternative fuel adoption in India which could prove useful for LNG adoption as well, such as the CNG case study, and the adoption of EVs following the start of the Faster Adoption and Manufacturing of Electric and Hybrid Vehicles in India (FAME) initiatives.

Global LNG adoption: A review of the successful models for LNG adoption globally is presented by the team which covers a detailed analysis of policy initiatives, public and private enablers to understand the success of LNG adoption globally. The countries chosen for this analysis are China, Italy, Spain, The Netherlands, and Germany. The analysis of the various geographies is then utilized to present learnings for India.

Environmental and economic benefits: An assessment of the environmental and economic benefits of adopting LNG HDVs is completed. Detailed literature review of studies from Europe to compare the various emissions for LNG HDVs and diesel HDVs is covered. A reduction in the CO2 emissions over a ten-year time frame taking relevant assumptions is also assessed to present the case for LNG in HDV. The impact of LNG adoption on economic costs such as the oil import bill which is a key concern for a country like India is computed likewise over a ten-year frame.

Business and financial models: The team analyzed and prepared the business models for LNG HDV segment. Focus was given specifically to the business models for energy companies and fleet operators, due to their importance for the LNG infrastructure and creation of demand. Based on interactions with the stakeholders, the team gained insights into the business models for the players in the LNG value chain, and these insights are shared along with a sensitivity analysis. Financial models for the LNG HDV segment are also covered. The team prepared a variety of financial models for LNG dispensing stations on a per station basis and aspects related to transport and storage of LNG for dispensing were covered.

Recommendations and roadmap: The recommendations are captured based on the stakeholder interaction and analysis conducted using those inputs. The inputs obtained from the previous stages of the project are utilized to develop a comprehensive roadmap for implementation. The team identified the specific requirements of the different stakeholders through one-to-one discussions. Finally, a roadmap for the adoption of LNG in HDVs is presented covering the implementation approach of the recommendations, and detailing which bodies can be tasked with the execution of each recommendation.

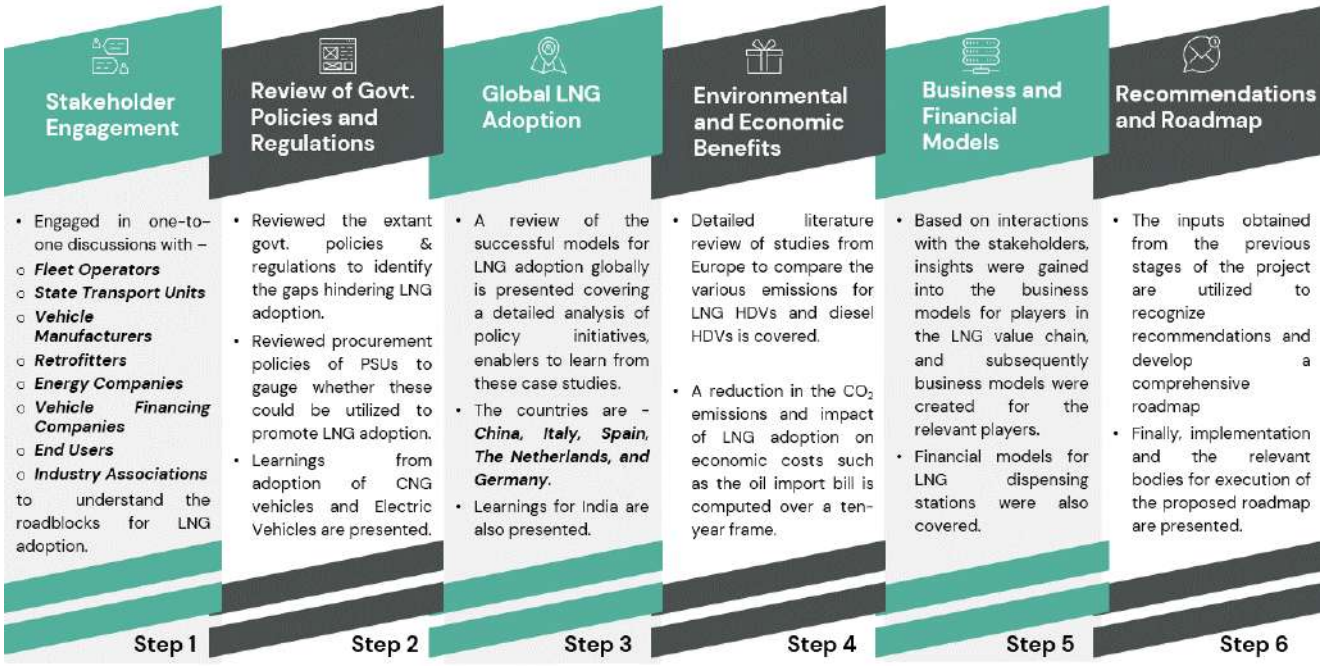


Figure 2-2: Approach & Methodology followed in the report

3 Understanding Stakeholders' Perspective

The value chain of LNG as a transportation fuel includes multiple stakeholders – from the supply and transportation of LNG to developing the retail outlet infrastructure, to vehicles running on LNG to fleet operators planning to adopt LNG fleet, and finally the end users of such vehicles in the value chain. While the above value chain is well established in case of conventional fuels, the advent of new fuels and its acceptability takes time. This has happened previously with CNG too as regards its acceptability as a transportation fuel, as there were the initial challenges of setting up the entire value chain. Nevertheless, India has been able showcase significant achievement in this and is now leading towards becoming one of the largest markets of CNG vehicles in the world.

While LNG as a transportation fuel is relatively new for India, it is well known that there exists a robust value chain in countries like China and some parts of Europe. To help set up ecosystem, there is a need for consensus building and identifying the key bottlenecks that prevent large scale adoption of LNG as a transportation fuel. To identify these bottlenecks, engagements were carried out with stakeholders across the value chain to capture their diverse perspectives and to understand opportunities for devising a robust approach and tackling issues faced at the ground level. On a practical level, stakeholder engagement identifies areas of agreement as well as disagreement, and hence provides a unique opportunity to understand with complete clarity what might be the driving factors.

In the current work, for the adoption of LNG in HDVs, it became crucial to understand the ground reality, and how such adoption will affect key stakeholders. By understanding those issues, we were able to identify the steps needed to ease and promote the adoption of LNG vehicles and utilization of LNG as a transportation fuel. The figure below illustrates the key stakeholders involved in the value chain for LNG in HDV transportation –

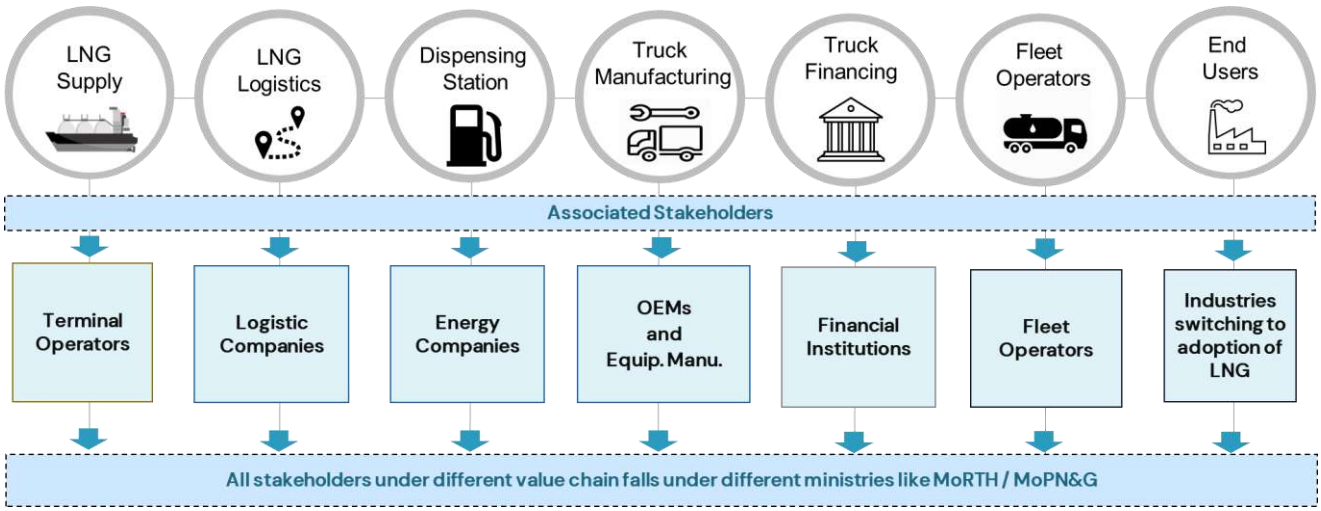


Figure 3-1: Key stakeholders involved in the value chain for LNG in HDV transportation

Discussions were held with multiple stakeholders from each category shown above. The names of the stakeholders interacted with are mentioned in the following table.

Table 3-1: Overview of the number of stakeholders interacted during the study.

Type of stakeholder	Name of stakeholders interacted	Total stakeholder interactions
Fleet Operators	TCI Logistics, Bharat Roadways, Indian Tankers, EFC Logistics, Freight CO, Seros Logistics, CCI Logistics, Om Logistics, Sure ECO Motion, Delhivery	**10**
State Transport Undertakings (STU)	Maharashtra State Road Transport Corporation (MSRTC) and Karnataka State Road Transport Corporation (KSRTC)	**2**
Vehicle Manufacturers/ OEMs	Tata Motors, Volvo, Cummins, Daimler Truck AG	**4**
Retrofitters	Cryogas, AutoLNG, Shigan, Prala, Advantech Fuel Systems	**5**
Energy Companies	IOCL, BPCL, ExxonMobil, PLL, GAIL	**5**
Vehicle Financing Companies	Sriram Transport Finance, HDFC Vehicle Finance, Dealership of Tata Motors	**3**
End Users	Saint Gobain, DCM Shriram, IOCL	**3**
Industry Associations	AIMTC, FIPI, CII	**3**
Testing and Certification Bodies	ARAI, ICAT	**2**
Ministry Body	Ministry of Petroleum & Natural Gas (MoPNG)	**1**
Total Stakeholders Engaged in the Study		**38**

In the subsequent sections, a summary of the questionnaire and discussions originally shared with the stakeholders to understand their position and in a way better recognize the key bottleneck in their perspective to develop this ecosystem, has been shared.

3.1. Fleet Operators

Engaged with 10 fleet operators.

Operational fleet of 15,000+ vehicles, with around 5,000 HDVs owned

Fleet operators (FO) play a central role in the transportation sector and are one of the major consumers of High-Speed Diesel (HSD). If we ignore the HSD consumption in year FY 2021 (downside owing to COVID 19), on an average, the total diesel consumption in the country has been in the range of 80 – 83 MMTPA. It is estimated that the share of HDVs in total diesel consumption in India is in the range of 28-30 per cent, which translate to a total share of diesel consumption by HDVs in the range of 22.5 – 25 MMTPA. This provides a significant opportunity for the adoption of LNG as a fuel.

If we consider the road transport sector in India, the transportation costs are usually high, and capacity utilization is low due to several issues faced by fleet operators. A NITI Aayog report titled *Fast Tracking Freight in India* highlights that average daily truck running in India is around 250-400 km, compared to 500 km in BRICS countries, and 700 km in Europe and the USA. The report explores these issues in depth, but to

summarize, the following key factors are identified for this reduced distance covered by trucks on a daily basis. They are:

- Old and under-powered trucks, with lower capacities and speed
- Lack of use of technology in load and route planning, and operational inefficiency
- Highly fragmented market, with more than 75 per cent fleet operators owning less than five (5) trucks

  Delays on road, and longer waiting time at ports, warehouses, and factories

The National Logistics Policy (NLP) aims to address these issues via several initiatives, but that will take some time, and may not benefit all fleet operators equally. Hence, with such challenges, fleet operators are less likely to invest in any new technology that increases the total cost of ownership (TCO) any further, or make their operations less reliable. Keeping this in mind, the engagement with fleet operators focused on their immediate and foreseeable concerns in adoption of LNG-fueled HDVs. Additionally, their feedback helped in better understanding of the value chain for purpose of building a financial model for setting up LNG dispensing infrastructure and enabling demand for LNG as a transportation fuel.

Major questions brought up in the questionnaire are listed below:

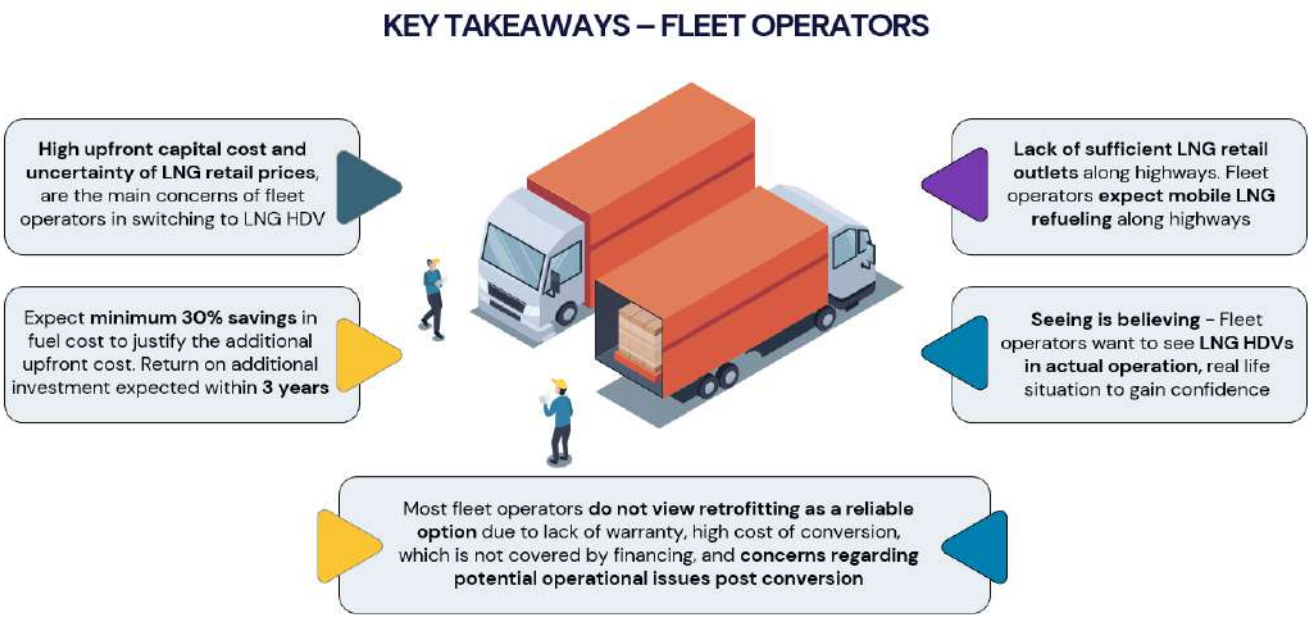
- Details of current fleet, emission standard, life, operational info, fuel purchase facilities, spending on fuel and vehicle performance tracking.
- Questions on annual maintenance contracts, bulk purchase of trucks, discount availability, financing options, financing availed, and financing institutions approached.
- Would they consider replacing old trucks with LNG? If not, details on why and how this can be changed. If yes, how much additional cost are they willing to incur?
- Discussion on company's policy or target for adoption of clean fuels or reduction in emissions.
- Support expected/requirement to adopt LNG in their fleet from entities, such as Govt. of India, vehicle manufacturers, oil companies and financing agencies.
- Details on current alternative fuel fleet, if any. Information on cost differential, refueling arrangement, and financing.

Following are the key attributes of fleet operators engaged for this study:

- Engaged with 10 fleet operators.
- Operational fleet of 15,000+ vehicles, with around 5,000 HDVs owned, and remaining on lease
- Covered the entire country with hubs in i.e., Mumbai, Kolkata, Chennai, Bengaluru, Ahmedabad, Kochi, Lucknow, and Jamshedpur.
- Utilize all major national highways, including the Golden Quadrilateral
- Provide transportation services to key sectors, like FMCG, bulk, fuels, chemicals, metals, containers, and express cargo
- Most of the fleet operators mentioned that their annual running is between 60,000 and 80,000 km.

a. **Most fleet operators running between 60,000 to 80,000 km.**
b. **Fleet operators expect minimum 30% fuel cost savings and return additional investment withing 3 years.**
c. **Most fleet operators do not view retrofitting as a reliable option.**

- Ownership of HDV is five years (in case of high annual running), and 15 years (in case of specialized trucks and tankers).



3.2. State Transport Undertakings

One of the key issues for adoption of LNG is the lack of LNG infrastructure, which is also related to the scarcity of LNG vehicles. As we have observed from successful adoption of LNG across the world, we understand that this initial impasse created between infrastructure and vehicle scarcity can be usually solved by introducing government obligations for ensuring demand for alternative fuel for vehicles.

Engaged with Maharashtra State Road Transport Corporation (MSRTC) and Karnataka State Road Transport Corporation (KSRTC).

25,750 intercity buses in total, running an average of 1,40,000 km per year.

State Transport Undertakings (STUs) can play a key role for creating and ensuring this initial demand of LNG for vehicles. STUs have large fleets of buses running intercity routes where LNG adoption can come into play. While there are counterarguments that CNG is ideal for buses, but for long distances, LNG as a transportation fuel appears to be better, considering the long range and less refueling time.

Feedback from STUs is vital to understand how such obligations that have been used in other countries, could be utilized in India, and thus benefit the State Transport Undertakings as well.

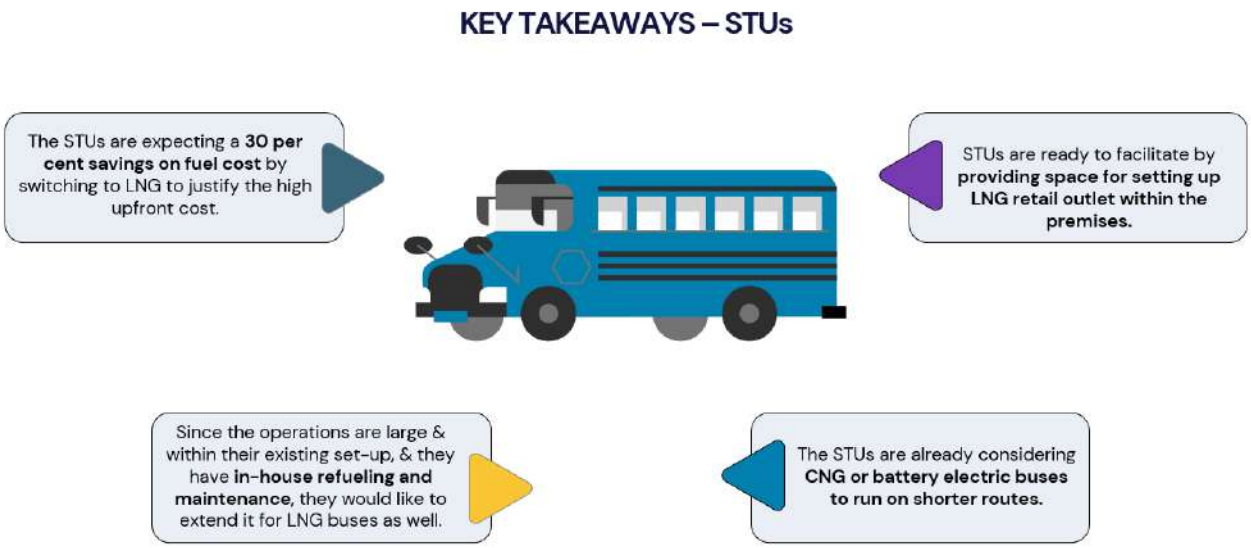
Major questions brought up in the questionnaire are listed below:

- Details on current fleet of buses, emission standard, and percentage of CNG buses.
- Discussion on operational parameters of buses, such as life, km run, mileage, and size of interstate and intrastate fleet. Details on maintenance contracts with OEMs.
- Specifications on fuel purchase, existence of long-term contract, refueling facility and expenditure on fuel.
- Discussion on pilferage of fuel and its importance to the STU, and method or technology currently employed to prevent it.

- Discussion on CNG buses and differences in operating CNG vs diesel bus, and issues faced in case of CNG. Positives and negatives of CNG over diesel, and how they can be addressed.
- Discussion on existence of any STU policy for reducing carbon emissions, how it is currently being followed, and whether LNG could be considered for interstate travel, and also availability of depot for LNG dispensation.

During our stakeholder discussions, we carried out interaction with Maharashtra State Road Transport Corporation (MSRTC) and Karnataka State Road Transport Corporation (KSRTC). Following are the key attributes of the State Transport Undertakings (STUs) engaged for this study -

- 25,750 intercity buses in total, with an average running of 140,000 km per year
- The estimated annual fuel expenditure of both STUs amount to Rs. 4,000 crore
- The life of the buses running with them is between 8 and 12 years
- One of the STU is looking at procurement of energy-efficient/alternate-fueled buses, such as electric buses
- The maintenance and refueling of the buses are done at company-owned depots



3.3. Vehicle Manufacturers / OEMs

Vehicle manufacturers are key stakeholders who are essential to solve one of the key components in the value chain i.e., by providing OEM-backed LNG fueled transportation vehicles. From the interactions with multiple fleet operators, it emerged that reliability of transportation business is of utmost importance, and the fleet operators have less confidence on retro fitment of diesel vehicle with LNG kits. With this in context, the role of Original Equipment Manufacturers (OEMs) become critical to ensure that there is a widespread adoption of LNG fueled M&HCVs. During our discussions with various other stakeholders, one of the most mentioned issues was the lack of LNG vehicles available in the Indian market. As we observed while reviewing successful models across the world, we find that availability of LNG vehicles in the market is essential to build confidence among the remaining stakeholders.

Engaged with Tata Motors, Volvo, Cummins India and Daimler Truck AG.

Tata Motors is working on type approval for NG HDVs in 19 MT+ segments.

Volvo is selling LNG HDVs globally and can import kits.

Cummins India developing 250 HP natural gas engines for HDVs.

During our discussions with the vehicle manufacturers, we focused on finding the causes for the lack of LNG vehicles. Understanding these issues is the first step towards addressing them and ensuring that these do not hinder the vehicle manufacturers for long. Their support is vital for the adoption of LNG in HDVs.

Major questions brought up in the questionnaire are listed below:

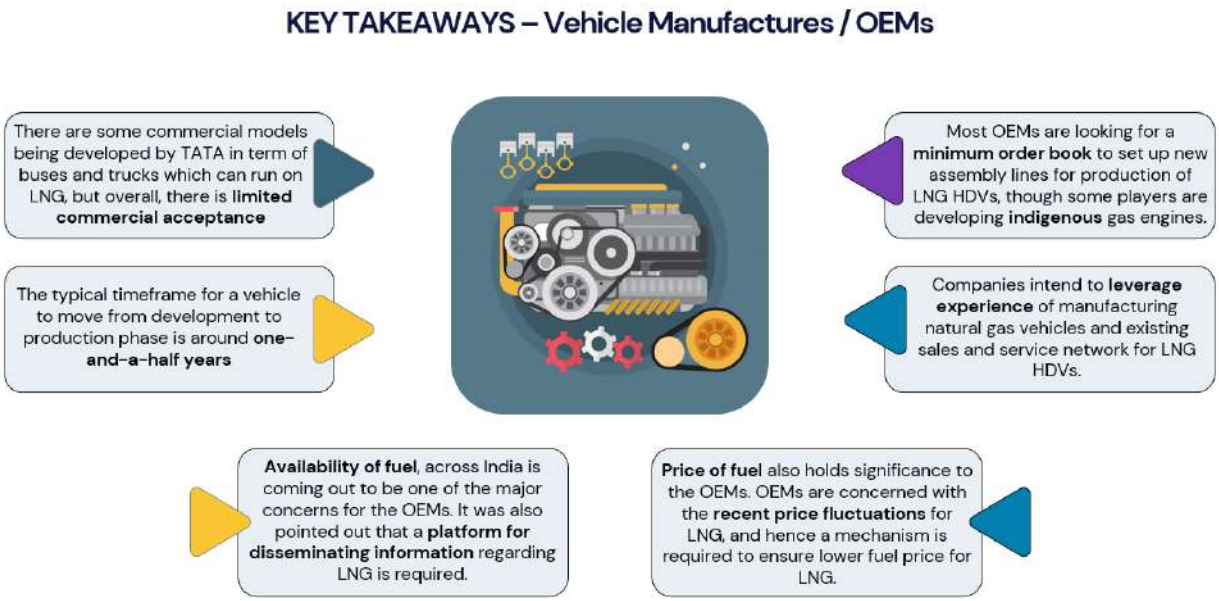
- Information on annual production capacity of engines for M&HCV segment, for different engine HP.
- Most produced diesel and natural gas power engines in M&HCV segment currently.
- Minimum order size to produce new natural gas engine and whether that would entail additional R&D/licenses to better understand the time frame for such a model to begin production.
- Technical aspects of utility of natural gas-powered engine in both CNG- and LNG-fueled vehicles, and differences between the two with respect to engines. Differences in warranties, performance, and maintenance for the two types of engines.
- Estimated cost differential between natural gas and diesel variants for BS-6, and discussion on how such differential could be minimized.
- Discussion on support required from Govt. of India, regulators, certification bodies, local suppliers, and other stakeholders to introduce natural gas engines.

During our discussions, we engaged with Tata Motors, Volvo, Cummins India and Daimler Truck AG. The following are the key attributes of the vehicle manufacturers engaged for this study -

- Tata Motors is working on type approval for NG HDVs in 19 MT and above segments, and has already provided LNG buses to Petronet LNG Ltd. (PLL) which are being used in the PLL's campus. The technical specifications of the LNG bus developed by Tata Motors is specified in Annexure 1 of this report. It is also understood that Tata Motors is testing[5] an LNG-fueled model under their series of Tata Prima LNG truck, which could be available for commercial sale in near future.
- Volvo is selling LNG HDVs globally and can import kits to assemble vehicles locally in 420 HP segment.

[5] https://www.91wheels.com/news/upcoming-tata-prima-lng-truck-spied-testing-read-all-the-details-here

- Cummins India developing 250 HP natural gas engines for HDVs.
- It was stressed by Daimler Truck AG, that availability of LNG stations is a major concern that needs to be alleviated.



3.4. Retrofitters

As we observed from adoption of alternative fuels in India and abroad, we came across a common initial problem that every country/sector faced. The key challenge which arose, as we found, was a lack of infrastructure in the initial stages, due to which companies were hesitant to bring out alternative fuel vehicles. This, in turn, led to a circular loop and the adoption got halted. This was, however, usually overcome with the help of retrofitters. They could assist in installation of a new fuel systems in the existing vehicles. The test case for retro fitment has been seen in India as well, where retrofitters played a key role in the beginning to build a market for the adoption of CNG in vehicles throughout India, which was then expanded by the involvement of OEMs to start manufacturing and launching of CNG-based vehicles.

Engaged with Cryogas, AutoLNG Cryo Solutions, Shigan Quantum Tech, PRALA Corporation, and Advantek Fuel Systems.

To obtain certification, retrofitters require a minimum order book of 200 HDVs for commercial viability

Hence, discussions with retrofitters become important, to understand if any roadblocks are currently present for retrofitting HDVs with LNG kits and if there any avenues that can be explored for cost cutting on a large scale. It also led to discussions on what steps could be taken to increase the confidence among fleet operators, and convince them to go for retrofitting. We were able to gain an understanding if there are any issues in the process of retrofitting, and what performance might be expected by the stakeholders that go for it.

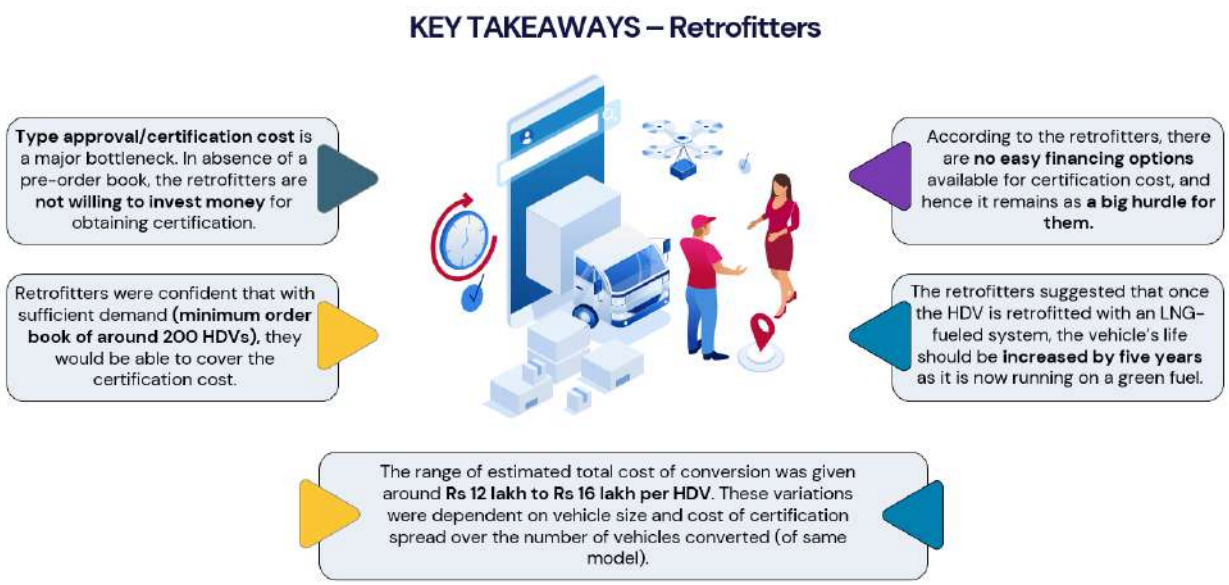
Major questions brought up in the questionnaire are listed below:

- Understanding of types of HDVs which can be retrofitted for LNG, key components required, their GST rates, which components need to be imported, and their customs duty.
- Parameters considered during retrofitting, safety in operations of retrofitted vehicle, performance comparison with diesel, and cost comparison of retrofitting with purchasing new LNG HDVs.

- Costs incurred for a retrofitting business in type approval and certifications, and how much orders might be required to amortize this cost.
- Understanding the logistics of getting certification and timeline for the same.
- Current acceptable order sizes, and understanding the time frame for retrofitting a truck, delays caused due to lead time of components, and how to optimize the same.
- Discussion on support required from Govt. of India, regulators, certification bodies, local suppliers, and financing agencies.

During the stakeholder discussions, we engaged with five (5) retrofitters namely – Cryogas, AutoLNG Cryo Solutions, Shigan Quantum Tech, PRALA Corporation, and Advantek Fuel Systems. Following are the key attributes of the retrofitters engaged for this study -

- The retrofitters mentioned that the cost of type approval is approx. Rs. 50 lakh per model, which is on the higher side, as type approval is to be taken for all types of vehicles.
- The warranty offered by the retrofitters is typically in the range of six months to a year after conversion.
- The retrofitters mentioned that the lead time for first conversion, including type approval, is generally up to six months. But they were confident that once there is sufficient demand, they could optimize their conversions around the lead time, and so it wouldn't impact their business. According to their estimate, the time of conversion for an HDV would be 3-5 days, subject to availability of all components.



3.5. Energy Companies

One of the major issues faced by any alternative fuel in the initial stages, is the lack of refueling infrastructure. Hence, discussions with energy companies on their plans to install LNG retail outlets become paramount. As we understood in detail while reviewing successful models across the world, we realized that the establishment and success of the first group of LNG retail outlets (RO) installed often led to successful adoption of LNG in HDVs very swiftly. Therefore, it becomes essential to understand the perspective of energy companies, the problems they might be facing, and to swiftly come up with solutions for the same.

Engaged with IOCL, BPCL, GAIL, ExxonMobil and PLL.

50 LNG RO are expected to be operational by Q2 2022.

Estimated 3,000+ LNG HDV needed on road to justify 50 LNG ROs.

Our discussion revolved around plans that energy companies have thought up for installing the LNG infrastructure, and the presence of any roadblocks that might hinder their plans. We also wanted to understand the detailed procedure and intricacies involved in running an LNG retail outlet, and also discussed models for setting up the outlets and investments that are allocated for these plans. Their inputs on these, would help us identify the extent of LNG adoption that can be expected in the coming few years.

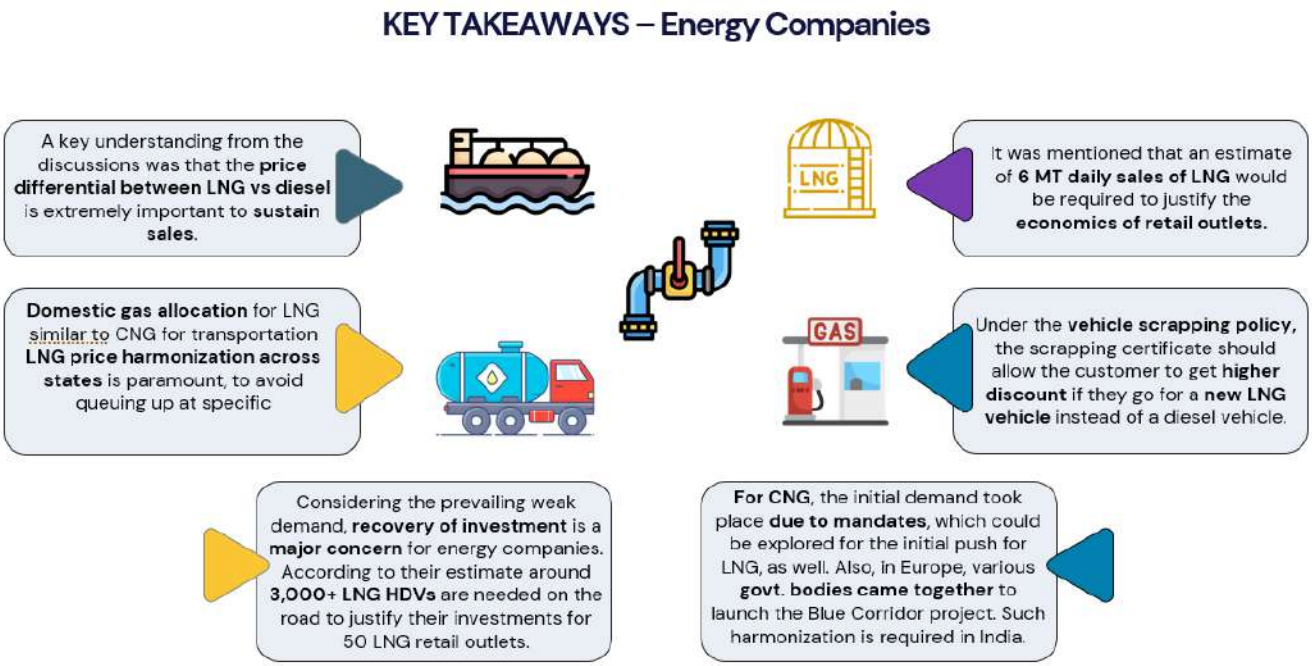
Major questions brought up in the questionnaire are listed below:

- Current plans of developing LNG retail outlets. Status and issues, if any faced with acquiring CGD GA license, land, statutory approvals, and expected opening data of stations.
- Details regarding LNG/LCNG stations and whether the planned LCNG stations act as a natural gas supply source to GA as well.
- Discussions on investment allocated to set up a station on standalone basis, or mixed retail outlet. Understanding expectations for ensuring viability of investment.
- Whether there is any necessity for policy or regulatory support from state or central government in setting up stations or creating demand to make the stations viable.
- Steps taken by them, such as talking to fleet operators and transporters to ensure demand. Types of roadblocks faced while taking these steps.
- Discussion on best model for setting up LNG/LCNG stations, anticipated price point to sell LNG, and method of procuring or transporting LNG from terminals.

During our discussions with energy companies, we engaged with five (5) major companies namely – IOCL, BPCL, ExxonMobil, GAIL India, and PLL. Following are the key attributes shared by the energy companies engaged for this study -

- It was mentioned that while 50 LNG retail outlets are being planned around the golden quadrilateral, however most of the developments are happening by establishing LCNG stations which can be readily converted to LNG stations by adding a dispenser. Since investments are on the LCNG side, the retail outlets are being developed in the CGD authorized area, and not all are planned on the golden quadrilateral.
- The energy companies explained that most of the LNG retail outlets are planned as an extension to the existing fuel retail outlet.
- They revealed that a couple of LCNG stations are also planned in authorized GAs.

- It was mentioned during the discussions that truck differential cannot be more than 20-25 per cent, and this fact needs to be conveyed to the OEMs as the Indian customer is price sensitive.
- In Europe, various government bodies came together to successfully complete the Blue Corridor Project to kickstart LNG adoption. Such harmonization between government bodies needs to be executed in India as well.
- In the US, fleet operators have access to a comprehensive website, which contains details of fuel stations, pricing, questions and queries that help them to better plan their trips, as well as gain confidence for alternative fuel vehicles. Such initiative would be helpful in India, too.



3.6. Vehicle Financing Companies

Vehicle financing companies act as enablers by providing financing options for LNG HDV buyers and/or operators. To ensure that a steady demand for LNG is created after the requisite infrastructure has been installed, it is necessary for vehicle financing companies to finance LNG HDVs for the relevant stakeholders. In the heavy duty segment, most companies depend on vehicle financing to build their fleet. Hence, coordinated action by vehicle finance companies is required to create the ideal conditions for the market to adopt LNG in HDVs.

Engaged with HDFC Commercial Vehicle Finance, Sriram Transport Finance and a Dealership of Tata Motors.

Typical rate of interest is 8-10%.

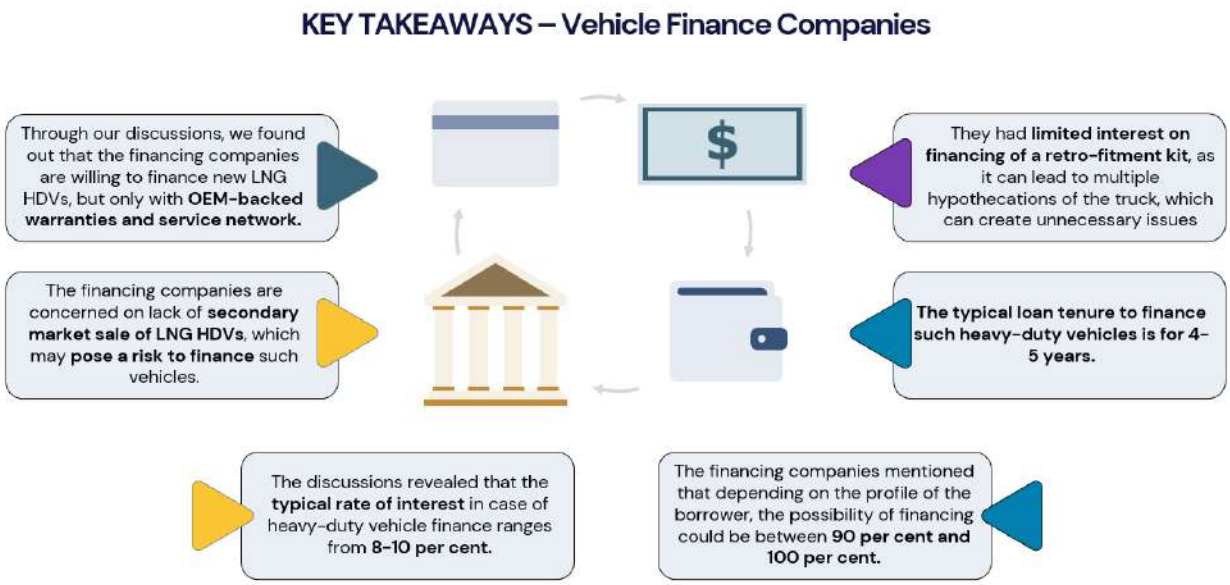
Typical loan term is of 4-5 years

As such, our discussions with vehicle financing companies were important to ensure that once other requisites for LNG adoption have been arranged, the growth of the market is not hindered due to unavailability of financing options for fleet operators. Our discussions revolved around details of vehicle financing and thoughts that the companies had on financing alternative fuel vehicles. We wanted to understand in case any roadblocks might be present for LNG-specific financing, and if so, how these could be removed.

Major questions brought up in the questionnaire are listed below:

- Typical term for which M&HCV is financed, and discussion on factors taken into consideration for assessing truck owners and fleet operators.
- Information on maximum debt offered, average lease payback period, and rate of interest charged for trucks, and whether these rates vary as per owners' rapport with the lending institutions.
- How is new technology viewed in the domain of vehicles financing, what concerns are present, and do these affect financing terms?
- Discussions on LNG-specific terms of financing, whether the fuel savings from LNG can allow for favorable financing terms for LNG trucks, and additional conditions required for such favorable financing?
- Have they acted as facilitator for alternate vehicles/ any vehicle segment in the past?
- Would retrofit trucks be considered for financing, and what terms might be appropriate for the same?

During our discussions with vehicle financing companies, we engaged with three (3) major stakeholders namely – HDFC Vehicle Finance, Sriram Transport Finance and a dealership of Tata Motors. Following are the key takeaways from the discussions with vehicle finance companies engaged for this study –



3.7. End Users

End users can also play the role of an enabler by bringing in or modifying existing procurement policies, to shift focus from fossil fuels to alternative fuel vehicles. The end users that regularly utilize long range transport, can focus their attention on LNG, due to it being the only alternative fuel currently with capabilities for long range transport in the heavy duty sector. We have observed that many companies across the world have set targets for net zero emissions and have declared strategies and plans to reduce their emissions in the coming decade. In today's age, the global consumer is climate conscious, and hence, many multi-national companies (MNCs) have shown clear signs of moving towards net zero emission norms. This works in our benefit for the adoption of LNG, as there is a presence of many large global firms that operate in India and utilize HDVs for long range transport. These companies would benefit greatly in meeting their emission reduction targets with the use

Engaged with Saint Gobain, DCM Shriram and IOCL.

Profitability is more important than emission reduction for companies in the Indian context.

of LNG. Hence, our approach involved discussions with end users, as we believe that they have the push needed to reduce their emissions, and with changes in their procurement policy, they could incentivize the fleet operators to adopt LNGs to keep their business with these firms.

So, our discussions with the end users became vital to probe around the possibility of such procurement policy changes, which would favor alternative fuel vehicles. We discussed details around their exposure to long range transport, ownership of their own fleet, existence of any policy for GHG reduction, specifically in India, and if so, the steps currently being taken to achieve the emission reduction and net zero targets of the company.

During our discussions with end users, we engaged with three (3) major companies – Saint Gobain, DCM Shriram and IOCL. Following are the key attributes of the end users engaged for this study –

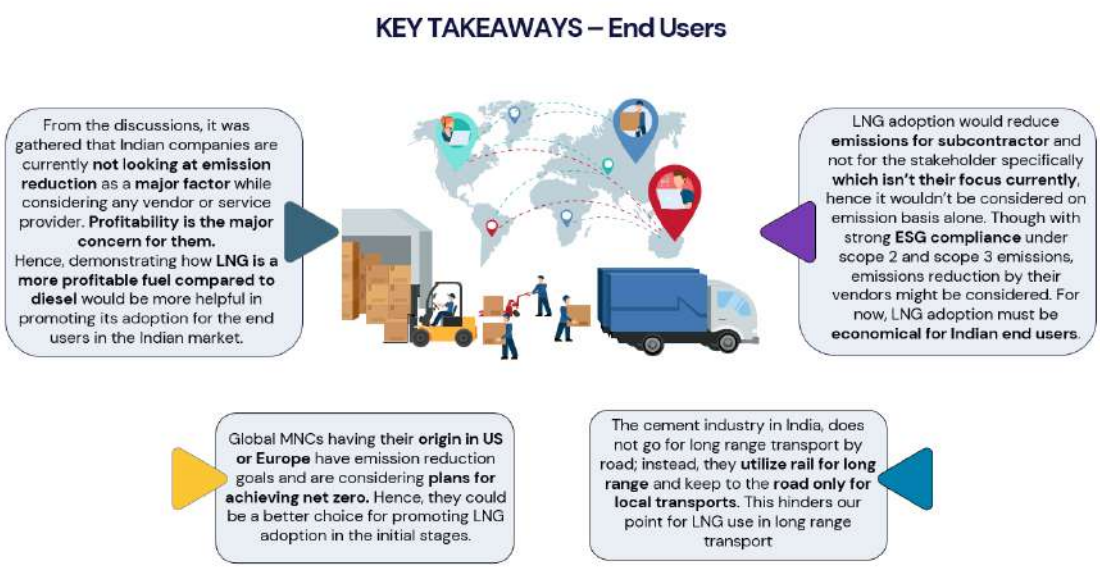
- Saint Gobain has set a target of 2050 to achieve net zero carbon emission and has even published its CO_2 roadmap. It also set a target for 33 per cent reduction in scope 1 and 2 emissions in absolute terms, and 16 per cent reduction in scope 3 emissions compared to the 2017 baseline level. Scope 1 emissions are direct emissions on site, while scope 2 include indirect emissions, which are mainly linked to the use of electricity. Scope 3 emissions are those that are present in the upstream and downstream of the value chain.

- Some stakeholders also mentioned the use of decarbonized fuels and improving fuel efficiency as levers to achieve their targets.

- It was revealed that within the cement industry, the process of procurement is through third party, and vendors are not changed frequently, unless better terms could be offered by others.

- It was also mentioned that the major factors while choosing a transporter are transport rate and past record, and local transporters are preferred. They mentioned that the transportation business is state specific, and certain transporters specialize in their given states. The trucks utilized are generally overloaded (10-20 per cent), and here, local transporters can offer better rates as well as handle the police. Local transporters also always make it a point to gain access to all districts and at all possible times, which is done through gaining passes for these districts.

- The cement industry follows a process of reverse auction to set the transport costs for the day, and it works pretty well for them. Cement companies don't travel beyond 250-300 kms by road as it risks their profitability.



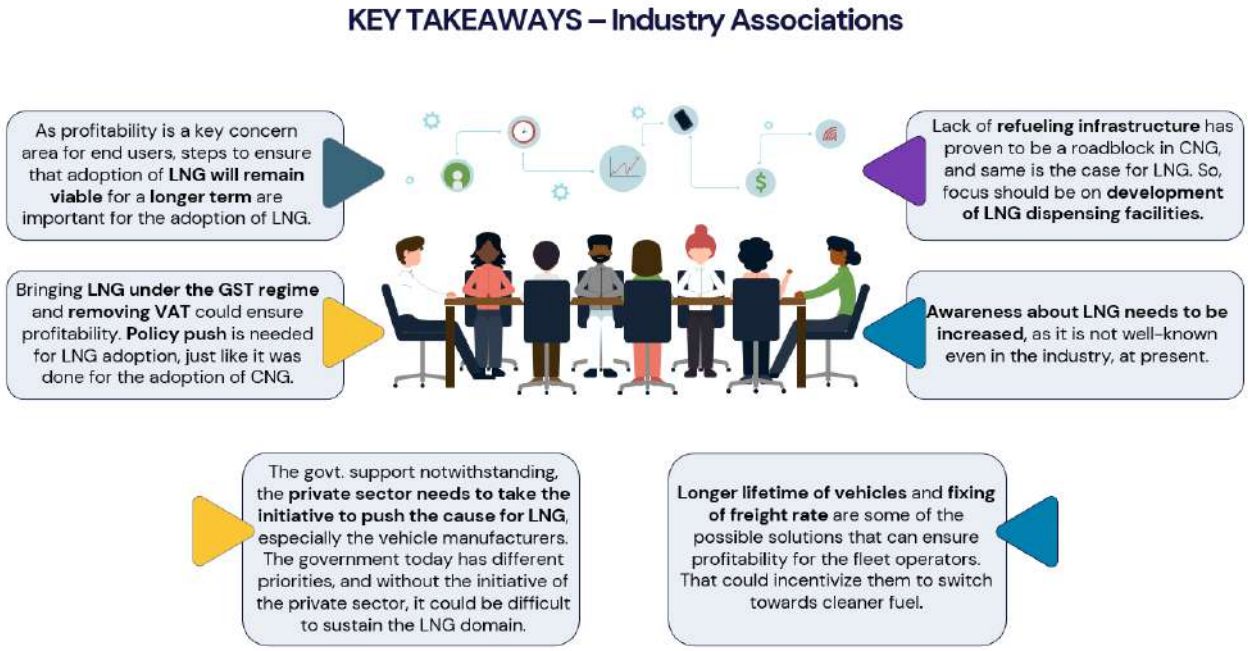
3.8. Industry Association

Industry associations have close linkages with a variety of stakeholders, and therefore, have a consolidated view of the industry, which is extremely helpful in understanding the challenges existing in the sector and the policy initiative needed to overcome them. Through these associations, the industry is able to put forward its views to the government, and here too, it can represent to a certain extent the thought process of the companies towards adoption of LNG as an alternative fuel to diesel for the transport sector.

Engaged with All India Motor Transport Congress (AIMTC), Federation of Indian Petroleum Industry (FIPI) and Confederation of Indian Industry (CII).

Hence, our discussions with the industry association were important to have a complete idea of the on-ground reality. During our discussions with industry association, we engaged with AIMTC (transport), FIPI (oil and gas) and CII. Following are the key attributes shared by the industry association engaged in this study –

- With adoption of natural gas vehicles (CNG), refueling of vehicle in terms of time taken and infrastructure availability remains an issue which leads towards hassle in its adoption.
- There existed the challenge of low pressure and availability of CNG at some of the stations.
- The association is of the view that natural gas vehicles should be allowed to run for a longer time frame, which is currently not possible due to existing vehicle scrappage policy.
- The government should fix the minimum freight rate for alternative fueled vehicles to ensure profitability.
- Natural gas should be considered under the GST regime, and VAT should be discontinued.
- From the opinions shared, the driving force for CNG adoption wasn't the price difference, but the court order towards CNG adoption. In case of LNG vehicles, there are no strong policy drivers for LNG adoption.
- The industry associations are of the view that in case of LNG adoption, aggregation model to bring down the cost (like EVs) can only be successful if there are adequate players in the market to compete for the supply of LNG vehicles. No such scenario exists for LNG vehicles at present.



3.9. Testing and Certification Bodies

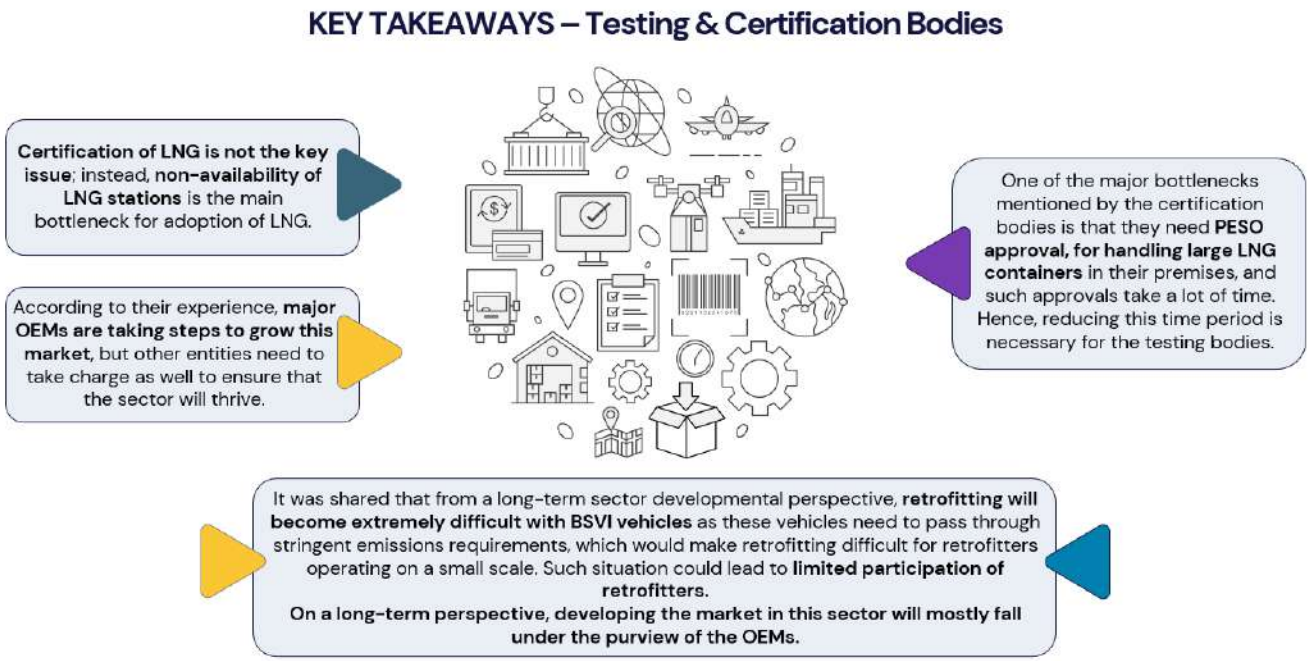
Discussions with different stakeholders in the LNG value chain led to multiple references of vehicle certification and the process associated with the same. For the OEMs it is necessary to get their engines tested and certified, but more importantly, it is also necessary for the retrofitters to get their kits certified. During our interaction with the retrofitters, we found that the testing and certification is considered expensive and acts as a hurdle, unless they have a visibility on their order book. The retrofitters also mentioned that getting a certification is also a time-taking process. Hence, to gain a better understanding of the entire testing and certification process, and get an insight from them about LNG adoption, we conducted discussions with relevant testing and certification bodies as well.

Engaged with Automotive Research Association of India (ARAI) and International Centre for Automotive Technology (iCAT)

We engaged with ARAI and iCAT, to further our understanding about the challenges and requirements of testing and certification. Following are the key attributes that we captured:

- According to their understanding, certification of LNG is not the key issue; instead, non-availability of LNG stations is the main bottleneck for adoption of LNG.
- They revealed that Tata Motors has already certified some of its HDV models, which are running as buses in Kerala, and commercial trucks could soon be launched as well. Also, Ashok Leyland is working aggressively towards this, and they, too, are expected to certify their models soon.
- According to their experience, major OEMs are taking steps to grow this market, but other entities need to take charge as well to ensure that the sector will thrive.
- In their opinion, dual fuel is still relatively new, and it won't give much benefit to the sector. Also no one has yet certified any vehicle running both on diesel and LNG.
- They also explained that in case an agency gets the certification, it can utilize the same for its sub-dealers located across India.

- They shared the view that from a long-term sector developmental perspective, retrofitting will become extremely difficult with BSVI vehicles. Since BSVI vehicle need to pass through stringent emissions requirements, it would be extremely difficult for retrofitters operating on a small scale to potentially meet these stringent requirements. This could lead to limited participation of retrofitters. On a long-term perspective, developing the market in this sector will mostly fall under the purview of the OEMs.
- It was also revealed that most tests applicable to CNG could be utilized for LNG as well, as the only difference between the two is with regards to the fuel-handling operations. They also revealed that in the case of diesel vehicles, there are a greater number of emission testing procedures required as compared to LNG or CNG vehicles, due to which the overall process is more lengthy and costly for diesel vehicles. Due to this reason, dual fuel vehicles also require to undergo a greater number of tests, as they would need to be certified for both diesel and LNG.
- One of the major bottlenecks mentioned by the certification bodies is that they need Petroleum and Explosives Safety Organization (PESO) approval, for handling large LNG containers in their premises, and such approvals take a lot of time. Hence, reducing this time period is necessary for the testing bodies. The requirement of these containers is due to the low LNG availability and a lack of LNG infrastructure outside the testing facility. Hence, for their testing requirements, they need to keep relatively higher quantity of LNG inside their premises.



3.10. Ministry of Petroleum & Natural Gas (MoPNG)

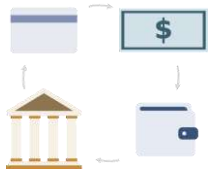
The Ministry of Petroleum and Natural Gas (MOP&NG) is a ministry of the government of India which is responsible for the exploration, production, refining, distribution, marketing, import, export, and conservation of petroleum, natural gas, petroleum products, and liquefied natural gas in the country. It is the leading body for all the decisions made by the government concerning natural gas. The adoption of LNG in HDV segment also fall under its purview, and hence it has already released the Draft LNG Policy which envisions the utilization of LNG across multiple domains especially in transportation. Therefore, any strategy for the adoption of LNG in the heavy duty sector is incomplete without the inputs of the apex body - MoPNG.

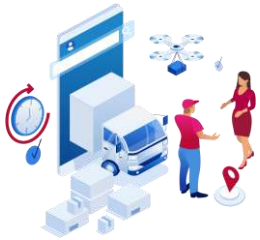
- **49 LNG Retail stations by January 2023.**
- **250 LNG Retail stations in South India targeted under the next phase.**
- **Domestic Gas Allocation is being considered for the sector.**

Due to the role that MoPNG plays for natural gas in the industry, it was paramount to understand where they stand currently, and what steps are being taken for promoting LNG as a transportation fuel from their end. Our discussions led to the Ministry sharing some of the key steps underway that would support this sector. These key attributes captured are listed below:

- It was mentioned by the Ministry that 49 LNG retail stations are anticipated to be installed latest by January 2023 around the golden quadrilateral.
- They mentioned that under the next phase of the project, they have a target to develop approximately 250 LNG retail stations with a focus on South India.
- It was brought up that supply of LNG in northeast region could be done through a pilot project to distribute LNG for transportation sector.
- The Ministry mentioned that to support this sector allocation of domestic gas is being considered. Here swapping of LNG supplied with domestic gas pricing could be explored. At this stage they are considering options to operationalize the same and how settlement mechanism would be formulated.
- The Ministry is considering retrofitting LPG trucks of OMCs to create demand for LNG in the transportation domain. They have identified specific routes where such point-to-point movement can be tapped for the sector.
- The Ministry acknowledges the additional cost needed for retro fitment and is considering alternative business models which could be used for financing retro fitment of trucks.
- Due to the excessive cost of LNG equipment, there is a focus on creation of ancillary equipment within India and in this regard Nashik's facility is trying to develop indigenous LNG dispensing units.

3.11. Summary

Stakeholder	Key Takeaways		
Fleet Operators (FO) 	**Average Utilization of HDVs**	**Pricing of LNG**	**Focus on reliability in operations**
	• Annual running is 60,000 km to 80,000 km per HDV. • Typical duration of ownership of a new HDV is 5 to 10 years.	• Need recovery of additional investment within 3 years. • Looking for LNG to be 20% to 30% cheaper than diesel.	• New LNG HDV is preferred by FOs over retrofitting. • Fuel availability on highway is crucial • Different colored numberplate, priority at ports and PSU contracts
State Transport Utilities (STUs) 	**Higher Utilization and Average Life**	**Pricing and Availability of LNG**	**Concentrated Demand**
	• Average running is 120,000 to 140,000 km run per bus per year. • Average life of buses is between 8 to 12 years.	• Looking for average discount of 15% to 25% in fuel price • Availability of fuel at depots is needed and STUs are ready to provide land for this.	• STUs are operating around 10,000 to 12,500 buses. • Annual fuel expense to the tune of Rs. 2,000 Crore
Energy Companies 	**Sales & vehicles to justify investments**	**Need for price harmonization**	**Viability of RO is key concern**
	• LNG HDVs needed to achieve break even for 50 LNG RO's are 3,000+ (on road). • Minimum LNG sales required to justify economics → 6 tonnes per day	• LNG retail price consistency along the highway is needed. • Maintaining price differential of LNG vs diesel is key to sustain LNG sales. • Domestic gas allocation for LNG HDVs for initial 3-5 years to seed the market.	• Strong emphasis on demand creation is needed for fast adoption of LNG HDV. • CNG Sales if allowed along with LNG at the RO would ensure extra viability
Financing Companies 	**Loan Terms**	**Interest Rates**	**Prefer financing New Vehicles**
	• Typical loan terms is of 4 years for a truck / HDVs • OEMs backed financing companies may offer longer term	• Typical interest rates of 8% to 10% depending upon customer profile	• Open to financing new LNG HDV only with OEM warranty and service coverage. • Retro-fitment financing not preferred, and to be evaluated on case-to-case basis.

OEMs 	**Need for a firm orderbook**	**Incremental Cost of LNG HDVs**	**Challenges**
	• Firm order-book required to begin production • Vehicle development to production time is reported as up to 1.5 years.	• LNG HDV is expensive mainly due to fuel tank and NG engine; differential close to Rs. 12+ lakhs. • Need local manufacturing of key components to reduce cost.	• Eco-system should develop within 3 years • Challenge with type approval due to limited facility to test with LNG
Retrofitters 	**Warranties and additional Life**	**Incremental Cost of LNG HDVs**	**Need of an orderbook**
	• Warranty of 1 year is offered by many retrofitters. • Additional life of 5 years as claimed by retrofitters.	• Rs. 12 to 16 lakhs for diesel to LNG conversion with single 450L / 180 kg tank. • Reducing type approval cost will allow smaller fleet operators to convert	• Orderbook of 200+ to amortize the high type approval per model. • Financing of conversion cost will be helpful for FOs.
End Users 	**Profitability more important than emission reduction**	**Reduction in Emissions of Subcontractor**	**Global MNCs have defined plans for Net Zero**
	• In India, profitability is a much more dominant factor than emission reduction. • Demonstrating LNG as a more economical fuel than diesel would be helpful.	• LNG adoption would reduce emissions for subcontractors and not for the stakeholder specifically. This is not the focus of end users currently.	• Many global MNCs originated in US & Europe have set goals to achieve net zero. • Such global MNCs can help in achieving visibility for LNG adoption.
Industry Associations 	**Profitability is a key concern**	**Push from Private Sector is Needed**	**Lack of refueling infrastructure and awareness of LNG**
	• Steps to ensure that adoption of LNG will remain viable for a longer term are needed to ensure profitability. • Bringing LNG under GST regime and removing VAT could ensure profitability.	• The private sector needs to take the initiative to push the cause for LNG, especially the vehicle manufacturers as the government today has different priorities.	• Lack of refueling infrastructure was a roadblock for CNG and same is the case for LNG. • Awareness about LNG needs to be increased

4 Review of Existing Policies and Regulations for Adoption of LNG HDVs in India

The existence of supportive regulations and policies is one of the most crucial requirements for the growth of any alternative fuel adoption in India. Time and again, we have observed that without necessary policy mandates and regulations, adoption of any alternative fuel remains stunted. In later chapters, we will focus our attention to successful global case studies and observe that the importance of supportive policy initiatives is cemented across the globe.

The adoption of any alternative fuel always shows challenges in the initial stages. These challenges range from the classical 'chicken and egg problem' to those related to infrastructure and vehicle manufacturing to even doubt and hesitancy in the market regarding the newer technologies. In these circumstances, the role of the government becomes critical to assuage the concerns of the stakeholders involved. Hence, in these initial stages, the mix of right policy support and swift modifications of existing regulations can make or break the nascent alternative fuel market. We further observed this in the case of CNG and electric vehicles, which will be discussed in the subsequent sections in detail. In the case of LNG as well, it is of utmost importance that during these initial years of adoption, necessary policy support and regulations are present, for such continuous engagement by the government in the sector would lead to an increase in the confidence level among the remaining stakeholders to do their part and take decisive action.

Hence, it was important to conduct a review of existing policies and regulations that the government has come up with for the adoption of LNG. An exhaustive review of the current government actions would help us in identifying the possible roadblocks that might need to be cleared and help us gauge the resolve of the government to promote LNG, so that an understanding could be built on the level of support that could be expected in the future stages of developing the market for LNG as an alternative fuel for HDVs.

Emission reduction and reducing oil import dependency form the core of the long-term sustainable strategy for the government of India.

India has set extremely ambitious targets for emission reduction and reducing its oil import dependency in the coming decade. We understand that these issues are central for the long-term sustainable strategy for the Government of India. The transport sector accounts for a large percentage of the emissions in the country and the transport sector is heavily dependent on oil. So, targeting LNG in the heavy-duty sector tackles both issues that form a core of India's emission reduction strategy. We further observed that the government has been privy to this fact and has also begun to lay the groundwork for LNG in this sector through certain policy initiatives and regulations. Some of the regulations and policies specific to LNG in HDV that have been brought are listed in the subsequent sections.

4.1. Current regulations and policies pertaining to LNG HDV

Following policies and regulations are already in place with regard to use of LNG in HDVs –

1. (April 2018) Petroleum & Explosives Safety Organization (PESO) Guidelines[6]: As per the gazette notification dated 23 April, 2018, the Ministry of Commerce and Industry notification to amend the Static and Mobile pressure vessels (Unfired) Rules, 2016, G.S.R.388(E) and has covered a) guidelines for storage installations and handling of LNG at the dispensing station b) guidelines for safety relief valves provided on the inner vessel of the LNG transport tank c) aspects of operation, maintenance

[6] SMPV(U) Amendment Rules 2018 | Petroleum & Explosive Safety Organisation (peso.gov.in)

and training, d) fueling and non-fueling facilities at LNG dispensing stations e) boil-off gas management etc.

2. (November 2018) Use of LNG as a transport fuel along with allowing retro-fitment of the diesel vehicle to LNG-fueled vehicles (complying with the emission norms): GSR 1151(E)[7] dated 29 November, 2018 by MoRTH

3. (January 2020) In the Natural Gas Conclave organized by the Government of India, LNG was identified for M&HCV segment for long distance transport. A target of setting up 1,000 retail outlets was also declared.

4. (January 2020) Allowing dual fuel classification for vehicles having diesel with LNG: Allowing O.E. or Converted, Dual Fuel or Dedicated Dual Fuel (for vehicles with GVW below 3.5 T); Vehicles having Diesel with Compressed Natural Gas (CNG) or Bio-Compressed Natural Gas (Bio-CNG) or Liquefied Natural Gas (LNG) as dual fuel: GSR 37(E)[8] dated 17 January 2020, by MoRTH.

Regulatory clarities still required:

- **Use of ISO Containers for LNG transport.**
- **Sale of CNG through LNG stations.**
- **Clarification from PNGRB with regards to exclusivity in a CGD network.**

5. (May 2020) Bharat Stage VI Emission Standards for quadricycle models (Category L7) were released by MoRTH under GSR 308 (E)[9] dated 22 May, 2020. It also covers test requirements for Type Approval for BS VI, including LNG vehicles.

6. (June 2020) PNGRB[10] concluded that any entity can set up an LNG station in any geographical area (GA) or anywhere else, even if it is not the authorized entity for that GA. This brought the matter of setting up of LNG stations to clarity, and also opened the doors for private players to set up LNG stations.

7. (November 2020) The foundation stone for 50 LNG retail outlets was laid along the Golden Quadrilateral, with the deadline to set up 1,000 retail outlets by 2023.

8. (February 2021) Draft LNG Policy[11] was released which targeted the promotion of adoption of LNG for usage in green-field sectors, where LNG is not being used currently. It focused on creation of LNG terminals and regassification facility, along with virtual pipelines for the upstream sector. It focused on dedicated highways, and mobile dispensing among other things for the midstream domain. It also set targets for LNG stations, marketing, and sale of LNG for the downstream domain. The policy also promotes increased use of LNG in the transportation and mining sector.

9. (May 2021) Mass emission standards with LNG in agriculture industry equipment, such as tractors, power tillers, construction equipment vehicles, and combine harvester: GSR 336 (E)[12] dated 4 May 2021 by MoRTH

[7] Microsoft Word - 6901gi (morth.nic.in)
[8] GSR 37(E) dated 17 January 2020 mass emission standards for Di Methyl ether and M85.pdf (morth.nic.in)
[9] GSR 308 (E) 22 May 2020 Emission Standards Bharat Stage VI (BS-VI) for Quadricycle.pdf (morth.nic.in)
[10] PN02062020.pdf (pngrb.gov.in)
[11] Draft-LNG17021_0001-(1).pdf (mopng.gov.in)
[12] https://egazette.nic.in/WriteReadData/2021/227093.pdf

From our analysis and discussion with the stakeholders, a significant number of the technical regulations pertaining towards adoption of LNG in vehicles are already approved. Even the regulatory ambiguity regarding investments in LNG stations situated in geographical area developed by other entities has been clarified by the regulatory board. However, there were some additional regulatory clarities according to the stakeholders:

a. Use of ISO containers for transportation of LNG

b. Sale of CNG through the LNG stations to manage the boil-off gas, and to ensure viability of stations till a large number of LNG trucks start plying on the road

c. Clarification is required from PNGRB in the interpretation of exclusivity in a CGD network, and sale of LNG by any entity should be allowed through virtual mode i.e., by cascades or any other mode other than pipeline in any GA. This is necessary to ensure development of the LNG ecosystem

4.2. Review of Procurement Policies of PSUs

A review of the procurement policies of prominent players, such as IOCL, Container Corporation of India (CONCOR), National Fertilizers Limited, BPCL and Central Coalfields Limited (A Miniratna Subsidiary Company of Coal India Limited) was conducted to study the enabling provisions, which can be introduced in the procurement services to help the adoption of LNG vehicles. Tenders floated by these organizations were reviewed in detail, and an analysis of the procurement terms through the lens of aiding LNG adoption was done.

Through the review it was observed that a significant number of provisions for aiding different stakeholders are already present. Therefore, the expectation of similar provisions for LNG is justified and could definitely aid in the adoption of LNG vehicles, thus creating an initial demand for them.

Some of key provisions mentioned in the tenders from the review are listed as follows:

- The duration of the contract varied from 1-5 years across the tenders, with most contracts offering 2-3 years initially which can be extended later. Hence these are good durations of contract which could help fleet operators recover the higher capex requirement for LNG vehicles, by securing a contract with a duration of 2-3 years.
- Though not all tenders included the total number and type of trucks required, most of the tenders reviewed did have a stipulation on these parameters, with some even listing the carrying capacity, which is required for the job. As can be observed, tenders for PSUs include the parameters and details of trucks required based on the job requirements. Likewise, in areas where reduction in noise pollution and lower emissions are required to be followed, LNG trucks can be listed for the job requirement.
- It was noticed that for the IOCL tender, a limit on the quantity of trucks per bidder was intimated. This provision to ensure that the entire tender is not fulfilled by only 1-2 large players, helps support the smaller players in the industry. Hence, similar provisions to reserve certain number of trucks from each tender for LNG vehicles could help its adoption in the market.
- Many tenders included provisions detailing the allowed age/model of the trucks that could be used to complete the job. One tender included such provision for the emission norm compatibility, stipulating the use of only BSIII and above3 trucks for the specific job. Other tenders had requirement for the age of trucks being used. For some trucks, the age stipulation was less than seven years, while for some it was less than three years. Instructions were also in place, in case the stipulation of age and model were not met. Certain tenders also specified that newer models would be expected to be purchased by the

bidder. Along with such emission and age requirements, stipulations for the use of LNG can also be brought in to aid its adoption.

- The Procurement Policy for many tenders had provisions for reserving some portion of the total requirement for MSMEs and SC/ST bidders. Similar reservations could be made for alternative fuel vehicles, and especially LNG vehicles, as currently, LNG is the only alternative fuel possible to be used economically in the HDV domain.
- On the financial front, provisions for escalation and de-escalation of prices as per the variation of diesel prices have been provided. Such provision for LNG prices would help ameliorate the concerns raised towards LNG price fluctuations by stakeholders, as was revealed during discussions.

Thus, it can be observed that a significant number of provisions for aiding different stakeholders are already present. Therefore, the expectation of similar provisions for LNG is justified and could definitely aid in the adoption of LNG vehicles, thus creating an initial demand for them.

Reviewing all the key provisions, recommendations involving LNG adoption are provided below:

- LNG-based trucks could be prioritized, as LNG being cheaper, allowed for agreement for lower project cost as against bidders having diesel trucks.
- During allocation of trucks, priority could be given to LNG trucks, due to their lower emissions.
- For specific jobs with requirement of traveling through or near cities, lower noise pollution and lower emission vehicles running on LNG could be preferred.
- The limit of trucks per bidder could be increased for LNG vehicles, thereby incentivizing bidders to replace their fleet with LNG vehicles.
- As certain reservations are already present in the tenders now, additional reservation for LNG vehicles can also be included.
- Provision for escalation and de-escalation for LNG would alleviate all concerns for fleet operators, who are wary of LNG due to the capricious nature of LNG price.

In the following page we cover an example of a demand aggregator in India, which has been doing lots of work to attract demand for vehicles in a new segment i.e., electric vehicle (EVs) and was able to achieve a significant reduction in prices for electric buses through one of the biggest tenders issued in the sector.

CESL success towards aggregation of electric buses under "Grand Challenge"

- **Objective**
  Convergence Energy Services Limited (CESL), a subsidiary of EESL recently discovered lowest ever prices for the biggest ever tender of 5450 electric buses in 5 cities through Grand Challenge under FAME India Scheme Phase-II. The rates discovered are 27% less than diesel and 25% less than CNG without subsidy. This was achieved by aggregating the demand and floating a unified tender with standardized parameters and contract terms.
  Based on this outcome, CESL has been requested by NITI Aayog and MoRTH to scale up the model and to play the role of program manager to deploy 50,000 electric vehicles under a "National Electric Bus Program (NEBP)". Such program facilitates tendering of e-buses and creation of supporting infrastructure to deploy e-buses on Indian roads. The aggregated demand will be tendered out for price discovery by a centralized agency CESL

- **Bidding process**
  For the Grand Challenge, CESL adopted a single-stage, two-envelope process for selection of the Bidder for award of the Project. Under the process, Bid was invited under two envelopes. Along with the Bid, the Bidder was asked to pay an amount to CESL as cost of the process.
  Eligibility and qualification of the Bidder were first examined based on the details submitted under first envelope (Technical Bid). The Financial Bid under the second envelope was then opened only for those Bidders whose Technical Bids met with the requirements set.

- **STU responsibility**
  - Sign Concession agreement for deployment of E-Buses, including defining of optimal routes for facilitating E-Bus deployment.
  - Escrow account to be created by the STU/Authority into which the STU shall maintain monies equal to the normative two months payment of the operator.
  - Authority/STU shall bear the cost of electricity charges related to charging of buses subject to power consumption up to 0.9 kWh/Km for 9 m non-AC buses; 1 kWh/km for 9m AC buses and 1.1 kWh/ km for 12m non-AC buses & 1.3 kWh/ km for 12m AC buses, trued annually to account for seasonal variations.
  - Provide adequate vacant land at the depot, free from encumbrances, along with road connectivity and right of way, civil structures for management of transit operations, electric connection of (11kV or higher) along with sub- stations and all requisite license/ permissions for setting up and operation of maintenance depots, charging infrastructure, and parking of buses
  - Collect 100% advertisement revenue from buses while ensuring no damage to the buses or maintenance and charging infrastructure. Any damage caused to the buses or associated charging and maintenance during to installation, operation or removal of advertisements would be fully borne by the STU on actuals within a month from the damage being reported

- **CESL responsibility**
  - Standardization of parameters and contract terms through consultation with subscribing STUs/ transit agencies
  - Aggregate demand from STUs/Authorities through subscription
  - Floating of RfP/tender to select bidders (OEM/ Operators) for E-Bus deployment
  - Notification to STUs of results, etc.

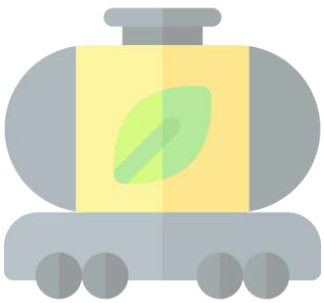
4.3. Learning from adoption of CNG vehicles in India

About 20 years ago, Delhi considered adopting CNG as a fuel under court orders. Even at that time, there were concerns related to performance and additional adoption costs. Ashok Leyland and Telco received type approval from the Automotive Research Association of India (ARAI) for their CNG engines. Telco estimated the cost of retrofit to be around Rs. 7.3 lakh per bus (plus taxes), while Ashok Leyland quoted a price of Rs 6.4 lakh per bus (plus taxes)[13]. During initial phases of implementation of the CNG buses in NCT Delhi, the private operators were not willing to buy the more expensive buses. The price of a diesel bus was Rs 9 lakh, whereas that of a CNG bus was Rs 16 lakh[14] (price as quoted around year 2000). It is interesting to know that Delhi Transport Corporation was the first transport undertaking coming forward and placing orders for 2000 buses.

Since the adoption of CNG was mandatory, the scale at which CNG vehicles were manufactured helped to bring down the costs. Yet the initial costs to retrofit existing vehicles or purchase new technology vehicles were still high, which was a deterrent in 2000. In early 2000, the Supreme Court also directed the Government of Delhi to reduce the capital cost of the CNG program by giving fiscal incentives to a segment of commercial vehicle owners. Though it can be understood that any subsidy program did not continue for long, but the sheer scale of manufacturing and supply of retro fitment cost was able to significantly bring down the cost of kits and CNG buses. Today, we face the same challenge for adoption of LNG as a transportation fuel. Today, it costs about Rs 12 lakh more to retrofit or purchase an LNG truck compared to a diesel truck, which may be brought down with some initial demand-side incentives being created to ensure that an adequate scale is reached to bring down the cost of LNG-fueled M&HCVs.

Even in an established CNG market, demand growth was not always purely driven by fuel price and policy measures were required to create an impetus for demand growth.

Even in an established CNG market, demand growth was not always purely driven by fuel price, and policy measures were required to create an impetus for such demand growth. If we compare the prices of diesel and CNG during the time frame of diesel price de-regulation as well as allocation of domestic gas to CNG segment, there was a significant gap between the diesel and CNG retail price. However, the growth in CNG consumption happened when there were policy initiatives taken to reduce air pollution in Delhi NCR by implementing an Environmental Compensation Charge (ECC) on diesel trucks entering into Delhi and a mandate for vehicles registered under cab aggregators like Uber / Ola to run only on CNG.



[13] https://www.downtoearth.org.in/coverage/cng-bus-market-16119

[14] History, Politics and Technology of CNG – Diesel Bus Switch in Delhi, Rakesh Mehta

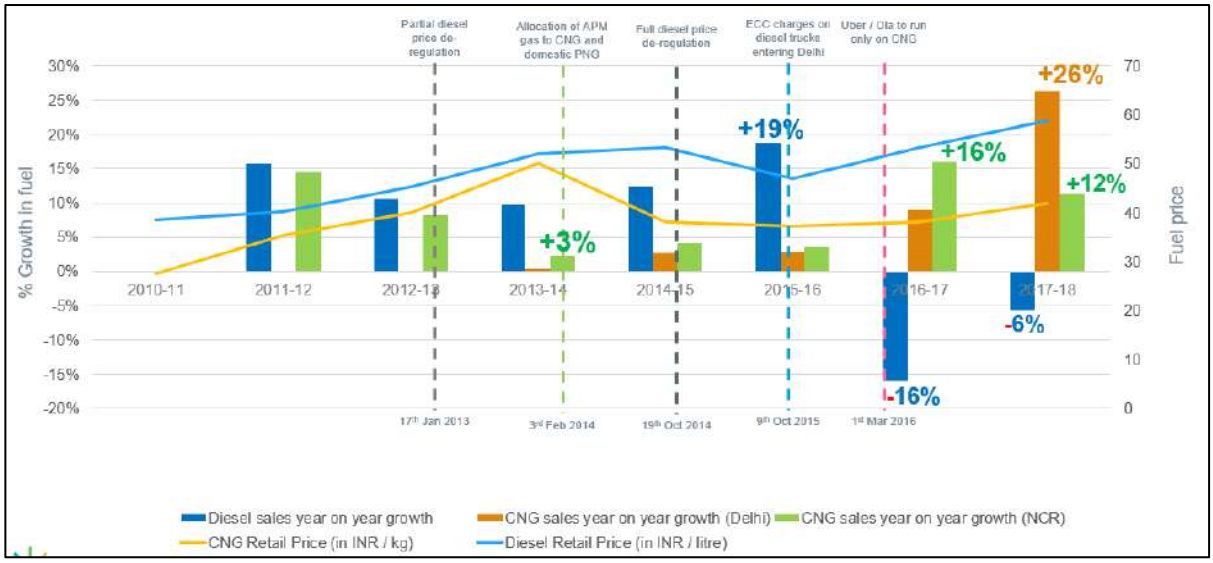


Figure 4-1: Enablers for growth of CNG and comparison of sales and fuel price for CNG & Diesel

The above chart shows that the growth in CNG consumption was not very significant even with increasing price gap between diesel and CNG, however policy/government orders were the major drivers for the growth.

4.4. Learning from adoption of electric vehicles in India: FAME-II Scheme

The failure of NEMMP plan presented an important lesson about the importance of effective implementation. Nevertheless, the plan provided the country with an initial boost for EVs and increased the overall state of awareness among the consumers.

The adoption of electric vehicles in India also showcases an interesting study. Initially, adopted in 2013, the National Electric Mobility Mission Plan (NEMMP) 2020 laid down the vision and roadmap for EV penetration in India. The NEMPP outlined incentives and focused on four priority areas for EVs, namely – demand incentives, manufacturing of EVs, charging infrastructure development, and research and development. The original plan was supposed to be that the government of India would support the infrastructure development in the initial stages, during which pilot projects could be rolled out in cities. Later on, this would be taken up by private sector participation. Even with considerable planning and strategy deployment, the NEMMP ultimately failed to achieve the EV penetration targets. The failure of the program presented an important lesson – that without effective implementation, even the best of plans would result in failure. Nevertheless, the actions taken under the NEMMP provided the country with an initial boost for EVs and also increased the overall state of awareness among the consumers.

The FAME (Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles) scheme was launched in 2015 as a flagship scheme under NEMMP 2020 Mission Plan.

FAME-I was in effect from April 2015 to March 2019, with a total outlay of Rs. 895 crore. The funds allocated were utilized to provide direct subsidy to customers, grants for pilot projects, research and development (R&D). Public charging infrastructure components were also sanctioned under the scheme. A total of 465 buses were sanctioned under the scheme as well.

Outcomes of FAME-I scheme:

- Throughout the entire running of the FAME-I scheme, it was only able to utilize 41 per cent of the sanctioned funds, and in total, about 2.8 lakh vehicles were sold.

- Although the scheme failed to utilize sanctioned funds, it succeeded in providing a stepping stone for the uptake of EVs in India, as well as increasing the awareness and generating momentum for the EV market.

FAME-II was notified by the MoHI&PE in March 2019. It has now been extended up to March 2024. The scheme has a total outlay of Rs 10,000 crore, which includes the unutilized funds from FAME-I. The scheme is implemented and monitored by the Ministry of Heavy Industries and Public Enterprises. The budget will be spent on –

FAME-I failed to utilize the sanctioned funds but provided a steppingstone for the uptake of EVs by creating awareness.

- Demand incentives for purchase of EVs (including buses)
- Establishment of public charging networks
- Administration and publicity
- Committed expenditure of FAME-I

Following are highlights of FAME-II:

- **Focus on demand incentives:** As much as 86 per cent of the scheme outlay i.e., Rs 8,600 crore is reserved for demand incentives alone, (Rs 3,500 crore is to be spent on electric buses).
- **High incentives on buses:** The incentive per electric bus is up to Rs 50 lakh, at a rate of Rs 20,000 per kWh, while a cap of 40 per cent on the vehicle cost is listed. The plan is to support up to 7,000 electric buses. Disbursement for the incentive is through STU and public sector transport companies.
- For other segments (2W, 3W, and 4W), disbursement for the incentives is directly to OEMs.
- The scheme plans on supporting the sales of around 1.56 million vehicles, which includes 1 million 2W, half-million 3W and around 55,000 4W vehicles.
- The subsidies under the scheme are limited to EVs using advanced Li-battery and newer technologies only.

After a low response to FAME-I, the FAME-II policy focused heavily on demand incentives allocating 86 per cent of the scheme outlay for them alone.

Energy Efficiency Services Limited (EESL) is acting as the demand aggregator for the deployment of electric vehicles in government ministries and departments. The aim is to replace a total of 500,000 vehicles, with the procurement process already completed for 10,000 EVs in the first stage. EVs are deployed on both lease as well as purchase models. EESL is also engaged in developing the EV charging network.

EESL will also act as a demand aggregator for e-Buses in Mumbai, Delhi, Bangalore, Hyderabad, Ahmedabad, Chennai, Kolkata, Surat, and Pune. The e-Buses would be deployed on an OPEX basis.

The EESL model of demand aggregation can be adopted for LNG HDVs:

- **Clear signal to manufacturers:** Demand creation and aggregation to give clear signals to manufacturers for consistent future demands to launch LNG HDV models.
- **Cost optimization:** This can be achieved through bulk procurement.
- **Optimizing utilization of LNG HDVs:** Any LNG HDV that remains underutilized could be leased out to another entity where it is needed. It also optimizes the utilization of LNG HDVs across the different end-user sectors.
- **Better financing terms:** With high order volumes, it is possible to obtain better financing terms.
- **LNG retail developments:** With clear signs of such demand, it would also promote development of LNG retail outlets, and private players could start coming into the fray.

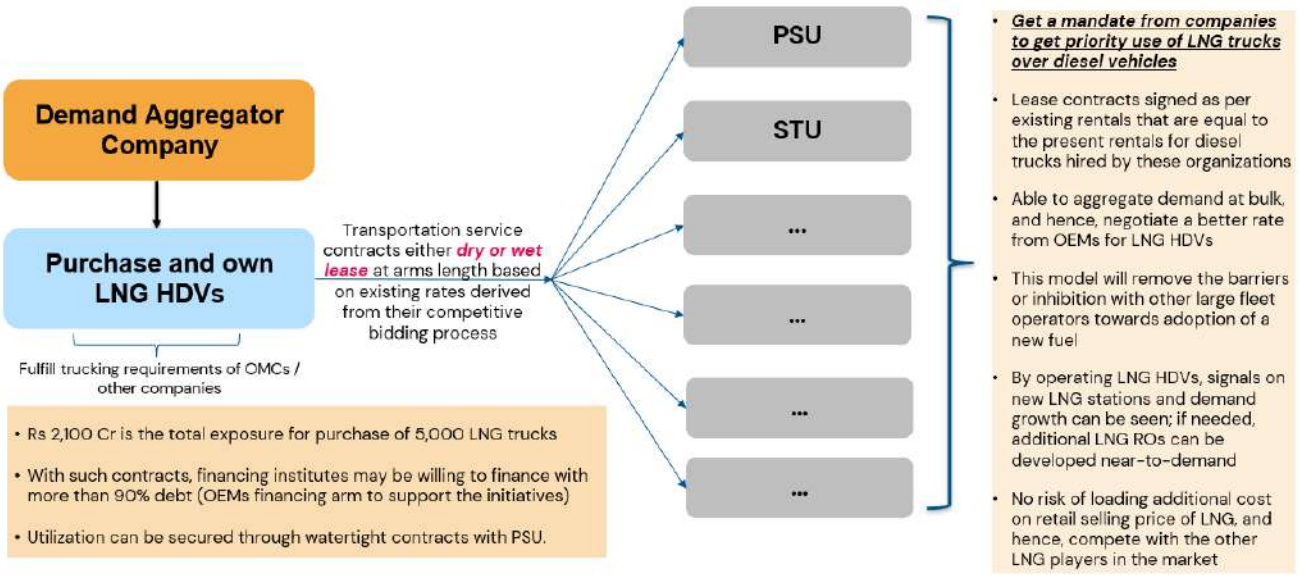


Figure 4-2: Adoption of LNG vehicles In India: Role that can be played by a demand aggregator

Along with prioritizing the use of LNG trucks over diesel vehicles, STUs can also initiate tenders to develop a captive RO station for their requirement by providing the requisite land and launching a separate tender for the sourcing of LNG.

From our review of electric vehicle policies and initiatives, we can come to the conclusion that the role of a demand aggregator is extremely important, and such a role in the case of LNG adoption would solve a lot of the key roadblocks that are currently present – both from incentivizing financing companies with higher order volumes, to ensuring clear signals for market development to reach to the private sector.

5 Review of Successful Models Adopted Globally

There are over 580,000 LNG HDVs globally, of which China accounts for almost 99 per cent. Europe has a fleet of 7,000-plus LNG HDVs, most of which are registered in Italy, Spain, the Netherlands, and Germany. Though the number of LNG HDVs in Europe cover a small percentage of the total LNG HDVs in use worldwide, the lessons to be learned from Europe's focus towards LNG adoption are extremely vital.

The role of coordinated policies, incentives and drivers among member countries and the European Union played a huge role towards the adoption of LNG as a fuel. Cross-country initiatives, such as Blue Corridor played their role in developing an ecosystem and spreading awareness for LNG vehicles. All the countries chosen for review may have had different fundamental drivers for adopting LNG as a fuel, but the general policy support, fiscal and non-fiscal incentives, and the role of private sector has remained consistent across all borders. As this report explores, rapid development of LNG infrastructure and fiscal incentives have proven to be crucial for the adoption of LNG in China and Europe as an alternative fuel for the HDV industry.

5.1. China

China is spearheading the usage of LNG in the transportation sector in the world. LNG, as a transportation fuel, has gone through a lengthy journey in China since the first research on LNG vehicles in 1961. Road transportation is the main contributor to the uptake of LNG as a transportation fuel in China. LNG for marine bunkering in China is still in its infancy. At present, China has a fleet of over 582,000 LNG heavy duty trucks, combined with 4,800 LNG stations, thus making it the world's largest market for LNG HDVs.

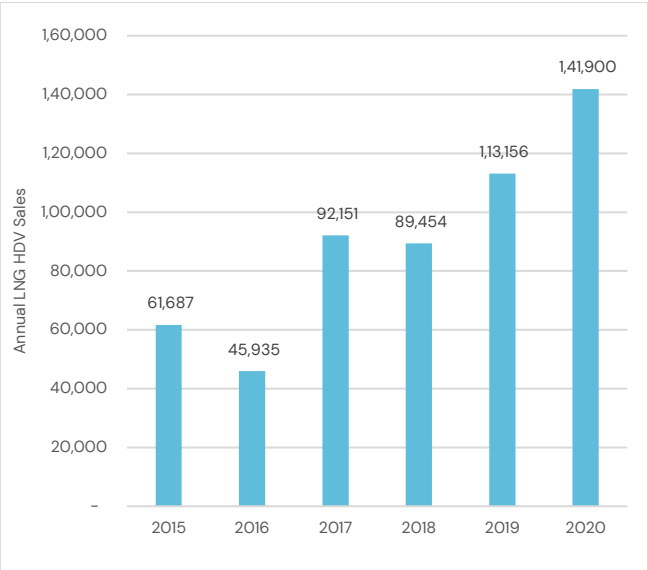


Figure 5-1: Annual LNG HDV Sales in China (2015-2020)

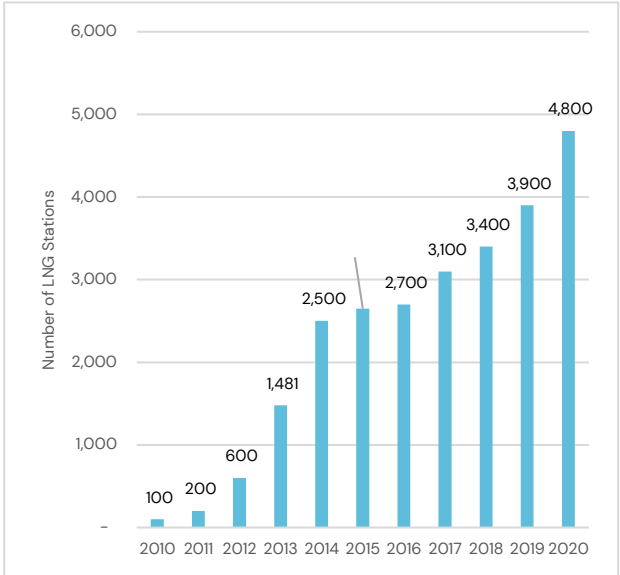


Figure 5-2: Growth of LNG Infrastructure in China (2010-2020)

5.1.1. Key drivers for adoption of cleaner fuel

One of the major drivers for adoption of LNG in China was due to concerns over worsening air pollution. While a significant thrust towards adoption of natural gas in the energy mix came up very recently, China started taking steps to tackle the deteriorating air pollution concerns rather seriously.

a. In 1973, with a focus on balancing economic development and environmental protection, China began to take action to tackle the deteriorating air pollution. This led to the formation of the National

Environmental Protection Agency in 1984, followed by the enactment of the Environment Protection Law in December 1989.

b. Until the period of the 11th Five-Year Plan (2006-10), the main measures to tackle air pollution were focused on the reduction of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions, and the results were successful. The new plan made environmental policy a core national strategy and offered solutions for harmonizing China's excessive economic growth, while simultaneously addressing the country's growth-inhibiting resource depletion and deteriorating environmental problems. Targets for achieving superior urban air quality in key cities, and reduction of SO_2 emissions by 10 per cent from the 2005 levels were adopted. During this period, the use of natural gas was initially promoted in the power generation sector to reduce SO_2 emissions, but this use shifted to the industrial sectors later due to the problem of price competitiveness of natural gas.

c. In 2008, LNG utilization in the transportation sector was recommended and accepted in the National High-Tech R&D Program of China (the 863 Program, 2008-2010) in the 11th Five-Year-Plan. This allowed LNG vehicles to enter the first fast development phase. The main gas producers and suppliers (i.e., the National Oil Companies (NOCs)) played an essential role to gather industry participants to push this through.

d. In 2010, the government published a comprehensive policy document on air pollution, which set out to meet the Grade II National Air Quality standard targets in key cities and regions by 2015. Local governments were pushed to introduce regional laws and regulations, as well as establish regional cooperation mechanisms. Major firms also had to attain national environmental standards. One important point of the new guidance was that NO_x and particulate matter (PM_{10}) were added to the objectives of air pollution measures, in addition to SO_2.

e. Following the excellent performance during the 11th Five-Year Plan, the 12th Five-Year Plan (2011-15) went further by setting targets for a 16 per cent reduction in energy consumption per unit of GDP, and an 8 per cent reduction in SO_2 emissions by 2015. It also set new binding targets for similar reductions of 10 per cent in NOx emissions.

f. Despite this strengthening of action to tackle air pollution in China, smog and other emissions in Beijing and major cities were still not improved. Then the $PM_{2.5}$ monitoring data published on Twitter by the US Embassy in Beijing, from around the autumn of 2011, increasingly caused an international stir. Due to such developments, China announced the inclusion of $PM_{2.5}$ in air pollution standards in 2011.

g. The results of these steps were still not satisfactory. Local governments were given a greater role and responsibility for implementation of the environmental measures.

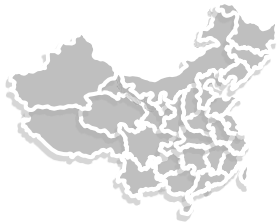
h. The year 2013 was a major year for China's environmental policy. The Air Pollution Prevention and Control Action Plan (2013–17) (Action Plan 2013), set more concrete numerical targets for air pollution, and also laid out more robust policies to achieve them. Natural gas was positioned as an important solution for environmental protection, and the plan laid out strategies in accordance with the 12th Five-Year Plan, including the development of infrastructure, such as pipelines, LNG receiving terminals, and city gas supply systems.

i. In 2018, China launched the three-year action plan for cleaner air, also called Blue Sky War. It is a comprehensive strategy to improve air quality through actions across all key sectors. The key objective of the action plan is to reduce emissions of major air pollutants and greenhouse gases, and reduce the number of days with high air pollution. The action plan includes targets such as 15 per cent reduction in SO_2 and NO_x emissions, and 18 per cent reduction of $PM_{2.5}$ by 2020, compared to the 2015 levels.

j. To achieve the targets, an ambitious plan has been set, including adjustment of industrial structures, transformation of energy system towards a cleaner, more efficient energy system, efficiency improvements across all end-use sectors, and development of a green transportation system.

5.1.2. Key policy initiatives and drivers for adoption of LNG as a transportation fuel

A strong consideration towards bringing down the local air pollution levels by reducing the concentration of PM_{10} and $PM_{2.5}$, and further buoyed by the cost competitiveness of LNGs over diesel, has contributed to the rise in the number of HDVs run on LNG in China. The price differential fluctuates, as the domestic LNG price reacts to supply and demand balance, while China's regulated diesel price is indexed to a basket of international crude oil prices, which leads to either incentives or hesitation for the adoption of LNG trucks. The period 2014-17 experienced the most extraordinary price cycle. LNG vehicles sales also rose dramatically during this period on the back of fast development and expansion of the refueling station network during 2012-14, along with good price competitiveness over diesel. At the end of 2014, the cost competitiveness was hit hard due to a remarkable oil price drop, along with the rise of domestic LNG price, due to higher feed-in pipeline gas price during 2013-15. The sales of LNG HDVs dropped considerably in two consecutive years – in 2015 and 2016.



Estimated LNG Heavy Duty Trucks: **582,000**

LNG Stations: **4,800**

Although LNG HDVs sell at a higher price compared to diesels, fuel cost savings can pay back this difference within a relatively short period of time. The typical payback period to incentivize LNG HDV purchasing is 1.5 years, given that the average life cycle of an HDV in China is 4-5 years. When oil prices are high, truck owners can be tempted to make the switch, such as during 2017-19, when the Brent crude oil price averaged $65/bbl, resulting in a period of robust sales.

Key Policy Initiatives and Trends for Adoption of LNG in China	
More than 20 million HDVs that did not meet China III standards were phased out, supported by a subsidy (¥ 25,000 subsidy in Beijing)	Monetary incentives to scrap old vehicles and replace with new one (up to 10% of cost of new vehicle)
Provincial subsidies on LNG HDVs up to 15% of vehicle cost	Government ordered ban on diesel HDVs in Beijing-Tianjin Hebei in 2017 for curbing pollution, and promoted LNG with no excise tax
13th Five-Year-Plan set a target for 10 million NGVs and 12,000 LNG stations	Strong fuel price advantage in conjunction with subsidies and anti-pollution measures drove demand for LNG HDVs

5.2. European Union

European Union is a unique case for adoption of LNG in heavy duty vehicles. LNG vehicles could be seen in Europe as early as 2013. Between 2011 and 2014, countries spent € 117.2M in total (up to 50 per cent EU contribution) across various projects to kickstart the utilization of LNG in the HDV segment.

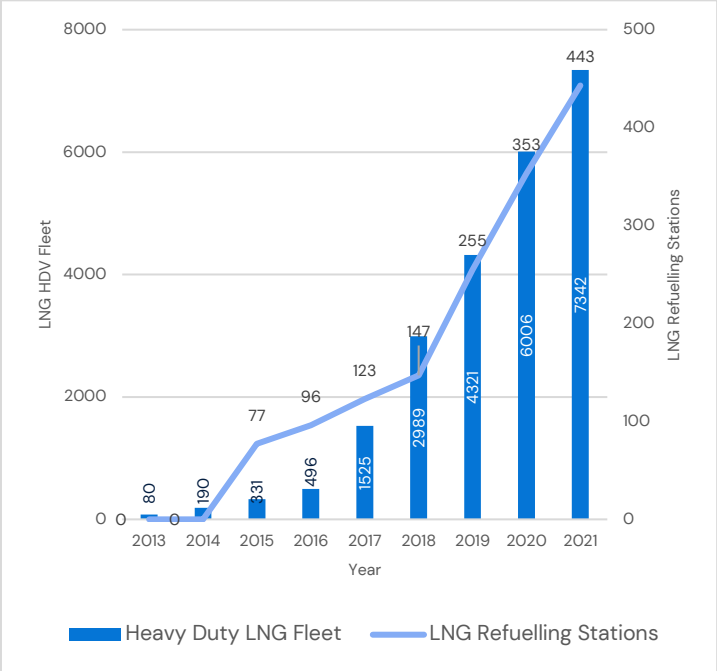


Figure 5-3: Year-wise LNG HDV Fleet and LNG Refueling Stations in Europe

Various initiatives, such as the Blue Corridor (2014-18) and LNG Motion (2016-20), helped in infrastructure development, market harmonization, standardization, and outreach. Some of key policies and initiatives that proved to be game changing for LNG in heavy duty are detailed below:

1) **Directive on Alternative Fuel Infrastructure (DAFI), 2014**

a. It mandates member states to develop national policy frameworks for market development of alternative fuel and infrastructure, and the setting up of consumer information on alternative fuels, including price comparison methodology.

b. It also includes directives for setting up LNG retail outlet at least every 400 km on the Trans-European Transport (TEN-T) network corridors by 2025.

c. It includes mandate for setting up LNG refueling infrastructure for maritime vessels and inland waterways.

2) **LNG Blue Corridor, 2014-18**

a. Under this initiative, €14.3M funding was provided for the procurement of 140 LNG HDVs and development of 12 LNG retail outlets along four highway corridors identified across Europe.

b. Collaborations with 22 partners (including vehicle manufacturers and energy companies), and 30 fleet operators were facilitated as well.

c. It helped in standardization, marked development, business case demonstration, and outreach.

d. Within the time period, a total of 31.5 million km was covered by LNG-run vehicles, with an average of 50,000 km per truck per year.

Estimated LNG Heavy Duty Trucks: **7,342**

LNG Stations: **443**

3) **LNG Motion, 2016-20**

a. Under this initiative, €55.6M funding (50 per cent EU support) was provided for procurement of 200 LNG HDVs and 42 LNG retail outlets along TEN-T corridors by 2020.

b. Partners, such as AS24, Primagaz France, Charles André Group (GCA), and PitPoint LNG developed the initiative of LNG Motion project.

c. The initiative included objectives to study commercial, operational, and environmental aspects of LNG use in trucks by conducting real-life trials that undertook feasibility study on Bio-LNG.
d. Countries involved in the initiative were France, Belgium, the Netherlands, Germany, Poland, Spain, Italy, Hungary, and Romania.

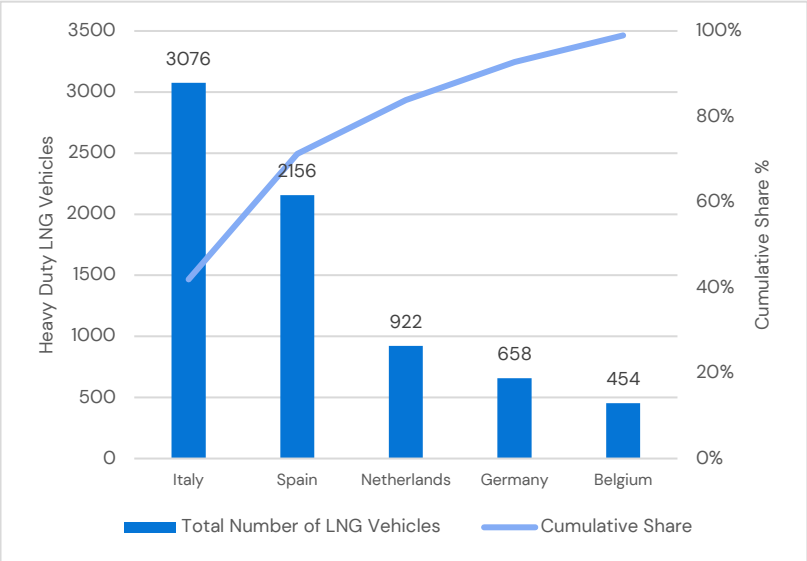


Fig 5-4: Top 5 countries in Europe based on LNG HDVs and cumulative share

4) **Other EU Policies Zero & Low Emission Vehicles (ZLEV), 2019**

a. Stricter emission standards were released for heavy duty vehicles, with a target of achieving 15 per cent reduction in emissions during 2025-29 compared to 2019-20.
b. Binding quotas were introduced to improve the adoption of cleaner Zero and low emission vehicles (ZLEV) by public authorities, including HDVs.
c. Manufacturers were encouraged to produce more ZLEVs, as they would be counted as more than one vehicle in the calculation of the average CO_2 emissions, which would lower their average emissions.

From the chart, we find that 93 per cent of the total heavy duty LNG fleet operating in Europe are registered in four countries – Italy, Spain, Germany, and the Netherlands. Hence, to understand the key enablers for adoption of LNG as fuel, we will restrict our study and attention to these four countries.

5.3. Italy

Italy presents a success story in adoption of natural gas vehicles in Europe. At present, Italy has over 3,076 LNG-powered heavy duty trucks, and 103 LNG refueling stations. Italy having the largest fleet of LNG trucks in Europe, offers valuable insight in its study.

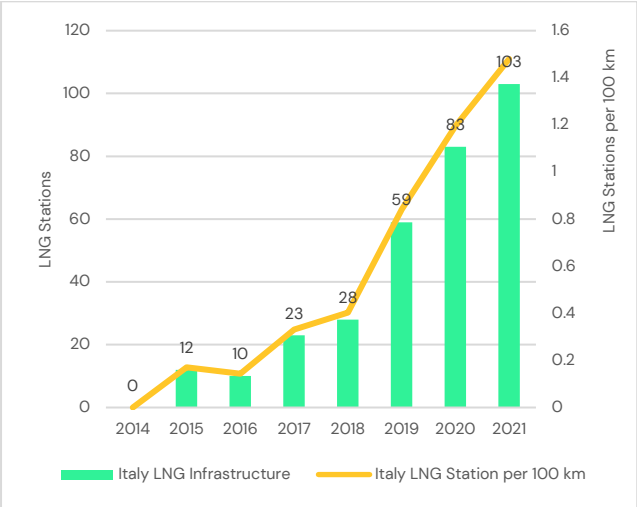


Figure 5-5: Year-wise LNG Infrastructure and LNG Station per 100 km in Italy

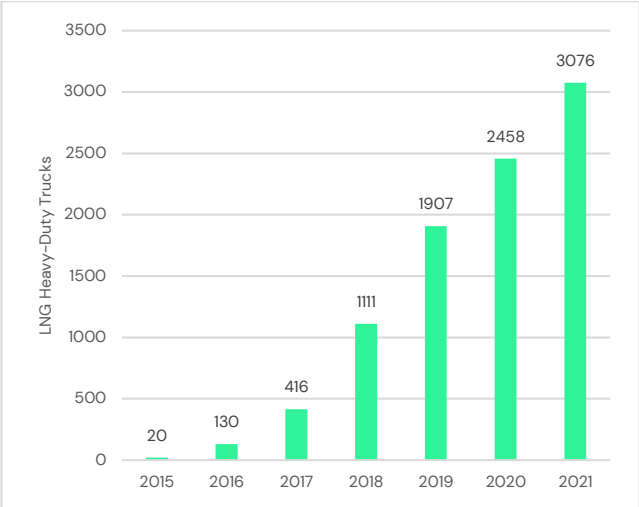


Figure 5-6: Year-wise LNG Heavy Duty Trucks in Italy

5.3.1. Key policy initiatives and drivers for adoption of LNG as a transportation fuel

The use of natural gas as fuel and its expansion in Italy began a long time back. The huge role of private companies and existing natural gas infrastructure makes the case study for Italy unique.

a) **Use of natural gas as motor fuel started in Italy around the 1970s**, when cars were retrofitted for CNG-use because of the global oil crisis. Retrofitting continued in the 1990s as well. The government incentive programs (such as low taxation on CNG conversions) continued the gradual growth of natural gas vehicles (NGVs) in Italy during those years.

b) **Worries about air pollution** pushed the government to favor NGVs, and between 2008 and 2010, the government ran a subsidy program that supported both the conversions of existing cars for CNG use, as well as the purchase of new NGVs, which led to 68 per cent growth in NGVs.

c) **Low CNG prices than gasoline and diesel:** Italy imports most of the natural gas from Russia and Algeria, CNG prices are still significantly lower than gasoline and diesel prices.

d) A key role for the popularity of NGVs in Italy was played by the national gas transmission company, SNAM. As part of its sustainability program, the company has been extremely active in advocating the use of NGVs by promoting the construction of refueling facilities and raising awareness through dissemination of information. It is also clearly of benefit to increase the network sales and utilization.

e) **Snam4Mobility, a subsidiary, was established in 2017 to promote natural gas for transport distribution network through direct investments.** It also aims to expand the refueling network to enhance coverage in regions that are presently less adequately served. SNAM4Mobility has signed partnership agreements with the fuel retailing arms of ENI and API60 to develop and operate new CNG and LNG stations over a 20-year period. Snam4Mobility is also developing 110 LNG & CNG

refueling stations, at a total cost of €56 million, of which €25 million is financed by the European Investment Bank (EIB).

A significant role in the promotion of NGVs in Italy was played by the national gas transmission company of Italy. The company promoted NGVs through direct investments to expand the refueling network, liquefaction infrastructure and much more.

f) SNAM has also helped in establishing NGV System Italia (NGV Italy) to organize and promote actions to develop a viable, long-term NGV sector. The group was responsible for ensuring that standards and regulations were in place for vehicles and refueling systems.

g) **SNAM and Baker Hughes are also building a micro-liquefaction infrastructure to serve the NGV and marine sector.** They plan to invest €50 million to €80 million for up to four plants having a total production of 140,000 tons of LNG and bio-LNG.

h) SNAM is also looking to invest €150 million during 2020-24 to expand the CNG and LNG distribution infrastructure, and build micro-liquefaction plants with capacity of 150 KTPA.

i) **The role of government has also been crucial in developing the sector,** not least to help counter the purchase premium. The government opted to promote CNG cars in the early 2000s as an alternative to petrol for both environmental and fuel security reasons.

Estimated LNG Heavy Duty Trucks: **3,076**
LNG Stations: **103**

LNG Specific Incentives in Italy	
2017-18: €10.5 million allocated for subsidy towards purchase of new vehicles with GVW of 7 MT or greater, with subsidy amount up to €20,000	**2019-20:** Subsidy of €20,000 for LNG vehicles with GVW of 16 MT or more
On average, diesel trucks costs about €40,000 lesser than LNG trucks, which is offset by combination of subsidy and lower price of LNG	In Italy, the price of natural gas at the pump is about half the price of diesel
Obligation for public bodies during replacement of fleets to purchase at least 25% of vehicles powered by CNG, LNG or electric motors (2016)	Directive to increase LNG retail outlets from current value to around 800 in 2030.

5.4. Spain

In terms of adoption of LNG as a transportation fuel, Spain comes next after Italy in terms of the current fleet of LNG Trucks. Spain has a fleet of 2,156 heavy duty LNG trucks and 76 LNG refuelling stations.

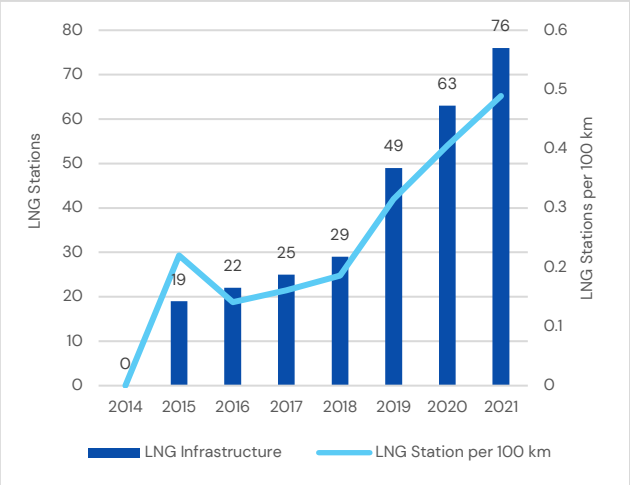


Figure 5-7: Year-wise LNG Infrastructure and LNG Station per 100 km in Spain

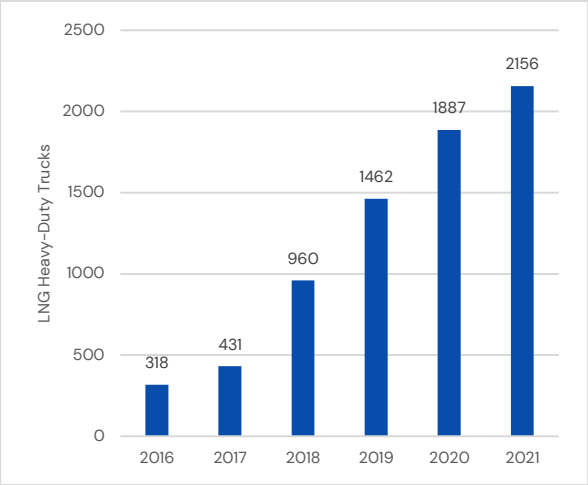


Figure 5-8: Year-wise LNG Heavy Duty Trucks in Spain

5.4.1. Key drivers for adoption of LNG as a transportation fuel

In certain aspects, Spain presents a situation which can be seen as the closest to the situation in India. The motivation for Spain to adopt natural gas came from the urge to reduce its import bill. Along with this, Spain, which has the largest number of LNG plants, makes for an interesting study.

a) The first European LNG plant was commissioned in Le Havre in 1965, shortly followed by a terminal in Barcelona, Spain (where, in 1969, an LNG unloading, storage and regasification operation took place for the first time). This was the starting point to of a new natural gas supply to Europe, allowing a country far away from significant production regions to access this energy, and later, allowing Europe to diversify its supply routes and sources.

b) Spain is the country with the highest number of LNG plants, accounting for seven terminals.

c) **Transport is the highest energy-consuming sector in Spain**. Road transport accounts for around 80 per cent of transport energy demand and is dominated by oil products (80 per cent), the majority of which is imported (over 96 per cent). This explains the high energy import dependency in Spain, as it is among the eight most energy import dependent countries in the EU.

Transport sector is the highest energy-consuming sector in Spain, and it is dominated by oil products, most of which is imported. Reduction of this import dependency is a key driver for Spain for adoption of alternative fuels.

d) To alleviate these effects, the transport sector is a strategic target for many energy and environmental policies, with special attention dedicated to private cars, buses, and trucks, which account for the greatest share of road transport consumption.

e) **The use of alternative fuels in transport is one instrument with which to offset the negative impact of transport** and contribute to Spain's energy and environmental policies. It also presents a business opportunity for the Spanish automotive industry, where Spain already occupies a leading position in the EU market as the second largest manufacturer of light vehicles, and the first in industrial vehicles in the EU market.

f) Since the publication of the Directive on Alternative Fuel Infrastructure (DAFI), Spain approved the Strategy for Boosting Alternative Energy Vehicles (VEA) in 2015. A further step involved the approvals

by Royal Decree 639/2016 on the alternative fuels infrastructure and of the National Action Framework for the development of the market, and the infrastructures for alternative fuels in the transport sector, Marco de Acción Nacional (MAN), through which this directive is transposed. The MAN involves a wide package of measures to guarantee compliance with the objectives assumed in the DAFI context, which at present, in Spain are aimed at road and sea transport. In general, the measures are structured around three priority axes: market, infrastructure, and industrialization. These are linked through a fourth axis – a stable regulatory framework – which provides continuity to the actions undertaken, allowing guarantees to be offered to the market and the investors. Most measures are aimed at the transport sector. Hence, following the publication of DAFI, Spain has taken active concrete steps to incorporate strategies and approvals for expansion of alternative fuel infrastructure, especially focusing on road and sea transport.

g) With regards to the obligation of installing 44 LNG refueling stations by 2025 under NPF, **Spain has already achieved beyond its NPF target by installing 76 LNG stations.**

h) **Concerning sea transport, Spain is in an optimum position for developing the new LNG market**, due to its geostrategic situation as a logistic platform of Southern Europe, and its existing infrastructures and its experience acquired regarding LNG storage and transfer. In addition, Spain has the longest coastline (4,964 km) in the EU, which has enabled it to develop an integrated state port system of 43 operative ports of general interest, 13 of which form part of the TEN-T core network.

i) Private sector investment for developing natural gas infrastructure has also brought the much-required momentum for natural gas vehicles in Spain.

Private sector investment for developing natural gas infrastructure has brought the much-required momentum for NGVs in Spain. The country presents an example of how transport companies, logistic providers, and trucks makers can work together to lead the shift towards a sustainable transport system

j) Gas Natural Fenosa (Naturgy) is one such example. Through the BESTWay Project, the multinational power company worked on building Paris/Algeciras gas refueling corridor to support the widespread roll-out of natural gas as an alternative fuel. The BESTWay Project was launched to identify, implement, and validate novel solutions for LNG/CNG refueling all along the France-Spain Atlantic corridor. The project consisted of nine refueling stations between northern France and southern Spain to link with other sustainable mobility corridors in Europe. This project was financed (50 per cent) by the European Union through its Connecting Europe Facility (CEF), which represents significant backing from the European authorities.

k) To support the expansion of natural gas vehicles, Gas Natural Fenosa led two projects: the BESTWay Project; and the ECO GATE Project to build more than 20 gas refueling stations along the Atlantic and Mediterranean corridors of the road networks in Spain, France, Germany, and Portugal.

l) Other private players such as HAVI & Scania also responded to consumer demands for sustainable transports. HAVI joined forces with Scania to roll out a five-year roadmap towards significantly reducing the carbon footprint and overall environmental impact of McDonald's supply chain.

m) In Spain, these two businesses also pushed the boundaries further by accelerating the deployment of alternative fuel delivery vehicles. The partnership is an example of how transport

Estimated Heavy Duty LNG Trucks: **2,156**

LNG Stations: **76**

companies, logistic provider, and trucks manufacturers can work together to lead the shift towards a sustainable transport system.

5.4.2. Key policy initiatives for adoption of LNG as a transportation fuel

Along with the motivation to reduce high import and bill, and the existing natural gas infrastructure in Spain, incentives, such as the MOVEA (The Plan to Boost Mobility with Alternative Energy Vehicles) and MOVALT (Development of Recharging Infrastructure for Alternative Vehicles Spain), which financed all types of natural gas vehicles with an allocation of more than €11 million have also played a role in building an ecosystem for LNG. The funds were allocated to the direct acquisition, leasing, or renting of new vehicles. The amounts ranged from €200-20,000 depending on the vehicle size.

Other initiatives, such as the "ECO" label were also utilized for natural gas transition. Under the "ECO" label scheme:

- Vehicles with CNG/LNG as fuel qualify for the ECO label are allowed to be used on high-pollution days in major cities to benefit from lower car taxes.
- In Barcelona, a discount is offered to NGVs that park in the city's central blue zone.

Key Policy Initiatives and Drivers for Adoption of LNG in Spain	
High fuel import bill for transportation sector is a key driver for LNG adoption	Longest Coastline in EU (4,964 km), with over 43 ports, aimed at use of LNG in sea transport
Vehicles with CNG/LNG as fuel qualify for the ECO label and are allowed to be used on high-pollution days in major cities to benefit from lower car taxes	**2018:** the MOVEA and MOVALT plans financed all types of natural gas vehicles with an allocation of more than €11 million. (Amount ranging from €200-20,000 depending on the vehicle size)
Participation of transport companies, logistic providers, and truck manufacturers working together to lead the adoption of LNG	In Barcelona, a discount is offered to NGVs that park in the city's central blue zone

5.5. Netherlands

The Netherlands, in line with the European Union, had set a GHG reduction target. The Dutch government wanted to reduce GHG emissions by 20 per cent until 2020, and 80 per cent until 2050, compared to the 1990 levels. A second country-specific driver was noise reduction from road transport in cities.

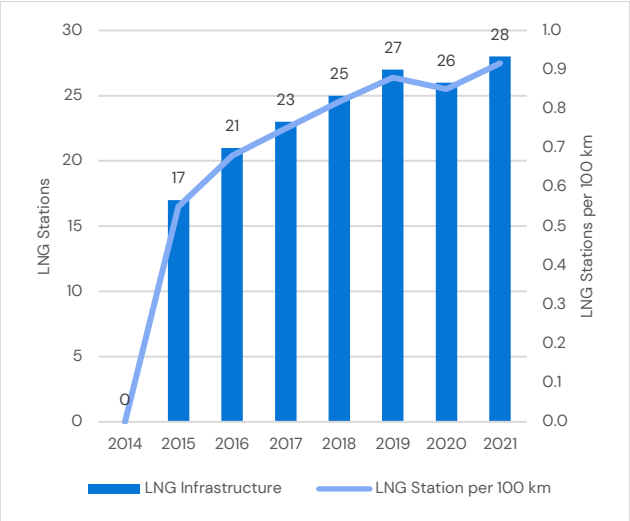


Figure 5-9: Year-wise LNG Infrastructure and LNG Station per 100 km in Netherlands

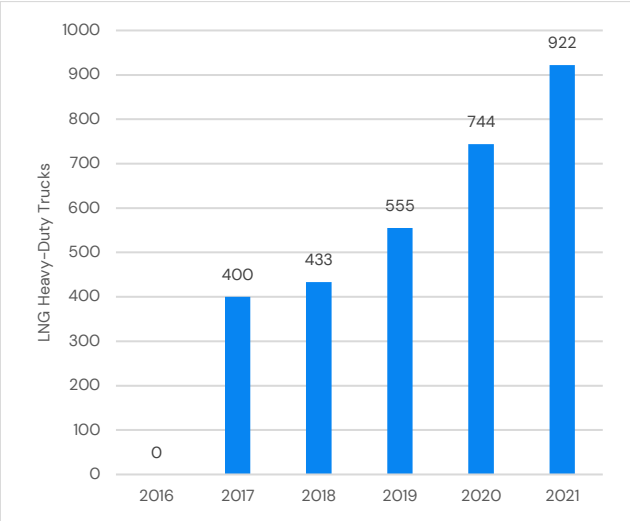


Figure 5-10: Year-wise LNG Heavy Duty Trucks in Netherlands

5.5.1. Key policy initiatives and drivers for adoption of LNG as a transportation fuel

The Netherlands was one of the first countries in the European Union to initiate policies and take steps towards adoption of LNG as a fuel as early as 2012, known as, "Rhine and Wadden" Green Deal. The plan commenced by focusing on two areas: the Wadden Sea-North Sea, and the Rhine region close to the Netherlands. Such early steps and unique priorities in the Netherlands present a study which can be emulated in advanced cities in India.

a) **The Green Deal, 'LNG Rhine and Wadden'** was agreed in 2012 to promote LNG in all (heavy) transport segments, including road, inland waterway, and coastal shipping. The goal was to substitute crude oil-derived fuels with 2.5 million tons of LNG by 2025 (a fleet of 40,000 LNG-fueled trucks). The target set at the time seemed ambitious, and hence, in 2019, the government modified it to target more diverse alternative fuel fleet, such as electric and hydrogen HCVs. The 2030 targets for these are higher as compared to that for LNG. In 2019, the government also revised its 2025 target to 2,925 due to slow uptake in LNG HDVs. Another early initiative taken up by the Dutch government was the creation of a "National LNG Platform," with the intention of connecting companies and government authorities who are committed to the introduction of liquefied natural gas as an alternative fuel in the Netherlands. The objective was to ensure that by 2015, at least 50 inland navigation vessels, 50 seagoing vessels and 500 trucks will be powered by LNG.

To further promote alternative fuel vehicles, the Netherlands has also had its municipalities create low emission zones, also called environmental zones. Vehicles running on fuels other than diesel are allowed in all low-emission zones.

b) **The National LNG Platform was founded to focus specifically on LNG.** It projected a population of 50 LNG-fueled trucks by 2015. It called for a working program that was implemented by a three-

pillar structure for LNG as a transport fuel, including safety/permitting, financial-economic, and stakeholder dialogue. Although the target of setting up 50 LNG fueled trucks could not be achieved at that time, the platform continues to serve as a place where members can facilitate discussions as well as share knowledge among themselves.

c) **To further promote alternative fuel vehicles, the Netherlands has also had its municipalities create low emission zones, which are also called environmental zones (milieu zones).** Fifteen Dutch municipalities have low-emission zones. The low-emission zone rules usually only apply to trucks and coaches, and sometimes also to diesel-powered passenger cars and vans. Road signs show which vehicles are prohibited in the low-emission zones. Vehicles using a fuel other than diesel are allowed in all low-emission zones. For passenger cars and vans, the diesel vehicle's emissions standard is used to determine whether it will be allowed to drive in a yellow, green, or purple low-emission zone. From January 1, 2022 there is only purple zone for diesel-powered trucks and coaches. Only diesel trucks and coaches with emissions standard 6 are allowed to drive into the purple zones.

Estimated Heavy Duty LNG Trucks: **922**

LNG Stations: **28**

LNG Specific Incentives in Netherlands	
Reduced excise duty on LNG: Partial tax refund and €125 tax reduction for every 1,000 kg of LNG (2014-18).	Reduced tax on LNG: Between January 1, 2020, and December 31, 2021, trucks refueled with LNG had a tax incentive of €18.7 per kg.
Local truck purchase subsidies on LNG trucks; maximum subsidy of €10,000 per truck in the province of Overijsel (2014)	Trucks not complying to Euro IV or above are not allowed to enter Milieu zones
PIEK Program to foster low-noise emission distribution of goods. Under the PIEK regulation, LNG trucks are allowed for inner city goods distribution in early morning hours. Lower noise emissions of LNG trucks brought competitive advantage for LNG fleet operators in delivery business	Stimulering Duurzame Energieproductie (SDE+): Competitive auctions to award operational subsidies to renewable energy projects. From 2011-2020, SDE+ allocated €60 billion of subsidies, to be paid over 15 years, based on renewable energy generated. The program was launched to promote carbon capture and storage (CCS) and bio-LNG.

5.6. Germany

The growth of LNG HDV fleet in Germany only happened recently. At present, Germany has a fleet of 658 LNG HDV trucks and 74 LNG refueling stations.

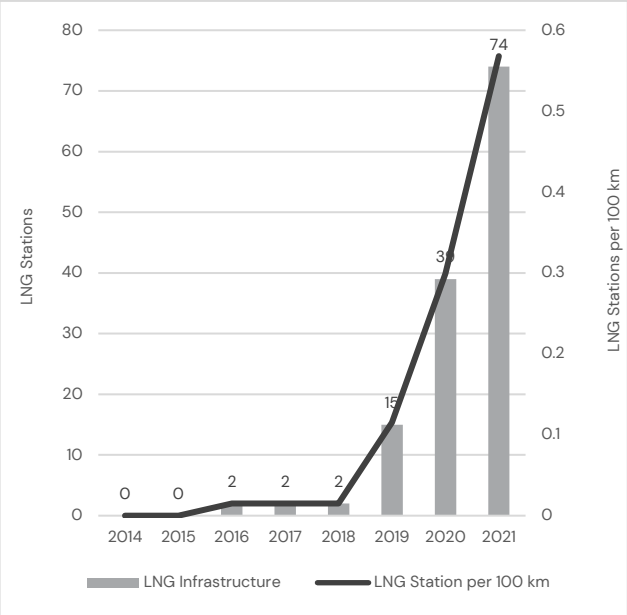


Figure 5-11: Year-wise LNG Infrastructure and LNG Station per 100 km in Germany

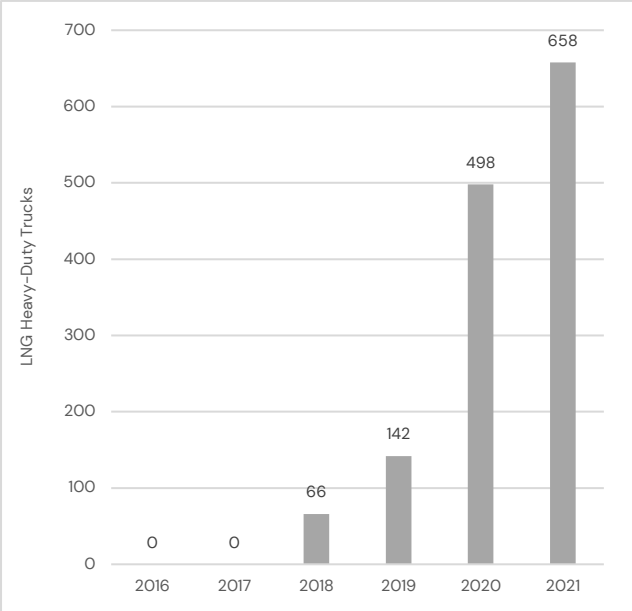


Figure 5-12: Year-wise LNG Heavy Duty Trucks in Germany

5.6.1. Key policy initiatives and drivers for adoption of LNG as a transportation fuel

In Germany, the LNG Infrastructure and truck sales started expanding only recently. It is observed that multiple key initiatives working together led to this expansion. Understanding these helps us to gain an idea into the importance of certain initiatives, such as exemption of road toll for this sector.

One of the key initiatives that came alongside the expansion in adoption of LNG was the road toll exemption. It was originally, launched in 2019 for a period of two years, but recently extended to 2023.

a) In the case of Germany, it was observed that one initiative kickstarted the adoption of LNG in HDV. **The government had amended federal highway toll law to exempt lorries powered by natural gas from tolls from January 1, 2019 for a period of two years**. The change was designed to help address the country's growing CO_2 emissions from the transport sector, and at the same time provide a stimulus for the natural gas vehicle sector. Subsequently, many private sector investments started coming in for setting up LNG refueling stations across Germany. This was observed by the steep rise in number of LNG refueling stations between 2018 and 2021, from two to 74 stations.

b) The installation of the LNG Infrastructure was followed by a rise in LNG HDV fleet, from a mere 66 in 2018 to 658 in 2021.

c) The estimated savings due to road toll exemption are up to €20,000 over five years, which amounts to around 15 per cent of the cost of an LNG HDV (taking the cost of an HPDI LNG model at €135,000). **With visible growth in the NGV sector, the government decided to extend the road toll exemption up to 2023.**

d) LNG trucks in Germany are promoted through various instruments. **In addition to the toll exemption, there is also the directive on the promotion of energy-efficient and/or low CO_2 heavy goods vehicles in road haulage companies, which was in force until the end of 2020, and supported the purchase of LNG trucks with a €12,000 subsidy.** Second, there is the energy tax relief for natural gas as fuel in motor vehicles, which is valid until 2026. The energy tax rate, however, will be successively increased until 2026. Nevertheless, due to the current tax relief, the subsidy currently amounts to around €34,000 for an HPDI-NG truck, and €42,000 for an SI-NG truck over a five-year period.

e) One of the key private initiatives was taken up by Shell in Germany. Shell unveiled its plans for a network of 40 LNG refueling stations by the end of 2022. It has already opened five such LNG stations, and work on the other stations has also begun. Shell is also planning to build a complete supply chain for CO_2 neutral LNG based on liquid bio-methane, along with a 100,000 tons gas liquefaction plant in the Rhineland refinery.

Along with the road toll exemption, private investment in the sector also started expanding. Organizations, such as Shell and KP Logistik unveiled plans to enhance the refueling network and expand their fleet as well.

f) In 2019, KP Logistik decided to expand its fleet by 100 vehicles powered by LNG. The decision was taken for availing financial incentives as well as to support the transition towards cleaner fuels. The company benefits from the exemption of road tolls and subsidies for gas-powered vehicles, which have been in force in Germany. Scania supplied the trucks. KP Logistik also worked closely with fuel supplier Liquind 24/7, which had plans to open two liquefied gas filling stations in Germany.

g) The presence of supporting regulations also helped the natural gas sector:

- **Regulation for reduction of CO_2 emissions** of the new vehicle fleet by 15 per cent by 2025, and by 30 per cent by 2030
- **Financial penalty on vehicle manufacturers if they fail to achieve the required CO_2 reduction** of the new vehicle fleet

h) As for LNG in maritime, in both maritime shipping and inland waterway transport, the focus is currently on the introduction of LNG as a marine fuel, and on upgrading the shore-side power supply with the aim of improving the air quality. The market rollout of LNG-powered vessels is about to begin. The 2015 National Ports Strategy, and the 2019 Inland Waterway Transport Masterplan form the strategic framework for the use of alternative fuels. In the reporting period, no stationary LNG bunkering stations were in use in the German inland waterway and the maritime sector. The supply is provided by trucks (truck to ship); and for the future, a supply by bunkering vessels (ship to ship) is foreseen. As far as the Federal Government knows, truck-to-ship bunkering has already been performed at the following seaports: Bremerhaven, Brunsbüttel, Cuxhaven, Emden, Hamburg, Lübeck, Rostock, Sassnitz (Rügen). The establishment of an LNG distribution network along the Rhine in Germany is currently being pushed forward by private companies.

Estimated Heavy Duty LNG Trucks: **658**

LNG Stations: **74**

Key Policy Initiatives and Drivers for Adoption of LNG in Germany	
The government exempted LNG-operated trucks from road toll in 2019 (up to 2023), triggering sales of LNG HDVs (Savings of up to €20,000 over five years)	LNG models with range of over 1,000 km being offered by IVECO, Scania, and Volvo.
Energy tax relief valid until 2026 (cost savings of up to €42,000 over five years for an SI-NG truck)	Subsidy of €12,000 for purchase of LNG HDV
Regulation for reduction of CO_2 emissions of the new vehicle fleet by 15% by 2025, and by 30% by 2030	Financial penalty on vehicle manufacturers if they fail to achieve the required CO_2 reduction of the new vehicle fleet

5.7. Conclusion and Learnings for India

Through a review of successful models globally, the importance and impact of government incentives and private initiative can be seen across the market. Though it is clear that in almost all countries observed, fiscal incentives were provided alongside non-fiscal incentives and initiative from private industry, we also observed that unique solutions in the form of non-fiscal incentives were important to facilitate the adoption and change the public perception for alternative fuel vehicles. Hence, it can be concluded that non-fiscal incentives especially played a key role in bringing the change in mindset for alternative fuel vehicles in the respective markets, and together with the government's push, including some fiscal incentive, they were successful in leading the adoption of LNG HDVs in certain geographies across the world. Some of the major non-fiscal incentives that presented unique solutions, which can be tweaked and presented in the Indian market are listed below:

- In China, the government ordered a ban on diesel HDVs in Beijing-Tianjin Hebei region for controlling the pollution levels, and promoted the use of LNG HDVs. This led to truck operators in the region shifting to alternative fuels such as LNG, to access the region, which proved to be a key enabler for the LNG HDV market. Such bans might be tough to uphold in India, as it could lead to protests by the people, whose income would be heavily affected by the ban. But minor versions of such bans could be emulated in India, where lower emission vehicles can be provided the right of way, or special lanes can be created to expedite the travel of alternative fuel vehicles.

- Spain brought in a unique solution to promote the transition to natural gas. Vehicles running on CNG/LNG as fuel were qualified for the "ECO" label. Vehicles with "ECO" labels were allowed to be used even on high-pollution days in major cities, and also benefited from lower car taxes. In Barcelona, a discount was also offered to natural gas vehicles that parked in the city's central blue zone. Beyond providing incentives to natural gas vehicles, such unique solutions also increase the visibility of alternative fuels for the average person and raises their awareness. It also helps in creating a sustainable centric mindset for the consumers in the market, as any transition towards alternative fuel has to face skepticism from the consumers. Such initiative for "ECO" labeling can be brought in alongside colored number plates, as a form of identification for alternative fuel vehicles, and minor incentives, such as free parking or preferential right of way can also be provided. This will also increase the visibility of alternative fuel vehicles in the market.

- Speaking of increasing awareness, the Dutch government came up with the "National LNG Platform" to connect companies and government authorities, which were committed to the introduction of LNG as an alternative. To further promote alternative fuel vehicles, the Netherlands also has had the municipality create low emission zones, which are also called as environmental zones (milieu zones). At present, there are 15 such municipalities with low-emission zones. There are also rules set in place to promote alternative fuel vehicles in these zones. All vehicles using fuel other than diesel are allowed access to the zones. Though these rules are mainly applied on trucks and coaches, in certain regions, lighter vehicles are also included. In such cases, the emission standard of vehicle is used as a determination factor. Such zones could be used in India to tackle region-specific pollution concerns. In highly polluted cities like Delhi, such zones can aid in the transition towards alternative fuels, as the public is also conscious of the heavy pollution.

- Another unique solution by the Dutch government was the PIEK program. It was brought in to foster low-noise emission distribution of goods. Under the regulation, trucks running on LNG were allowed to carry out inner city goods distribution, even in early morning hours, while this privilege was not granted to diesel vehicles, which have higher noise emission. Though this appears to be a region-specific concern, as noise pollution in India is not considered a major issue, it still provides us with an example on how to promote alternative fuel vehicles by tackling region-specific concerns.

- Italy brought in an obligation for public bodies that while replacing their fleet, at least 25 per cent of new vehicles purchased must be powered by CNG, LNG or electric motors. A similar quota for public bodies was also established by the European Union. Such obligations are not new, and India too needs to bring in such obligations for the promotion of LNG vehicles.

6 Assessing Environmental and Economic Benefits of Adopting LNG HDV in India

India has set ambitious targets for emission reduction in COP 26. India has targeted a reduction in the total projected carbon emissions by one billion tons till 2030. It has also vowed to reduce the carbon intensity of its economy by 45 per cent by 2030. And it has set the target for net zero by 2070. To achieve such ambitious goals, a coordinated approach in a variety of sectors is required. The Indian transport sector is responsible for around 13.5[15] per cent of India's energy-related CO_2 emissions, with road transport accounting for around 90 per cent of the sector's total energy consumption. Thus, reduction of emissions in road transportation sector is essential to achieve the goals set in COP 26. The heavy-duty sector is responsible for a major chunk of the emissions under the road transportation sector. Hence, targeting the heavy-duty sector would lead India one step closer to achieving its 2030 target of one billion tons in carbon emission reductions. At present, LNG provides the best option for this sector due to its compatibility with long-range travel. Even with ambitious targets that have been set for emission reduction, it is essential that for any significant adoption to take place, LNG also proves to be economical to the consumers. In the subsequent sections, we explore the environmental and economic benefits of adopting LNG in the heavy-duty sector.

The Indian transport sector is responsible for around 13 per cent of India's energy-related CO_2 emissions, with road transport accounting for around 90 per cent of the sector's total energy consumption.

6.1. Environmental benefits of LNG HDV adoption

Through secondary research, we were able to determine that LNG has 24 per cent lower Emission Factor (gCO_2/kg-fuel) than diesel, but the difference in engine efficiency plays an important role in determining per km emissions. Studies performed on Euro VI LNG & diesel HDVs report tailpipe CO_2 emission reduction in the range of 2.7-10.9 per cent.

Even with lower emissions reported for LNG vehicles, it should be noted that lower fuel efficiency can erode the emission improvements drastically. Studies in Europe have showed that improvement is possible, and if the efficiency of natural gas engines is sufficient, then significant improvement can be observed in tailpipe emissions as well.

Fuel efficiency plays an important role in emission calculations, and therefore, adequate designing of engines is needed to ensure emissions reductions.

Another factor of consideration for LNG is the well-to-tank emissions, which is discussed in detail in the subsequent sections. Available data from European studies suggests around 20 per cent additional well-to-tank emissions in case of LNG HDVs, and these are dependent on the source of the LNG as well as its composition.

The following table shows the comparison of emissions between diesel and natural gas (LNG and CNG) operated vehicles –

[15] https://climateactiontracker.org/documents/832/CAT_2020-12-09_Report_DecarbonisingIndianTransportSector_Dec2020.pdf

Table 6-1: Various emissions comparison between diesel and LNG/CNG vehicles

Emissions	Units	Diesel	LNG/CNG
CO_2	g/km	770 – 1,302	655 – 1,250
CO	mg/km	862 – 1,200	650
THC	mg/km	5 – 25	70 – 220
NO_x	mg/km	519 – 712	273 – 618
NO_x	mg/kwh	400 – 2,000	40 – 600
PM (TE study)	mg/kwh	12.5	10
PM (for buses)	mg/km	391.46	31.07

As we will see in the following section, the gas engine technology used has a significant impact on the emissions per km due to varying efficiencies of the engine.

6.2. Gas Engine Technology

Compared to conventional diesel engines, there is a reduced fuel efficiency of around 10 per cent with CI engines, and 15-20 per cent with SI engines. But combining CI engines with the latest HPDI technology – as Volvo has done – is claimed to eliminate these efficiency losses.

Gas-powered trucks can either be equipped with a spark ignition (SI) or a dual-fuel compression ignition (CI) engine, which can also be combined with the HPDI (High Pressure Direct Injection) technology. HPDI engines retain the operating principles of the base diesel engine: i.e., direct injection near TDC (Top Dead Centre), auto-ignition of the fuel sprays, diffusion flames, and the thermodynamic diesel cycle. SI engines are solely powered by methane, while the dual-fuel CI engine, though mainly powered by methane, uses some amount of diesel as a pilot fuel to ignite the fuel-air mix. Compared to conventional diesel engines, there is a reduced fuel efficiency of around 10 per cent with CI engines, and 15-20 per cent with SI engines, whereas combining CI engines with the latest HPDI technology – as Volvo has done – is claimed to eliminate these efficiency losses.

6.3. Green House Gas (GHG) Emissions

Use of gas in road transport results in GHG emissions from multiple sources, including the tailpipe as well as upstream from the production, processing, transport, and distribution of methane. GHG emissions comprise CO_2, and the more potent greenhouse gases – methane (CH_4) and nitrous oxide (N_2O) – which have a much greater heat trapping ability in the atmosphere than CO_2. The global warming potential (GWP) – a measure of how powerful a climate warming agent is compared to CO_2 – is generally calculated over a 20-year and 100-year period. The GWP values for CO_2, methane and nitrous oxide are listed in Table, and are based on the Fifth Assessment Report of the IPCC.

Table 6-2: Global Warming Potential of major greenhouse gases

Greenhouse Gas	Carbon Dioxide Equivalent (CO_2e)	
	20-year GWP	100-year GWP
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	84	28
Nitrous Oxide (N_2O)	264	265

Studies in Europe selected for review included a mixture of urban, rural and some motorway driving (URM) in varying percentages. One study also utilized the European Commission's simulation tool for CO_2 certification of HDV. The details of the studies reviewed are given in the following section.

6.4. Major Reports Reviewed

Looking at the success of LNG HDV adoption in Europe, reports from Europe were chosen to understand the emission performance of LNG as compared to its diesel counterpart. Also, as the emission targets under Euro 6 and BS VI protocol are similar, though there is a difference in driving cycles due to lower driving speed, nevertheless due to the similarity in emission targets, a review of European studies involving Euro 6 compliant HDVs gives an insight into the Indian context as well, when LNG HDVs compliant to BS VI come in the market.

The reports chosen are listed below:

1. Transport & Environment: Emissions testing of a diesel- and a gas-powered long-haul truck
2. ICCT: Decarbonization of on-road freight transport, and the role of LNG from a German perspective
3. Cenex: An Innovate UK Research Project to assess the viability of gas vehicles
4. TNO R11336: Emissions testing of two Euro VI LNG heavy duty vehicles in the Netherlands: tank-to-wheel emissions
5. TNO R10193: Emissions testing of a Euro VI LNG-diesel dual fuel truck in the Netherlands

6.5. Tank-To-Wheel (TTW) Emissions

Tank-to-wheel (TTW) GHGs include CO_2, CH_4 and N_2O emissions from both tailpipe and non-tailpipe vehicle sources. Carbon dioxide accounts for the majority of TTW GHG emissions. However, CH_4 and N_2O are also emitted in smaller amounts.

Tank-to-wheel (TTW) GHGs include CO_2, CH_4, and N_2O emissions from both tailpipe and non-tailpipe vehicle sources. Carbon dioxide accounts for the majority of tank-to-wheel GHG emissions.

6.5.1. Tailpipe CO2 Emission

As we have explored above, there are various gas engine technologies available, and depending on the technology used, emissions also vary for natural gas vehicles.

Stoichiometric SI engines operate on the Otto Cycle, due to which they have some fundamental efficiency disadvantages compared to diesel engines. The inferior efficiency of SI engines has immediate consequences on the CO_2 emissions performance too: The tank-to-wheel CO_2 emissions are directly proportional to the fuel energy use per unit of work output as well as to the carbon content of the fuel.

Table 6-3: Energy Consumption and CO_2 emission comparison between SI NG and diesel engines

Energy Consumption Relative to Diesel Engine (%)	CO_2 Emissions Relative to Diesel Engine (%)	Source
19	-7.1	Cenex(2019)
16.8	-12	NGVA Europe (2017)
24.3	-3.2	LBST (2016)
21	-0.5	IFEU (2015)
23.1	-7.4	IFEU (2015)

According to the literature review, on average, SI NG engines consume about 21 per cent more energy than diesel HD engines. They also emit on average 6 per cent less CO_2 than their diesel equivalents due to the lower carbon content present in the fuel.

As HPDI engines retain working principles of base diesel engines, the theoretical efficiency of HPDI engines is not compromised by the same disadvantages affecting SI-NG engines.

The following table presents a summary of the literature review for comparison of HPDI engines and diesel engines. The table presents the efficiency (i.e., energy consumption), and CO_2 emissions comparison separately.

On average, SI NG engines consume about 21 per cent more energy than diesel HD engines. They also emit on average 6 per cent less CO_2 than their diesel equivalents due to the lower carbon content present in the fuel.

Table 6-4: Energy Consumption and CO_2 emission comparison between HPDI NG and diesel engines

Energy Consumption Relative to Diesel Engine (%)	CO_2 Emissions Relative to Diesel Engine (%)	Source
3.1	-19.4	Cenex(2019)
3.5	-20.3	NGVA Europe (2017)
0.2	-23.7	LBST (2016)

According to the literature review, on average, HPDI engines consume around 2.3 per cent more energy than diesel HD engines. They also emit on average 21 per cent less CO_2 than their diesel equivalents due to the lower carbon content present in the fuel.

6.5.2. Tailpipe Methane Emissions

According to the literature review, on average, HPDI engines consume around 2.3 per cent more energy than diesel HD engines. They also emit on average 21 per cent less CO_2 than their diesel equivalents due to the lower carbon content present in the fuel.

Unburned CH_4 emissions are a challenge for all natural gas-fueled engines, as they have combustion efficiency issues. This can lead to high tailpipe emissions of CH_4. Where the temperature in the cylinder is not high enough for post-oxidation, CH_4 will leave the engine and would need to be handled by the after-treatment system.

The table presents a summary of the literature review of the tailpipe CH_4 emissions for SI and HPDI natural gas engines. The table presents the values as methane-slip, that is, as a fraction of the LNG fuel consumed by the engine. HPDI engines have a higher methane-slip than SI engines in all literature sources consulted. On average, stoichiometric SI engines have 0.22 per cent methane-slip, while for HPDI engines, the figure is 0.38 per cent. As a reference, the Euro VI methane limit of 0.5 g/kWh corresponds to a methane-slip of approximately 0.25 per cent.

Table 6-5: Comparison of tailpipe CH_4 emissions from SI and HPDI engine

SI Engine (%)	HPDI Engine (%)	Source
0.25	0.61	Imperial College London (2019)
0.04	0.18	TNO (2017)
0.40	0.81	Clark et al. (2017)
0.13	0.15	NGVA Europe (2017)
0.28	0.36	LBST (2016)
0.21	0.34	Burnham et al. (2016)
0.20	0.24	Kofod and Stephenson (2013)

6.5.3. Non-tailpipe Methane Emissions

Although the design of LNG trucks strive to curtail the venting of CH_4, it is not possible to prevent small amounts of the gas from escaping into the atmosphere. Non-tailpipe emissions of CH_4 can occur due to the following reasons:

- boil-off venting of the LNG inside the truck's tank
- crankcase emissions
- dynamic venting of the fuel system
- refueling, and
- manual opening of the venting valves

6.5.4. N_2O Emissions

Nitrogen oxides are formed inside the emission control systems. During the catalytic reduction of NOx to nitrogen, N_2O is formed as an intermediate and unwanted product. Three-way catalysts, such as those used in stoichiometric SI NG engines, and selective catalytic reduction (SCR) systems, such as those used in HPDI NG engines, can produce non-negligible amounts of N_2O, depending on the catalyst formulation.

Table 6-6: Comparison of N2O emissions from SI and HPDI engine

SI Engine (%)	HPDI Engine (%)	Source
0.1	12.1	Imperial College London (2019)
0.7	1.3	NGVA Europe (2017)
0.4	2-30	TNO (2017)
2.6	3.3	LBST (2016)

6.5.5. TTW Conclusion

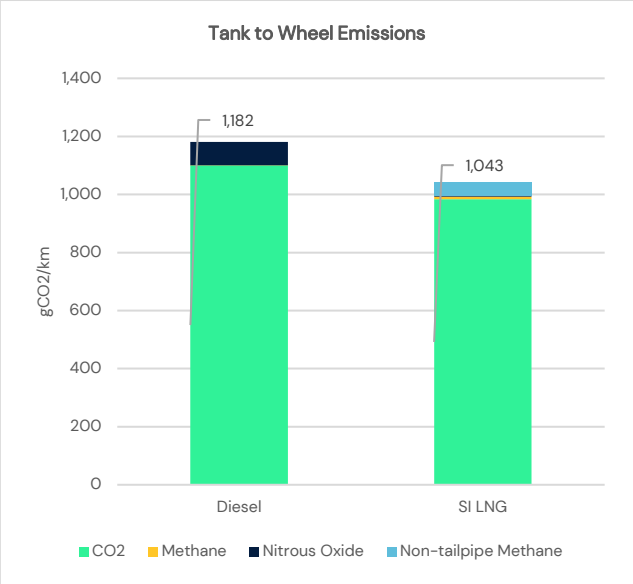


Figure 6-1: Components of tank-to-wheel emissions and a comparison between diesel and SI LNG as reported in T&E study

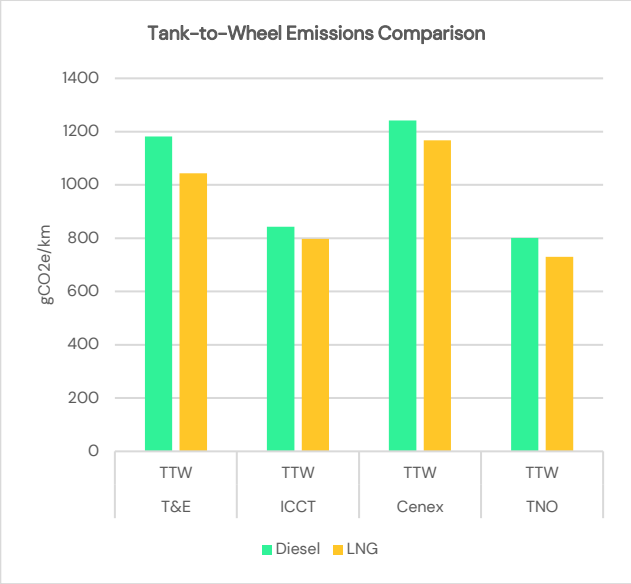


Figure 6-2: Tank-to-wheel emissions comparison between diesel and LNG as reported in reviewed studies

As can be observed, the tank-to-wheel emissions in the case of SI LNG are around 12 per cent lower as compared to diesel. Similar results were also reported across varying studies researched during the literature review.

A chart to show the comparison of the tank-to-wheel emissions between diesel and LNG vehicles is also shown as reported in various studies.

6.6. Pollutant Emissions

Methane which is the simplest of all hydrocarbons, is the major constituent of natural gas, which led to the reputation of natural gas as a clean-burning fuel. This conventional terminology comes from the fact that diesel combustion produced large amounts of soot and nitrogen oxides (NOx) that require complex aftertreatment systems. While, historically combustion of natural gas has not produced significant soot emissions and has required only simple aftertreatment systems to tackle NOx emissions. The section provides details regarding these pollutant emissions comparison with recent studies utilizing the latest engine and after-treatment technologies.

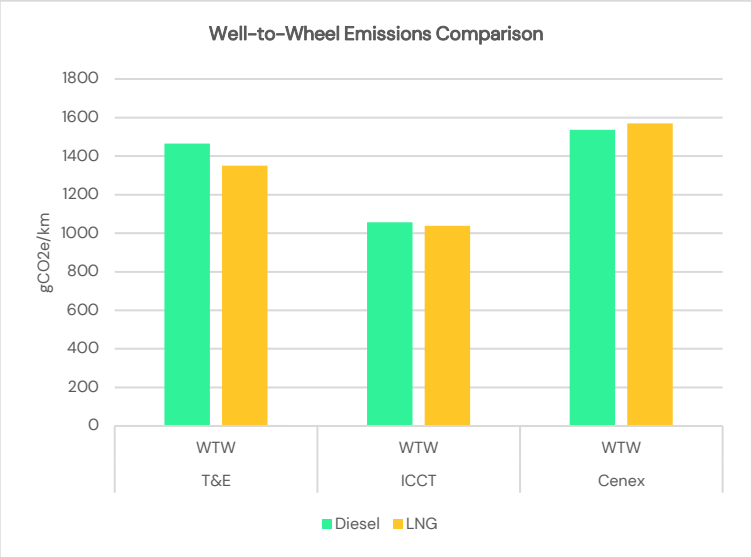


Figure 6-3: Well-to-wheel emissions comparison between Diesel and LNG as reported in reviewed studies

Particulate Emissions

Particulates are formed through complex mechanisms, as in lean combustion with diffusion flames (diesel and HPDI engines) soot particles are formed in fuel rich pockets with elevated temperatures that decompose the fuel into elementary carbon particles. Meanwhile, in SI-NG engines, particle formation takes place mainly due to the unwanted combustion of lubricant oil.

Though NG engines produced significantly lower engine-out particle mass (PM) emissions as compared to diesel engines, but the recent diesel engines are equipped with particulate filters (DPF), that make the final PM emissions of both engines comparable.

But if a comparison between older diesel and natural gas vehicles is taken, it is concluded that natural gas vehicles offer huge reductions in PM emissions. A US based study by Burnham et al. reports such a case and presents previous literature to back up its claim and divides the vehicles based on model year (MY) 2007. It shows numerous published studies from pre-MY 2007 which pointed to the fact that lean-burn SI NGVs, developed prior to the issuance of the 2007 and 2010 EPA and CARB standards, lead to about 90% lower PM emissions [27, 28, 33 60, 61]. Meanwhile prototypes of the CI HPDI LNG tests had 38% lower PM emissions.

Though post MY 2007, due to stricter emission standards and better engine designs that included TWC, the differences in PM emissions lowered, and both NGV and diesel vehicles had very low PM emissions and these depended on the duty cycle. But specifically for the regional-haul duty-cycle most fitting of what the HPDI was designed for, the PM emissions were 10-11 per cent lower.

Nitrogen Oxides (NOx)

NOx emissions are produced in elevated temperature conditions during the combustion of any fuel. Based on the air-fuel ratio utilized, two distinct aftertreatment systems are present to navigate tailpipe NOx emissions.

Selective catalytic reduction (SCR) systems are used for lean combustion (such as diesel and HPDI engines), and it can achieve NOx conversions rates higher than 99 per cent if properly calibrated according to Neely et al. 2019.

Three-way catalyst (TWC) that concurrently reduced the emissions of CO, NOx and unburned hydrocarbons are utilized in SI-NG engines. Research has shown that TWCs can be extremely effective at reducing NOx emissions when engine is operated within a narrow band of air-fuel ratios near the stoichiometric point.

It can be concluded that NOx emissions of LNG and diesel engines are heavily dependent on the emissions control design and the calibration of the system. There is no technology limitation that is hindering the reduction of NOx emissions on either type of engines. The conclusion is further backed by findings from a recent TNO report (2019) and the Equilibre project. The TNO report tested three LNG vehicles through on-road testing and compared the results of NOx emissions to its database of diesel emissions. The test included trucks having SCR and TWC emission control systems. The results showed that for rural, motorway and combined NOx emissions, the data from LNG trucks was within the spread of the diesel vehicles, and especially in motorway, the maximum value of NOx emission was higher than the maximum values for LNG trucks. Meanwhile, for urban test cycle, some LNG trucks showed higher NOx emissions than even the highest emitting diesel vehicle in TNO's database.

The Equilibre project, that assessed the NOx emissions of 5 NG tractor-trailers and 4 diesel tractor-trailers displayed similar results. The testing showed that the spread of NOx emissions of diesel and NG trucks overlap and that NG trucks can present emissions which are lower or higher than those of diesel trucks, depending on the test cycle, especially in the urban operation.

Though due to recent stringent standards, the NOx emissions have become dependent on duty cycle similar to some extent to the PM emissions, but originally NGVs offered significant reductions in NOx emissions compared to the diesel counterparts.

Burnham et al. presented a study of NOx emissions as well for pre-MY 2007 and post MY 2007 vehicles. The study reported that both SI NGVs and CI HPDI LNG tests, showed 35 per cent lower NOx emissions compared to diesel counterparts. Even for post MY 2007 vehicles, the NGVs outperformed diesel vehicles in duty-cycles with low speeds and low engine loads.

The following chart summarizes the results for NOx and PM emissions.

Figure 6-4: NOx and PM Emission Comparison Summarized

6.7. CO_2 Emission Projection

Based upon studies conducted on Euro-VI trucks using diesel and LNG as fuel, average TTW CO_2 emission reduction was estimated to be about 74.6 gCO_2/km.

Base case was taken assuming linear growth in percentage of LNG HDV in total HDV sales per annum, reaching 10 per cent by 2032. Low and high cases assume 5 per cent and 15 per cent sales by 2032, respectively.

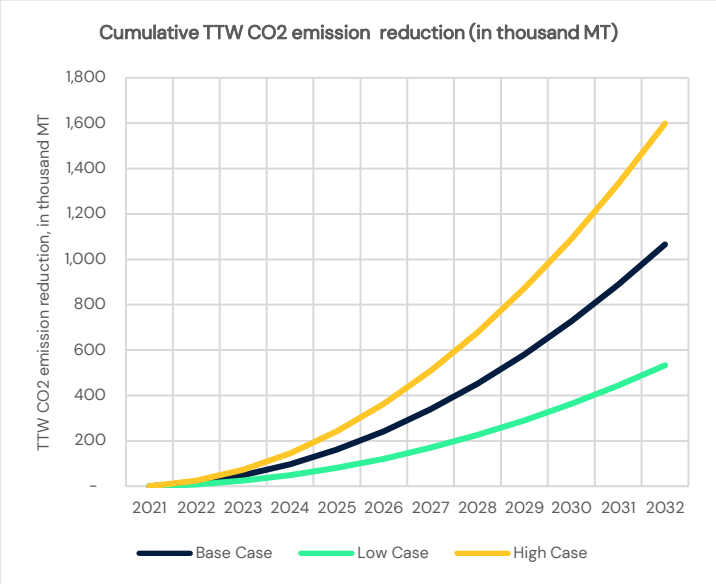


Figure 6-5: Projected Cumulative TTW CO_2 emission reduction (in thousand MT)

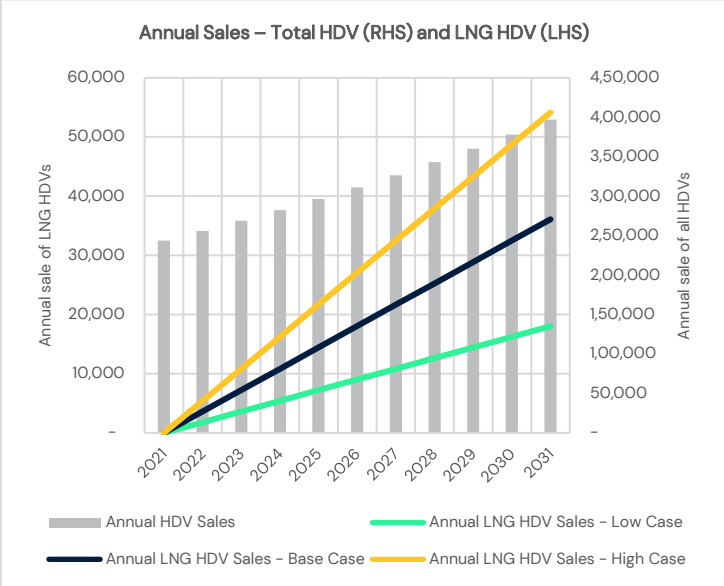


Figure 6-6: Projected Annual sales - Total HDV and LNG HDV

For an average HDV running 60,000 km per year, the base case adoption of LNG HDV can reduce the cumulative tank-to-wheel CO_2 emissions by about 2.8 million MT by 2032.

For an average HDV running 60,000 km per year, the base case adoption of LNG HDV can reduce the cumulative tank-to-wheel CO_2 emissions by an estimated 2.8 million MT by 2032.

6.8. Fuel Efficiency Standards[16]

Fuel efficiency standards have a direct influence on carbon emissions per liter of fuel and mileage. Hence, to achieve the goals set for CO2 emission reduction and incentivize the industry to adopt alternative fuel vehicles, a need for fuel efficiency standards at the corporate level is needed. Bharat Stage VI norms were brought in in an effort to improve emission standards. That said, the standards for energy reduction and carbon footprints of vehicles have remained weak.

The first-ever fuel efficiency standards for passenger cars in India were employed in 2017–18. A gazette notification (of April 23, 2015)[17] outlines these standards. The actual fuel consumption of every vehicle model, and the CO2 emissions in g/km are confirmed through tests during type approval certification of vehicles. The actual fuel consumption of electric models is also measured in kWh per 100 km. Subsequently, the respective "petrol equivalent fuel consumption values" of a particular vehicle model is calculated for all the

[16] India's Fuel Economy Benchmarks: How to make them work for an energy-efficient and climate-secure world. Centre for Science and Environment

[17] Ministry Of Power Notification S.O. 1072 (E) - https://beeindia.gov.in/sites/default/files/Fuel%20Efficiency%20Notification%20%2823April2015%29.pdf

different fuels based on the conversion factors notified in the regulations. Thus, actual fuel consumption of vehicles is derived from CO2 emissions (g/km) tested at the time of vehicle certification.

For passenger cars, the compliance is monitored at the corporate fleet level. This means that for each manufacturer, the average fuel consumption (in terms of petrol equivalent - liter per 100 km) is computed and weighted against the sales of each make and model during the fiscal year.

Currently, the fuel efficiency standards for passenger vehicles are also provided for super credits for predefined technologies, which include EVs, among others, and allow manufacturers to lower their average fuel consumptions by moving towards electric or other alternative fuel vehicles.

India took the initiative to craft fuel consumption standards for heavy duty vehicles in 2016–17[18]. But implementation was kept on hold. These norms were further modified after the implementation of BSVI emissions standards in 2020 and were notified for implementation in April 2023. The reason for this deferment is the industry opposition to the design of the standards. Apparently, the standards for HDVs are designed on 'per-vehicle' fuel consumption basis, similar to the BSVI standards, in which each model is tested for certification. This is in stark contrast to the corporate level standards for passenger cars, where manufacturers have control over their product portfolio to meet the fuel consumption standard. The HDV standards don't provide flexibility to the industry to select and choose their own methods of lowering fuel consumption, and also restricts the option for choosing a diverse product portfolio.

Although moving towards corporate average standards is possible, but at first, the stage 1 standards need to be implemented in complete capacity. Subsequent stages can incorporate the feedback from the industry. At present, the need of the hour is to implement fuel consumption standards for HDVs, as they are responsible for a large proportion of the emissions from the transport sector.

Points of Notice from the Fuel Efficiency Standards

The standards must be implemented: At present, there is no significant information available to get the status of implementation of the HDV standards. While currently, no further delay should be allowed, and the 'per-vehicle' standards can be implemented, it should be noted that corporate average standards can be brought in later revisions.

Alternative method of testing: According to the BEE, the current test procedure for HDVs is extremely costly and time-consuming. Hence, the development of a tool has been proposed, which can evaluate the fuel efficiency of a vehicle model without the utilization of a physical test. An example of such methodology is the VECTO model currently in use in Europe. Similar models can be created for the Indian context, too.

6.9. Economic benefits of LNG HDV adoption

The success of any alternative fuel ultimately boils down to the question whether it is economical for the consumers to adopt or not. In the case of LNG, it is essential that governments feel that the adoption of the fuel would align with their long-term targets. For India, the government has set aggressive targets to reduce its dependence on crude oil imports. It is an extremely vital issue for the Indian government, and any fuel which would aid it in this trajectory towards that goal would be beneficial for India. LNG shows an exciting opportunity in this case.

An import bill reduction of $1.5 billion (nominal) can be achieved by the year 2032 even at 10 per cent penetration.

We conducted an analysis to understand the impact of adopting LNG in HDVs on the import bill for India. Import bill reduction can be estimated using difference between diesel FOB cost and LNG DES price (crude

[18] Ministry of Power Notification S.O. 2670 (E) - https://beeindia.gov.in/sites/default/files/HDV%20Gazette%20Notification.pdf

linked long-term contract, 12 per cent slope). We considered an average running for an HDV to be 60,000 km per year.

The results showed that even for the base case, which assumes linear growth in percentage of LNG HDV in total HDV sales per annum and reaches 10 per cent by 2032, an import bill reduction of $1.5 billion (nominal) can be achieved by the year 2032.

The following graph shows the yearly reduction in import bill that could be achieved for the base, low, and high cases. The low and high cases assume 5 per cent and 15 per cent of HDV sales by 2032, respectively.

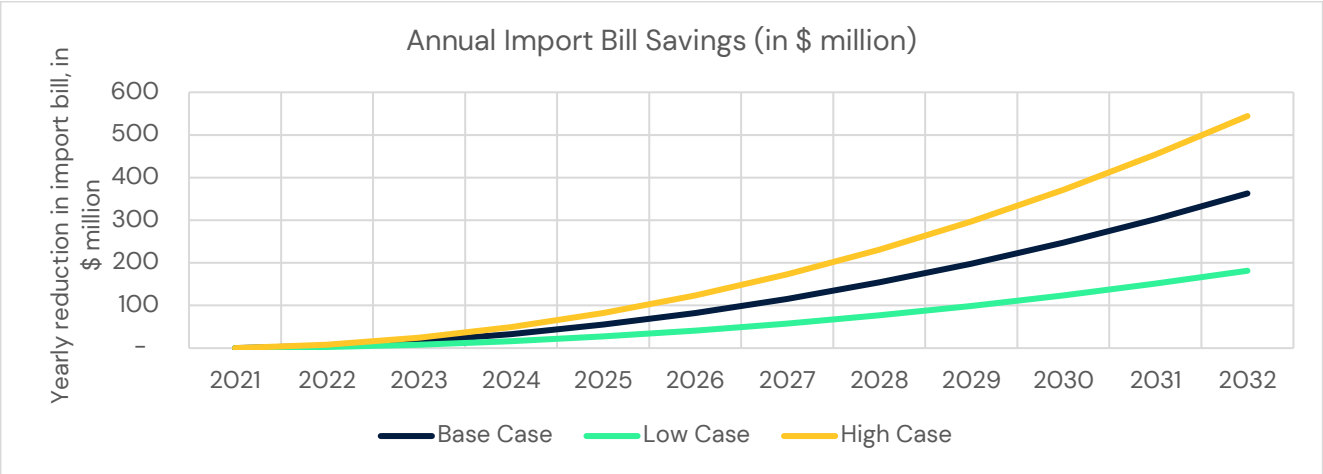


Figure 6-7: Projected Annual Import Bill Savings (In $ million) by Switching to LNG

6.10. Conclusion

After reviewing multiple European reports comparing the emissions of LNG and diesel trucks, we have come to the conclusion that LNG trucks, on average, have lower total WTW emissions as compared to diesel trucks. Multiple studies have reported that, on average, LNG trucks have 12 per cent lower TTW emissions and 8 per cent higher WTT emissions as compared to their diesel counterparts. Although they have higher WTT emissions due to upstream processes, their TTW emissions are able to compensate for higher WTT emissions, thus resulting in overall lower WTW emissions and GHG savings of 7.9 per cent for LNG trucks, as compared to diesel trucks. Similar results were observed across different studies.

Coming to engine technologies, we found that the new HPDI technology in Europe is able to eliminate efficiency losses, which are present in SI LNG engines. Through the elimination of these efficiency losses, new LNG trucks in Europe are able to perform extremely well, and report much lower emissions, as compared to SI LNG engines. That said, we do not currently expect this new technology to come up in Indian markets, and hence, most, if not all, LNG vehicles in India are expected to use SI engine technology, thus leading to higher efficiency losses and higher emissions, as compared to HPDI engines. This would lower the gap in emissions between LNG trucks and diesel trucks, and therefore, might not allow for significant savings on greenhouse gases. During our analysis, we also observed that HDVs in Europe, on average, travel much longer distances in a year compared to Indian HDVs, and their average speed – due to better road conditions – is also much higher, thereby leading to better performance of these trucks in Europe.

7 Business Model

During our interactions with the stakeholders under Stage 1 of the project, ICF has gained an understanding of the business model of different stakeholders associated in this value chain. Also, utilizing other available information, we understand the major components of their business models.

The following chart shows the interplay between the stakeholders present in this value chain.

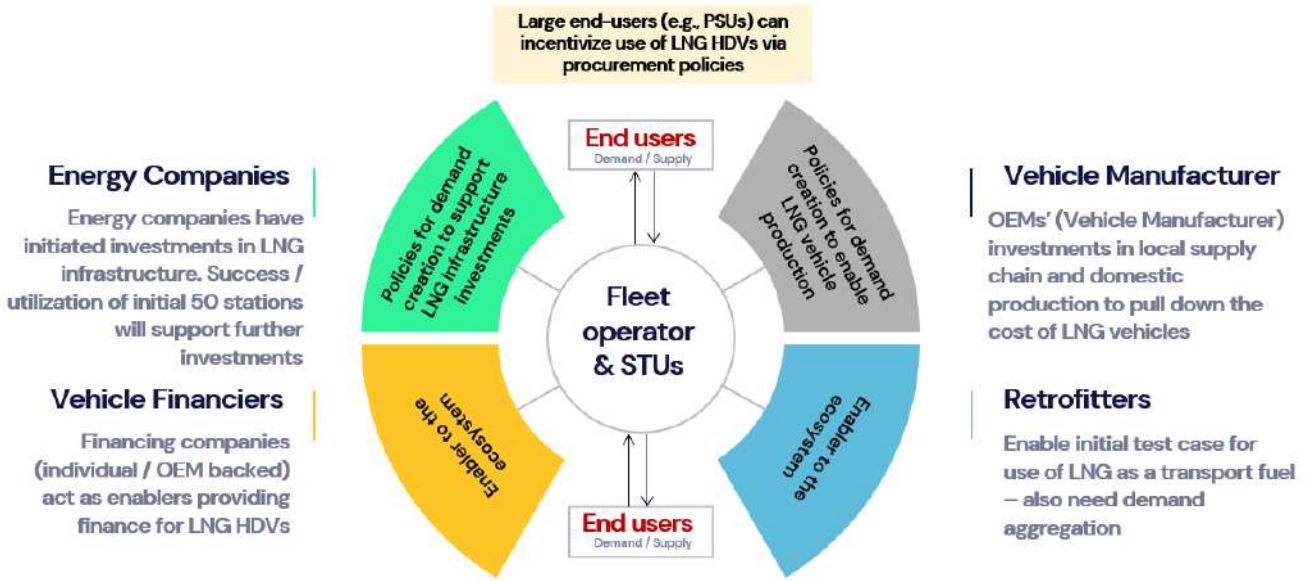


Figure 7-1: Interplay between relevant stakeholders in the LNG value chain

7.1. Fleet Operators[19]

Fleet operators are one of the key stakeholders of the value chain, and it is impossible to achieve a significant level of LNG adoption without meeting their interests and gaining their support. The transportation industry is extremely competitive, and the costs of transportation are usually high along with low utilization levels, due to a number of issues surrounding the fleet operators. Some of these issues with the transportation sector are shown below:

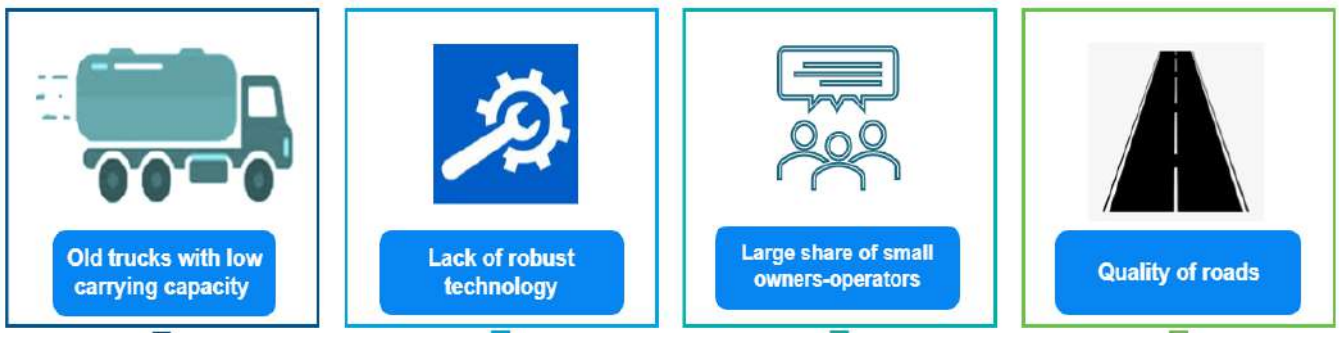


Figure 7-2: Major issues in the transportation sector

- Trucks in India usually have smaller engines, and thus operate at lower speeds. Most trucks here are MDVs or smaller HDVs, while in the United States and the EU, the truck market mainly consists of

[19] NITI Aayog: Fast Tracking Freight In India A Roadmap For Clean And Cost-Effective Goods Transport (2021)

HDVs. This makes it difficult for LNG trucks in India to amortize the additional capital expenditure, which is done with relative ease in Western geographies.

- Most of the trucks on the road are old. About 34 per cent of India's truck fleet has been on the road for at least 10 years.
- India's roads are not well-suited for heavy vehicles. Only 54 per cent of roads are surfaced with concrete, thus limiting the plying of heavy trucks for freight transport. Also, four-six lane national highways are limited in number.
- Transportation practices like load planning and vehicle routing are not digitized, standardized, or automated. For example, there is limited use of radio-frequency identification (RFID) tracking, as well as a lack of real-time visibility into inventory flow. The procedures and equipment to execute processes, such as material loading, unloading, and storing, are not standardized. This leads to widespread use of slow and inaccurate manual processes.
- There is lack of automation of common warehousing operations. This leads to excess inventory holdings by decreasing the speed through which the goods move across the supply chain, and inventory loss, as operators do not have proper visibility into inventory stocks and locations.
- India's trucking market is highly fragmented, a sentiment which was reiterated throughout our stakeholder interactions. **Around 75 per cent of the market is run by small owner-operators who own up to five trucks. Only 10 per cent of the market is run by big fleet operators who own more than 20 trucks.** For perspective, small fleet operators comprise ~67% of the road transport operators in India, though they own less than 25% of the trucks (>12T GVW). Medium fleet operators (6-20 trucks) and large fleet operators (>20 trucks) accounts for the rest. Indeed, barring the top 10-15 players (by turnover), most road transport operators in the country have turnover less than Rs 250 crore[20]. In terms of annual vehicles sold (ignoring the COVID19 years), on an averae sales of heavy goods vehicles are in the range of 2.5 lakhs annual vehicle sold.

	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Heavy Goods Vehicle	234,367	240,867	268,933	296,804	220,934	87,253	174,822
Light Goods Vehicle	454,677	470,706	537,195	640,308	613,474	400,610	453,032
Medium Goods Vehicle	28,867	32,366	31,006	42,591	40,586	23,793	36,209
Total	**717,911**	**743,939**	**837,134**	**979,703**	**874,994**	**511,656**	**664,063**

Small players are unable to optimize driving patterns, and have less ability to invest in larger trucks, digital tools and software, and the expertise required to operate them. This market structure leads to lower asset utilization and overloaded trucks.

- The warehousing sector in India is also highly fragmented, with unorganized players owning 90 per cent of the market. Most warehouses are small and local, rather than regional. Few have accessible connections with national highways and multiple transport modes.

[20] https://www.crisil.com/content/dam/crisil/our-analysis/reports/Research/documents/2018/november/crisil-research-opinion-road-turns-rough-for-small-fleet-operators.pdf

Comparing the transport sector in India with other developed nations shows the following key concern areas that need to be addressed to increase the utilization levels in India.

Table 7-1: A comparison of the transport sector in India with that of developed countries

Region	Daily Utilization (km)	Empty Running (%)	Load Factor
India	250-400	28-43	Trucks in India are usually overloaded, making load typically above 100%
Other Nations	BRICS: 500 US/Europe: 700-800	US: 13-29 Europe: 15-30	Average load factors in Europe fall in the 50-80% range

Low utilization increases the total cost of ownership: The low utilization resulting from lesser amount of distance travelled per day for trucks in India increases the total cost of ownership for Indian fleet operators. It also reduces the attractiveness of fuel-saving technologies, which have longer payback periods with lower utilization. Similarly, high empty running increases the total km traveled for each vehicle, which in turn increases emissions of CO_2 and other critical pollutants, along with an increase in fuel costs for the operators. Finally, overloading is not a safe practice. It can also compromise the integrity of the goods. The root cause of overloading is the fragmented trucking market structure in India where small truck operators are unable to afford new, bigger and better trucks. This results in heavy bulk freight for short haul being commonly carried with overloaded medium trucks. As India transitions more towards being a developed economy with more high value goods likely to be transported, it is expected that overloading will likely reduce.

India's logistics sector is very complex, with a large number of government agencies, export promotion councils, certifications, commodities, and a $160 billion market size. Being such a large and complex sector, it provides livelihood to more than 22 million people. Further, it is estimated that the Indian logistics market will be worth around $215 billion in the coming years compared to the $160 billion at present.

Recognizing the value of this sector, the government has announced the National Logistics Policy formulated by the Ministry of Commerce and Industry, which is aimed at targeting India's trade competitiveness, creating more jobs, improving India's performance in global rankings, and paving the way for India to become a logistics hub. Some of the key features present in the National Logistics Policy are shown below.

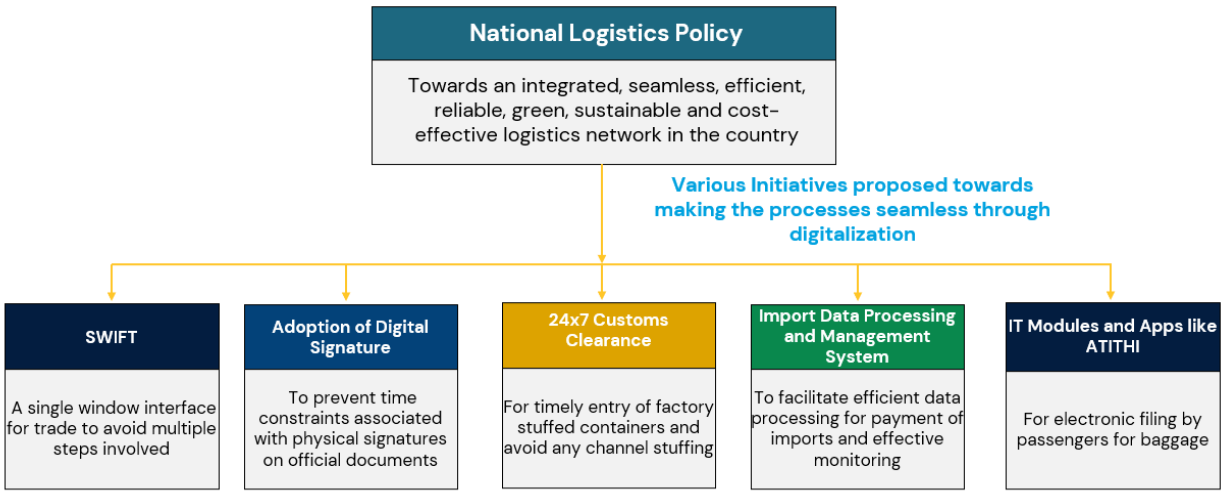


Figure 7-3: Key Features of the National Logistics Policy

Some of the steps to address the overall logistics challenges are mentioned below. The starting point for implementing these could be the LNG HDVs domain:

- While small truck operators cannot afford new, bigger and better trucks, larger players need to take the initiative of and start replacing their own fleets with newer LNG HDVs.
- **Replacing overloaded smaller trucks with bigger trucks** optimizes the load factor, thus ensuring safety.
- **Medium regional haul from warehouses to distribution centers** can be transported with medium trucks rather than overloaded light trucks.
- **Optimize routes to reduce travel time and distance**: Optimizing the delivery routes using parameters, such as delivery locations, number of stops, delivery time, vehicle speed, traffic, and congestion data to reduce the time and distance traveled.
- **Digitizing processes in warehouses**: Use of automation processes, such as warehouse management systems (WMS), which includes tracking and automatic inventory counts.

7.2. Total Cost of Ownership (TCO)

It is paramount that for creating a demand for LNG trucks, vehicle models are available, filling station network is well-established, and most importantly, the operation of LNG trucks are economical as compared to diesel trucks. Here, the concept of total cost of ownership (TCO) comes into play which gives us a comparison between the component costs of owning an LNG truck versus a diesel truck. Though LNG trucks incur higher acquisition costs, vehicle operation results in lower costs for fuels.

As explained in Chapter 1, the total cost of ownership of a vehicle is dependent on the following applicable costs:

- Capital cost
- Fuel cost
- Salary of drivers and staff
- Toll charges
- Annual maintenance and replacement costs

The TCO for diesel and LNG trucks will, therefore, be estimated and compared below based on the various component costs. The following important assumptions are made in the calculation:

Table 7-2: Assumptions taken for TCO calculations

Assumptions	
Loan term (years)	4
Debt to Equity portion	90% : 10%
Interest Rate on debt (%)	10
Capital cost (Rs lakh)	42 for LNG vehicle 30 for diesel vehicle
Annual maintenance and tyre replacement (Rs lakh)	1.6
Toll charges (Rs/km)	6.2
Total running (km)	82,500
Fuel cost (Rs/litre); (Rs/kg)	87 (diesel); 73 (LNG)
Life of vehicle (years)	10

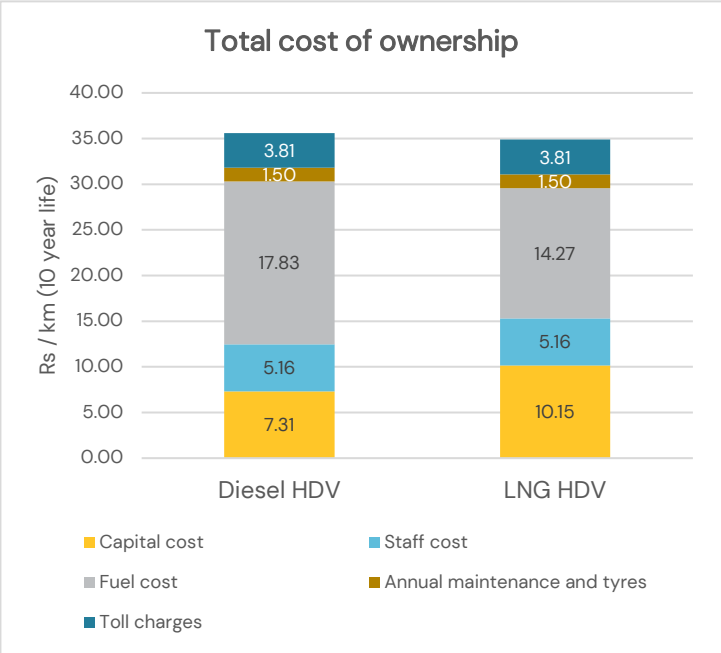


Figure 7-4: Comparison of average TCO and its components for diesel and LNG truck

Based on the listed assumptions, the average TCO was calculated and is presented in the figure alongside. The figure shows a comparison between the TCO of a diesel truck and an LNG truck. TCO of the diesel truck comes out to be Rs 35.61 per km, while TCO for the LNG truck comes out to be Rs 34.88 per km. Hence, based on our analysis, we find that the TCO of diesel truck is approximately 2 per cent higher than that of an LNG Truck. This difference between the two can be further increased to drive LNG adoption by lowering or exempting toll charges, which has been done in certain regions in Europe.

Note that considering a simple payback calculation, this TCO could help achieve repayment of 1.2 lakhs (10% equity component of the additional vehicle cost of 12 lakhs) within a period of 2.06 years.

7.3. Fleet Operator – recovery of additional investment in LNG HDV

To drive the adoption of LNG, it is essential that fleet operators recover their additional investment made for the purchase of an LNG HDV. Without this recovery, the entire basis of promoting LNG will **fall apart. Hence, to focus on this aspect, we conducted financial and sensitivity analysis to cover a diverse set of scenarios for the cost recovery of additional investment made by LNG fleet operators. These analyses are discussed in detail in subsequent sections. Some of the assumptions taken from the point of view of the fleet operators are:**

To understand the recovery of LNG investments, we created a model for the investment recovery period for fleet operators. The financing assumptions taken for the model are listed in the table below:

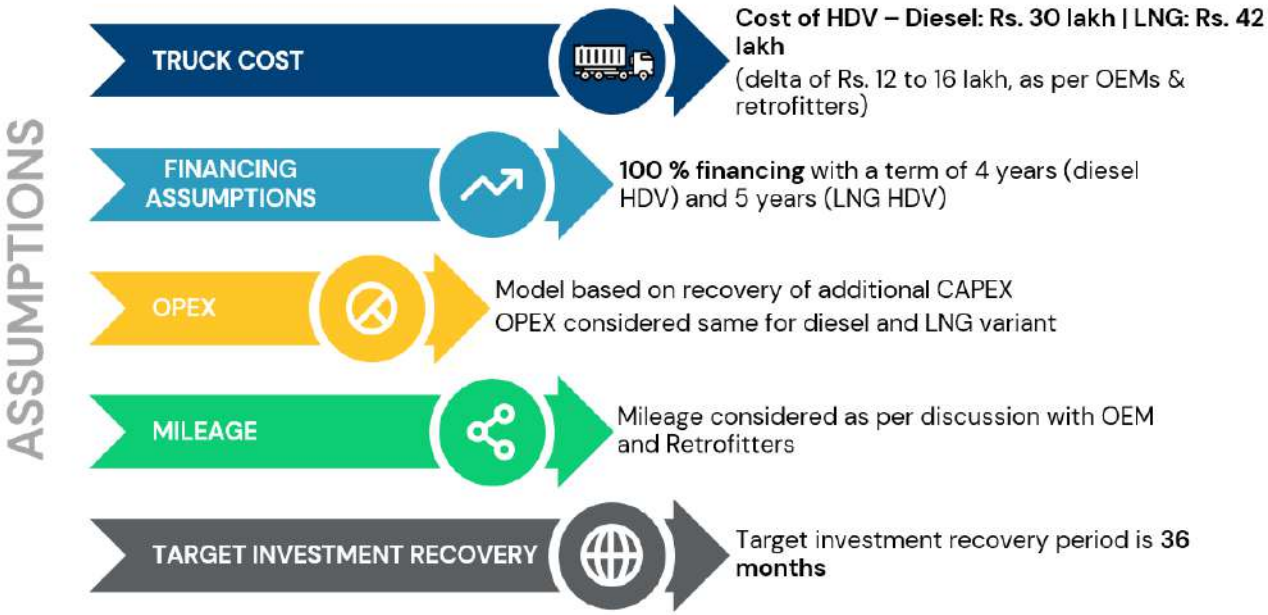


Figure 7-5: Assumptions taken from the point of view of the fleet operators

Payback period is an important determining factor for a fleet operator to undertake a decision on incurring additional capex on purchase of an LNG truck. The lower price of natural gas decreases the overall cost incurred by the fleet operators and **increases their revenue and profitability**, thus making LNG a suitable fuel for usage in HDVs. Further, the lower price of LNG attracts more investments in the industry. The reduced fuel cost of LNG in comparison to other fuels contributes to welfare of the society through improved conditions of the truck drivers. In the course of our analytical work, we also found out the factors which can contribute towards achieving lower paybacks. They are:

A. Annual utilization/running of vehicle

B. Subsidy on additional capital cost

C. Discount of LNG over diesel price

D. Additional capex over diesel vehicles

E. Subsidy on toll charges

The assessment helped compute the payback period for truck operators on purchase of LNG trucks. This is the timeframe (in months) in which the truck operator is able to recover the additional cost of an LNG truck through fuel savings, since LNG is priced at a certain discount to diesel.

Sensitivity Analysis (for Fleet Operators' Payback)

Fleet operators are a key stakeholder in the LNG value chain. Thus, it becomes important to study the various parameters influencing their investment recovery period. The target investment recovery period based on stakeholder consultations has been 36 months, as per the requirements of the fleet operators. As such, we developed a model to understand the enabling provisions which can be considered to achieve the payback of additional capex incurred within 36 months. We also conducted a sensitivity analysis to better understand the influence of following parameters from the perspective of the fleet operators:

- **Toll Charges**
  It was found through the TCO analysis that for an LNG vehicle, the TCO comes out to be Rs 34.38 per km, which is ~2 per cent lower in comparison to Rs 35.18 per km for a diesel vehicle. Analyzing the

components costs of TCO, it was observed that toll charges comprise approximately Rs 3.8/km for operation of any trucks.

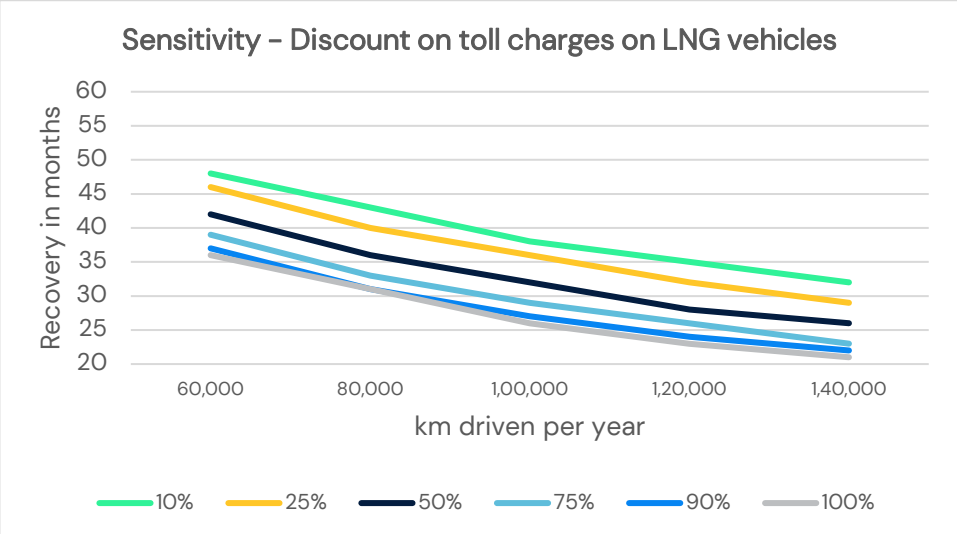


Figure 7-6: Sensitivity analysis considering discount on toll charges for LNG vehicles

In the earlier sections, we had analyzed from the global landscape, such as in Germany, where toll charges were exempted for a period of two years starting in 2019, and post which there was a significant expansion in LNG truck sales and the LNG infrastructure. Following the initial success, the German government also extended the toll exemption to 2023. Hence, learning from the example of Germany, and due to the significance of toll charge in our TCO calculation, we conducted a sensitivity analysis considering a partial-to-complete exemption of toll charges versus the total distance driven by an LNG truck in a year. On the same principle, we found that a complete exemption of toll charges on the grounds of LNG being a cleaner fuel than diesel, could lead to a TCO differential between LNG and diesel vehicles by approximately 11-13 per cent. Even with a partial exemption, the toll charges can significantly reduce the investment recovery period for fleet operators switching to LNG vehicles. The results are shown in the chart attached.

As can be observed from the chart, with a complete exemption of toll charges (100 per cent), the fleet operator can achieve the targeted investment recovery period of 36 months, even with an annual distance travelled of 60,000 km. Hence, partial or complete exemption of toll charge is an extremely impactful way of significantly bringing down the investment recovery period.

- **Subsidy on Additional Capex**
  One of the major constraints in switching to an LNG vehicle over diesel, from the perspective of fleet operators, is the additional capital cost incurred for purchasing an LNG HDV over a diesel HDV. Through discussions with a variety of stakeholders in the LNG value chain, it was found that this additional capex is usually in the range of Rs 12-16 lakh. For the creation of the fleet operator model, we considered the additional capex of LNG vehicle over diesel variant as Rs 12 lakh.

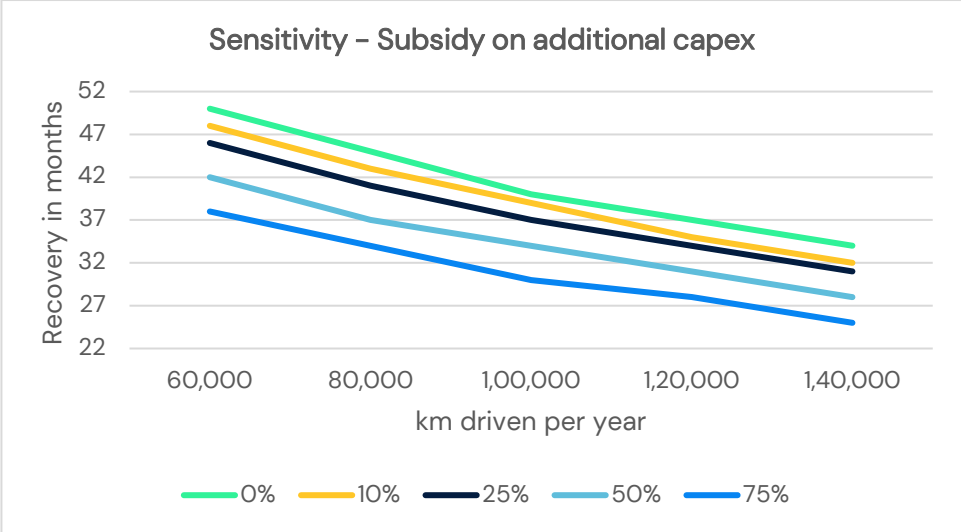


Figure 7-7: Sensitivity analysis considering subsidy on additional capex

From the TCO analysis, it was observed that the capital expenditure cost for LNG comes to Rs 9.84 per km, which is ~30 per cent of the TCO for LNG. Meanwhile, capital cost for diesel HDV is Rs 7.08 per km, which is significantly lower than that for LNG. Hence, bringing a subsidy for the additional capex could increase the TCO differential between LNG and diesel HDVs, thus making the former much more economical, and therefore, make it easy for fleet operators to switch to LNG HDVs. Through a global review of successful models of LNG adoption, our study came to the conclusion that in almost all the regions studied, the respective governments had to bring in subsidy as a first step to help in the adoption of LNG HDVs. Accordingly, we conducted a sensitivity analysis between the percentage of subsidy and the distance travelled per year by LNG HDVs to find the impact on the investment recovery period. The results are shown in the chart below.

As can be observed from the above chart, in the absence of any subsidy on additional capex, the fleet operators would need to run their LNG HDVs for more than 120,000 km a year to achieve the targeted investment recovery period. Such high utilization is not a business-as-usual scenario in the Indian transportation sector. With subsequent subsidies of 50-75 per cent, the targeted recovery period can be achieved even with 80,000-100,000 km per year.

- **Additional Cost of LNG Truck**

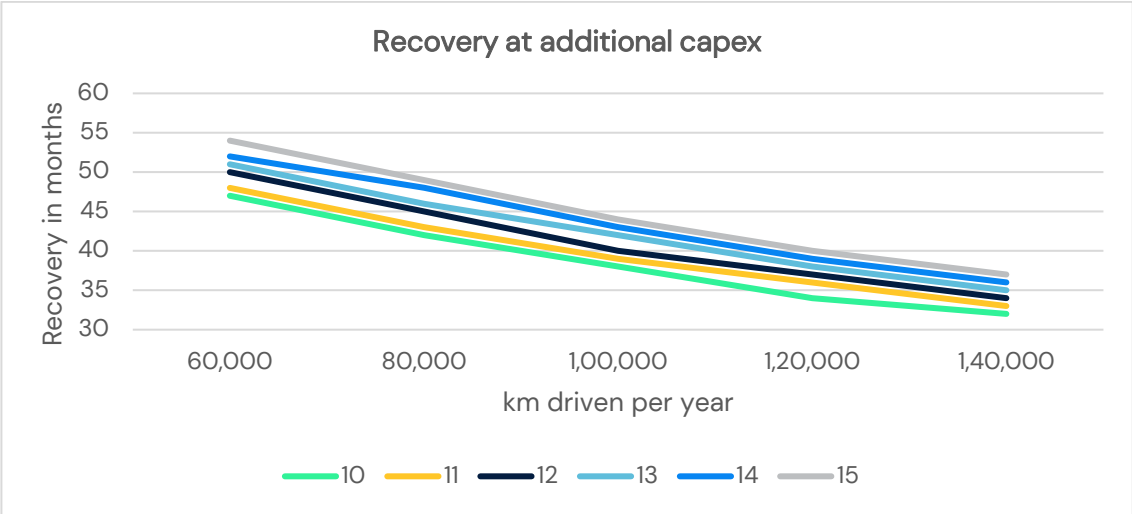


Figure 7-8: Sensitivity analysis considering recovery at additional capex

From the stakeholder interactions, it was seen that the cost differential between an LNG HDV and diesel HDV could be anywhere from Rs 12-16 lakh. As such, the focus needed to be given on how the different cost differential for LNG HDV could have an impact on the investment recovery period for the fleet operators. Since there was no clear certainty on the price of the LNG HDV model in India as of now, therefore, a sensitivity analysis was conducted between the various additional cost required for LNG HDV versus the distance travelled in a year by an HDV. To cover all bases, in case cost effective manufacturing was explored, the lowest additional cost considered was Rs 10 lakh for an LNG HDV. The results are shown in the chart below.

- **Discount to Diesel**

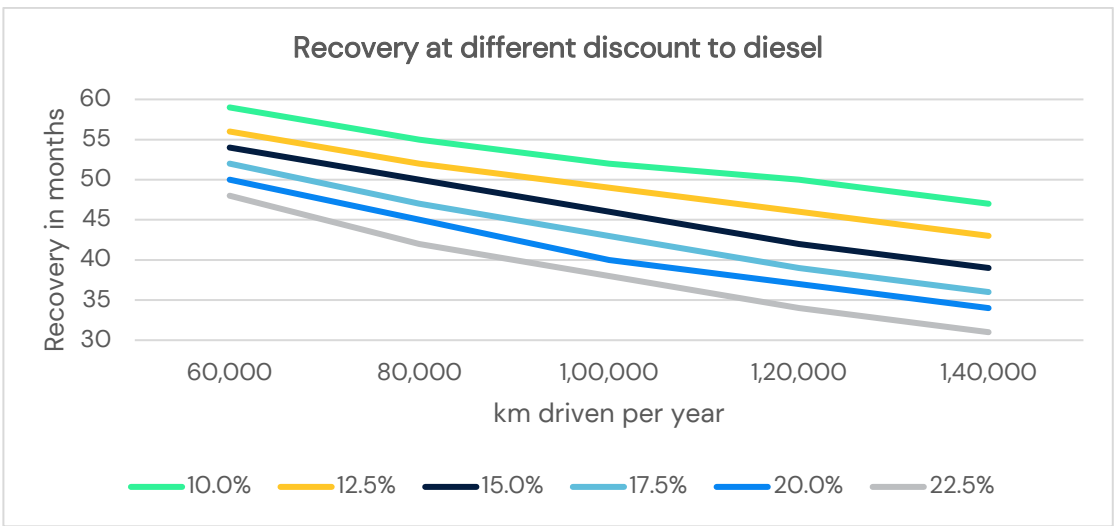


Figure 7-9: Sensitivity analysis considering different values of discount to diesel

The key incentive for moving towards LNG, other than environmental benefits, is the lower cost of LNG fuel as compared to diesel. Hence, maintaining this discount of LNG over diesel is essential to instill confidence among the fleet operators to move for a change from diesel to LNG HDVs. Since the prices of LNG and diesel are fluctuating, so, to understand the level of discount that is necessary to be

maintained for the requisite investment recovery period, a sensitivity analysis was conducted at different discount of LNG price to diesel price. The impact that such fuel cost differential can have on the fleet operator can be concluded clearly from the analysis. Such analysis is necessary, as the discount to diesel is one of major parameters reported in the stakeholder discussions. As can be seen from the chart, even with higher discount rates of 20-22.5 per cent, the LNG HDV needs to be driven beyond 100,000 km a year to achieve an investment recovery period of near 36 months.

- **Interest Rates**

  Financing is an integral part of the LNG value chain, and it is only through financing that significant LNG adoption can be ensured. Hence, financing essentially represents a make-or-break situation for the LNG value chain, as without proper financing mechanism in place, the adoption will not be sustainable in the long run. It is only with the support of financing institutions that necessary market conditions can be created for successful LNG adoption. During the stakeholder interactions with the vehicle financing companies, it was reported that the average interest rate come out to 8-10 per cent. Due to the unavailability of LNG models in the Indian market at present, a sensitivity analysis was conducted for the different interest rates reported, to cover all bases, and their influence on the investment recovery period was revealed. The results of the analysis are shown in the chart below.

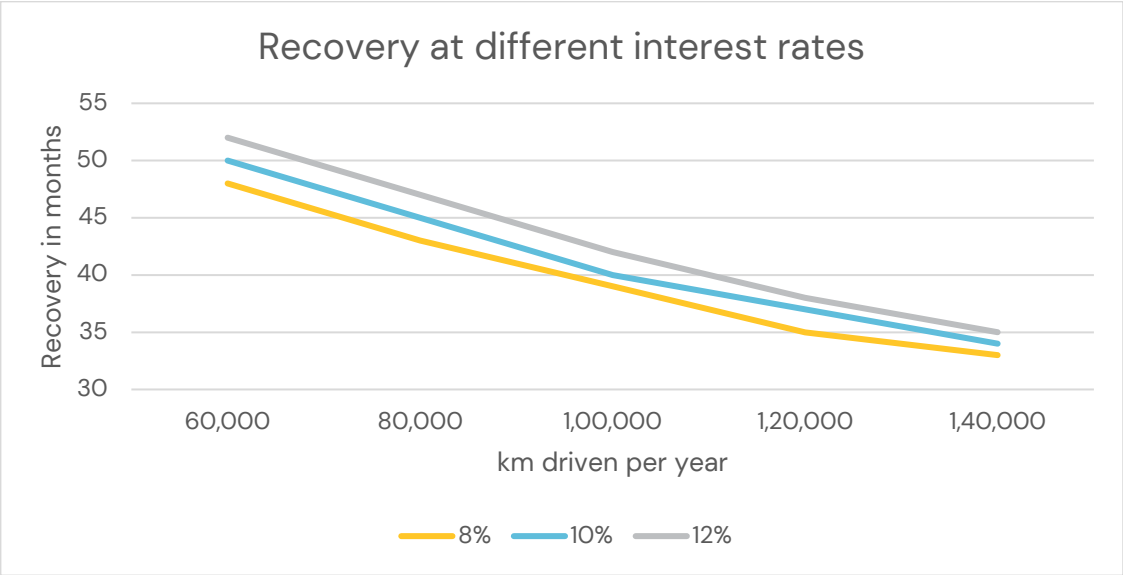


Figure 7-10: Sensitivity analysis considering different rates of interest

As can be seen, even with lower rates of interest, LNG vehicles need to be driven over 100,000 km a year – which is reportedly extremely difficult on Indian roads, as was learned through discussions with fleet operators – to achieve the target investment recovery period of 36 months.

7.4. Business Understanding for Other Stakeholders in the Value Chain

The LNG value chain consists of a variety of stakeholders coming together. Hence, for the successful adoption of LNG as a fuel for HDVs, the needs of all the stakeholders was considered, as the absence of any one of them would lead to a collapse of the value chain. During our interactions with the different stakeholders, an attempt was made to understand their requirements and expectations from adoption of LNG in the HDV segment. Based on the interactions, some of the key points for the stakeholders are shared below:

- **Retrofitters**

Retrofitters form a key part of the LNG value chain, as in the initial days of adoption, they will play a huge role by retrofitting diesel trucks with LNG kits, due to the unavailability of LNG models in India. Looking back

at the CNG adoption in the Delhi NCR region, the initial boost came from retrofitting existing models. During the stakeholder interactions, one of the major inputs considered was that there exists a high cost towards getting a type approval certificate from the testing agencies. According to the estimates provided, an order size of 200-500 vehicles would be required to amortize this cost and make the business viable. Hence, looking forward, it is to be understood that for the retrofitters to take an active role in LNG adoption, a sufficient order size would be required to amortize the cost needed to get type approval certificate and other certifications.

- **OEMs**

OEMs will play a similar role to retrofitters in the LNG value chain, but through the stakeholder discussions, it was observed that fleet operators were more comfortable with using OEM-backed vehicles than using retrofitted vehicles. Hence, due to this lack of confidence in retrofitters, it becomes pivotal for OEMs to produce LNG models to kickstart LNG adoption in the sector. Through discussions with OEMs, it was concluded that they would be able to invest in new engine technology and assembly line if they are able to see a visibility of large order book from the domain. It was mentioned that a production range of around 5000–10,000 vehicles per annum would be required to have a sustainable business in place. An understanding that the new engine technology needs to be amortized over a couple of years was built. Hence, if a significant demand for LNG HDVs is visible, which can ensure the achievement of production targets for OEMs, then models for LNG HDVs can be expected to hit the Indian market.

- **LNG Station operators**

Various kinds of business models are possible for an energy company to operate an LNG station:

Model - 1: Station is under ownership of CGD Company

The installation of equipment and maintenance are the responsibility of LNG station operator (the energy company) itself, while the civil work and operations, land and LNG supply/transportation are the responsibility of the CGD company or Oil Marketing Company (OMC).

In this case, the revenues are earned through dispensation rates of LNG/CNG, i.e., a margin (in Rs/kg) for investment recovery, which are fixed by the energy company in exchange for use of its equipment. Expenses include the cost of annual maintenance contracts for operation of the LNG/LCNG station.

Model - 2: Station is under ownership of LNG station operator:

In such a model, the revenues are earned by the energy company through sales of LNG/CNG at sales price, which are set at a certain discount to diesel prices. Expenses (apart from opex), include the cost of procurement of LNG/CNG, which also includes storage handling and transportation charges.

2a. Land Lease Model & CODO (Company Owned Dealer Operated)

In this, the complete investment on station and maintenance of equipment is done by the LNG station operator, but the station is operated by the dealer/OMC, which receives a dealer margin from the LNG station operator on Rs/kg basis. The station operator would have to pay the land lease and would also supply the LNG, including transportation.

2b. Land Lease Model & COCO (Company Owned Company Operated)

This model would be developed for such a scenario wherein everything ranging from investment on station, its land, and its operations and maintenance are undertaken by the LNG station operator. It also supplies the LNG, including transportation.

7.5. Financial Analysis for OEMs

OEM business is a well-integrated business wherein the existing OEMs bank upon their current capability and existing infrastructure to develop new vehicles. So to understand if the OEMs would be able to invest in assembly line for LNG vehicles, it is important to compute the volume foreseen by these companies going forward. As per discussions with one of largest OEMs, we understand that they might be looking at an orderbook of 3000 to 5000 LNG HDVs annually, to help recover the associated capex.

While it might be a bit difficult to analyze the margins associated with LNG HDVs on a standalone basis, but the gross margin per vehicle currently earned by these companies might be helpful to understand the overall revenue share/ margin share they would like to achieve from LNG as well. For this purpose, two of the major players in the country in Medium and Heavy Commercial Vehicles (MHCVs) segment – Tata Motors and Ashok Leyland have been analyzed. Since MHCVs form a large part of the overall vehicle sales of these companies, it helps provide a better picture on the margins expected out of this segment.

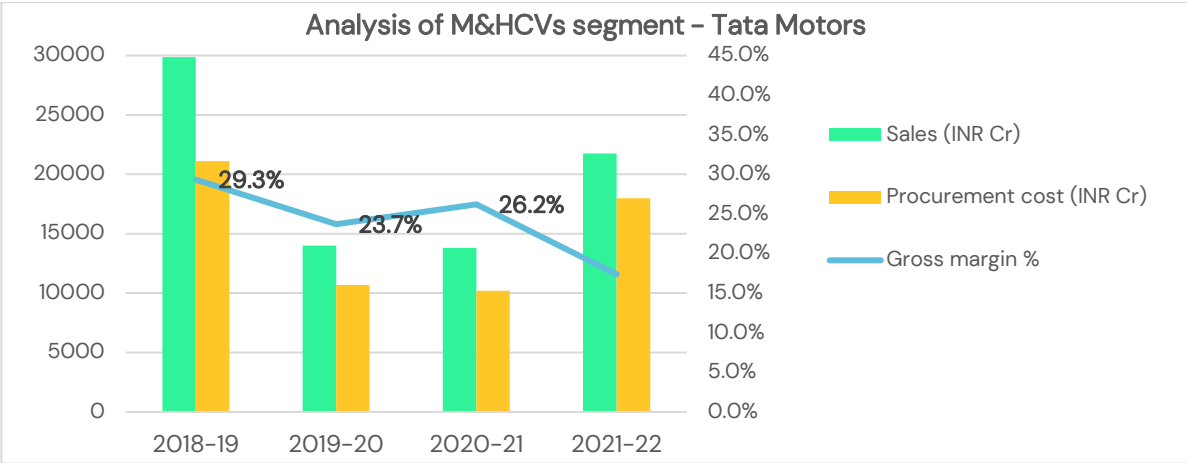


Figure 7-11: Analysis of M&HCV segment – Tata Motors

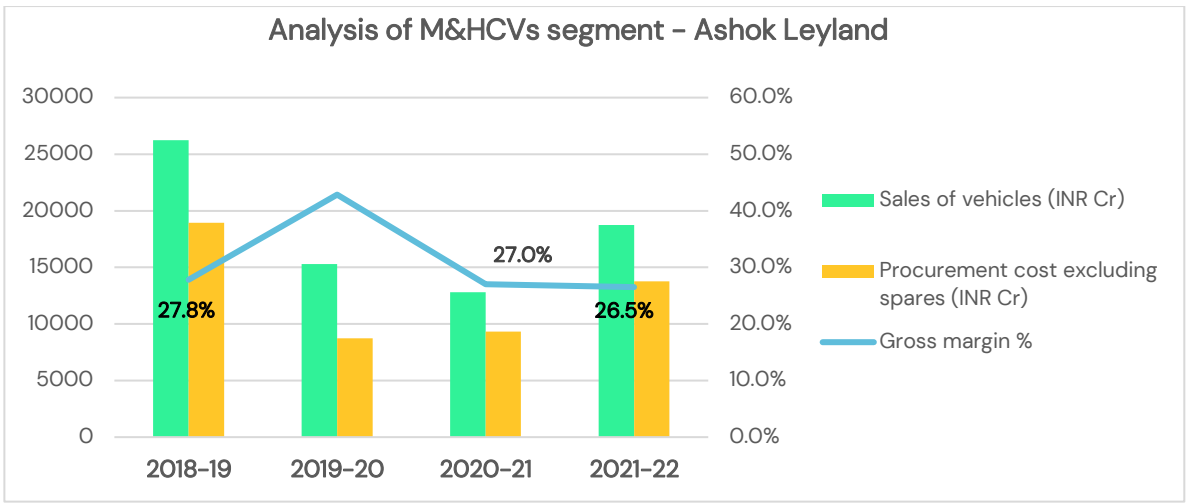


Figure 7-12: Analysis of M&HCV segment – Ashok Leyland

As can be seen from the above analysis, the gross margin (vehicle sales – procurement cost) for such companies averages out to be in the range of 26% to 27%[21]. This refers to the margin expected by these companies on each vehicle, if they are to go ahead with a new investment.

As per discussions held with fleet operators, total sales price of INR ~42.4 lakhs is anticipated for an LNG truck. Considering factors like dealer margin, GST and other costs, the sales price charged by OEMs for an LNG truck is INR ~32.5 lakhs *(Refer Annexure for detailed computation).* Considering the cost margin as computed above and the minimum orderbook of ~3,000 vehicles anticipated, the **OEMs might be looking at a margin of INR 8.5 lakhs from the sales of a single LNG truck and INR ~260 crores from the sales of their expected orderbook.**

Following table summarizes the level of margin that OEMs would like to ensure for capex recovery if they go ahead with investing in LNG trucks-

Particulars	Value
Cost of LNG truck *(as per market information)*	INR 42.4 lakhs
Sale price of LNG truck for OEM *(Refer Annexure for detailed computation)*	INR 32.5 lakhs
Expected cost margin	26%-27%
Expected margin from sale of single LNG truck	INR ~8.5 lakhs
Expected orderbook of LNG trucks	3,000–5,000
Minimum expected margin from sale of expected orderbook	INR ~260 crores

7.6. Financial Analysis for LNG Retail Outlets

Development of financial model

A financial model was prepared for an LNG/LCNG dispensing station on per station basis. The model has been created to showcase under what circumstances the business model is feasible, so that the policy asks with respect to demand generation could be asked for. While the actual numbers might show a slight deviation from the assumptions taken in the model, ***the objective is to understand what values of truck traffic, LNG prices and, LNG discount % would lead to viability of the LNG station in long run***.

For reference, close to 1,75,000 Heavy Duty vehicles were sold in FY 2022[22]. The number of LNG-fueled HDVs assumed to be catered by 50 LNG stations is 2500 in the first year of station operation, which is merely ~1.4% of the total HDV sales. So out of the total market segment, we are trying to capture only 1% to 2% of the HDVs and then assuming an escalation of 5 trucks per year for each LNG station.

Table 7-3: Major assumptions considered in financial analysis

Assumptions (per station)	Unit	LNG station	LCNG station
Capex	INR cr	7.15	9.98
Opex	INR cr	0.68	

[21] Excluding any outliers in the analysis. Refer Annexure for detailed computation

[22] Parivahan data, Ministry of Road Transport & Highways

Truck Traffic (Base Year)	#	50
LNG Volume (Base Year)	tons/year	1310

The model covers all aspects related to transportation and storage of LNG for dispensing. The financial model developed included the income statement, balance sheet, and cash flow statement, along with schedules for depreciation, deferred tax asset/liabilities, and debt amortization. Valuations were based on discounting of cash flow (FCFF and FCFE). The financial model was prepared in such a way that changes made in operating and financial assumption sheet were automatically reflected in all the three financial statements, and the impact of the same could be seen on deciding the criteria (NPV and IRR). Such financial statements helped in assessing the estimated operating costs, revenue, and profitability ratios like EBITDA, EBIT, and PAT, among others.

Possible scenarios based on Brent Crude Price

Various scenarios were developed in the model depending on the price of brent crude oil, that would further define the prices of diesel and LNG.

- Scenario 1.a – Brent Crude Price of ***$60/bbl*** - LNG Station
- Scenario 1.b – Brent Crude Price of ***$60/bbl*** - LCNG Station
- Scenario 2.a – Brent Crude Price of ***$80/bbl*** - LNG Station
- Scenario 2.b – Brent Crude Price of ***$80/bbl*** - LCNG Station
- Scenario 3.a – Brent Crude Price of ***$100/bbl*** - LNG Station
- Scenario 3.b – Brent Crude Price of ***$100/bbl*** - LCNG Station

Following table shows the cost price of LNG and selling price of Diesel as well as LNG derived for different prices of brent crude oil. The computation has been provided for the ***year 2040.*** Detailed information on the computation of these prices has been provided in the *Annexure*.

Table 7-4: Derived prices of Diesel & LNG

Year	Unit	Crude price of $60/bbl	Crude price of $80/bbl	Crude price of $100/bbl
LNG Cost Price	INR/kg	47.4	57.4	67.5
Diesel Selling Price	INR/litre	79.2	91.9	104.6
LNG Selling Price (@20% discount to diesel)	INR/kg	66.5	77.2	87.9

Outcomes from the financial analysis of an LNG station

Listed below are some key project outputs achieved from financial analysis carried out for one LNG/LCNG station, under different scenarios:

Table 7-5: Model Outputs for different scenarios of running LNG/LCNG Station

Parameters		Scenario 1.a	Scenario 1.b	Scenario 2.a	Scenario 2.b	Scenario 3.a	Scenario 3.b
Rate of Return	**Project IRR**	14.80 %	16.62 %	12.89 %	15.48 %	10.76 %	14.28 %
	Equity IRR	21.21 %	24.51 %	17.63 %	22.30 %	13.80 %	20.02 %
Coverage Ratio	**Average DSCR**	1.02	1.11	0.82	0.99	0.82	0.86
Payback	**Payback Period**	90 months	81 months	104 months	88 months	104 months	98 months

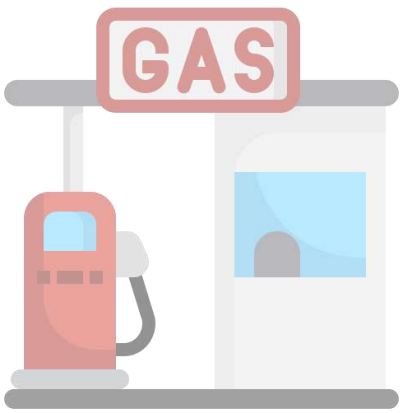
Net Present Value (NPV)	**Project NPV**	Rs. 3.31 cr	Rs. 6.57 cr	Rs. 2.11 cr	Rs. 5.43 cr	Rs. 0.91 cr	Rs. 4.31 cr
	Equity NPV	Rs. 0.96 cr	Rs. 2.30 cr	Rs. 0.29 cr	Rs. 1.68 cr	Rs. (-0.39 cr)	Rs. 1.06 cr
EBITDA Margin	**Avg. Operating Profit**	Rs. 1.6 cr	Rs. 2.6 cr	Rs. 1.3 cr	Rs. 2.4 cr	Rs. 1.1 cr	Rs. 2.2 cr
	Avg. Revenue from Operations	Rs. 14.1 cr	Rs. 22.5 cr	Rs. 16.6 cr	Rs. 26.8 cr	Rs. 19.1 cr	Rs. 31.0 cr

As can be seen from the above tables, the outputs from the financial analysis shows that the business model of operating an LNG station could be viable in most of the scenarios. However, to make sure that it is a sustainable model, there are some key parameters on demand and pricing which need to be ensured:

3. **Number of trucks** – For 50 LNG/LCNG stations, around 2,500 trucks are required initially, which will go up to 5,000 trucks in the long term. This number is bound to grow further if the number of stations go up eventually. However, if the LNG infrastructure isn't set up on time, then it would impact the expected LNG demand. This shows that ***maintaining truck traffic, and hence, the demand is very critical to achieve the above expected results.***

4. **Prices of crude oil and LNG –** As seen from the model, the viability comes to be high for brent crude price of $60/bbl, but not for a price of $100/bbl. That said, LNG spot prices can go very low/high amid high volatility in crude prices. So, **if the LNG cost price goes high**, the margin for any energy company might reduce, since it is bound to sell LNG at a certain discount to diesel retail selling price (RSP). If the company chooses to reduce the discount offered on diesel RSP, it would not be able to convert many existing customers of diesel.

Thus, demand and pricing consistency are the key elements for ensuring success of this business model in the long term, without which the viability might get a hit.



8 Recommendations

The aim of this report was to understand the perspectives of relevant stakeholders and conduct a detailed analysis for the adoption of LNG in the HDV sector in India. Going through our discussions with relevant stakeholders, our review of current government policies, our review of successful models for LNG adoption globally, business, and financial analysis for LNG, we have come up with certain recommendations that could prove to be game changing for the adoption of LNG in the near future. The importance of holistic policy initiatives which work as market developers is extremely important in order to ensure that the adoption continues beyond the validity period for any policy. The key policy asks that we believe would ensure sustainable market development for LNG in HDV are shared in the subsequent section.

8.1. Key Policy Asks

- Road toll-fee exemption for LNG HDV: Fiscal incentive in the form of toll-fee exemption to LNG HDV will reduce the total cost of ownership, and could incentivize adoption. Our review of policies in China and Europe revealed that subsidies and reduction in taxes were the key enablers offered by the government to promote the adoption of LNG in HDVs.

- Reduction of VAT on LNG sale to HDV and natural gas to be under GST - A reduction of VAT to 5 per cent on the sale of LNG to HDV will help in LNG price harmonization across states and further bring down the LNG HDV operating costs. In addition, natural gas should come under GST to ensure availability of input tax credit.

- Demand aggregation model for LNG HDV adoption – We found that at present, the unavailability of LNG HDV models in the market was due to a lack of clear demand signals to the vehicle manufacturers. Demand aggregation would help in optimizing the cost of LNG HDV and will further improve its adoption. At present, EESL intends to procure 10,000 EVs for government departments and public sector undertakings (PSUs), and will also act as a demand aggregator for e-buses in nine cities across the country. EESL-like model should be extended to private fleet operators too, at least on a pilot basis, with options for both leasing and outright purchase. Such demand aggregation for LNG HDVs could help in sustaining viability of the retail outlets.

- Non-fiscal incentives for demand creation: A procurement policy could be formulated for the adoption of LNG HDVs in PSUs for transportation service contracts. We understand the importance of demand creation for the adoption of any alternative fuel from our review of CNG and EV adoption. We also reviewed successful models for LNG adoption globally, and found that non-fiscal incentives play a key role in signaling the governments' push for adoption of a certain alternative fuel. Such incentives for LNG could lead to the private sector in getting involved in the market development for the alternative fuel.

- Allocation of domestic gas to LNG in HDV for initial 3-5 years - MoPNG may allocate domestic gas to LNG fuel retailers for use of LNG in HDV sector for initial 3-5 years. This may be implemented by swapping mechanism where swapping arrangements may be agreed between domestic gas producers and LNG retailers. This will allow market seeding of LNG in HDV sector and support LNG in HDV till it becomes self-sufficient.

- Regulatory interventions – LNG retail outlets are kept out of the purview of CGD authorization, which is a step in the right direction. Regulations for mobile refueling of LNG HDV are to be approved (by PESO) to alleviate fuel availability concerns, which have been raised by fleet operators. A limited time approval for mobile LNG dispensing is required by OEMs for the purpose of testing. Regulatory clarity on LNG supply to other business segments within a GA is also required.

- Signaling and outreach – A "Natural Gas Mobility Dashboard" must be created with information of LNG refueling stations, locations, and retail prices for fleet operators to plan and deploy LNG HDVs accordingly. The performance of new and retrofitted LNG HDVs, models available, fiscal and non-fiscal incentives, shall be included on the dashboard and publicized widely to increase the awareness among the stakeholders. Dashboard can be expanded to include CNG details in the future as well.

- Corporate Level Fuel Consumption Standards for HDVs- Currently the fuel consumption standards notified for HDVs are designed on 'per-vehicle' fuel consumption basis, wherein each model is tested for certification. These are similar to the BS VI standards with respect to the 'per-vehicle' methodology. But this does not allow manufacturers the freedom to choose their own product portfolio to meet the fuel consumption standard at the corporate level, and hence 'per-vehicle' standards do not promote the shift towards alternative fuel vehicles. These standards must be revised to include corporate level fuel consumption and credits should be offered for alternative fuel vehicles such as LNG / electric vehicles / hydrogen.

Table 8-1: Key policy asks along with their impact

Key Ask	Impact / Alleviated Concern	Relevant Body
Road toll fee exemption	**Fleet Operator:** Improved Savings **STUs:** Improved Savings **End Users:** Increased profitability **Industry Associations:** Increased Profitability	**MoRTH & NHAI**
Reduction of VAT on LNG and NG under GST	**Energy Companies:** LNG Price Harmonization and GST on storage and dispensing equipment can be made to 5 per cent. **Industry Association:** Working towards this already, could benefit from the support **Retrofitters:** GST on LNG retrofitment kit to be made 5 per cent	**MoPNG & GST Council**
Demand Aggregation Model	**Fleet Operators:** Increased visibility of LNG HDVs on road **OEMs:** Ensures demand, and helps meet their minimum order book requirement **Energy Companies:** Assures recovery of investment for ROs with clear demand signal **Finance Companies:** As they are willing to finance new LNG HDVs instead of retrofitting **Industry Association:** Can lead to installation of more ROs due to clear demand.	**MoPNG, MoC, MoF**
Natural Gas Mobility Dashboard	**OEMs:** Platform for dissemination of LNG information **Industry Association:** Increased awareness of the LNG value chain	**MoPNG**
Non-fiscal Incentives	**Fleet Operators:** Helps bring LNG HDVs on road **OEMs:** Signals demand creation for OEMs **Retrofitters:** Extension of LNG truck life by 5 years was asked. **Industry Association:** Longer lifetime of LNG HDVs	**National Green Tribunal with OMCs/ MoPNG**

Regulatory Interventions	**Fleet Operators:** Mobile Refueling **Industry Association:** PESO approval for handling of LNG	**PESO & PNGRB**
Corporate Level Fuel Consumption Standards	**OEMs:** Allows OEMs to diversify product portfolio to meet the standards	**MoRTH, MoP & BEE**

9 Roadmap Development

Combining India's collective vision of clean energy economy and supportive conditions with a change model based on collective approach, experimentation, and learning can set India on a transformative path to a new future driven by LNG.

While the recommendations listed in the previous sections form a basis for actionable solutions, there is a need to clarify the implementation approach and provide a framework for the same. Sequencing these solutions provides a prioritized timeline, which is dependent on the readiness of systemic change and the order of operations. This requires setting up an order of priority for these solutions, based on the level of impact they are expected to make on LNG demand, and readiness of the market (including various stakeholders) in accepting the change-

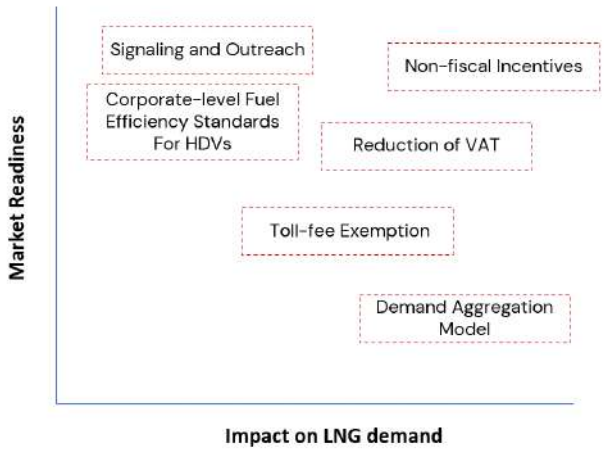


Figure 9-1: Market Readiness and impact on LNG demand for proposed solutions

9.1. Demand Aggregation model

As many energy companies are developing LNG retail stations, there is a need to ensure that adequate demand measures are taken so that the assets are optimally utilized. Even now, the perception of uniform availability of LNG is a key bottleneck, which was shared by many stakeholders. With that understanding and background, demand aggregation is one key solution which could help achieve cost reduction, while mapping demand and supply sources with the number of initial LNG vehicles plying on the road can lead to an improvement in the demand in the longer run. The roadmap towards a demand aggregation model would involve the following steps:

- **Demand aggregation** is one key solution, which could lead to a significant improvement in demand to effectively address the issue of lack of LNG demand. This would involve an **"Aggregator",** i.e., a demand aggregator company for deployment of LNG-based vehicles along with applying certain mandates to meet the transportation need through alternative fuel vehicles. Such an entity would act with some

key objectives in hand – cost reduction with higher order volumes and providing clear signals for market development for a reach towards the private sector.

- **Mandate for adoption of alternative fuel vehicles (LNG/EVs/Hydrogen):** As per a recent Gazette notification[23], in addition to conventional fuels, the entities setting up their retail outlets (RO) are required to install facilities for marketing at least one new generation alternate fuels like CNG, biofuels, LNG, EV charging points etc. at their proposed site. However, the implementation of such a mandate could only be successful if similar mandate is brought up with respect to the types of vehicles too. Thus, there is a need to define the category of LNG, EVs and Hydrogen HDVs as "Alternative fuel vehicles," or "New age fuel vehicles", and then mandating 5 per cent of the transportation requirement to be met through alternative fuel vehicles in the immediate term, which can be further increased to 10 per cent for the medium term. Major entities involved in bulk purchase of vehicles like STUs and PSUs could specifically be mandated to convert a percentage of their vehicles to new age fuel in 2-3 years from now.

  Such mandate could be based on the total vehicle km travelled (VKT) basis, which can help increase the utilization of alternative fuel vehicles, and hence, increase their viability. As the vehicles start running on roads, both the aggregator and the OMCs would collaborate to support timely development of the LNG refueling infrastructure. Such mandate can also be extended to State Transport Utilities for procurement of buses for provision of bulk supply of LNG.

- **Ownership** of such aggregated vehicles could be undertaken by CESL, a subsidiary of state-owned EESL already working towards creating demand for electric vehicles aggregated across the country. Given the existence of such a demand aggregator, it would send out a clear signal to manufacturers for consistent future demands, thus encouraging them for investments towards development of LNG fueled vehicles and will also ensure reduction in costs of such vehicles.

- **Role of STUs:** The Aggregator could start with inviting demand for LNG HDVs via Expression of Interest (EoI) from any public state transport undertaking (STUs), transport corporations or other transport authorities engaged in public transport operations – since such entities are supported by the government and would operate large number of vehicles as well. The STUs would endeavor to provide a favourable ecosystem for bus operators to deploy the HDVs such as identifying the dedicated depots, development of infrastructure, providing parking space, tech-enabled depots for real time monitoring etc.

  The selected STUs would sign concession agreement for deployment of vehicles pay to CESL a basic participation fee, in exchange of which CESL should aggregate demand from STUs through certain subscription also notify them of results from time to time. An example of such a model between CESL and STUs has been covered in Section 4.2 of this report.

- **Target geographies** for the initial phase could be selected based on two important criteria – air pollution levels and proximity to LNG terminals. With this approach, the North-West Indian belt could be targeted first since Delhi-Mumbai highway is one of the busiest highway in the country in terms of truck traffic, and this belt has been witnessing high pollution levels specifically in the states of Haryana, Delhi and Rajasthan. Thus, it might be most prudent to target states along this corridor with Gujarat and Maharashtra having major operational LNG terminals (Dahej, Hazira, Dabhol) and having operational LNG truck loading bays. Going forward, once the model is successful in that belt, the

[23] https://mopng.gov.in/files/marketing/retailOutlets/Resolution_Transportation.pdf

eastern Indian states of WB, Odisha, Andhra Pradesh and Tamil Nadu could also be targeted due to their proximity to Ennore LNG terminal and upcoming Dhamra LNG terminal.

- **Business Model:** The Aggregator would purchase the LNG HDVs in the form of bulk procurement in order to achieve cost optimization. On lines of the model adopted by CESL, the LNG HDVs could be offered to STUs (for buses), PSUs other logistics companies (for trucks) on service model basis with an assurance of recovery which can be developed by creating a payment security mechanism. Based on the LNG HDVs utilization, trucks can be leased out to another entity where it is needed and can ensure savings. It also optimizes the utilization of LNG HDVs across the different end-user sectors.

- **Financing of vehicles:** Aggregation of demand at bulk would help in negotiating better rates from the OEMs. This would provide a case for financing companies, which have been skeptical towards LNG HDVs due to their higher cost price. The financing arms of OMCs can play an important role in enabling this ecosystem. The role of Non-Banking Financial Companies (NBFCs) will also be important to help in financing the bulk procurement of LNG HDVs due to several factors. As per a NITI Aayog report[24] the vehicle finance market share of NBFCs has been increasing over the past five years - By 2020, NBFCs had surpassed banks to account for 52 percent of market share in the formal vehicle financing market, as compared to 43 percent in 2016. Secondly, NBFCs typically have a higher risk appetite and provide smaller pools of finance when needed, which is crucial in case of a new segment like LNG. In the EVs sector, new fintech-based NBFCs have started enabling greater EV penetration in tier 2 and tier 3 cities

- **Adoption of LNG in mining operations:** Diesel is consumed in the mining sector mainly for automotive and power generation. It is estimated that the CIL subsidiaries alone has over 2,500 dumpers running in its opencast coal mines and it consumes about 65% to 75% of the total diesel consumed by the company. Such energy intensive focused point could be suitable candidate for retrofitment of diesel vehicles to LNG. From the stakeholder's discussion it is understood that certain companies are planning for a pilot project which could be starting point. Such pilots could help in streamlining and finding alternate ways to address the following issues a) timely approvals from PESO for setting up LNG filling facilities b) Focus on development of indigenous retrofitters for mining trucks and associated warranties c) Reduction of import duties on costly imported kits for the pilot purposes d) Ensuring adequate utilization to ensure cost recovery.

- **Purchase of LNG-based HDVs:** The aggregator would set well-defined targets to replace specific number of vehicles every year. To ensure optimum utilization of the initial 50 LNG retail outlets and with LNG station growth anticipated considering minimum viability, the following targets need to be defined:

Table 9-1: Targets for optimum utilization of LNG Stations

Year	Cumulative no. of LNG stations	Target of operating trucks
2023	50	2,500[25]
2024	110	5,750

[24] "Banking on Electric Vehicles in India", January 2022 Report

[25] initial impetus needed

2025	180	9,900
2026	270	15060
2027	380	21895
2028	500	29980
2029	640	39385
2030	790	~50,000

For the initial part of the aggregator-based demand push, the aggregator would purchase vehicles with the objective of owning them, and then deploy them as per the targets defined. It would also ensure that the procurement prices of LNG trucks are reduced with bulk orders.

- **Private Player Participation:** Once the cost of LNG HDVs is reduced through aggregator model, with advanced ecosystem and by limiting the price differential due to increase in capex and opex of BSVI vehicles, more private sector participation is anticipated.

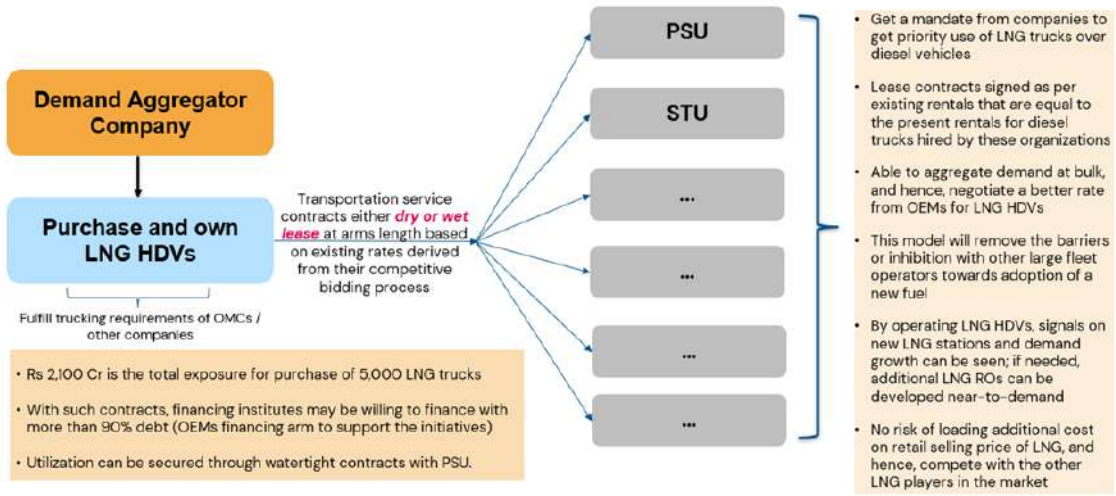


Figure 9-2: Adoption of LNG vehicles In India: Role that can be played by a demand aggregator

As seen from our review of EV policies and initiatives in Section 4.4, we conclude that the role of a demand aggregator is extremely important, and such a role in the case of LNG adoption could solve roadblocks toward LNG adoption.

Responsible Ministry / Body:

- Associated Ministries: MoP&NG, Ministry of Coal, Ministry of Fertilizer, and others with large transportation requirements to mandate adoption of alternative fuel vehicles
- Implementing body: A JV among oil and gas companies to promote LNG as a fuel, or CESL, as they are already associated with OEMs on implementation of EVs in the bus segment.

9.2. Non-Fiscal Incentives

Looking at unique solutions in the form of non-fiscal incentives in China, Spain, the Netherland and Italy, as described in Chapter 5, it can be understood that across a diverse group of countries, all governments understood the importance of bringing incentives to change or adapt the mindset of the industry towards alternative fuel vehicles. They can essentially work as a long-term strategy, where, as the public continually

observes alternative fuel vehicles around, it leads to changes in buyer preference among customers and in the market as well and faces lower amount of skepticism while promoting the adoption of specific alternative fuels. At present, in India, it can be seen through stakeholder discussions that inherent skepticism over a newer technology is heavily prevalent in people's mind across the market due to a lack of personal experience observing alternative fuel technology. Hence, to bring to the ease of the consumers in India, certain non-fiscal incentives can play a key role in developing a sustainable mindset in the market. Some of these incentives are listed below:

- **Targeting high pollution cities/zones:** Such zones could be identified across India and categorized into red, orange, and green areas. Special **Low Emission Zones** can be created in these cities, starting with the red category. Alternative fuels should be allowed unrestricted movements in these zones, while diesel vehicles can be heavily restricted in these zones. This can work in building an awareness, as well as a market for alternative fuel vehicles in these specific regions. These zones can also be roadways or passages which are frequently used for goods transport. Needless to mention, before implementation of such provisions, there should be an adequate plan in place towards accessibility of retail LNG along the targeted corridor, as such restrictions can heavily impact the trade and economy in the region. The pollution levels in these cities could be tracked post creation of such low emission zones. Any reduction in pollution emissions would provide a basis for implementing this solution in orange, and subsequently in green cities.

- **Preferential Right of Way:** To incentivize alternative fuel adoptions, heavy duty trucks running on LNG can be allowed to always enter cities, and diesel trucks can be banned and/or levied with entry charges as has been done in Delhi by implementing the environmental compensation charge (ECC) for all diesel heavy duty trucks.

- **"ECO" labels differentiating, alternative fuel vehicles from fossil fuel vehicles** can be introduced too. Colored license plates can also be used to clearly indicate which vehicles are running on alternative fuels. Along with the labels and colored plates, certain incentives, such as priority for reloading in industries where these trucks are being used, can be brought in to promote the utility of alternative fuel vehicles, and at the same time, promote its awareness among the stakeholders.

- **Priority lane access**, and free parking for LNG vehicles can be provided as non-fiscal incentives to promote LNG. Major cities and roadways need to be recognized, and such priority lane access can be tested first in major cities and roads.

- **Fuel Cards** can be introduced to ensure easier refueling of LNG for fleet operators. Such cards would enable certain offers for the trucks and help obtain (potentially) significant savings both on the current price of fuel and on administrative costs. The fleet operator would receive a single weekly invoice and hence any hassle associated with payments could be avoided.

- **Extension of LNG truck life by 5 years** could be provided once it gets retrofitted out of a diesel truck, which must be scrapped after completing its life of 15 years. Thus, just at the cost of retro-fitment, the truck owner would be able to get services of a new converted truck for 5 years.

Responsible Ministry/Body:

The National Green Tribunal can develop an action plan in discussions with the OMCs/MoPNG to ensure fuel availability before implementation.

9.3. Natural Gas Mobility Dashboard

HDVs ply on long distance routes, and thus, if they are operating on LNG, they need to ensure sufficient availability of refueling stations throughout the route. However, apart from availability, they also need to be aware about the locations of such stations. Another important factor is the knowhow on retail prices of LNG at different locations, since a cheaper price (compared to diesel) is one of the biggest incentives for any fleet operator. To address these factors, it is suggested that a dashboard for a national gas mobility is formed at both the national and the state level.

National-Level Natural Gas Mobility Dashboard

The national level dashboard with GIS mapping would act as a central data bank managed by the central government (MoPNG). The following figure shows an illustration of such a dashboard:

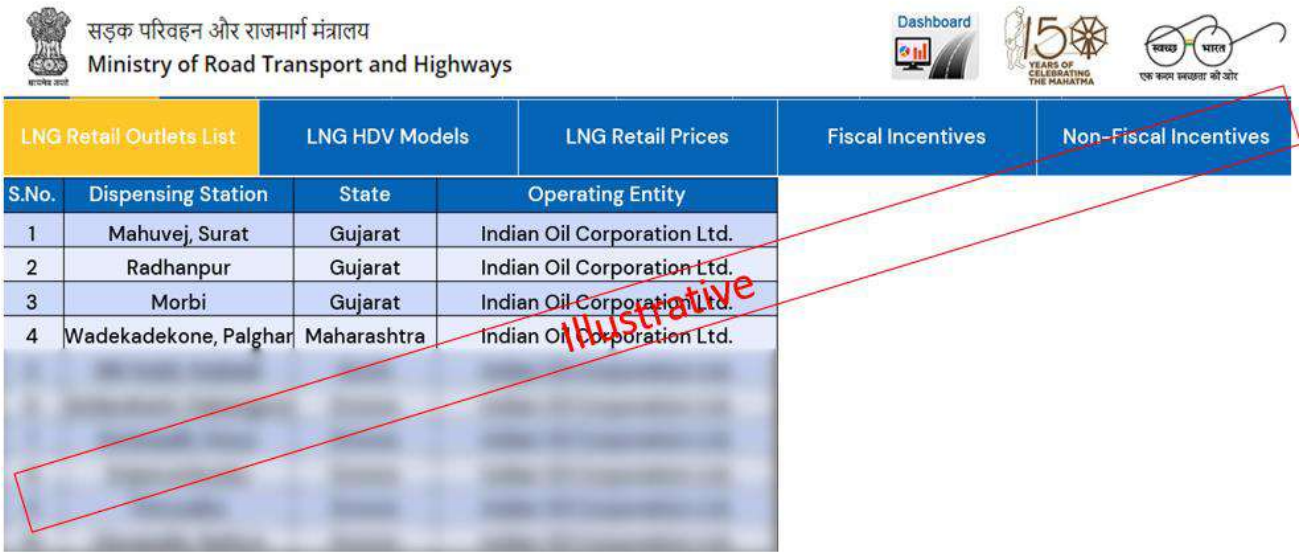


Figure 9-3: Illustration of National-level Natural gas Mobility Dashboard

The purpose of this dashboard/geographic information system (GIS) mapping of the retail outlets would be to aid truck operators/drivers involved in carrying out transportation between different states. The dashboard would include nationwide information on the following:

- Names and locations of LNG refueling stations
- Operating entities of LNG stations
- Retail prices at each LNG station - Dynamic, gets updated every day
- Models of LNG HDVs along with technical specifications
- The performance of new and retrofitted LNG HDVs
- Fiscal and non-fiscal incentives being offered by the ministry

This information would help fleet operators towards decision making in planning, procurement and effective deployment of their LNG HDVs. This information could be publicized widely to increase awareness among the different stakeholders. This dashboard can further be extended to include CNG retail outlets in the future.

Responsible Ministry/Body:

The Ministry of Petroleum and Natural Gas in support with a gas/LNG company as an implementing agency

9.4. Fiscal Incentives

Bringing Natural Gas and LNG under GST

VAT is a tax controlled by the state governments, unlike excise. Every state has its own VAT rates, so diesel and LNG retail prices will get impacted with a significant variation among different states. This is the reason why is some states, this rate is quite high and leads to a significant rise in retail selling prices of diesel as seen in section 7.6; thus, impacting the price differential between diesel and LNG. Reduction of VAT on sale of LNG to HDV to 5 per cent and bringing the retail LNG price under the 5 per cent GST bracket will help in achieving tax rate harmonization across states and will effectively bring down the LNG HDV operating costs.

- The initiative could be led by MoPNG and the GST Council. There have been multiple representations made to bring natural gas under GST. This will be very crucial to properly support the LNG HDV segment, as fleet operators and LNG players will be able to take input tax credit.
- For this purpose, a detailed price computation could be carried out for LNG under various scenarios of Brent crude oil prices, import charges, transportation tariffs, and price differential between diesel and LNG. This would help arrive at the ideal rate of GST/VAT, which needs to be incurred so that a target price differential is maintained, and LNG is made affordable under the expected price range by the stakeholders.

LNG HDV Vehicles and LNG equipment under 5% GST

To give an impetus to the LNG vehicle adoption and to bring the cost differential to a reasonable range, GST on LNG trucks can be reduced to 5 per cent in line with EVs. This scheme for GST reduction can be limited to the first 5,000 LNG trucks sold, and can be further reviewed based on the capex reduction achieved. Since many fleet operators have been resorting to retrofitment before purchasing new vehicle, even the GST on retrofitment kits too could be set at 5 per cent.

Apart from the vehicles, equally important in the LNG ecosystem is the infrastructure. GST on LNG storage and dispensing equipment too needs to be 5 per cent to provide a boost to the station operators for whom huge capital outlay of the project might be a challenge

Responsible Ministry/Body:
MoPNG and GST Council

Revised Depreciation schedules for LNG vehicles and RO developers

Payment of taxes is a key expense for the OEMs as well as energy companies involved in developing Ros. To reduce the initial cash outflows for these stakeholders, there is a need to bring about a change (amendment) in depreciation schedules to incorporate accelerated depreciation for LNG vehicles and the LNG storage/dispensing equipment. This helps shift the tax burden from initial years to the later stages of the project, when the stakeholder starts getting enough cash inflows from the LNG business.

Responsible Ministry/Body:
MoPNG and Central Board of Direct Taxation - Income Tax Department

Toll Fee Exemption

Toll charges form more than 10 per cent of the total cost of ownership as detailed out in Section 7.2; while this manifests the importance of exemption of toll fee for LNG HDVs for their rapid adoption over diesel-

based vehicles, the market readiness of this solution is a bit low, since it needs to be implemented at more than 500 toll plazas across the country.

This would again require the intervention of the Ministry of Road Transport and Highways to amend the National Highways Fee (Determination of Rates and Collection) Rules. This could also require discussions with National Highways Authority of India (NHAI), since there needs to be a system to identify LNG-based HDVs at various toll plazas across the country. Separate systems also need to be in place to avoid any misuse of this exemption by vehicle operators of other fuels. Meetings would need to be held with the state level highway authorities to arrive at a common system for implementing this solution.

The change could help address the country's growing CO_2 emissions from the transport sector. Such Similar rulings have been made in countries like Germany previously, where the estimated savings due to road toll exemption were up to €20,000 over five years; this amounts to around 15 per cent of the cost of an LNG HDV.

Responsible Ministry / Body:
MoRTH and NHAI

Production Linked Incentive

The Production Linked Incentive (PLI) Scheme for Automobile and Auto Component Industry had been notified in the Gazette of India dated 23rd September, 2021[26]. As per the scheme, OEMs or even new non-automotive investor companies are supposed to get benefits based on their determined sales value, subject to meeting a 10% year-on-year growth criteria. The scheme covers various categories of vehicles like Battery Electric Vehicles and Hydrogen Fuel Cell Vehicles of all segments – 2 wheelers, 3 wheelers, passenger vehicles, commercial vehicles, Tractors, Automobile meant for Military use and any other Advanced Automotive Technology (AAT) components.

With regards to the LNG based vehicles, there is a limited list of AAT components eligible under the PLI scheme, viz. Cryogenic Cylinders, Pressure Regulator and Electronic Control Unit. However, the ***overall development of LNG vehicles is not covered for OEMs under this scheme*** unlike Battery vehicles and Hydrogen fuel cell vehicles. Thus, there is a need to include the LNG-fueled vehicles in the list of AAT vehicles eligible for PLI Scheme, providing a major boost to OEMs to manufacture and produce additional LNG vehicles.

Responsible Ministry / Body:
MoRTH and Ministry of Heavy Industries

9.5. Defining Corporate Level Fuel Efficiency Standards for HDVs

Fuel efficiency standards have a direct influence on carbon emissions per liter of fuel and mileage. To understand the potential of fuel efficiency standards, one only has to look at the standards notified for passenger cars in India. Though there are improvements to be made in those standards as well, but the general methodology proposed in the standards allows manufacturers to lower their fuel corporate average fuel consumption by transitioning towards alternative fuel vehicles.

[26] vide S.O. no. 3946(E)

These fuel efficiency norms were notified by The Ministry of Power, in consultation with the Bureau of Energy Efficiency (BEE). Thus, it would require their intervention to add revisions to the existing HDV fuel consumption norms and make it more like the norms notified for passenger cars. Though, at present, the focus should be on implementing the currently notified standards, and then subsequently move towards revisions. A review of the impact of fuel efficiency norms in promoting alternative fuel vehicles can also be conducted, and through feedback, the methodology can be improved further and then subsequently brought in for HDVs as well.

Such corporate level fuel efficiency standards would help manufacturers choose a diverse set of product portfolio, including alternative fuel vehicles in order to lower their average fuel consumption. The credit system can also be created for manufacturers who achieve significant lower fuel consumption than the one notified.

Responsible Ministry/Body:
MoRTH, Ministry of Power and BEE

9.6. Key regulatory asks

While most of the regulatory hurdles have been addressed in this sector, there are some points which have been raised by the stakeholders:

1. While currently all of the LNG demand is being catered through LNG imports, it has an impact on the cost price due to high contract prices as well as costs of regasification and transportation. On the other hand, fuels like CNG and PNG (in the CGD sector) have been able to witness low prices due to domestic allocation of has to CNG sector. Therefore, domestic gas allocation to LNG RO operators inline with CGD sector could be a gamechanger for LNG since it could lead to higher discount percentages over diesel.

2. The Petroleum and Explosives Safety Organisation (PESO) should approve the use of the International Organisation of Standardisation's ISO 1496/3 design, which allows for the containerization of tanks for the intermodal transport of LNG. PESO should also approve the transport of these containers on railway wagons.

3. Regulations for mobile refueling of LNG should be approved to address the fuel availability concerns raised by fleet operators.

4. With the measures suggested above, the demand for LNG as a transportation fuel could take some time. Therefore, to justify the investment, measures need to be identified for adequate utilization of infrastructure created, i.e., catering to CNG or nearby industrial segment. For this purpose, inline with the PNGRB Act, PNGRB needs to issue a clarification specifically on the marketing freedom of LNG, so that the LNG marketers are able to search for other customers and make LNG sales until the LNG transport ecosystem is fully developed.

5. Clarification is required from PNGRB in the interpretation of exclusivity in a CGD network, and sale of LNG by any entity should be allowed through virtual mode i.e., by cascades or any other mode other than pipeline in any GA. This is necessary to ensure development of the LNG ecosystem

Responsible Ministry/Body:
PESO, PNGRB

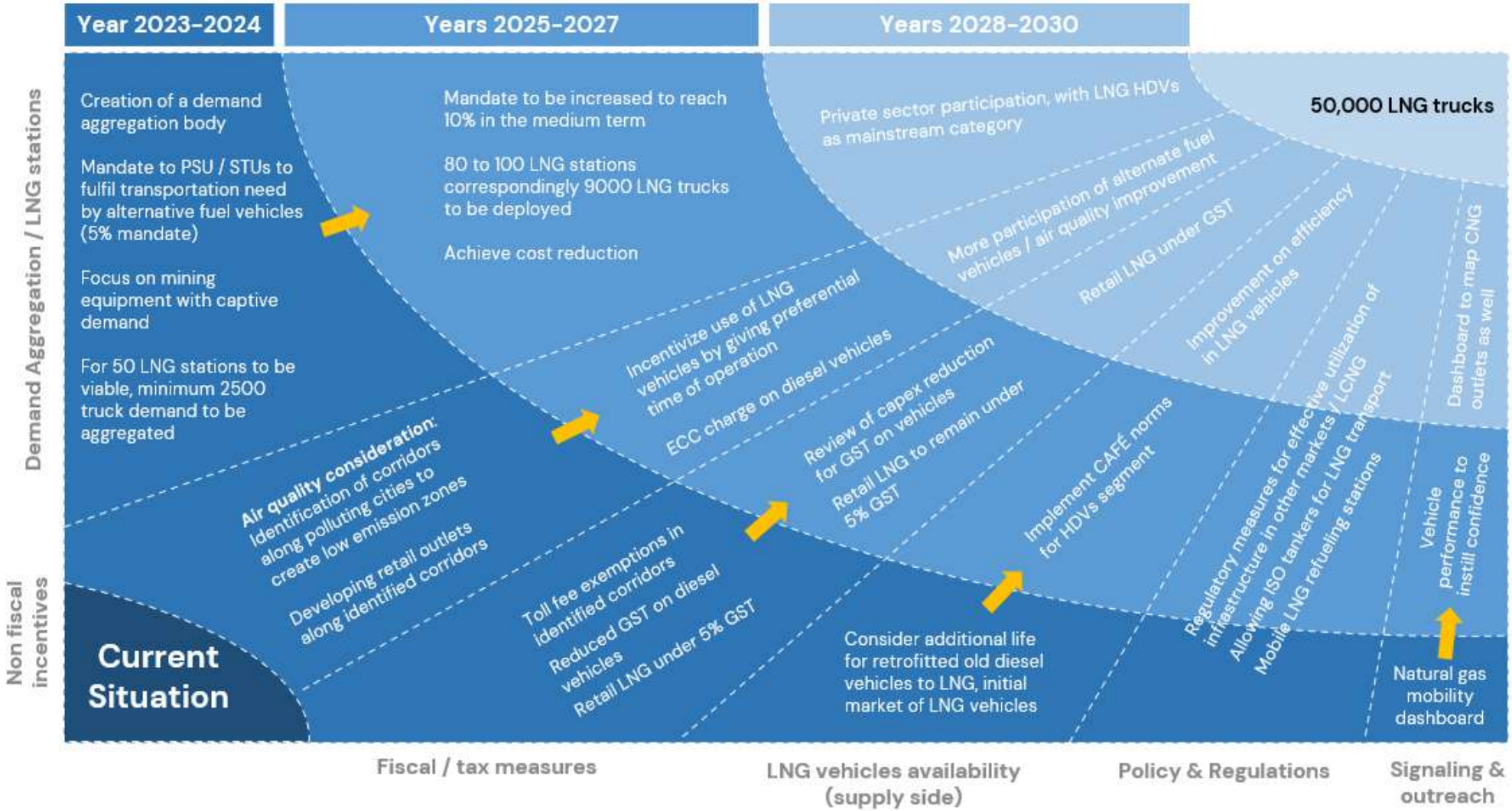


Figure 9-4: Roadmap for LNG adoption

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Abbreviations

Abbreviation	Meaning
2W	Two Wheeler
3W	Three Wheeler
4W	Four Wheeler
AIMTC	All India Motor Transport Congress
APM	Administered Pricing Mechanism
ARAI	Automotive Research Association of India
Bbl	Barrel
BEV	Battery Electric Vehicle
BRICS	Brazil, Russia, India, China, and South Africa
BS norms	Bharat Stage Norms
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CEF	Connecting Europe Facility
CGD	City Gas Distribution
CI	Compression Ignition
CII	Confederation of Indian Industry
CNG	Compressed Natural Gas
COCO	Company Owned Company Operated
CODO	Company Owned Dealer Operated
COP	Conference of the Parties
DAFI	Directive on Alternative Fuel Infrastructure
DES	Delivered Ex-Ship
EBIT	Earnings Before Interest and Tax
EBITDA	Earnings before Interest, Taxes, Depreciation, and Amortization
e-Bus	Electric Bus
ECC	Environmental Compensation Charge
EESL	Energy Efficiency Services Limited
e-HDV	Electric Heavy Duty Vehicle
EIB	European Investment Bank
EU	European Union
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles
FCET	Fuel Cell Electric Truck
FCEV	Fuel Cell Electric Vehicle
FIPI	Federation of Indian Petroleum Industry
FMCG	Fast Moving Consumer Goods

FOB	Free-on-Board
GA	Geographical Area
GHG	Greenhouse Gas
GST	Goods and Service Tax
GVW	Gross Vehicle Weight
GW	Giga Watt
GWP	Global Warming Potential
HDV	Heavy Duty Vehicle
HP	Horse Power
HPDI	High Pressure Direct Injection
Hr	Hour
HSD	High Speed Diesel
ICAT	International Centre for Automotive Technology
ICCT	International Council on Clean Transportation
IPP	Import Parity Pricing
IRR	Internal Rate of Return
ISC	In-Service Conformity
ISO	International Organization for Standardization
KSRTC	Karnataka State Road Transport Corporation
KTPA	Kilo Tonne Per Annum
kWh	KiloWatt Hour
LCNG	Liquid to Compressed Natural Gas
LNG	Liquefied Natural Gas
M&HCV	Medium and Heavy Commercial Vehicle
MAN	Marco de Acción Nacional
MDV	Medium Duty Vehicle
MMBTU	Million Metric British Thermal Units
MMT	Million Metric Tonne
MNC	Multi National Company
MoHI&PE	Ministry of Heavy Industries and Public Enterprises
MoPNG	Ministry of Petroleum and Natural Gas
MoRTH	Ministry of Road Transport & Highways
MOVALT	Development of Recharging Infrastructure for Alternative Vehicles Spain
MOVEA	The Plan to Boost Mobility with Alternative Energy Vehicles
MSRTC	Maharashtra State Road Transport Corporation
MT	Metric Tonne
MMTPA	Million Metric Tonne Per Annum
NAAQS	National Ambient Air Quality Standards
NCR	National Capital Region
NEMPP	National Electric Mobility Mission Plan

NGV	Natural Gas Vehicle
NOC	National Oil Companies
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OMC	Oil Marketing Company
OPEX	Operating Expenses
PAT	Profit After Tax
PEMS	Portable Emissions Measuring Systems
PESO	Petroleum & Explosives Safety Organization
PM	Particulate Matter
PNGRB	Petroleum and Natural Gas Regulatory Board
PSU	Public Sector Undertaking
RFID	Radio Frequency Identification
RO	Retail Outlet
RSP	Retail Selling Price
SCR	Selective Catalytic Reduction
SDE+	Stimulering Duurzame Energieproductie
SI	Spark Ignition
STU	State Transport Undertaking
T&E	Transport & Environment
TCO	Total Cost of Ownership
TDC	Top Dead Centre
TEN-T	Trans-European Transport
THC	Total Hydrocarbons
TTW	Tank to Wheel
URM	Urban, Rural and motorway
USD	United States Dollar
VAT	Value Added Tax
VECTO	Vehicle Energy Consumption Calculation Tool
WMS	Warehouse Management Systems
WTT	Well to Tank
WTW	Well to Wheel
ZLEV	Zero and Low Emission Vehicles

Annexures

India's future fuel landscape – A multifuel strategy

Overview

The M&HCV segment (trucks), which plays a pivotal role in the country's logistics sector, has high diesel dependence. With the economy growing, the segment is expected to grow further, thereby increasing diesel fuel consumption in the country. Thus, decarbonization of transport sector will require a multifuel strategy where various alternative fuels such as CNG, LNG EVs and hydrogen will play an increasing role going forward. These alternative fuels have their own advantages and challenges and thus comparison needs to make on key parameters such as technical maturity, fueling infrastructure, level of independence from imports, level of diversification, cost/ economic comparison, and environmental impact to develop India's future fuel snapshot.

Key parameters considered for developing India's future fuel roadmap are illustrates as below:

- **Technology maturity** refers to the where on the evolutionary curve a given technology is. Mature technology means widespread use so that most of its initial faults have been reduced or removed.
- **Fueling infrastructure** refers to the number of retail outlets in India currently serving M&HCV segment.
- **Level of self-dependence** refers to the domestic availability of fuel and limited import requirement.
- **Diversification** refers to number of sources for fuels available (both domestically sourced our imported)
- **Total cost of ownership** refers to total cost (in Rs/km) for all fuels, including capital cost, staff cost, fuel cost, annual maintenance and tyres and toll charges.
- **Emissions savings** refers to total reduction on overall emissions for M&HCV sector in comparison with diesel.

Detailed analysis

The table covers in detail the various comparisons for diesel, CNG, LNG, green hydrogen, and electric HDVs across the parameters defined above.

Table 1 Detailed Comparison between different fuel options for M & HCV segment

Fuel	Diesel	CNG	LNG	Green Hydrogen	Electric HDVs
Technology Maturity	High	Moderate	Moderate	Low	Low
	Commonly used in heavy-duty vehicles such as trucks, buses, and off-road equipment. Over 95% of new HDV registrations in	Well established for use in HDV for intracity transportation but limited use in long haulage 4% of new HDV registrations in	LNG engines are commonly used in heavy-duty vehicles such as trucks and buses in Europe, US and China. In Europe, LNG HDV fleet has grown from	FCEVs are still in the early stages of development and not yet been widely adopted for use in heavy-duty vehicles. Pilots are being run	Limited by range of vehicles and weight of battery

	2022 came from diesel HDVs.[27]	2022 came from CNG HDVs.[28]	nearly 0 in 2014 to over 7000 in 2021. In China, the annual LNG HDV sales have grown from ~61,000 in 2015, to over 1,41,000 in 2021.	across EU and US.	
Fueling Infrastructure	Widely available	Limited availability for interstate travel (Majorly available inside specific cities)	Limited availability but LNG stations are being developed at the highways	Zero availability	Limited Availability
	India has network of 84614 retail outlets. Only around 10% of total outlets have alternate fuels.[29]	There are 4800 CNG stations in 230 GAs being operated by about 50 CGD entities but very limited CNG stations on major interstate highways.[30]	In November 2020, the foundation stone was laid for the first 50 LNG fuel stations with plans to increase that to 1000 LNG stations in near future.[31]	Green hydrogen fuelling infrastructure is not yet widely available in India.	Limited infrastructure available for fast charging stations in India
Level of self-dependence	Low	Moderate (Domestic gas would be limited in the future, and dependency on LCNG station)	Low	High	Moderate (due to Batteries)
	More than 80%[32] of crude oil is imported.	50% of natural gas requirement is met through domestic gas	LNG is an imported fuel	Green hydrogen is not yet widely produced or used as a fuel,	Electric heavy-duty vehicles do not require a specific fuel, but

27 https://vahan.parivahan.gov.in/vahan4dashboard/

28 https://vahan.parivahan.gov.in/vahan4dashboard/

29 PPAC Ready Reckoner

30 PPAC Ready Reckoner

31 https://mopng.gov.in/files/Whatsnew/Draft-LNG17021_0001-(1).pdf

32 MOPNG: Indian Petroleum and Natural Gas Statistics

		with CNG as priority sector. In future, lack of domestic gas availability may results in use of LCNG.		but electrolysis can be done in India, and therefore it is unlikely that green hydrogen will be imported. Hence, green hydrogen can help India on the path to achieving import independence.	the materials required for batteries are imported.
Level of Diversification	Low	Moderate	Low	N/A	Low
	In 2021-22, over 73% of crude oil was imported from only 4 major countries – Iraq, Saudi Arabia, UAE, and USA.	Multiple diversification options due to domestic gas and imported LNG	Over 79%[33] of LNG was imported from 4 major countries – Qatar, USA, UAE and Nigeria. Diversification is increasing with large number of suppliers/traders selling LNG.	Green hydrogen will be produced domestically, therefore diversification is not applicable.	Electric heavy-duty vehicles do not require a specific fuel, but batteries introduce diversification risk. Currently, India imports almost 70%34 of its Li-ion cell requirement, which are the most critical part of the e-mobility value chain, from China and Hong Kong. Due to this, there is low level of diversification for EVs.
TCO[35]	Moderate	Moderate	Moderate	High	High

[33] GIIGNL Annual Report 2022

[34] https://www.adlittle.com/en/insights/viewpoints/e-mobility-cell-manufacturing-india

[35] ICF Analysis

	TCO of diesel HDVs comes at around Rs 34-36/km with high dependence on fuel cost and thus high volatility in pricing.	CNG is generally cheaper than diesel due to domestic gas availability. TCO for CNG vehicles are at discount to diesel vehicles encouraging conversion or new build CNG vehicles.	TCO for LNG HDV can come in the range of Rs 33-35/km. LNG is highly volatile particularly spot LNG and hence there may be significant difference in TCO	Hydrogen heavy-duty vehicles are expected to be significantly costlier than diesel HDVs currently, as the technology is extremely new. Even hydrogen costs are significantly higher, and the TCO is expected to lie in the range of Rs 60-62/km.	Electric heavy-duty vehicles can be more expensive to purchase upfront compared to vehicles powered by fossil fuels. However, they can be cheaper to operate and maintain due to lower fuel costs and fewer moving parts. Their TCO is expected to lie in the range of Rs 42-44/km.
Emissions Savings[36]	Low	Moderate	Moderate	High	High
	Diesel engines emit air pollutants such as nitrogen oxides (NOx) and particulate matter (PM), which can have negative impacts on air quality and human health.	CNG engines emit 10% lower carbon, fewer air pollutants such as nitrogen oxides (NOx) and particulate matter (PM).	CNG engines emit 10% lower carbon, fewer air pollutants such as nitrogen oxides (NOx) and particulate matter (PM).	Hydrogen heavy-duty vehicles have no tailpipe emissions. Tank-To-Wheel CO2 Emission is 75% less than diesel for green hydrogen.	Electric heavy-duty vehicles have no tailpipe emissions. Tank-To-Wheel CO2 Emission is 65% less than diesel for electricity grid with 60% of power from renewable sources.

Summary

In summary, LNG emerges as a viable alternative fuel option for heavy-duty trucks in India for the transitional period of next 10-15 years.

[36] Comparison between Diesel and LNG covered in detail in chapter on emissions

Table 2 Comparison of various fuel alternatives for the M & HCV segment

Fuel	Diesel	CNG	LNG	Green Hydrogen	Electric HDVs
Technology Maturity	High	Moderate	Moderate	Low	Low
Fuelling Infrastructure	Widely available	Limited availability for interstate travel	Limited availability	Zero availability	Limited Availability
Level of self-dependence	Low	Moderate	Low	High	Moderate (due to Batteries)
Level of Diversification	Low	Moderate	Low	N/A	Low
TCO	Moderate	Moderate	Moderate	High	High
Emissions Savings	Low	Moderate	Moderate	High	High

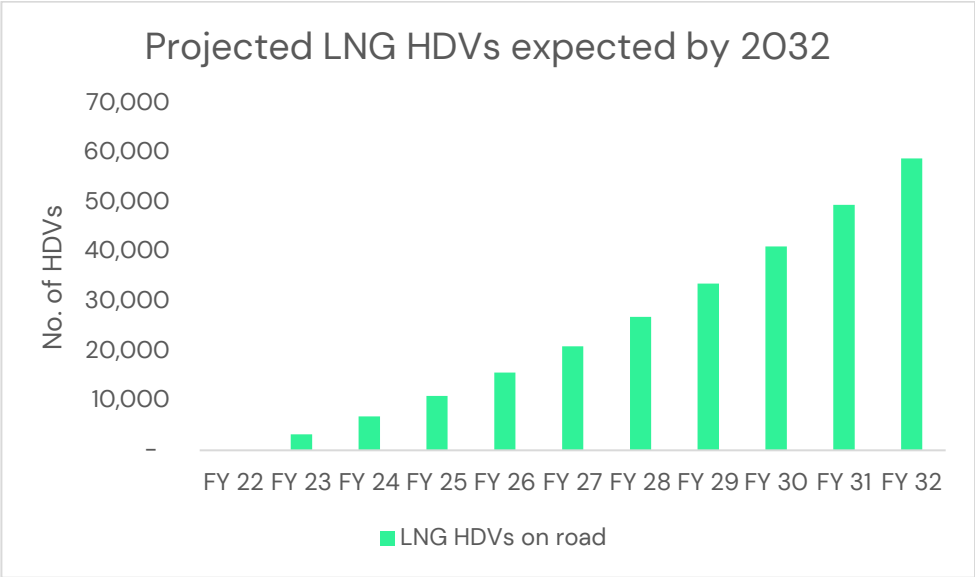
Role of LNG in M & HCV segment

Based on the above analysis, LNG and CNG will likely coexist in the medium and heavy-duty transport sector in next decade. CNG could provide an alternative to diesel fueled goods carrier especially in urban cities owning to range limitation of CNG vehicles and higher penetration of CNG refueling infrastructure within city limits through City Gas Distribution networks. LNG fueled HDVs will provide a robust alternative for long range diesel trucks (inter-state transportation). Diesel, with its developed infrastructure, and ease of availability could continue to have a large share in the fuel mix for medium and heavy-duty sector, LNG is a cleaner-burning fuel than diesel, has a lower carbon footprint, offers a significant long range (as high as 1200 km range) before refueling is required therefore making it an ideal option for heavy-duty vehicles and a practical choice for interstate fleets.

Hydrogen and electric vehicles could start becoming relevant post 2030 as technology matures, cost come down and overall infrastructure improves. Hydrogen fuel cells and hydrogen Internal Combustion Engine (ICE) are green option, but technology maturity and infrastructure availability remain distant. Subsidies under the FAME scheme and state tenders under the Gross Cost Contract (GCC) are expected to drive adoption of electric buses but use of electric trucks will remain muted till technology and charging infrastructure matures.

In conclusion, India will have mosaic of different fuel options including diesel, CNG, LNG, hydrogen and EV to allow for greater flexibility and adaptability regarding fuel availability and cost. Integrating different fuel sources such as LNG, diesel, and CNG in the next decade, with the potential for hydrogen and electric vehicles in the long term, is likely to result in a more sustainable and efficient heavy-duty sector. It will also help India to achieve its goals for decarbonizing the HDV sector and ensure diversification of fuel mix for the transport sector.

To ensure the successful development of this multifuel strategy, focus on LNG adoption for the coming decade is paramount. With the initial push to install LNG retail outlets, LNG HDVs will become a self-sustainable market. Based on the government plans and ICF analysis, the following fuel mix is possible by 2032.



Key Assumptions for the model

- Average running of HDV truck will be 60,000 kms per year
- Diesel trucks will have similar mileage of 3 km/lite while LNG trucks will have mileage of 3km/kg
- Share of HCV/LCV in total diesel sales will remain at 55% (based on the study done by CRISIL for PPAC on sectoral demand of petrol and diesel October 2020-September 2021).
- The growth in freight for heavy duty segment will be around 7% (as per freight report from NITI Ayog)
- CNG fueled goods carrier especially will replace diesel trucks within the city limits
- LNG will make inroads in the heavy-duty segment (particularly for long haul) and will increase its share to 1-2%.
- EVs and hydrogen vehicles will remain at pilot stage with miniscule share of heavy-duty segment.

The significant share of on-road HDVs in 2032 is still expected to remain diesel. However, its share will continue to reduce as infrastructure availability for LNG keeps increasing and the market develops further. This only marks the beginning of the multifuel approach for India, but over time LNG and other alternatives can reduce the dominance of diesel in the HDV sector. Based on the model. India may achieve 50,000+ LNG trucks in next 10 years, considering the given share and supportive policy and regulatory framework by the Government. Through this achievement, the LNG value chain is significantly developed and capable of surviving further without government intervention.

Importance of LNG as the *Transition fuel*

At the recent COP 26, India has made very ambitious targets to align its goals towards sustainability. Prime Minister Narendra Modi presented five essential elements or 'Panchamrit' to deal with the challenge of climate change as follows–

To achieve such ambitious goals, coordinated action from a variety of sectors is needed. The transport sector in India accounts for about 13.5 per cent of the energy-related CO_2 emissions, with the road transport sector accounting for around 90 per cent of the sector's total energy consumption. Hence, it becomes essential for India to target the road transport sector to achieve its emission reduction goals. Limited pollution inventory studies in the heavy duty segment in different cities of India show that the segment is the most significant contributor to air pollution and largest consumer of fossil fuels. Nationally, its contribution to the particulate matter load from on-road transport sector is as much as 66 per cent[37]. Even though, according to the Road Transport Yearbook, good vehicles made up only 4.65[38] per cent of the total registered vehicles population in 2019. Therefore, the heavy duty sector or the long-range transport sector presents an opportunity for the utilization of LNG, which could offer solutions for India's long-term strategy. The adoption of LNG in the heavy duty sector would not only allow for emission reduction, but also work well to lower India's oil import bill, which plays a key role in India's long-term strategy.

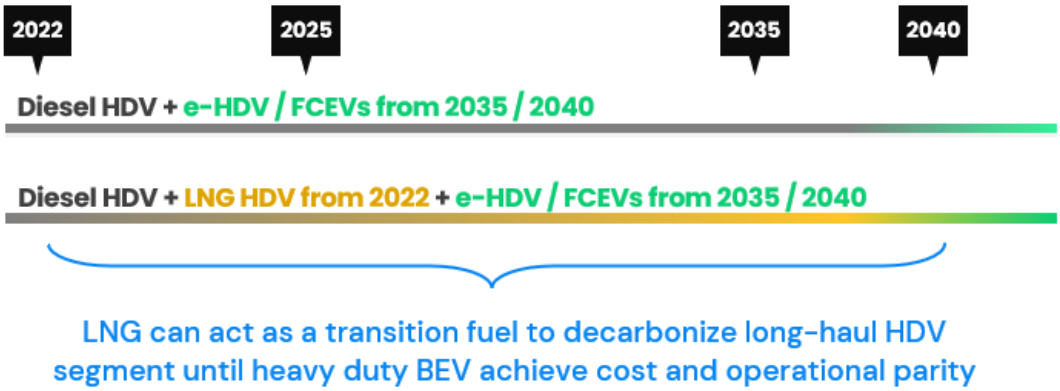
Comparison of LNG with other fuel technologies

Use of natural gas in transportation is not new, and in India itself, it has been around for the past 20 years, in form of CNG vehicles. The use of CNG in both personal and commercial passenger and goods vehicles has demonstrably alleviated pollution levels, but CNG vehicles are limited by range due to limited storage of gaseous fuel onboard. Use of LNG is thus aimed at heavier and long-haul vehicles.

However, in the past 10 years, battery-powered electric vehicles (EVs) and hydrogen-based fuel-cell electric vehicles (FCEV) are also providing options in the market, subject to fiscal support being provided to such vehicles under various schemes.. Here we bring in the concept of total cost of ownership (TCO), which includes the purchase price of a vehicle, and considers the operating costs incurred over the vehicle's life. While TCO is one parameter to assess, in case of EVs and FCEVs the debate is still ongoing to have a proven technology, battery sizing ensuring adequate range, supply assurance and fast charging infrastructure to ensure charging of HDVs. Today, various forecasts suggest on the cost of EVs and BEVs to come down and achieve a parity; LNG on the other hand is a tested technology, with multiple geographies have adopted the same. It is needless to mention that any new age fuel takes significant time frame for a widescale adoption, and the same has been seen in the case of CNG vehicle adoption as well in India. Since gas is a proven technology, and in case of LNG we are using natural gas in a different form. Needless to mention that still in India the high upfront cost is a inhibitor for adoption of new fueled vehicles and in case of EVs and FCEVs is almost 4 to 5 times the diesel vehicle cost, which will always remain deterrent if we look at the fragmented trucking industry of India. While in case of LNG HDVs the cost differential is in the upward range of 40% which if the operations can be carried out in large scale / large orderbook may come down, as it happened with CNG around 20 years back.

[37] Trucks: Heavy-duty Pollution and Action, Centre for Science and Environment, New Delhi

[38] https://morth.nic.in/sites/default/files/RTYB-2017-18-2018-19.pdf



The total cost of ownership of a vehicle is dependent on the following applicable costs:

- Capital cost
- Fuel cost
- Salary of drivers and staff
- Toll charges
- Annual maintenance and replacement costs

Hence it becomes an important metric to bring a comparison between different HDVs. Through extensive research and analysis, we at ICF have estimated the current TCO for HDVs running on different fuels. The following chart presents the results of our analysis. The TCO of HDVs was estimated for an average fleet operator running 80,000 km annually and as per operating costs of 2022.

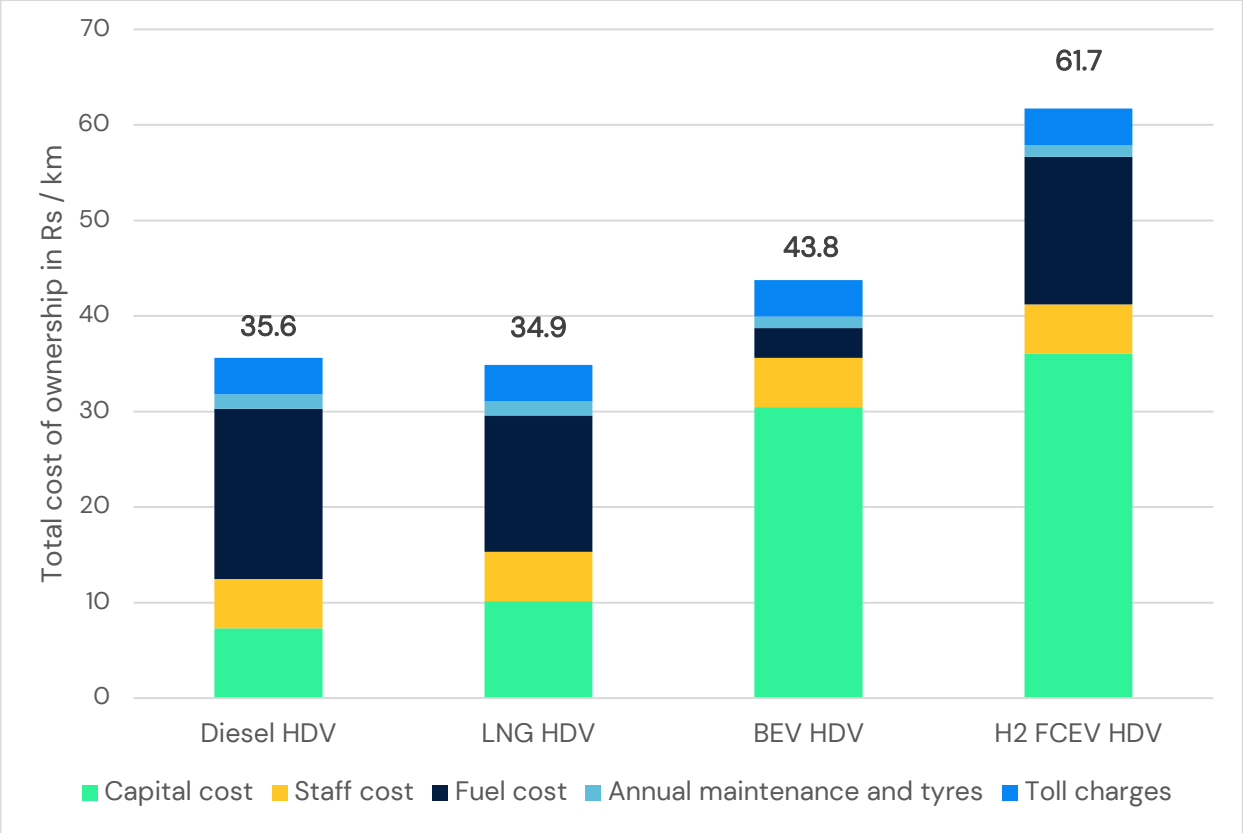


Figure 1: Total cost of ownership comparison between different fuel-powered HDVs

As can be observed, diesel and LNG vehicles have very similar total cost of ownership, while that for EVs and FCEVs are significantly higher. So, such high TCO presents a significant problem for the adoption of EV and H_2-powered FCEVs, at present.

Table 1: Detailed Comparison between different fuel-powered HDVs

	Diesel	LNG	BEV	H_2 FCEV
Total Cost of Ownership (Rs / km)	Rs. 34-36/km	Rs. 33-35/km	Rs. 42-44/km	Rs. 60-62/km
Upfront Cost vs Diesel HDV	1.0	1.5	4.2	5.1
Tank-To-Wheel CO_2 Emission Compared To Diesel	-	-5% to -10%	-20% (Current grid) to -65% (60% renewable grid)	+70% (Current grid) to -75% (100% renewable)
Refueling Time	< 10 min	< 10 min	4 hr to 7 hr	< 20 min
Range	800 km	560 km	800 km	400 km

	(275 L fuel tank)	(180 kg single cryogenic tank)	(800 kWh battery pack*)	(18 kg single H_2 tank)
Refueling Infrastructure	Existing	New LNG RO required, High Cost	New Charging RO required, Medium Cost	New LNG RO required, High Cost
User Familiarity	High	Medium	Medium	Low
Payload Penalty Compared To Diesel HDV	-	Nil	- (13 to 16) %	- 2%

As can be concluded from the above comparison, in terms of upfront cost, refueling time, and range, LNG vehicles outperform the electric and hydrogen options. Since the Indian market is extremely cost sensitive, the immense high upfront costs required for electric and hydrogen trucks act as impassable roadblocks in the current market situation. Even if the total cost of ownership (TCO) of e-HDVs might achieve some parity with diesel/LNG based HDVs in future, most fleet operators would not be accustomed to considering TCO when purchasing a vehicle, so they would perceive the cost of owning an e-HDV over time to be higher than it really is. Similarly, the need for expanded public fast charging would need to rise with the growth of EVs. However, the growth in the number of EV charging stations in the country has not been in concurrence with the growth of EVs. The adoption of EVs saw a significant rise in the country between FY20 and FY22, with EV sales rising 155% year-on-year to 4,29,217 units in FY22[39]. However, the number of operational public charging stations in the country stood at 1,640 towards the end of FY22, a rise of only 77% from June 2020[40]

Also, especially in the case of HDVs, for better range of vehicle, large batteries will be required, raising the weight of the HDV and possible lowering its payload capacity. This is a significant issue, especially for the transportation industry, where success of fleet operators heavily depends on their ability to transport as much payload as possible. Therefore, this could lead to hesitancy amongst the fleet operators to switch to electric HDVs. Meanwhile, such payload concerns are not present for LNG HDVs, and as the market develops, LNG HDVs could appear to fleet operators as a better option for switching their fleet away from diesel HDVs.

With large batteries, another cause for concern, comes from the time required to charge such batteries. Such concerns, over batteries and charging, could prove to be inhibiting for large scale EV adoption, and LNG HDVs could be preferred. Add to that, the range anxiety that most people associate with EVs, it could prove to be difficult to achieve significantly high market penetrations of EVs to either cause detriment or completely displace LNG or even CNG vehicles. Looking at the case of CNG adoption, we can observe that it took significant time to achieve an established CNG market. It was not purely driven by lower cost, but additional policy measures were also required to finally develop the market to a significant level. Similarly for LNG and other alternative fuel vehicles, it would be short-sighted to expect immediate market adoption and therefore, all different types of alternative fuel fleet might play a role in the vehicle mix of 2030. A key

[39] as per Federation of Automobile Dealers Associations' (FADA) data

[40] as per the Ministry of Power's data

point to note is that the technology for LNG vehicles is already present and no innovations are required to improve the viability of LNG HDVs from a technological standpoint. The only roadblock, in the case of LNG HDVs, is in the market development. Meanwhile, for EVs and hydrogen FCEVs, a significant aspect which is being taken for granted is that the viability of these vehicles completely depends on the assumption that significant technological innovation will take place in the coming 10 years, to solve all the present issues for these vehicles. Hence, the technology readiness level for EVs and hydrogen FCEVs is poor, along with their costs being high currently. In both these parameters LNG HDVs are ahead of its counterparts.

As technology advances, these roadblocks might eventually be removed but widespread adoption of e-HDVs might take long. Moreover, the process of shifting from traditional fuels like diesel to new age fuels would not be smooth considering the large share diesel currently witnesses in HDV market. Therefore, in the interim period of the coming decade, the focus should be on popularizing LNG as an alternative fuel to make the transition to decarbonization smoother.

Testing Methodology

The details of the various testing methodologies utilized in the reports is detailed below.

Transport & Environment

As per the methodology detailed by Transport & Environment[41], two IVECO tractor-trailers having a maximum gross vehicle weight (GVW) of 40 tons were chosen for the project. The truck specifications are given in the table.

Table 1: Truck Specifications in Transport & Environment study

Vehicle	Year of Registration	GVW (MT)	Payload (MT)	Engine (L)	Rated Power (kW)	Mileage (km)	Axle and body configuration
IVECO Stralis Euro VI - D	2019	28	12.5	11.1	353	216,224	4x2 tractor (Diesel)
IVECO S-Way Euro VI-D	2020	28	12.4	12.9	338	7,500	4x2 tractor (SI LNG)

Two test cycles were developed, namely: in-service conformity (ISC) test, and regional test. The ISC test is based on a typical on-road testing route used to check for pollutant emissions compliance, and covers urban, rural and motorway driving. Regional test represents regional supermarket delivery cycle. It also includes a mixture of urban, rural and motorway as shown in the table.

Table 2: Details of test cycles utilized in the study

Test Cycle	Distance (km)	Time (mins)	Driving Share (%)			Average Speed (km/h)		
			Urban	Rural	Motorway	Urban	Rural	Motorway
ISC	61.3	70.5	15	29	56	20.7	55.2	83.7
Regional	52.5	87.5	26	51	23	18.5	47.5	81.1

It was concluded that the tested LNG truck delivered much lower GHG savings than expected. Over a 100-year GWP, the LNG truck achieved a GHG reduction, including the non-tailpipe emissions (boil-off, refueling and maintenance) of around 8 per cent compared to the tested diesel truck. As explained in subsequent sections, the tank-to-wheel emissions, or the tailpipe emissions, reported are ~12 per cent lower for LNG truck as compared to diesel trucks. Meanwhile, the well-to-tank emissions (or the upstream emissions) reported are ~8 per cent higher for LNG trucks than diesel trucks. Combining the two, we arrive at the final emissions impact (also known as well-to-wheel emissions), which is reported as ~8 per cent lower for LNG trucks compared to diesel trucks.

ICCT

According to an ICCT report, ICCT had used vehicle simulation to assess the emissions of LNG HDV over various test cycles. The simulation tool used was VECTO, which is the tool used by the European Commission for CO_2 certification of HDVs. A simulation of VECTO's generic diesel tractor trailer was conducted. VECTO's

[41] Transport and Environment is a leading clean transport campaign group in Europe

standard diesel tractor-trailer was simulated over the regional delivery as well as long-haul cycles. Consistent with the CO_2 certification regulation for HDVs, two payloads were utilized in the simulations. A low payload of 2.6 tons was used for both the regional delivery and long-haul cycles. The high payload case used 12.9 tons for the regional delivery cycle and 19.3 tons for the long-haul cycle.

It was concluded that LNG trucks had a CO_2 advantage over diesel trucks. Stoichiometric SI NG tractor-trailers emitted 4.5-7.4 per cent lower CO_2 as compared to a diesel engine, depending on the LNG quality. HPDI NG tractor-trailers emitted 17.4-19.7 per cent lower CO_2 than diesels. However, the climate benefits were significantly reduced when non-CO_2 GHGs were included in the tank-to-wheel estimates.

CENEX

As per the procedure detailed in the CENEX report, the project deployed a total of 20 EURO VI vehicles, which consisted of CNG and LNG trucks using both spark ignition (SI) and compression ignition (CI) technology. Cenex was given the responsibility for monitoring the trials and evaluating the data collected. The trial vehicles travelled over 2.2 million km.

The project also conducted drive cycle tests to measure the emission and fuel consumption in a controlled environment. Two tests were organized as part of the project.

a) Tests performed by Emissions Analytics at the HORIBA MIRA tracks using Portable Emissions Measuring Systems (PEMS). The tests were performed at 60-100 per cent payloads.

b) Tests performed at Millbrook and commissioned by CENEX on a chassis dynamometer at 50 per cent payload. These tests included N_2O measurement and mass of PM.

The following table lists the PEMS drive cycle requirements.

Table 3: PEMS drive cycle requirements

	Long Haul	Regional Delivery	Urban Delivery	City Centre Delivery
Distance (km)	>20	>7.5	>7.5	>4
Average Speed (km/h)	>65	50-60	30-45	15-25
Stops/km	<0.2	0.2-0.7	0.8-1.2	>1.2
Aerodynamic Speed(km/h)	75-85	65-75	50-60	20-30
Characteristic Acceleration (m/s^2)	0.07-0.09	0.09-0.13	0.12-0.25	0.12-0.25
Kinetic Intensity (per km)	0.14-0.18	0.20-0.36	0.7-1.1	2.5-3.1

The study revealed an extremely interesting result. It was found that the total emissions, including tailpipe emissions and the upstream emissions for an LNG truck were higher by ~2 per cent as compared to the diesel truck. Though the tank-to-wheel emissions or the tailpipe emissions were reported as ~6 per cent lower for the LNG truck, the upstream emissions (well-to-tank), which were reported ~36 per cent higher in case of the LNG truck, overshadowed the lower tailpipe emissions.

TNO R11336

According to the TNO R11336 report, the emissions of two Euro VI LNG tractor semi-trailer combinations were measured on real-world test routes with portable emissions measurement equipment (PEMS). Several different routes were driven, and two different payloads were used. According to the European regulation, standard measurement equipment – PEMS – was utilized to assess the emissions of vehicles.

Each LNG vehicle was tested along various test trips that represented the typical deployment of such vehicles. Euro VI ISC trips, which are prescribed by the European emission regulation (N3) were also included.

Test Trips:

i. Reference trip, round trip Helmond – Eindhoven, 55 per cent payload, warm start

ii. Reference trip, round trip Helmond – Eindhoven, 55 per cent payload, only cold start until the engine warms up

iii. Euro VI trip (N3), conform EU regulation specifications, cold starts with 55 per cent and 10 per cent payload

iv. Representative trip for supermarket supply with 55 per cent and 10 per cent payload

v. To assess the impact of driving style for the vehicles, two trips with varying driving styles were measured for the vehicle with a manual gearbox

The following table details the test trip specifications

Table 4: Overview of test cycles utilized in the study

Test Cycles	Distance (km)	Average Speed (km/h)
Supermarket supply trip DC-supermarket	16.0	28
Supermarket supply trip supermarket - DC	16.0	28
N3 trip urban	16.5	22
N3 trip rural	48.2	55
N3 trip motorway	132.8	80
Reference trip	72.4	39

The results of the urban/rural/motorway driving were combined in the ratio, 15/25/60 per cent to represent average driving conditions.

The two LNG vehicles that were tested in the program were:

i. IVECO Stralis Hi-Road Euro VI 400 hp with an automated gear box

ii. Scania G340 Euro VI 340 hp with a manual gear box

It was concluded in the report, that tailpipe emissions were lower by ~5-10 per cent in the case of LNG trucks over diesel trucks. It was also reported that tailpipe emissions varied significantly with change in driving, and hence, emissions were higher for urban driving as compared to driving on the motorway, due to

more idling and a lower payload present in case of urban driving. The study reported that due to a lack of reliable data for emissions due to boil-off and leakage of LNG, an accurate analysis for the final emission impact of the trucks was not achieved.

TNO R10193

As mentioned in the TNO R10193 report, the test vehicle utilized was the VOLVO FH420 tractor with a EURO VI certified heavy duty dual fuel engine with LNG as the main fuel. For different PEMS tests, varying payload of 10 per cent, 53 per cent and 100 per cent were used.

A variety of test routes were driven, which are detailed below:

I. N3 route: the PEMS test route that is prescribed by EU emissions legislation for vehicles of category 'N3', GCW > 12t. The route was driven at varying payloads, and the process was repeated thrice to determine the total repeatability of the test.

II. Old N3 route: old version of the N3 route, which were used for earlier vehicles.

III. Representative route: This route represented the typical use of the vehicle. The route included highway driving, loading, city center, and back to highway.

Table 5: Overview of test cycles utilized in the study

Test Cycles	Distance (km)	Average Speed (km/h)
DC-DC operation conditioning	16	28
Supermarket supply trip supermarket - DC	16	28
N3 trip urban	23	23
N3 trip rural	41	57
N3 trip motorway	114	80

In the N3 route, time share of urban, rural, and motorway operation was taken as 20 per cent, 25 per cent and 55 per cent.

It was concluded in the study that over a long haulage route with a medium payload, the measured CO_2 emissions were 19 per cent lower than diesel trucks. The differential changed with different operations of driving. During the motorway operation, the LNG truck released 23 per cent lower CO_2 emissions, while during the urban driving operation, the LNG truck released 8 per cent lower emissions as compared to the diesel trucks. It was also reported that a significant concentration of N_2O was present in the exhaust, though the level of emission was not determined. The report, therefore, advised that in future studies, N_2O emissions of vehicles also need to be tested.

Assumptions in Financial Analysis of LNG Retail Outlets

LNG cost price assumptions and build-up

Gas purchased from LNG imports is priced at prices as defined under the contracts. At present, multiple long-term LNG contracts with a total volume of close to 20 MMTPA are signed by various entities in India. More than 25 per cent of this long-term volume is linked to Henry Hub, whereas the remaining is linked to Brent crude oil, thereby creating a mix of contracts. India occasionally receives spot cargoes of LNG at current market prices. India's dependence on spot-, short-, or medium-term LNG imports has increased considerably, climbing to around 55 per cent of the total imports.

LNG Pricing: Methodology for Deriving Retail Price

I. The LNG pricing (in $/MMBTU) is derived considering a per cent of slope over Brent crude price ($/Barrel) as Delivered Ex-Ship price (DES price) of LNG in India

II. The import duty is levied followed by storage and handling charges by the port over the DES price

III. A per cent of the escalation price is charged over the gross price of LNG for loading the LNG to cryogenic tankers for further transport

IV. This is followed by levying transportation charges, inclusive of GST

To assess the LNG transport charges, the following methodology was considered:

- Based on identified cities for setting up LNG retail outlet, the nearest LNG terminals were identified, and the distances from these terminals were calculated
- Travel time and delay in onward and return trip was assumed considering the distance calculated, and the average speed was considered for the HDVs
- Based on the above information, the total run per year per truck was calculated and the operation cost was assessed based on the total annual cost and the cost per ton of LNG

Computation of Diesel Selling Price

During the period from 1976 to 2002, based on the recommendations of the Expert Committees, the pricing of petroleum products was brought under the Administered Pricing Mechanism (APM), which was based on cost plus principle, under which all kinds of cost (pricing, refining, marketing. etc.) are included. However, APM was found to be increasingly unsuitable for the long-term growth and efficiency of the oil industry. Therefore, the Government of India constituted a Strategic Planning Group on Restructuring of the Oil Industry (A-Group) for developing a financially sound and internationally competitive hydrocarbon sector. Based on the report of the A-Group (September 1996), the government decided to abolish APM in a phased manner from April 1998 to March 2002, replacing the 'cost plus' pricing of petroleum products with the Import Parity Pricing (IPP). Subsequently, in June 2006, the government changed the pricing of petrol and diesel from IPP to Trade Parity Pricing, i.e., 80 per cent of IPP and 20 per cent of Export Parity Price (EPP).

After dismantling APM in April 2002, since the prices of petroleum products were linked to international prices, the public sector oil marketing companies (OMCs) carried out revision in prices of petroleum products in line with international prices. However, in view of the continuous increase in oil prices in the international market since 2004 onwards, the government started modulating the retail selling prices of sensitive petroleum products, including diesel. The government maintains the retail price through excise duty when the crude prices go up or down (as witnessed recently amid fluctuating crude prices).

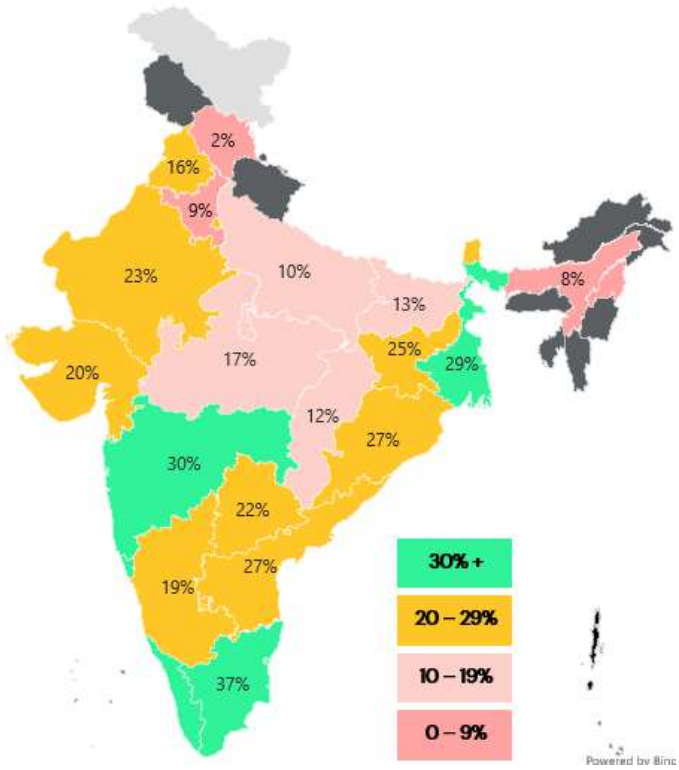
The following are the major components which are added to arrive at the final retail selling price of diesel:

- **Diesel FOB:** Free-on-board price for diesel means the price at port when a fuel is imported. The buyer has to bear the shipping prices for transportation.
- **Ocean Freight**: The ocean freight rate covers all the transportation cost of the fuel. It is dependent on the location from where the fuel is being shipped and the destination.
- **Import Charges**: Import charges include insurance costs, which are to be taken up by the shipping entity in case of any fuel losses while shipping, which can result in huge economic losses. Port handling charges are also factored in import charges.
- **Customs Duty**: Custom duty is a tax levied by the government on import/export of commodities. It regulates the movement of goods in and out of the country, and ensures a country's economic stability with creating a balance between domestic goods and imported goods.
- **Import Parity Price:** IPP represents the price that importers would pay in case of actual import of diesel at the respective Indian ports.
- **Export Parity Price**: Export parity price represents the price which oil companies would realize on export of diesel i.e., FOB price of product plus advance license benefit.
- **Inland Freight & Delivery charges**: These charges consist of costs involved in transporting fuel from refineries to the retail outlets. Usually, heavy tonnage tankers are used for inland deliveries.
- **Marketing Cost and Margin of OMCs**: Oil marketing companies launch a host of sales promotional schemes like discounts, loyalty programs, and media commercials to garner a higher share in the market.
- **Excise Duty on Diesel:** This is a form of indirect tax that is levied on goods that have been manufactured in the country. It is levied by the government, and ideally has to be paid by the manufacturer of goods at the time of introduction of goods into the market. Excise duty by government usually makes up 40-50 per cent of the total retail cost for diesel.
- **Dealers Commission**: Dealers get a commission for selling every liter of diesel from OMCs. These commissions are a method of incentivizing the diesel sales for the dealer.
- **VAT:** A value added tax (VAT) is a consumption tax placed on a product, whenever value is added at each stage of the supply chain, from production to the point of sale. The amount of VAT that the user pays is on the cost of the product. Unlike excise, VAT is a tax controlled by the state governments. As every state has its own VAT rates, so the retail price of diesel changes from state to state.

While there is a link between LNG price and crude price as can be seen in the price build-up of the LNG cost price, the value of LNG selling price can be much lower in comparison to the diesel price. That's because it would depend on several factors, such as the distance of the LNG retail outlet from the LNG terminal and the VAT rates applicable. The imported LNG could be available at a considerable discount (15-20 per cent) when compared to diesel. With this discount, fleet operators could save on running costs and potentially save on higher capital costs incurred toward the purchase of an LNG-run truck.

The following India map shows the state-wise variation in how much fuel price differential can be offered due to differences in LNG transport cost and VAT[42]:

[42] Analysis done as per state VAT rates applicable in December 2021



Analysis suggests that achieving more than 20 per cent differential in fuel price (LNG vs diesel) is not viable since the margins of the energy company would take a hit amid rising crude prices, thereby increasing LNG cost prices, too. LNG sourcing via spot- or short-term contracts could further erode its viability and reduce the fuel price differential which can be offered to consumers.

Figure 1: State-wise variation in how much fuel price differential can be offered

Methodology on Arriving at Final Retail Price of Diesel and LNG:

i. Based on historical regression between the Indian crude basket and diesel FOB prices, the diesel base price was computed and forecast for the next 20 years. An OMC spread (including inland freight and marketing margin) was charged; this cost varies and is in the range of Rs 5-7.

ii. Excise duty was then levied as per the current rates. Dealer's commission charges on gross diesel price was taken as Rs 2.58/liter[43] for base year.

iii. To arrive at the diesel RSP, state-wise VAT rate was then levied along with any cess/surcharge, or additional VAT applicable as per the states. For the purpose of financial analysis, an average of all state VAT rates was considered.

[43] https://iocl.com/uploads/priceBuildup/PriceBuildup_diesel_Delhi_as_on_1_Mar-2021.pdf

Pricing Mechanism (Build-up) of Diesel and LNG Retail Prices

Following tables show the detailed computation of the cost price of LNG and selling price of Diesel as well as LNG. The computation has been provided for the ***year 2040.***

Table 2: LNG Cost price assumptions and build-up

Price Build-Up factors	Units	Scenario 1	Scenario 2	Scenario 3
Brent Forecast[44]	$/bbl	60	80	100
Slope	%	12%	12%	12%
DES price	$/mmbtu	7.20	9.6	12.00
Import duty	$/mmbtu	0.20	0.26	0.33
LNG delivered to port	INR/mmbtu	802.02	1069.35	1336.69
Storage handling and truck loading charges	INR/mmbtu	151.62	151.62	151.62
Transport charge	INR/mmbtu	177.38	178.70	179.67
GST on Transport charge@12%	INR/mmbtu	21.29	21.44	21.5
Cost Price of LNG	INR/mmbtu	1152.30	1421.11	1689.5
Cost Price of LNG	**INR/kg**	**58.8**	**72.5**	**86.2**

Table 3: Diesel and LNG price build-up

Price Build-Up factors	Units	Scenario 1	Scenario 2	Scenario 3
Brent Forecast[45]	$/bbl	60	80	100
Indian Crude Basket [46]	$/bbl	58.51	77.49	96.5
Diesel FoB	$/bbl	67.71	89.40	111.12
Diesel FoB	INR/litre	46.17	60.95	75.74
OMC Spread (includes inland freight, delivery charges and marketing margin)	INR/litre	5.43	5.43	5.43
Diesel price before excise	INR/litre	51.60	66.38	81.17
Excise Duty	INR/litre	21.80	21.80	21.80
Dealers' commission (average)	INR/litre	6.52	6.52	6.52
VAT[47] (includes VAT on dealer's commission)	INR/Litre	13.39	15.86	18.34
Diesel Retail Selling Price	**INR/litre**	**93.30**	**110.57**	**127.83**
Discount to diesel	%	20%	20%	20%
LNG Retail Selling Price	**INR/kg**	**78.37**	**92.9**	**107.4**

[44] World Bank CMIE Forecast, October 2021

[45] World Bank CMIE Forecast, October 2021

[46] Based on historical regression
[47] Average of State VAT Rates

Assumptions on Capital and Operating Costs

The following tables list out the various capex and opex components considered in the model for operation of the LNG/LCNG stations. The major capex components considered in the model apart from land were CNG dispenser, LNG storage tank, and LNG dispenser and compressor.

Table 4: Various capex components considered in the model for operation of LNG/LCNG stations

Capital Costs	Unit	Value
LNG Equipment		
LNG Storage bottle	INR Crores	1.00
Offloading Skid	INR Crores	0.40
LNG Dispensing Pump	INR Crores	0.85
Saturation Skid	INR Crores	0.80
LNG Dispenser	INR Crores	0.90
LCNG Equipment		
LCNG Pump and Compressor	INR Crores	1.25
LCNG High Pressure Vaporizers	INR Crores	0.50
LCNG Dispenser	INR Crores	0.18
CNG Buffer storage (Cascades)	INR Crores	0.40
Other LCNG station equipment	INR Crores	0.50
Miscellaneous		
Miscellaneous capex items	INR Crores	2.20
Civil Works		
Civil Works	INR Crores	1.00

Based on the above assumptions, the total capital expenditure for LNG and LCNG station facilities was computed at **INR 7.15 crore** and **INR 9.98 crore,** respectively. Based on a **D/E ratio of 70:30**, the debt and equity components came out to be Rs 5 crore and Rs 2.15 crore, respectively for LNG station, and Rs 6.98 crore and Rs 3 crore for an LCNG station.

Table 5: Various opex components considered in the model for operation of LNG/LCNG stations

General Operating Costs		Value	Y-O-Y Escalation (%)
Manpower	INR lakh/month	6.3	3
Power	INR lakh/month	1.2	3
Land lease payment	INR crore/year	1.0	1

Assumptions on Traffic and LNG Volume handled by LNG Station

The number of trucks catered by the LNG station in the first year was considered as 50, beyond which the number was assumed to be increasing by five every year. To compute the corresponding LNG volumes, the standard values were considered for the following factors:

- LNG flow rate[48]: 60 kg/min
- Fuel tank capacity of truck: 180 kg
- Total time in filling of 1 LNG truck: 10 minutes
- Capacity of LNG storage tank: 25 tons
- Days of operation of trucks in a year: 330 days
- Daily run of trucks: 250 km
- Truck mileage: 3.15 km/kg

Sensitivity Analysis for LNG Station Model

It should be noted that based on site specific conditions, the project costs could vary by a factor of +-20 per cent. That said, if the current site conditions and external factors would more or less remain constant at the time of construction of the project, the assumptions listed above would lead to the project outcomes as projected through financial analysis.

Under the financial model prepared, sensitivity could be run on several factors so that the user is able to assess the profitability of the project under different scenarios. Some of these factors are-

- LNG discount to diesel price
- Traffic (Number of trucks arriving at station)
- Capital costs
- Operating Costs
- LNG slope to crude oil

[48] Based on average of maximum LNG Flow Rates of LNG Stations under the Blue Corridors Project of Europen Commission

List of fleet operators engaged in this study for the stakeholder discussions:

Fleet Operator	Fleet Size (HDVs)	Business Domain	Geography
TCIL	~1,200	Vehicle carriers, bulk commodities, FMCG, project cargo	50 hubs PAN India, deploys around 12,000 trucks (90% on lease) daily across the country
Indian Tankers	~600	Liquid bulk and chemicals (ethanol, oils, molasses, and acids)	Gorakhpur, Bareilly, Lakhimpur, Lucknow, Kanpur (90% fleet) Bihar, Uttaranchal, Delhi, Haryana
EFC Logistics	600+	FMCG, steel, tires, polymers	Kolkata – Bangalore Kolkata – Cochin Kolkata - Mumbai
Om Logistics	~600	Automotive, FMCG, manufacturing, appliances, energy, fashion	Pan India coverage
Freight Co.	~300	FMCG, beverages	Kolkata-Bombay Kolkata-Delhi
Seros Logistics	~250	LNG tankers, packaged goods, chemicals	PAN India coverage
Bharat Roadways	~230	Industrial, FMCG	Kolkata – Jamshedpur, Gujarat, Chennai, Bangalore, Mysore, Cochin
Delhivery	~200	Agriculture, Commodity, Corporate, Internal, Transporter	Delhi – Bangalore, Ahmedabad, Surat, Mumbai
Sure, Eco Motion	~110	Rice, coal, cement	Karnal-Kandla
CCI Logistics	~100	Pharmaceuticals, FMCG	Mainly North, West and South India

Description on Tata Motors Model on LNG

TATA MOTORS
Connecting Aspirations

TATA

for immediate use **PRODUCT NOTE**

TATA LPO 1613 LNG

Tata Motors is a leader in heavy duty and light duty natural gas vehicles in Indian market and a leading vehicle manufacturer globally. Tata Motors has always been at the forefront of innovation providing products and mobility solutions catering to discerning needs of the society. Taking a leap Tata Motors displayed LNG technology on TATA PRIMA Truck at Auto Expo 2014 followed by the country's first LNG Powered bus in November 2016 at Kerala. LNG is the cleanest form of alternate fuel, which is much safer than conventional fuel and CNG.

TATA LPO 1613 LNG – Tata Motors is the first OEM to Offer a Passenger Vehicle with Integrated LNG system for Indian market. This is a Standard floor height Bus (1100 mm), built on LPO 1613 platform for City application with improved TCO, increased utility space, best in class NVH and Safety. It is environmental friendly with 30% lesser Greenhouse gases emission. It offers best in class fuel economy as LNG is the cheapest fuel available and has high density. It contains enhanced safety features such Fuel and vapour shut off valve, Excess flow valve, Primary and secondary relief valve. A single LNG tank used in the vehicle results in increased range, lesser complexity of operation and lower maintenance. The LNG tank and LNG system has been approved by PESO.

USP:

- Offer Higher Range - LNG has 2 times range of the fuel density of CNG.
- LNG operates at lower pressure - as operating pressure for LNG is 15 bar against CNG of 200 bar.
- LNG is more safe - evaporates quickly and being lighter than air it does not stick around it to catch fire.
- Faster fill times - 50% faster for LNG than for CNG.
- Best in class TCO

Applications:

- City Application

Technical Specifications:

Parameter	Description
Engine	TATA 5.7 SGI Bharat Stage IV- IOBD-II
Max Power	96 kw(130PS) @ 2500 RPM
Max Torque	405Nm (41.3mkg) at 1250-1500 RPM
Clutch Type	330 Dia
Gear Box	GBS 40- 5speed synchromesh+1 reverse
Front Axle	Rigid front axle
Rear Axle	RA 109RR heavy duty, hypoid gears, fully floating axle shafts
Suspension	Front & Rear Parabolic Suspension
Frame	Ladder type heavy duty frame

Body	Marcopolo Body
Battery	2x12V, 150 Ah
Fuel Tank Capacity	400 Ltr (LNG Tank)
Tyre	295/80 R22.5 – 16PR
Wheel Base	5800 mm
Max Speed	70.41 kmph
GVW	16200 Kg
FAW	6000 Kg
RAW	10200 Kg
Kerb Wt. (chassis)	6000 Kg
Gradeability	26.14 deg.
Restart Gradeability	24.34 deg.
Seating Capacity	55+D in 3x2 High Back Reclining Configuration

Computation of Gross margins for OEMs – Ashok Leyland and Tata Motors

Ashok Leyland

	2018-19	2019-20	2020-21	2021-22
Total Revenue (INR cr)	29654	18320	15836	22300
Revenue from vehicles (INR Cr) - ***A***	26243	15281	12795	18744
Revenue from spare parts (INR Cr)	3411	3039	3041	3556
Total Materials cost (INR Cr)	21680	11164	11769	16619
Estimated spare parts cost* (INR cr)	2729	2431	2433	2845
Procurement cost excluding spares (INR Cr) - ***B***	18951	8733	9336	13774
Gross margin % (using A and B)	**27.8%**	**42.9%**	**27.0%**	**26.5%**

**assuming 25% margin in sale of spare parts, considering industry average*[49]

Tata Motors

	2018-19	2019-20	2020-21	2021-22
Sales (#)	151004	75918	58528	88191
Revenue (INR Cr)	29863	14006	13808	21759
Procurement cost (INR Cr)	21103	10688	10191	17978
Gross margin % (using A and B)	**29.3%**	**23.7%**	**26.2%**	**17.4%**

**assuming 25% margin in sale of spare parts*[50]

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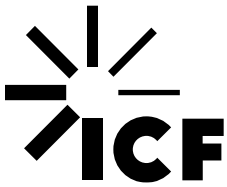
[49] https://www.mckinsey.com/industries/advanced-electronics/our-insights/industrial-aftermarket-services-growing-the-core



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