BATTERY ELECTRIC TECHNOLOGY IN THE HEAVY-DUTY VEHICLE SEGMENT

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Potential and Impact of Electrification of Medium and Heavy-duty Vehicles

Introduction

While the transport sector generates massive positive externalities namely, enabling mobility and job creation, it also contributes significantly to India's import burden, GHG emissions and air pollution. Transport sector accounts for the largest share in terms of consumption of petroleum products in India— nearly 70% of diesel and 100% gasoline are consumed by the transport sector (PPAC, 2014). In the last one decade, the use of oil by India's transport sector has risen by as much as 91%. About 90% of the total energy demand has arisen from the road transport sector, followed by rail and air[1].

As per The Energy and Resources Institute (TERI) estimates, the current total energy demand from the transport sector is about 90 million tonnes of oil equivalent (Mtoe). During the last two decades (between 2000 and 2020), India's oil demand which has arisen from the road transport sector has recorded the highest growth in the world. It is important to note that India's dependence on import to meet its fuel demand is as high as 85%[2].

Indian transport sector also plays a critical role in achieving the targets – reduce the emissions intensity of Gross Domestic Product (GDP) by 33–35% over 2005 levels, by 2030 – set under the nationally determined contribution (NDC)[3]. As per TERI estimates, it is estimated that the transport sector has a huge potential in energy savings – 40% by 2030 – mainly on account of electrification of vehicles and shift from private to public transport.

India's freight transport is dominated by the road sector, with about 70% of the total freight, in terms of net tonne km being moved by road (TERI, 2015). Within road,

Table 1:

India's road freight sector at a glance (2020-21)

Details	All energy sectors	Transport	Road Freight
Oil use (primary energy) / energy consumption (final energy) (PJ)	32,732	6,248	2,207
Carbon dioxide emissions (million tonnes)	2,611	419	NA
Freight activity (in BTKM)	–	–	2,791

Source: TERI

about 60% of the total freight transport demand is contributed by the medium and heavy-duty vehicles (MHDVs), while remaining by the light duty vehicles (LDVs). The rapid rise in share of road transport in India, especially in the last two decades, could be explained by factors such as – rapid economic growth, substantial improvement in highway infrastructure, inherent advantage of providing door-to-door service, and capability of transporters to provide customized solutions to the customers.

Reducing emissions from the sectors including – medium/heavy-duty long-distance transport, aviation and shipping, which constitute the 'hard to abate (HTA)' sectors will remain critical. The efforts in this direction will be vital in achieving India's as well as global emission intensity reduction target set under the NDC.

Vehicle Classification

According to MoRTH classification, there are two types of vehicles: transport and non-transport. Freight vehicles such as multi-axle vehicles, lorries, trucks, and light duty vehicles fall under the category of transport vehicles and are meant to be used as commercial vehicles. Other vehicles such as trailers and tractors fall under non-transport vehicles category and are used for carrying heavy goods. Further, transport vehicles like multi-axles vehicles, lorries, and trucks within the segments can be categorized into Medium or Heavy-Duty Vehicles (MHDVs) depending upon the Gross Vehicle Weight (GVW) and Tonnage. The report focuses on MDVs and HDVs (MHDVs) in India. *The definition of MHDVs is same in China as well.*

MDV: GVW > 3.5 tonne and < 12 tonne
HDV: GVW > 12 tonne

The focus of this study is to look into the current status as well as potential of electrification of MHDVs in India. It also looks into the progress China has made in this particular sector. The following section discusses the HTA sector – long-distance road transport involving MHDVs – in detail, including factors which could be considered as impediments to decarbonize the transport sector.

Heavy duty – Long distance trucking

As per TERI, it is estimated that India has over 55 lakhs on-road HDVs and the number of trucks added per year is increasing at rapid rate. The trucking sector also accounts for the largest share in diesel consumption. Of the 74% of the diesel consumed by the entire transport sector in India, HDVs and LDVs accounted for 33% (2014-15)[4].

What makes this sector HTA?

There are a number of areas, which need to be explored in the process to decarbonize the long-distance trucking/HDV sector. Some of these have been listed below.

- **Financial viability:** Better understanding of the commercial viability of deploying alternate fuel run vehicles will be critical. Commercial viability of electric HDVs[5] and semi-trucks[6] has been demonstrated across various regions of the world. However, such proof of viability is absent for the Indian case.

- **Infrastructure:** One of the biggest concerns is the availability/setting up of infrastructure along the highways supporting electric mobility or alternate fuel for the trucking industry. Better understanding of the fuel related ecosystem involving demand and supply sides is therefore pertinent.

- **Technical viability:** Availability of HDVs catering to the needs of the operators (assessing the trip distances vis-à-vis battery sizing, etc.).

- **Ownership pattern:** The ownership pattern of trucks is another challenge – more than 3/4th of the trucks are owned by people having less than 5 trucks. This would have significant implication on the affordability of such owners to deploy electric/hydrogen-fuel based trucks. Therefore, large fleet owners would be the target customers for electric/hydrogen-fuel based trucks.

- **Resale value:** The rate of electric trucks in secondary market/second-hand market will also be critical in determining the success of alternate technologies.

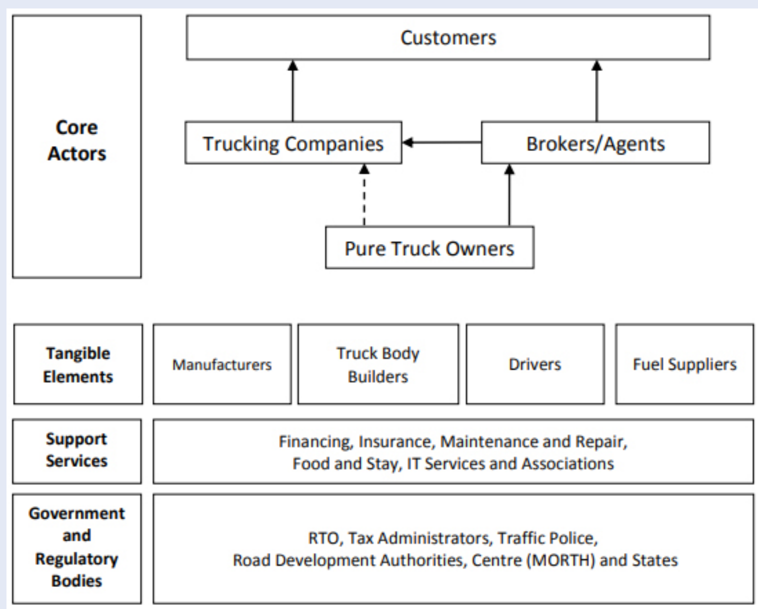
- **Driving condition and its effect on efficiency of alternate-fuel run HDVs:** Besides climatic condition, Indian road and traffic conditions will also play a determining role in the penetration of alternate technologies.

Market assessment

This section includes a detailed market assessment of both India and China MHDV sector. It includes analyses of the production and sales trends of MHDV sector in both the countries and detailed information regarding the current major players/Original Equipment Manufacturers (OEMs) and their MHDV models available in the market.

Indian Trucking Operation

- Indian truck transport is a dependent and fragmented business. At present, there are 55 lakhs trucks and trailers in the country.
- Operation on medium and long routes through national permit, inter-state and intra-state, there are almost 40 lakh drivers and 25 lakh helpers. Of this, almost 90% do not have any legal/socio-economic protection of minimum wages, etc. as prescribed under the Motor Transport Workers Act, 1961.
- The ownership profile has changed over the decades. From '95% of fleet owned by truck owners with less than 5 trucks in 1980s' to '75% of the fleet owned by truck owners with less than 5 trucks in 2010s'. It is quite clear that there is no fresh study conducted to estimate the ownership pattern in the Indian trucking industry. Based on recent developments in the industry and discussion with stakeholders, the authors believe that consolidation of fleet has been increasing significantly.
- Diesel and tires put together are 90% of the total variable expenses of truck operators. A number of medium and large truckers have the option of deferred payment facility for diesel and tires. The deferred payments are through oil cards and liberal credit by tire dealers on tire purchase, with 4-6 week credit.
- The Government of India has rolled out multiple initiatives, which have resulted in improvement in efficiency of trucking industry and operations. These include implementation of GST e-way bill, which has reduced the need for stoppages and spontaneous inspection, and RFID-based toll payment system and toll lanes (FASTag) that have reduced congestion at the toll plazas across the Indian national highways.



Source: (Raghuram, 2015)

- Replacement demand (purchase of new trucks to replace the heritage trucks) has picked up because there is very little repossession of Bharat Stage (BS)-4 trucks. As a result, there is a short supply of old trucks (2- 5 year old) in the market as their prices are up by 10-15% in second hand MHDV market across India.
- With higher activities in the cement sector and infrastructure projects, and exports, fleet utilization was reported to be over 75% as of June 2021 which has increased to 80-85% in March 2022.
- Other key cost for the truckers is the insurance premium and road/toll taxes. Since 2019, the Government has not allowed the Motor Insurance premium to be revised upward to protect the truckers. Further, road taxes, state and national permit free and fitness renewal fees were also not revised during the ongoing pandemic – March 2020 - till date (August 2021).

India

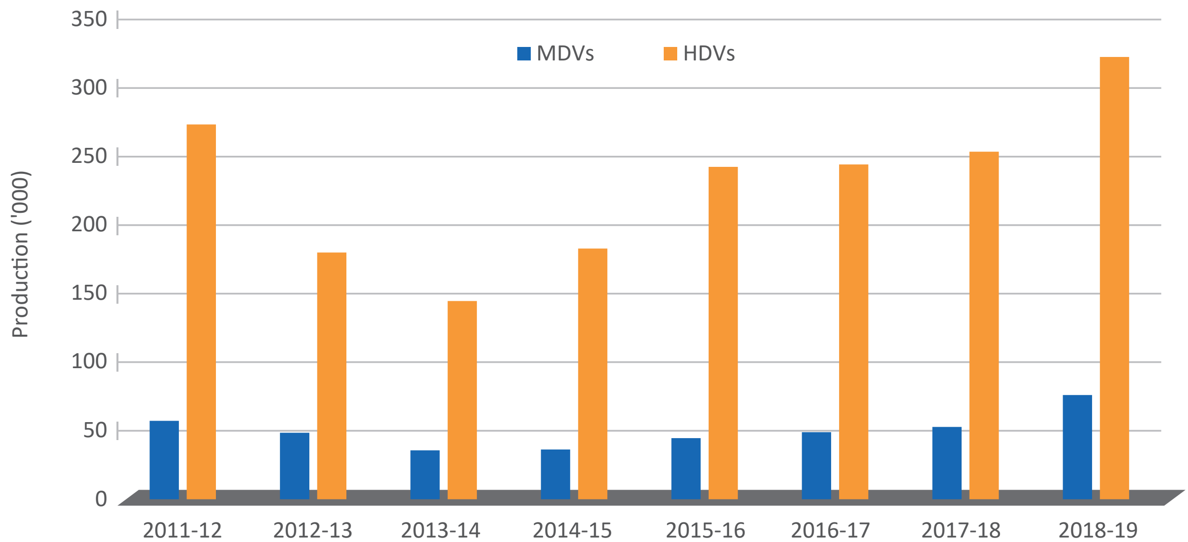
India has emerged as a hub for commercial vehicles in the last two decades. The upgrade in the technical advancement in this sector has really shaped-up the Indian commercial markets. The production capacity on the Indian MHDV market has doubled in the last five years. The sale of MHDVs also doubled during the same period. There was a slight shift in sales between engine sizes 2.5 ltr and 4 ltr, and 4.5 and 8 ltr, where sales of the smaller engine-vehicles declined while sales improved in the larger size category. The vehicle capacities witnessed advancements with increase in efficiencies and safety features as well. Emission standards were revised recently keeping in mind the environmental safety.

Production and sales: MHDV

The impact of COVID-19 in the production and sales has been adverse for the commercial segment, including the light-duty vehicles (LDVs). As per SIAM, production of commercial vehicles declined from 756,725 units in 2019-20 to 624,939 units in 2020-21, while the sale of commercial vehicles declined from 717,593 units in 2019-20 to 568,559 units in 2020-21.

This section looks at the production trend of MHDVs in detail from 2011-12 to 2018-19, and market share of sales for 2019-20 has been analysed to get the most recent picture. The historic analysis of production of HDVs shows that despite significant increase in the number of units sold, the sector has observed a slight decline in the production from 82.7% in 2011-12 to 80.9% in 2018-19 of the total production. On the other hand, the production data of MDVs shows a slight increase from 17.3% to 19.1% during the same span of time. However, HDVs continue to dominate the MHDV sector in terms of absolute numbers, which reflects the nature of traffic in India (Figure 1).

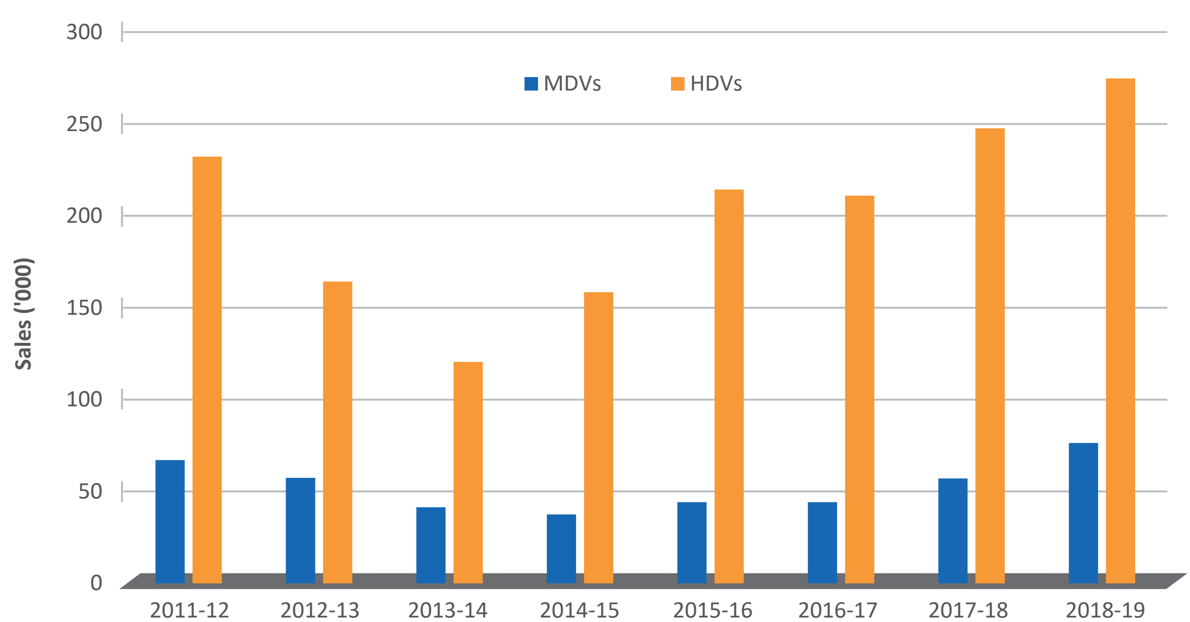
Figure 1: Production of MDVs and HDVs in India



Source: SIAM

As per Society of Indian Automobile Manufacturers (SIAM), domestic sales trend of MHDVs from 2011-12 to 2018-19 were found quite similar to the production trend for the same period. The domestic sales of HDVs continued to grow within the segment but the domestic sales declined for MDVs during the same time period. The share of domestic sales of MDVs declined from 22.4% in 2011-12 to 21.8% in 2018-19, while the share of HDVs in domestic sales increased from 77.6% in 2011-12 to 78.2% in 2018-19 (Figure 2).

Figure 2: Sale of MDVs and HDVs in India



Source: SIAM

Domestic production – company-wise

The major players in the MHDV sector in India are Tata Motors Limited, Ashok Leyland Limited, Mahindra & Mahindra (M&M) Limited and Volvo-Eicher Commercial Vehicles (VECV) Limited. Tata Motors and Ashok Leyland have dominated the HDV production, followed by VECV[7] and M&M.

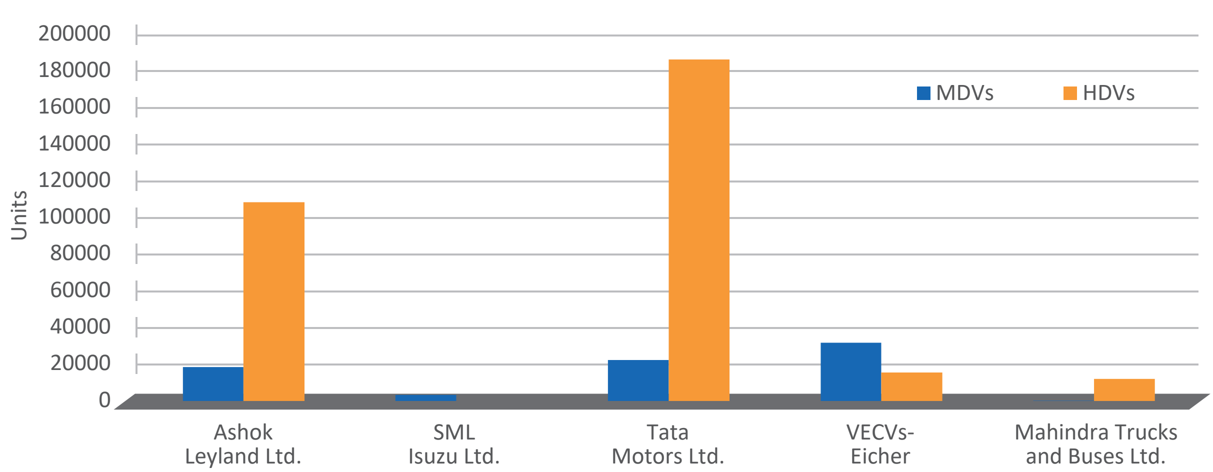
Unlike the HDV sector, VECVs-Eicher which is a subsidiary of Eicher Motors Ltd. has dominated the MDV sector in the last 6-7 years followed by Tata Motors, Ashok Leyland and SML Isuzu Ltd.

Tata Motors reported about 1.9 lakh units production of HDVs in 2018-19, while Ashok Leyland reported 1.08 lakh units during the same year, followed by VECVs-Eicher, and M&M. VECVs-Eicher Ltd. is the top manufacturer of MDVs with approximately 0.32 lakhs units produced in 2018-19, while Tata Motors produced 0.22 lakhs units, Ashok Leyland 0.19 lakhs units and SML Isuzu 0.03 lakh units (Figure 3).

Domestic sales – company-wise

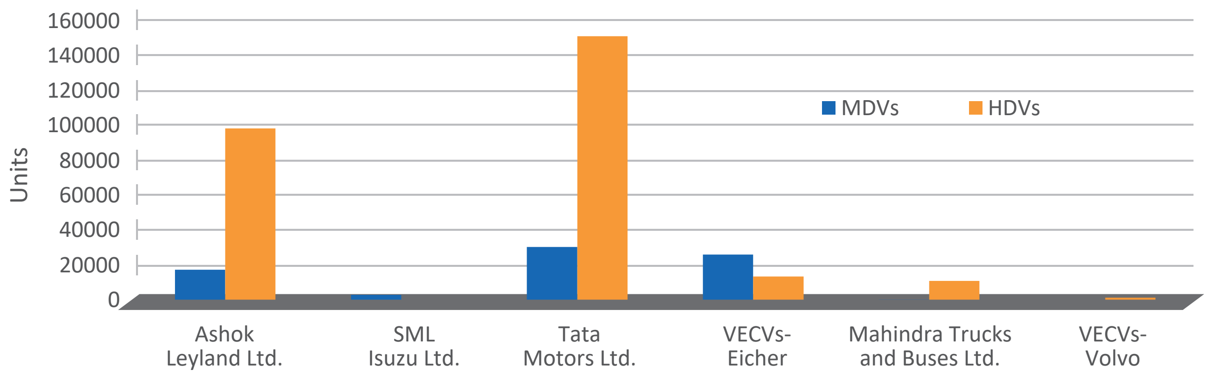
Similar to the production trend, Tata Motors, Ashok Leyland, Volvo-Eicher and Mahindra & Mahindra dominate the MHDV sales. In the HDV and MDV sectors, sales is dominated by Tata Motors, with about 1.5 lakhs units sold in 2018-19, followed by Ashok Leyland with 0.98 lakh units, VECVs-Eicher 0.13 lakh units, M&M 0.11 lakh units, and VECVs-Volvo 0.01 lakh units. In the MDV segment, Tata Motors sold 0.26 lakh units, followed by Ashok Leyland - 0.17 lakh units, SML Isuzu - 0.03 lakh units, and M&M sold 0.002 lakh units (Figure 4).

Figure 3: Total Production of commercial vehicles in India (Manufacturer -wise) 2018-19 (In Nos.)



Source: SIAM

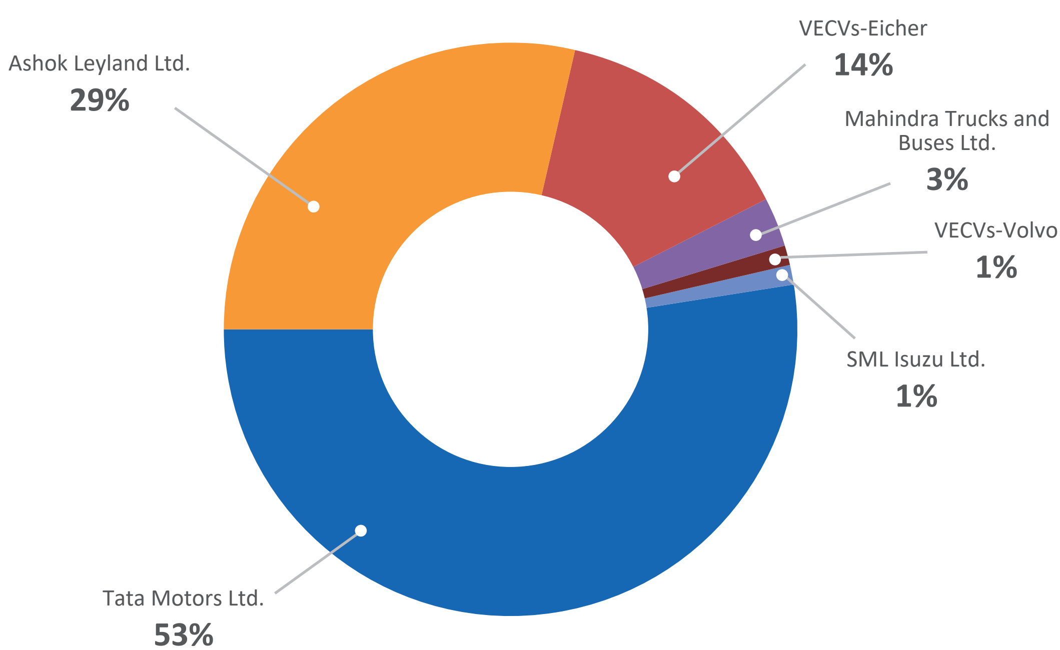
Figure 4: Annual domestic sales of commercial vehicles in India (Manufacturer -wise) 2018-19 (In Nos.)



Source: SIAM

Tata Motors dominates the MHDV market in India with about 53% market share in terms of total sales. As indicated in Figure 5, other key commercial vehicle manufacturers are Ashok Leyland, Volvo-Eicher, and M&M. We see that the share of Tata Motors and VECVs-Eicher increased by around 2% each, while the share of Ashok Leyland and VECVs-Volvo decreased by 4% and 1%, respectively, in the last five years.

Figure 5: Market share of MHDV manufacturers - 2019-20



Source: SIAM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NATIONAL PERMIT
ASHOK LEYLAND

Table below comprises of the MHDV models by the top five OEMs that are currently available in Indian market, with their gross vehicle weights (GVWs), engine specifications and fuel type. Tata Motors being the top manufacturer has a wide variety of models present in the current market followed by Ashok Leyland, M&M, Eicher Motors and Bharat Benz - which is a brand of Daimler India Commercial Vehicles (DICV), a wholly-owned subsidiary of Germany-based Daimler AG. The table also shows the dominance of diesel-operated vehicles in the Indian market despite having new technological interventions in other low-carbon fuels like LNG and CNG.

Table 2: Manufacturer-wise HDV and MDV models available in Indian market

Company Name	Vehicle type	Model Name	GVW	Engine Specification	Fuel Type
HDVs					
Tata Motors Ltd.	Rigid trucks[8]	ULTRA	18500 kg	TATA 5.0L Turbotronn BS6	Diesel
	Rigid trucks	LPT	18500 kg	Cummins ISBe 5.6 L | TATA 5.0L Turbotronn	Diesel
	ILCV[9]	LPT	13850kg | 16020kg | 13850kg	3.3L | 3.8L	Diesel | CNG
		ULTRA	14010kg | 16020kg | 16190kg	3.3L | 5L	Diesel
	Rigid trucks	LPT (COWL & SIGNA)	28000 kg | 35000 kg | 42000 kg | | 47500 kg | 49000 kg	Cummins ISBe 5.6 L | 5.0L Turbotronn | Cummins ISBe 6.7L | Cummins ISBe 6.7L | Cummins ISBe 6.7L	Diesel
	Tractor trailers[10]	SIGNA	39500 kg | 45500 Kg | 55000 Kg | 51000 Kg-55000 Kg (GCW)	Cummins ISBe 5.6L | Cummins ISBe 6.7L | Cummins ISBe 6.7L	Diesel
Ashok Leyland	ICVs	Boss	13,100 kg | 14,050 kg	H series CRS with iGen6 Technology	Diesel
		Ecomet	14,050 kg | 16100 kg	H series 4-cylinder CRS	Diesel
	Haulage	1920 | 2820 | 3520 | 4220 | 4225 | 4825	18500 Kg | 28000 kg | 35000kg | 42000kg | 47500kg	H Series, 6 Cylinder, CRS with iGen-6 Technology | A series CRS with iGen6 Technology	Diesel
	Tractors	4020 | 4620 | 5225 | 5425 | 5525	39500kg | 45500kg | 52000 kg | 55000kg	H Series, 6 Cylinder, CRS with iGen-6 Technology | A series CRS with iGen6 Technology	Diesel

Company Name	Vehicle type	Model Name	GVW	Engine Specification	Fuel Type
Mahindra & Mahindra	ICVs	FURIO	13100kg | 14050 kg | 16140kg | 17000kg	3.5L mDi Tech, 4 cylinders (With EGR + SCR Technology)	Diesel
	Haulage	BLAZO	28000 kg | 35000kg | 42000kg | 49000kg	mPOWER 7.2 L FuelSmart	Diesel
	Tractor trailers	BLAZO	39500 kg | 45500kg | 55000kg	mPOWER 7.2 L FuelSmart	Diesel
Eicher Motors	Medium Duty	Pro	12976kg | 14000kg | 16020kg	3.8L | 5.1L | 7.7L	Diesel | CNG
	Haulage	Pro	18500kg | 28000kg | 35000kg | 42000kg | 47500kg	3.8L | 5.1L | 7.7L	Diesel
	Tractor trailers	Pro	39500kg | 45500kg | 54000kg | 55000kg	5.1L | 7.7L	Diesel
Bharat Benz	Medium duty	MDT	13000kg | 14500kg | 16200kg | 55000kg	4D34i	Diesel
	Haulage	HDT-R	28000 kg | 35000kg | 42000kg	7200cc	Diesel
	Tractor trailers	HDT-T	33747kg | 49960kg | 52000kg | 54960kg	7200cc	Diesel
MDVs					
Tata Motors Ltd.	LCV	LPT	8750 kg | 9600kg | 10900kg | 11990kg |	3.3L | 3.8 SGI	Diesel | CNG
		ULTRA	8750 kg | 9600kg | 11250kg | 11990kg	3.3L	Diesel
	LCV	GOLD	4450 kg | 4995kg	4SPCR	Diesel
		SFC	5300 kg | 5950 kg | 6250 kg | 7490 kg	4SPCR | 3.8SGI (CNG)	Diesel | CNG
		LPT	7490kg | 7300 kg |	3.3L | 3.8 SGI (CNG)	Diesel | CNG
		ULTRA	7300 kg	4SPCR	Diesel
Ashok Leyland	LCV	DOST	3490 kg	1.5L	Diesel
		Partnet	6250 kg | 7200 kg | 7490 kg	ZD30Diesel Engine with DDTi	Diesel
Mahindra & Mahindra	ICVs	FURIO	11280kg | 11990 kg	3.5L	Diesel
	LCV	JAYO	4990 kg	mDi Tech, 4 cylinders	Diesel
Eicher Motors	Sub-5 tonne	Pro	4900kg	2.0L | 3.3L	Diesel | CNG
	Light duty	Pro	5400kg | 4590kg | 6950kg | 7490kg | 8990kg | 9700kg | 11100kg	2.0L | 3.0L | 5.0L | 3.3L	Diesel | CNG
	Medium duty	Pro	11990 kg	3.8L	Diesel
Bharat Benz	Medium duty	MDT	10600 kg | 10700kg | 11990kg	4D34i	Diesel

Source: Author's compilation (non-exhaustive)

China

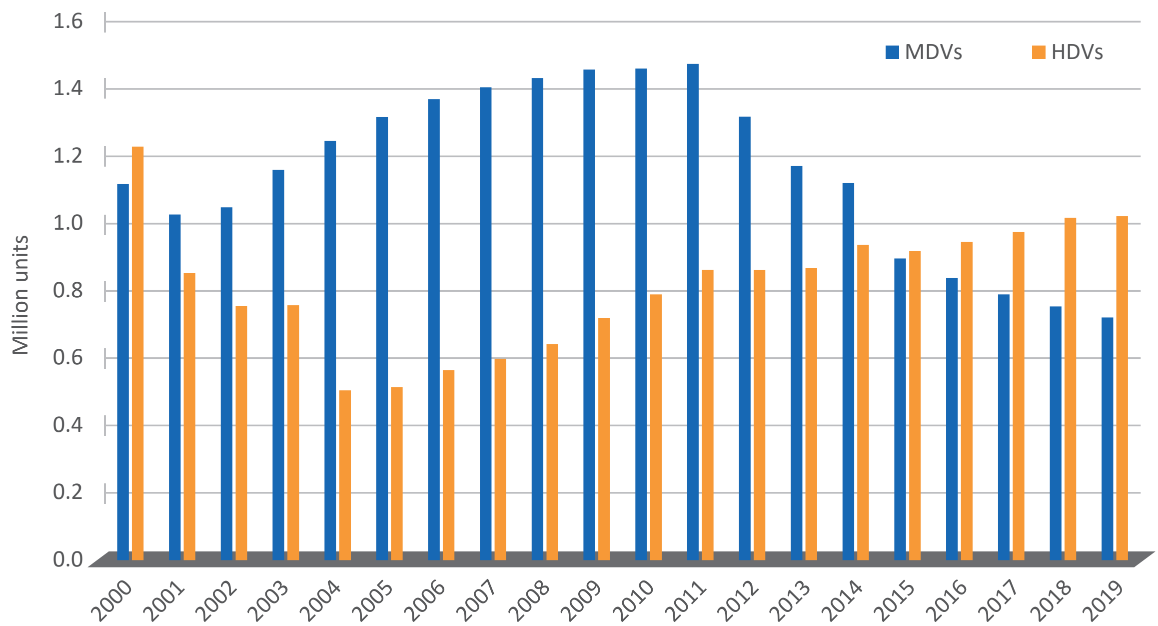
China's MHDV market has been growing at a rapid pace with an average annual increase of 5.7% by the year 2014. It has a comparatively higher number of manufacturers as compared to India. The size of the trucks is increasing with increased power and displacement with a good efficiency performance and that is leading to a good market share for China. The engines for these sectors are mostly supplied by domestic OEMs. The fuel consumption limits in the proposed Stage 3 standards was a worthy step for controlling the efficiency gap but longer-term measures are required to ensure the best fuel efficiency levels. Advancement in the technologies resulted in great potential to improve fuel efficiency of China's HDV sector and this may result in reduction of fuel consumption by 35% to 45% compared with the Stage 3[11] limits by 2030 (Karali, et al., 2017).

Production and sales: MHDV

China had MHDV sales of 1.7 million in 2012 and almost 2 million in 2013; this dropped to 1.8 million and 1.3 million in 2014 and 2015, respectively. China's HDV market began to recover in 2016, and by 2017, total sales returned to the same level as 2013. The decline in MHDV sales during 2014 and 2015 is a well-documented consequence of the broader economic turmoil during that period (Allen, 2015).

Diesel engines dominated the conventional HDV market in China during the evaluation period, accounting for over 95% of HDV sales. Still, natural gas powertrains have had a consistent market presence throughout the past years, peaking in 2014, when they represented 5% of new HDV sales. The penetration of gasoline powertrains in the HDV segments is negligible.

Figure 6: Stock of MDVs and HDVs in China (2000-19)



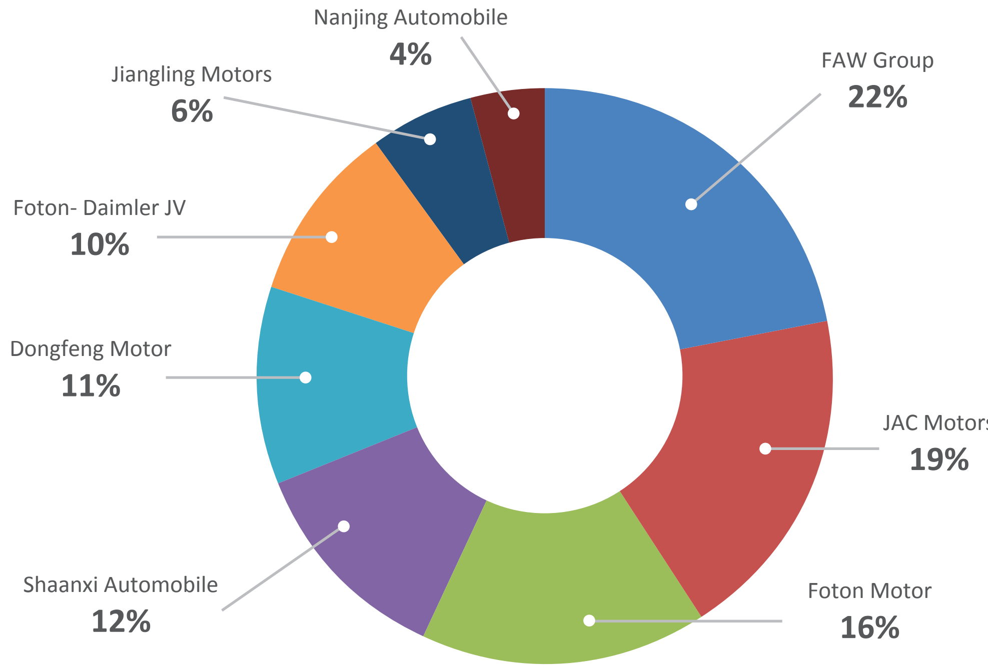
Source: Tsinghua University, China

Sales in the different vehicle segments were largely dominated by a few GVW categories. Straight trucks were mostly concentrated at GVWs of around 5 tonnes, which exemplifies how important small straight trucks[12] are within the regulatory category. Similarly, GVWs around 5 tonnes were also a large number of the sales of coaches and dump trucks. Most tractor-trailers were gathered around approximately GVW of 49 tonnes, which is the upper limit for the total weight of tractor-trailers in China (MIIT, 2016).

According to market estimates, there were about 670 commercial vehicle manufacturers in China, of which eight were responsible for approximately 48% of the total sales in the country in 2012. Five years later, the number of HDV manufacturers increased to over 700, and the share of top eight manufacturers increased to 51% (Shiyue, Pierre-Louis, & Rodriguez, 2021).

In the Chinese market, FAW Group dominated the sales market with 22% shares in the year 2017 with 300% growth during the last half decade, JAC Motors sealed the second position, with 19% share keeping its sales growing at the similar pace as the overall market and Foton Motor experienced a slight decline in the shares since last half decade and occupied third place with 16% of the market share. Figure 7 shows the manufacturers in 2017, and the vehicle categories that represented the bulk of their sales. Even though straight trucks were still the leading category for the majority of the manufacturers in 2017, the shares of tractor-trailers in their product portfolios increased significantly during 2012-17 (Shiyue, Pierre-Louis, & Rodriguez, 2021)

Figure 7: Market share of MHDV manufacturers – 2017



Source: Mao et al, 2021

Table 3 below comprises of the MHDV models that are currently available in China with their GVWs, engine specifications and fuel type by the top five manufacturing companies in the country. FAW Group being the top manufacturer has a wide variety of models present in the current market, followed by Dongfeng Motor, Sinotruk, Shaanxi Automobile and Beijing Automotive Industry Company (BAIC). We also see dominance of diesel vehicles in the Chinese market. The following table also depicts the fuel-technology based status of Chinese market – majority of the HDVs are still diesel with few LPG/CNG options available. While in the MDV sector, a technological shift can be observed with various low-carbon options available in the market.

Freight demand, energy and emissions – HDV sector

India's road-based freight transportation has increased rapidly in the last two decades. According to TERI estimates for the road freight sector, the total traffic, in terms of BTKM, increased from about 400 btkm in 2000-01 to 2,800 btkm in 2020-21 - a 7-fold increase. Of the total road freight, the volume of HDV segment increased from 330 btkm in 2000-01 to 2,219 btkm in 2020-21. Though the total volume increased significantly, the share of HDV segment in total freight declined slightly from about 86% in 2000-01 to 80% in 2020-21, largely on account on proliferation of LDV segment for the urban freight movement. The following

Table 3: Manufacturer-wise HDV and MDV models available in China

Company Name	Vehicle type	Model Name	GVW	Engine Specification	Fuel Type
HDVs					
First Auto Works (FAW)	J6P	Tractor	25000 kg | 18,000 kg	9L | 11 L | 13L	Diesel
First Auto Works (FAW)	J6M	Tractor	20000kg | 25000 kg | 18,000 kg	CA6DL2-35E5	Diesel
First Auto Works (FAW)	J6M	Lorry	20,010 kg	CA6DK1-28E5	Diesel
First Auto Works (FAW)	J6L	Lorry	25000 kg | 18,000 kg	CA6DK1-24E5	Diesel
First Auto Works (FAW)	J5p	Tractor	39,755 kg | 35,000 kg	Not mentioned	Diesel
Dongfeng Motor	Haulage	KR | KL	12495 kg | 18,000 kg	4.75 L | six-cylinder four-stroke turbocharged and inter cooled engine	Diesel
Dongfeng Motor	Tractors Trucks	KL	18,000 kg | 25000 kg	six-cylinder four-stroke turbocharged and inter cooled engin | YC6MK340N-50 | DGi11Y385-41	Diesel | liquefied natural gas | natural gas
Dongfeng Motor	Cargo Trucks	Dump Truck	15995 kg | 17995 kg | 18000kg | 24900 kg | 31000 kg | 31000 kg | 9120 kg	CY4SK151 | YC6A240-50 | ISL9.5-292E51A | YC6MK300N-50	Diesel | Natural Gas
Sinotruk	Cargo Trucks	HOWO	25000kg | 31000 kg	9.726 L	Diesel
Sinotruk	Tractors Trucks	A7 HOWO	18000kg (Total weight) | 8800kg (curb weight) | 8550kg (Dead weight)	9.726 L | WD615 Series | WD615.47	Diesel
Shaanxi Automobile	Prime Mover	M3000	20000 kg | 25000kg | 26000kg	WP 12.375N	Diesel
Shaanxi Automobile	Rigid Truck	M3000	30000 kg | 25000kg | 26000kg	WP 12.375N	Diesel
Shaanxi Automobile	Prime Mover	X3000	20000 kg | 29400kg	WP 12.375N | WP 12.43N	Diesel
BAIC	Tractors Trucks	Auman	>50000kg (Maximum total weight in use) | 30000 kg | 32000 kg	ISGe4-460 | ISGe5-360	Diesel
BAIC	Super Trucks	Uroair R Series	16000 kg | 18000 kg	4.5L | 5.9L	Diesel
BAIC	Cargo Trucks	Aoling	12390 kg		
MDVs					
First Auto Works (FAW)	J6F	Light Trucks	3500kg | 6000kg | 7000kg | 8000kg	Not mentioned	Diesel
First Auto Works (FAW)	J6F	Dump Truck	Kg. | kg.	11 L (350-420 HP)	Diesel
First Auto Works (FAW)	J6F				

Company Name	Vehicle type	Model Name	GVW	Engine Specification	Fuel Type
Dongfeng Motor	Cargo Trucks		4495 kg | 9120 kg | 7100kg | 4495 kg	YC4S140-50 | 45 kW	Diesel | Natural Gas | Electric
Sinotruk	Light Trucks	HOWO Light Dump | HOWO Light Van	5000 kg | 8000kg | 10000 kg	130HP-160HP	Diesel
Shaanxi Automobile	Light Trucks	Box truck	5500kg (curb weight) | 6500kg (curb weight)	YN4102QBZL (115-130HP)	Diesel
BAIC	Super Light Truck	Omarco	4500 kg | 6000 kg | 7500 kg | 12000 kg	2.5 L | 3.8 L	Diesel
	Trucks	Aoling	3500 kg | 4500 kg | 5000 kg | 6000 kg | 7200 kg | 9000 kg	2.5 L-4.5 L	Diesel
	Medium Trucks	Times Leader	18000 kg | 25000 kg	Not mentioned	Diesel

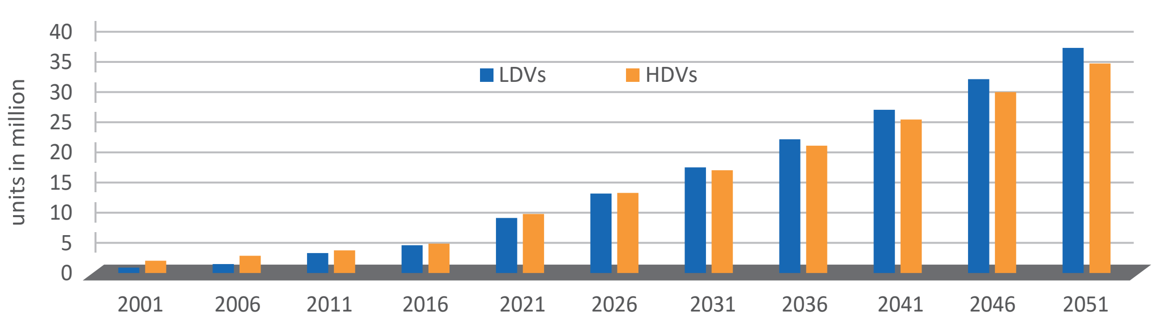
Source: Author's compilation (non-exhaustive)

section looks into the growth of the MHDV sector, which is based on modelling exercise conducted through TERI's transport[13] and MARKAL[14] models.

Stock of Commercial Vehicles

As per estimates, the share of commercial vehicles in total stock of vehicles on road stood at 8% in 2021, which is expected to grow to 10% by 2031. It is to be noted that the stock of LDVs has been increasing rapidly and overcame the HDVs, in absolute numbers, in mid-2010s, largely on account of growing urbanization and urban freight demand. By 2031, the total stock of HDVs on Indian roads is estimated to reach 17 million, with diesel technology dominating the entire stock in the business as usual scenario.

Figure 8: Estimated stock of LDVs and HDVs on Indian Roads



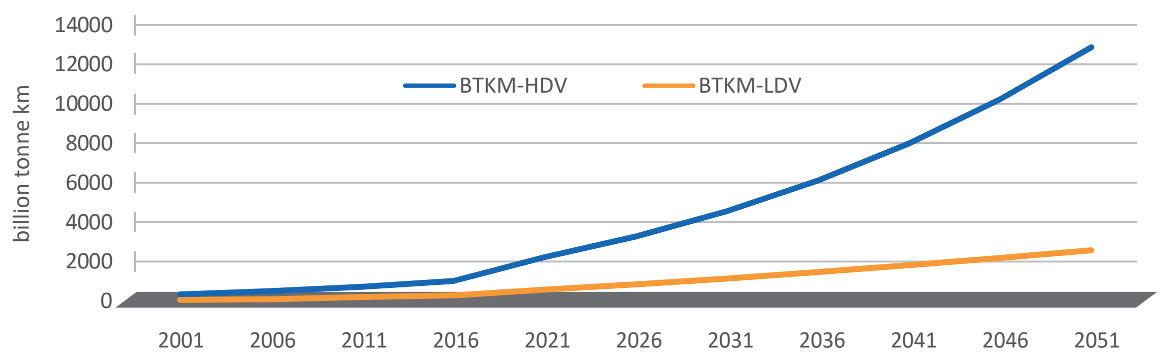
Source: TERI Analysis

Increasing freight demand

As mentioned earlier, the total freight carried by the road sector increased seven-fold between 2001 and 2021. The freight carried by the HDV sector, which accounts for a small share in total stock of vehicles, has been increasing rapidly and is estimated to touch 4,500 btkm by 2031. With rapid economic growth anticipated in the future, India's HDV segment is expected to cater to about 13,000 btkm by 2051, which would be approximately six-times the current estimated freight demand.

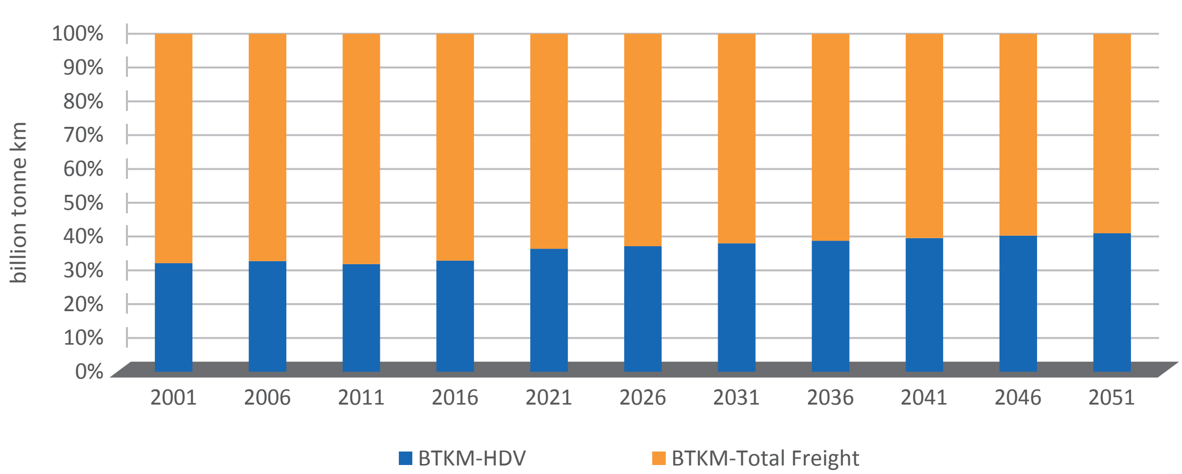
Looking at the share of HDVs in total freight, including rail and air sectors, it has increased from 47% in 2001 to 57% in 2021. In fact, the share of HDV in total freight is estimated to increase to as high as 60% in 2031, and further to 70% by 2051. This indicates the continuing dominance and reliance on the road sector in the freight traffic demand, economic activities and energy demand.

Figure 9: Freight traffic demand reported by the LDV and HDV segments of Road Transport



Source: TERI Analysis

Figure 10: Estimated share of HDVs in total freight demand



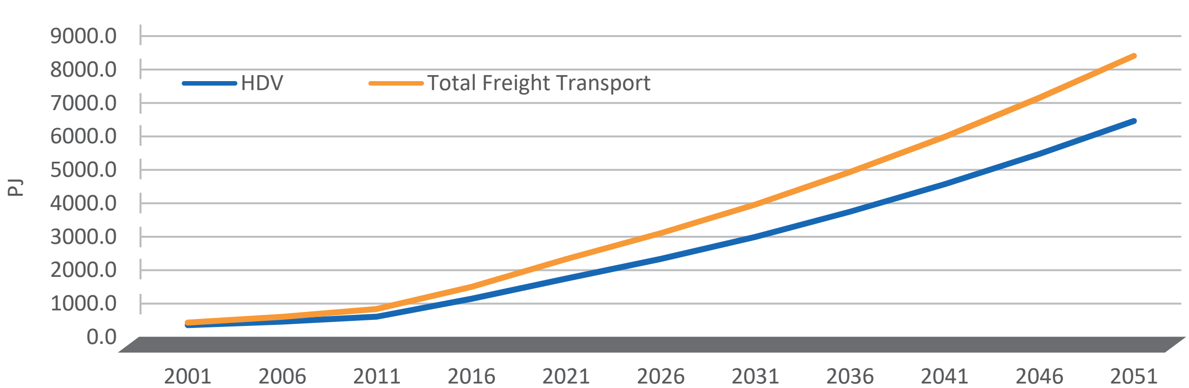
Source: TERI Analysis

Freight transportation and energy consumption

According to TERI estimates, total energy consumption on account of movement of freight (including road, rail and air) stands at 2.3 exajoules (EJ) in 2021. Over the years, the dominant share of road sector in freight transportation has driven the demand for the energy consumption. Over 90% of the energy consumption during 2021 was estimated to be on account of the road transport sector. As indicated earlier, the road freight sector is almost entirely dependent on diesel, which in turn, is produced from imported crude oil. Also, the share of railways in total energy consumption, which uses a mix of electricity and diesel, continues to be marginal as compared to the road sector.

Within road transport, the HDV segment accounts for about three-fourth of the total energy consumed on account of movement of total freight. It is estimated that the HDV sector reported consumption of 1.75 EJ of energy in 2021, increasing from 0.36 EJ in 2001.

Figure 11: Total energy consumption by HDV and Freight Transport



Source: TERI Analysis

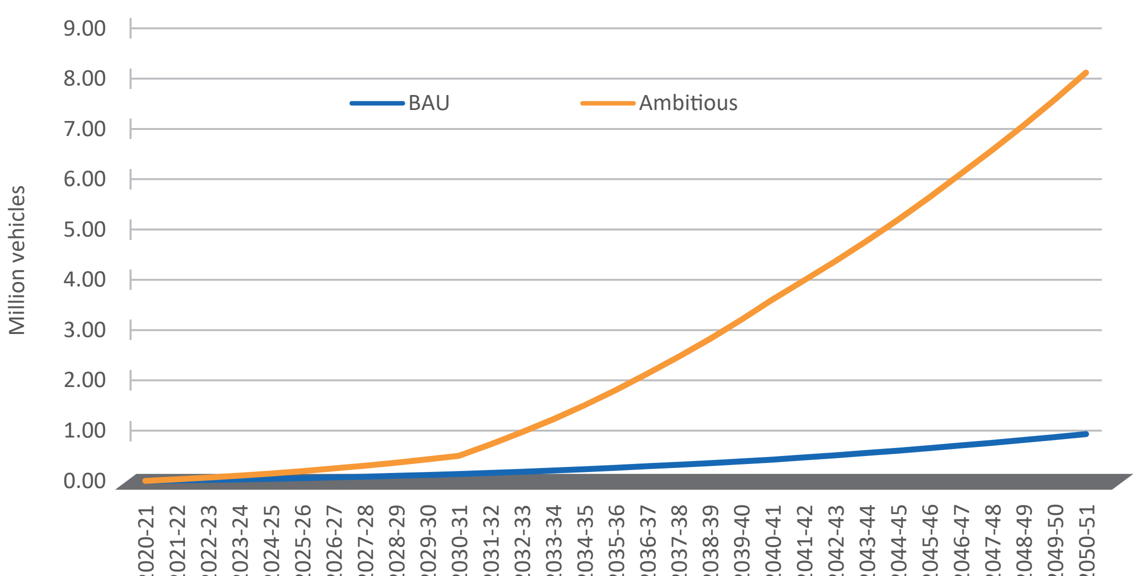
Freight transport and CO_2 emissions

Scenario Analysis

Based on interaction with the OEMs and key sector experts, it is expected that under the business as usual scenario penetration of electric technology in the MHDV segment will be tapered during the entire period of analysis. Under the ambitious scenario, the penetration of e-MHDVs are anticipated to be significantly higher, which in turn is based on technology learning and upfront cost reduction of EVs in the coming years. EV adoption is expected to be relatively higher in the MDV segment as compared to the HDV segment due to the size of battery pack and load restrictions. Details related to scenario-wise penetration of eMHDVs are shared in Annexure 2 of the document.

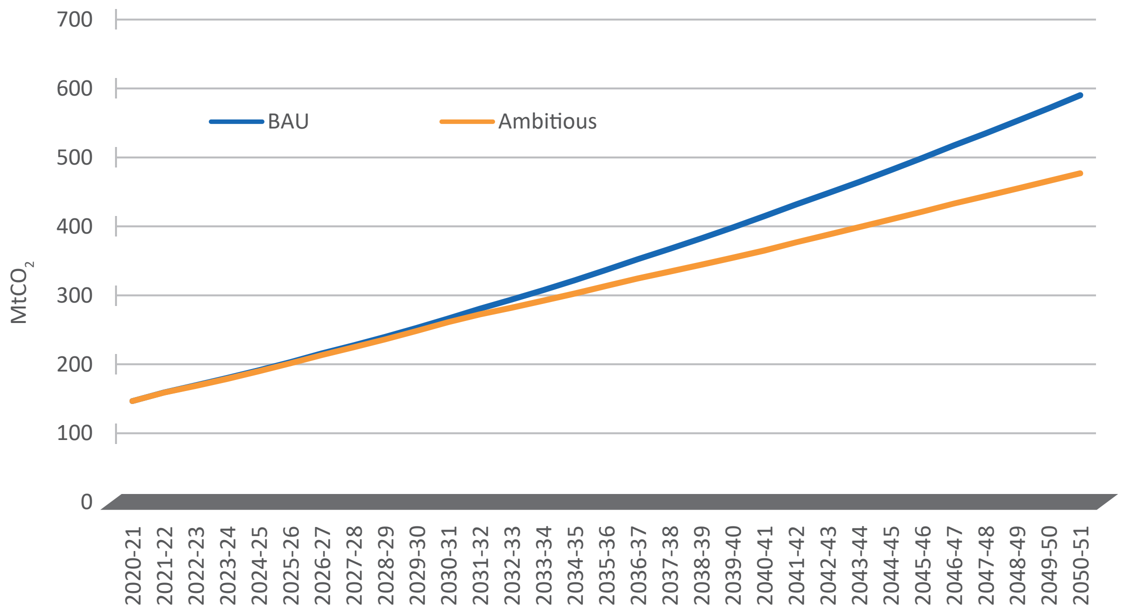
As per TERI analysis, with the induction of battery-electric technology, emissions on account of the MHDV segment is likely to decline by 20% by 2050 in the ambitious scenario vis-à-vis business-as-usual scenario.

Figure 12: Projected number of electric MHDVs in total sales in the business as usual and ambitious scenario



Source: TERI Analysis

Figure 13: Projected CO_2 emissions from the MHDV sector under the BAU and ambitious scenarios



Source: TERI Analysis

Low/Zero-carbon Technologies: HDVs

Initiatives to reduce emissions – India and China

Auto Fuel Policy

China and India have developed and implemented respective fuel emission policies, which are in line with the Euro Standards. In China, stage-wise emission standards have been rolled out since 2000 and China VI-b norm is scheduled to be rolled out in 2023. India, on the other hand, skipped the Bharat Stage (BS) V norm altogether and moved to the BS VI norm in April 2020, well before the scheduled adoption of BS VI in April 2024[15].

Table 4: Specifications of implemented Auto Fuel Policies in India and China

Country/ Phase	Implementation Date	Truck types regulated
CHINA		
China I	1 Jul 2000 (Type 1) 1 Oct 2001 (Type 2)	For Light Duty Vehicles
	1 Sep 2001	For Heavy Duty Vehicles
	1 Jul 2003	For Heavy Duty Gasoline Vehicles
China II	1 Jul 2005 (Type 1) 1 Jul 2006 (Type 2)	For Light Duty Vehicles
	1 Sep 2004	For Heavy Duty Vehicles
	1 Sep 2004	For Heavy Duty Gasoline Vehicles
China III	1 Jul 2008 (No EOBD required) 1 Jul 2009 (EOBD required for type 1) 1 Jul 2011 (EOBD required for others)	For Light Duty Vehicles
	1 Jan 2008	For Heavy Duty Vehicles
	1 Jul 2010	For Heavy Duty Gasoline Vehicles
China IV	1 Jul 2011 (Diesel) 1 Jul 2013 (Gasoline)	For Light Duty Vehicles
	1 Jul 2013	For Heavy Duty Vehicles
	1 Jul 2013	For Heavy Duty Gasoline Vehicles
China V	1 Jan 2017 (Diesel)* 1 Jan 2017 (Gasoline)	For Light Duty Vehicles
	1 Jan 2021** 1 Jul 2023	For Heavy Duty Vehicles
	-	For Heavy Duty Gasoline Vehicles
China VI	1 Jul 2020 (China 6a)[16] 1 Jul 2023 (China 6b)	For Light Duty Vehicles
	1 Jul 2019 (China VI-a)** 1 Jul 2020 (China VI-a)^ 1 Jul 2021 (China VI-a) 1 Jan 2021 (China VI-b)** 1 Jul 2023 (China VI-b)	For Heavy Duty Vehicles
INDIA		
India 2000	From 2000	Applicable to all vehicle types, including MHDVs
Bharat Stage II	From 2005 (Nationwide)	
Bharat Stage III	From 2010 (Nationwide)	
Bharat Stage IV	From 2017 (Nationwide)	
Bharat Stage VI	2020 (Nationwide)	

*EOBD: European On-Board Diagnostics; * For public bus, sanitation and postal trucks, and other civil vehicle fleets; ** For gas fuelled HDVs; ^ For public bus, sanitation and postal trucks, and other civil vehicle fleets*

Source: Author's compilation

Fuel Economy Standards

China introduced national truck fuel economy program in a phased manner since 2012 with an allotted compliance period and set benchmarks for the vehicle efficiency improvement standards. Fuel economy limits set under Stage 3 for new buses, trucks, and tractors is lower by 15.9%, 13.8%, and 15.3%, respectively as compared to the Stage 2 standard. Stage 3 standard was applied to all new heavy commercial vehicles in July 2021.

In India, efficiency norms are currently available for LDV sector only, popularly known as CAFE (Corporate Average Fuel Emission) norm, notified by the Ministry of Power in 2017. The nodal agency for implementation of CAFE norm is MoRTH[17]. The draft fuel consumption norm for HDVs was finalized in 2017. The norm for HDVs is still to be adopted, which has been in discussion for a long time.

Table 5: Specifications of implemented national truck fuel economy in China

Country/ Phase	Compliance period / Standard type (target metric)	Truck types regulated	Truck size categories	Average targeted efficiency improvement
China Phase I	2012-15 Fuel consumption (litre/100 km)	Tractors, trucks (excl. dump trucks,) buses and coaches.	8 bins for tractors > 3.5 t, 11 bins for non-tractor trucks > 3.5 t.	First standard to benchmark energy consumption of trucks. Consumption limits based on weight between 38 - 56 l/100 km for tractors, 15.5 – 50 l/100 km for non-tractor trucks and 14 – 33 l/100 km for busses/coaches.
China Phase II	2014-20 Fuel consumption (litre/100 km)	Tractors, heavy duty vocational vehicles, buses and coaches.	8 bins for tractors > 3.5 t, 11 bins for trucks (excluding dump trucks) > 3.5 t, 11 bins for dump trucks.	10.5% for coach buses, 11.5% for trucks and 14% for tractors, compared to MY 2012 Phase I fuel consumption limits from July 2014 (type approvals)/July 2015 (all sales), depending on truck type and size.
China Phase III	From 2019 Fuel consumption (litre/100 km)	Tractors, dump trucks, trucks (excl. dump trucks), buses and coaches.	8 bins for tractors > 3.5 t, 11 bins non-tractor/non-dump trucks > 3.5 t, 11 bins of dump trucks.	15.9% (for buses), 21.7% (for coach buses), 23.7% (for trucks [excl. dump trucks]), 14.1% (for dump trucks) and 27.2% (for tractors) compared to MY 2012 Phase I fuel consumption limits from July 2019 (type approvals) / July 2021 (all sales), depending on truck type & size.

Source: Author's compilation

Scrappage schemes

Scrappage scheme is a critical policy tool to discard old vehicles that exceed their fitness life and cause substantial harm to the environment if allowed to continue. The scheme contributes in cutting down the emissions from unfit vehicles and helps in bringing down vehicular air pollutants and also allows new technologically-advanced vehicles to come on-road with better and improved engine standards.

China started this scheme in 2009-10 and the policy was named as 'Old-Swap-New Policy', where trucks have to go under scrappage after their fitness lifespan. In India, the scrappage policy was first announced in the union budget 2021-22, but has been in discussion for many years. The key objective for the roll out of this policy is to reduce the number of old and defective vehicles, bring down vehicular air pollution, and enhance road and vehicular safety (MoRTH, 2021). Once rolled out, all old vehicles will have to go a mandatory fitness test at authorised and automated fitness centres, which will be implemented as per international standards[18].

Table 6: Scrappage schemes of China and India

Country	Scrappage	Year(s) of operation	Truck criteria	Premium offered
China	Old-Swap-New	2009-10	Between 10 and 15 years old	USD 1400-2400
India	-	Yet to be notified. There will be a mandatory fitness testing for heavy duty vehicles.	Commercial vehicles that are over 15 years old will have to undergo fitness tests	4-6% of ex-showroom price of a new vehicle The state governments may be advised to offer a road tax rebate of up to 15% for commercial vehicles. The registration fees may also be waived for purchase of new vehicle against the scrapping certificate.

Source: Author's compilation

Fuel taxes

Fuel taxes are among the simplest instruments of fiscal policy, they display a direct connection with the volume of fuel consumed and CO_2 emissions. These taxes directly imitate the environmental costs of emissions. Tax levels on diesel, which is primarily used by the heavy commercial vehicles and responsible for carcinogenic emission; tend to be lower than taxes applied to gasoline. For instance, emission on account of MDVs is equal to 0.6 kg CO_2/km compared to 0.73 kg CO_2/km on account of HDVs[19].

Countries like New Zealand and Europe have high tax rates on gasoline and European countries have high taxes on diesel as well, with few exceptions among Eastern European countries, where intermediate tax rates have been adopted. Fuel taxes in North America and Central America are appreciably lower than in Europe, while countries like Japan and Australia have moderate taxes. Middle Eastern countries generally subsidise fuel heavily, while countries in the ASEAN region subsidise diesel intermediately. North African countries, including Algeria, Egypt and Libya, subsidise gasoline heavily, while countries in Central Africa and Southern Africa tend to apply moderate-to-high fuel taxes (IEA, 2017). India has recently increased the tax rates (central and state taxes) on diesel and gasoline, which accounts for over 50% of the total retail price per litre of fuel.

Currently, taxes on road fuel, including diesel and gasoline, accounts for about 40% of the retail price in China[20]. On the other hand, India has one of the highest tax rates on fuel in the World as of May 2021. On average, state governments collect Rs 20 on every litre of petrol, compared to the Centre's levy of Rs 33 per litre (as of July 2021).

Table 7: Different levels of taxation on gasoline and diesel fuel in different countries

Fuel type	Low/intermediate taxes	High taxes
Gasoline	Africa, Australia, Canada, Central Asia, Japan, Latin America, United States	Europe, New Zealand, China, India
Diesel	Africa, Australia, Canada, Central Asia, Japan, Korea, Latin America, United States	Europe, China, India

The boundary between intermediate taxation and high taxation is the price of fuel applied in Luxembourg.

Source: The Future of Trucks, 2017 (IEA, 2017)

Alternative Fuel Options: MHDV Sector

LNG

In the MHDV segment, liquified natural gas (LNG) work similar to the gasoline-powered vehicles, with a spark-ignited combustion engine. LNG is stored in liquid form in a tank on the either side of a truck. It is typically an expensive alternative than compressed natural gas (CNG) and is most often used in MHDVs to meet long range requirement. Due to its characteristics at room temperature – energy density higher than CNG, higher volume of LNG fuel could be stored on-board a vehicle. This makes LNG well suited for the trucks that are traveling longer distances. With respect to CO_2 emissions, LNG trucks are more efficient compared to diesel hybrid trucks (Smajla, Karasalihović Sedlar, & Drljača, 2019).

China

China is one of the largest countries with LNG-based transport sector in the world. In the downstream LNG segment, Chinese transport sector accounted for 27% and 29% in the years 2017 and 2018, respectively (Yuan & Shell, 2019). This is the second-highest share in terms of LNG consumption after the industrial sector. Surge in sales of LNG vehicles was reported in 2017. It was primarily driven by LNG-based heavy-duty trucks, which grew year-on-year by 500%. By 2018, of the total population of LNG vehicles in China, two-thirds were heavy-duty trucks and the remaining one-third comprised of LNG buses and coaches. With regard to refuelling infrastructure, China had 2,552 LNG stations across the country as of end-2018. Like India, China is also dependent on imported LNG, mainly from the middle-east and Australia. China also has availability of LNG through domestically mini-liquefaction plants.

The sale of LNG-based trucks is inversely related to the price of the fuel. China reported high LNG during 2013-16 due to rise in pipeline gas price during China's natural gas price reform, which coincided with tapered sale of LNG trucks in the country. However, sale of LNG trucks increased significantly during 2017 on account of recovered fuel prices. The sale of LNG trucks again declined due to uncertainty in fuel supply and rising prices (Yuan & Shell, 2019).

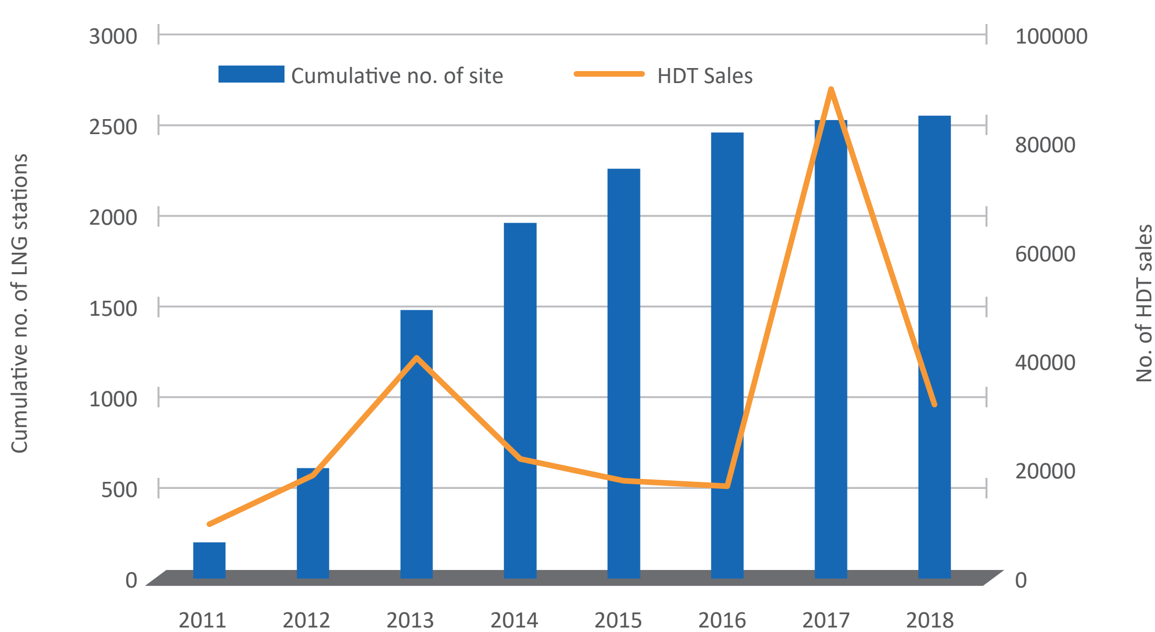
India

In India, government is pushing for the use of LNG for inter-city bus travels. In 2020, the Minister of Petroleum & Natural Gas laid the foundation stone for setting up of 50 LNG fuelling stations across the golden quadrilateral and major national highway corridors of the country, and aims to set up 1,000 LNG stations by 2023. India's leading commercial vehicle manufacturers, especially Tata Motors, already has LNG powered commercial vehicles in their portfolio. Tata Motors showcased their LNG bus model in 2014 and successfully conducted a pilot project in 2016 in Thiruvananthapuram, Kerala. Tata Motors also completed delivery of one LNG bus to LNG Petronet Limited in Dahej, Gujarat, and two LNG buses in Kochi, Kerala.

Electric Road System

Electric Road System (ERS) is defined as roads that support dynamic power transfer from the road to vehicles while the vehicles

Figure 14: Cumulative number of LNG refuelling stations and LNG HDT Sales



Source: (Yuan & Shell, 2019)

are moving, which could be a supplement to overcome some of the challenges of battery-EVs, especially performance related to range _(Schulte & Ny, 2018). Electric roads can be classified into three categories based on how the power transmission takes place (Mårtensson, 2020):

- **Overhead conductive:** In this, charging power is continuously transferred from overhead lines to the vehicle with the help of a pantograph. It is best suitable for trucks and buses that are elevated enough to reach the electric lines. It also works better with vehicles that travel in a predetermined route, with low friction, so that they can stay continuously connected to the lines.

- **Conductive Power Transfer from Road:** Here, the power is transmitted to the vehicle through rails embedded in or on top of the road surface.

- **Inductive Power Transfer from Road:** In this, power transmission is contactless and takes place between coils embedded in the road and vehicles. The high frequency AC power creates a magnetic field, which is picked up by the coils of the vehicle to generate voltage.

Under this technology, power moves directly into the propulsion system or used to charge on-board batteries. As soon as the vehicle moves to a non-ERS road, it switches to battery-electric or internal combustion engine (ICE) mode. ERS can be beneficial in providing a much cleaner alternative options in MHDV sector than other combustion and polluting engines. Extremely high upfront cost of infrastructure development, which could range from Euro 2-2.5 million per km[21], especially for a developing country like India may not be feasible. However, technical research works and feasibility studies need to be conducted before postponing the

technology adoption in India. High degree of traffic and closed-circuit operation of HDVs, implying high utilization, might make the technology viable even in India, provided innovative financing model is adopted.

Hydrogen-Fuel Cell Vehicle Technology

Hydrogen fuel cells produce electricity by combining hydrogen with oxygen. The hydrogen tanks built into the FCEV reacts with the oxygen to produce electricity, water, and heat. The electricity powers the electric motor and the only by-product is water vapour, thereby making it a zero-emission technology. Hydrogen can be produced from a range of domestic resources, like natural gas, biomass, etc. These are some of the potentials of hydrogen that makes it an attractive fuel option for transportation.

China has been undertaking numerous steps towards adoption of hydrogen fuel-cell electric vehicle (HFCEV) technology, including that for MHDV segment. In the Hebei Province, FTXT Energy Technology, a subsidiary of GWM, along with Dayun, Dongfeng Motor, and Foton, delivered 100 hydrogen fuel cell HDVs with 111 kWh capacity for Xiong'an construction project in August 2021. The authorities have already set up 10 fuel stations for refuelling the fleet, which is likely to be operational shortly. Currently, the fuel cell vehicles account for less than 5% of the commercial truck market in China and that could grow to about one-third of total market share in 2050.

India is proactively looking at hydrogen as one of the clean energy options. The National Hydrogen Mission was launched in August 2021 to reduce carbon emissions and increase the share of clean energy in the overall energy basket. TERI undertook a study on the potential role of hydrogen in India in 2020. It was assessed that sectors like industry, power sector, and transport (particularly heavy-duty vehicles) will emerge as key end-users. Table 8 looks at the role of hydrogen as a fuel in the transportation sector, with

Table 8: The role of hydrogen across Transport sector

Sector	Use-Case	2020s	2030s	2040s
Transport	Short-distance, regular-route heavy-duty transport	BEVs becoming competitive with ICEs. FCEVs not competitive	BEVs competitive with both FCEVs and ICEs	BEVs competitive with both FCEVs and ICEs
	Long-distance heavy-duty freight transport	ICEs competitive	FCEVs and BEVs becoming competitive with ICE	FCEVs likely to be competitive with ICE. BEVs partly competitive

Legends: Brown = fossil fuels dominate. Yellow = direct electrification without using H_2 as an energy vector, e.g. battery electric vehicles or Li-ion batteries in electricity storage. Green = mixed paradigm with several technologies including hydrogen.

Source: TERI analysis

Table 9: Multi-criteria assessment for heavy-duty trucks and inter-city buses

	Diesel	Electric	Hydrogen
Total Cost Ownership	Not competitive post 2030	Competitive for shorter distances post 2030. Potentially competitive across all relevant distances by 2050.	Competitive over longer distances
Refuel / charging time	15mins	2 hrs+	15 mins
Infrastructure requirements	Already in place	New high capacity charging network	New hydrogen refuelling stations
User acceptability	No change	Change to fleet operation required	Minimal change
Weight penalty of drivetrain + storage	Minimal	Significant for long distance	Minimal
Risks	Crude oil prices and fuel taxes	Minimal: confident in cost declines of batteries. Some uncertainty about pace of improvement in battery energy density.	Dependent on cost declines in fuel cells, tanks, and electrolysers

Source: TERI analysis

a future prediction taking several use-cases for the next three decades (Hall, Spencer, Renjith, & Dayal, 2020).

While TERI analysis suggested a handy competition between BEVs and FCEVs over the long-term, the adoption of hydrogen fuel cell technology in transport will be governed by reducing the recharging time, rolling out high capacity charging practices, raising awareness, and reducing the weight penalty. Apart from setting up of hydrogen refueling network, HFCEVs would be more competitive because of more rapid refueling and the similar operation of an FCEV truck or bus versus a diesel equivalent. Key benefit of hydrogen fuel cell technology is faster refuelling, which could take 10-15 mins, as well as range achieved by this technology reaching up to 500-800 km, based on the fuel storage capacity.

An overall impression that develops from this analysis is that HFCEV trucks may be a preferred option for longer routes, even though competitiveness of this option depends upon vigorous cost declines in several technologies and very low delivered costs of hydrogen.

Focus on Battery-electric vehicle (BEV) technology

BEV freight transport is much efficient and cleaner than HFCEV applications. Similar to the hydrogen-based trucks, upfront cost of battery-EV is significantly high, with major compromise on payload capacity due to high battery size. However, with high-capacity loading, BEVs can manage to accelerate faster than diesel vehicles due to the high torque capabilities of the electric motors (Smajla, Karasalihović Sedlar, & Drljača, 2019).

Manufacturing status

Currently, there are no OEMs in India manufacturing commercially available electric MHDVs, except for the passenger bus segment. Prototypes of electric trucks are being developed by Ashok Leyland Limited and is expected to be piloted on Indian highways (Delhi-Agra Expressway and Delhi-Jaipur Highway) in December 2021. In the battery electric bus segment, major players in India are Ashok Leyland Limited, Solaris Bus & Coach S.A., JBM Auto Limited, Olectra Greentech Limited, Tata Motors Limited, and Volvo Eicher Motors Limited (VECV Ltd).

JBM Solaris Electric Vehicles Ltd, is a joint venture between India's JBM Auto and Europe's Solaris Bus & Coach SA, and they launched their first electric bus series 'Eco-Life' in the Indian market in 2018. Olectra Greentech Limited also launched their electric buses 'K' series namely K6, K7, and K9. Based on discussion with the stakeholders from the OEM industry, it was highlighted that it would take 18 months for the manufacturers to come out with an electric MHDV.

Table 10: Manufacturing status of electric MHDVs in India

Company Name	Current Model/Series Name (if available)
Tata Motors Ltd.	Star bus, Ultra
VECV Ltd.	Skyline Pro
Olectra Greentech Ltd.	K6, K7, K9
JBM Solaris Electric Vehicles Ltd.	Eco life

Source: Author's compilation

Charging infrastructure

In an effort to promote electric vehicles in the country, government launched the FAME India scheme through which a subsidy will be provided to the owner on the purchase of new electric vehicles. Government is pushing deployment of EV charging stations by providing subsidy through the FAME India Scheme Phase II and state level initiatives. About 350 new charging stations under the second phase of this scheme have already been installed. Additionally, government has also delicenced the activity of setting up EV charging stations to attract private investments. The Ministry of Power (MoP) guidelines also suggests setting up of charging infrastructure every 100 km on each side of the highways for buses and trucks[22]. For urban centres, the guideline suggests setting up of charging infrastructure in *Transport Nagars*[23] and depots. With regard to the technical guidelines for setting of charging infrastructure for heavy duty vehicles, MoP guidelines suggest at least 2 chargers with minimum 100 kW (minimum 200-750 Volt) of different charger specification with single connector gun each.

Retro-fitment technology

A Gurugram based start-up – Infraprime Logistics Technology (IPLT) – has come up with country's first ever 60-tonne electric truck. The truck is basically a medium-haul logistics vehicle for transporting commodities such as aggregates from mines to the construction sites, cement, etc. The claimed range of this vehicle is in the range of 400 km (without payload) and 200 km (loaded) per charge. It is capable to handle a 20-degree gradient, which is higher than

Table 11: Specification of Charging Infrastructure

Charger Type	Charger Connectors*	Rated Output Voltage	No. of Connector Guns (CG)	Charging EV Type
Fast	Combined Charging System (CCS) (min. 50 kW)	200 – 750 or higher	1 CG	4-W
	CHArge de MOve (CHAdeMO) (min. 50 kW)	200 – 500 or higher	1 CG	4-W
	Type – 2 AC (min. 22 kW)	380 – 415	1 CG	4-W, 3-W, 2-W
Slow/ Moderate	Bharat DC-001 (15 kW)	48	1 CG	4-W, 3-W, 2-W
	Bharat DC-001 (15 kW)	72 or higher	1 CG	4-W
	Bharat AC – 001 (10 kW)	230	3 CG of 3.3 kW each	4-W, 3-W, 2-W

**In addition, any other Fast / Moderate / Slow charger as approved by Department of Science & Technology (DST) / Bureau of Indian Standards (BIS) standards whenever notified.*

Note: Type – 2 AC (min. 22 kW) is capable of charging electric 2-wheeler / 3-wheeler with the provision of an adaptor

Source: Ministry of Power

a typical EV. IPLT electric truck has been equipped with battery cooling system, which keeps the battery temperature close to 35 degree Celsius. The commercial run of this truck demonstrated up to 60% savings in overall operating cost over conventional diesel trucks. IPLT is already operating two charging stations on the Delhi-Jaipur highway and a fleet of 12 electric trucks is already on the road[24].

Other key highlights of the trucks are:

- Retrofitted in India (40% reduction in production cost)
- Reduce wear and tear of brakes
- 40% less maintenance cost than diesel trucks
- 98% more efficiency
- 4,000 cycle battery life

Conclusions

India has emerged as a hub for commercial vehicles in the last few years. The advancement in technology in this sector has shaped up the Indian commercial markets and the MHDV sector has witnessed an upsurge in production and sales by almost two-folds since 2014.

The production data from 2011-12 to 2018-19 shows the dominance of HDVs over MDVs in terms of production. It also indicates the nature of traffic India has been experiencing over the same period of time. Tata Motors Ltd. has dominated the market both in terms of domestic production and sales of MHDVs. Tata Motors has the maximum MHDV market share in India. Other players like Ashok Leyland, Volvo-Eicher, and Mahindra & Mahindra have emerged as key manufacturers of MHDVs in the country.

On the other hand, China's MHDV market has a comparatively large number of manufacturers and is much more consolidated. The engines for these sectors are mostly supplied by domestic OEMs. The size of the trucks is increasing with increased power and displacement with a good efficiency performance and that is leading to a good market share for both China and India.

Diesel engines dominate the conventional HDV market in China during the evaluation period, accounting for more than 95.3% of HDV sales. Natural gas-based trucks have recorded consistent increase in the Chinese market share. FWA Group dominated the MHDV sales market, followed by JAC Motors, and Foton Motor. FAW Group being the top manufacturer has a wide variety of models present in the current market followed by Dongfeng Motor, Sinotruk, Shaanxi Automobile, and BAIC.

With regard to traffic demand, Indian road transport sector reported rapid growth in freight traffic in the last two decades, and is expected to increase in the future as well. By 2031, the total stock of HDVs on Indian roads is expected to rise at a significant rate, with diesel technology dominating the entire stock in the business-as-usual scenario. The freight carried by the HDV sector, which accounts for a small share in the total stock of vehicles, has been increasing rapidly and is expected to increase at a good pace in the future as well.

Over the years, the dominant share of the road sector in freight transportation has driven the demand for energy consumption. Within road transport, the HDV segment accounts for about three-fourths of the total energy consumed on account of the movement of total freight. According to ambitious scenario estimates undertaken by TERI, CO_2 emission from the MHDV freight sector is projected to decline by 20% in 2051.

India and China are in the top 5 carbon emitters of the World. Both the countries have taken or initiating multiple measures to mitigate emissions from the transport sector, including commercial vehicle segment. These are mitigation policies and steps related to vehicle efficiency norm, fuel emission standards, scrappage policy, and alternate fuel technology, including EVs. Fuel taxes are among the simplest instruments of fiscal policy to regulate volume of fuel consumed and CO_2 emissions. Currently, India has the highest fuel tax in the world where the central government is collecting more tax on diesel and petrol as compared to the state governments.

There are various other alternatives present in the MHDV sector like LNG, electric road systems, hydrogen fuel cell technologies, that could contribute to making this sector less carbon-intensive. Investing in the charging infrastructure is very critical, investments attract business and for the electrification of this sector, infrastructure building should be at most priority. Retrofitted trucks could only be used as pilot projects or as an example because of the non-warranty tags with them. Battery swapping technology could be a critical option in case of heavy pack traffic in the city premises while waiting for charging the vehicle but it is definitely not a good option for long-distance trucks. The battery prices are coming down gradually with technical advancements in this field. Finance and insurance related market for battery-electric technology, particularly for commercial vehicles, is currently immature and requires huge regulatory and institutional support to push for rapid adoption of EVs. One of the key concerns is the absence of after-market and resale value of EVs.

Lastly, the need for a good policy is very crucial in this sector, policy has the power to turn around things and various policies on infrastructure building without worrying about the future, finding ways to for making the TCO less than that of diesel vehicles and distances between the charging infrastructures on important expressways, national/state highways, major district roads are required.

Key suggestions for future

Battery cost and density

Batteries are the primary important cost component for an electric vehicle. Lithium-ion batteries are currently the key choice for EVs and are largely available commercially. However, there are multiple lithium-ion battery chemistries that are used in different heavy-duty applications – lithium titanium oxide (LTO), lithium manganese oxide (LMO), etc. Battery requirement for MHDVs are different from those for light-duty ones, and it is mostly due to factors such as weight, driving cycle, and life expectancy. MHDVs are heavier and therefore require more power, larger and predictable lifetime mileages, and extra-duty cycles. Nevertheless, it is important to recognize the chemistry of the battery for the reason that of the differences in the material costs, technological advancements, production volumes which are some critical factors that influence the battery cost. Limitations in the data sets of present studies makes it challenging to estimate projections for specific chemistries of lithium-ion batteries for heavy-duty vehicle (California Air Resources Board, 2016).

Battery cost of these vehicles has eventually witnessed a downfall in the last few years and keeping the above-mentioned factors in mind, the cost is expected to decline in the future as well with new technological advancements, more investments and interests. According to BloombergNEF, the battery pack prices have fallen from $1,100 per kilowatt-hour (kWh) in 2010 to $137 per kWh in 2020, which is further expected to decline to $100 per kWh by 2023[25]. Already, some of the battery used in e-buses in China have reported price of $100 per kWh.

India has also approved the Production Linked Incentive (PLI) Scheme in May 2021 to promote manufacturing of Advance Chemistry Cell (ACC) and reduce import dependency of the country[26]. It could emerge as a game changer and give a boost to high-density batteries for heavy duty performance requirements. The aim is to bring in investment in battery manufacturing for which an outlay of Rs 18,100 crore has been set aside to be spent over a period of 5 years. Total battery manufacturing capacity envisaged to be established under the scheme is to the tune of 50 Giga-Watt hour (GWh) and 5 GWh of niche ACC. This will not only help reduce cost of battery, but also augment India's effort to promote indigenization of EV production.

Achieving highest energy density is a significant part in the development of batteries, it could also be understood as, with equal size and weight a battery is able to gather a higher energy quantity and hence maximum efficiency could be achieved with the maximum running time and in a cost-effective way. Therefore, the density of the battery is another sector that needs some attention while designing the batteries.

Battery Disposal

Properly disposal of EV batteries is a crucial practice if one of the prime purposes of electrification is to safeguard our environment. The disputes for MHDVs are seriously undermined if one of the side-outcomes of electrification will be an increasing amount of battery waste going to the landfills, garbage-dumps and roadsides. As these MHDVs uses a high voltage battery, the disposal of these types of Li-ion batteries increases serious environmental concerns. Although Li-ion batteries themselves are eco-friendly comparative to few others such as lead acid starter batteries, used high voltage Li-ion batteries come with a risk - possibility of stranded energy. A used battery lying in a landfill, garbage-dumps or by the roadside poses a potentially lethal risk to a person that touches it. It is important for public safety that all high voltage Li-ion batteries be completely decommissioned and irreversibly discharged at end-of-life (EOL) (Kelleher Environmental, 2019).

Vehicle Manufacturing

Build ecosystem

Currently, hard-to-abate road segments – long-distance buses and HDVs – account for more than 40%[27] of the total energy consumption and hence needs long-term resolutions. The major players in the sector are taking numerous steps right from installing charging infrastructure to investing in R&D for EVs that are appropriate for the Indian roads. Building an ecosystem for this sector is the most critical activities in the country like India, where the lack of adequate EV infrastructure is a challenge as compared to other countries.

Like any other vehicle segment or vehicle technology, the availability of fuel plays a vital role in widespread acceptability. This also applies to EV technology, including the MHDV sector. It is crucial that if we want to shift our focus from conventional fuel to battery-electric vehicle, we need to set-up an ecosystem on a topmost priority basis. This could be named as “You build it, they'll come” model for identified close-circuit operations of trucks or key corridors to start with. The running and maintenance costs of these vehicles are significantly lower than the diesel vehicles. Initiative towards providing charging infrastructure on India highway is underway, and EVCI facilities for e-buses would be launched on Delhi-Jaipur highway and Delhi-Agra Yamuna expressway shortly.

Electrification of this sector also results in the reduction of payload of the vehicle, hence directly affecting the cost of travelling and reduction in income opportunity that arises due to reduction in payload. Hence, we require a tech-solution like high power density batteries, and fast chargers to overcome the issue.

Similar to business strategy of e-bus segment in India, e-trucking sector also needs a similar approach and focus in meeting the daily-run requirements, including the critical support structure – charging infrastructure. Plug-in chargers and pantograph-based chargers are few technology advancements that need investments to enhance the electrification of this sector.

Electrification of MHDV sector has long been recognized as a potential pathway to reduce fuel expenses and emissions from the freight movement, yet expansion of a sustainable market for electrified CVs has lagged behind the LDV sector. Over the last few years, battery performance has witnessed improvements and battery costs have reduced considerably, making electrification of MHDVs more attractive. But these factors have still not been realized in this sector due to low volume purchases and customized pack specifications. The MHDV sector is expensive and capital-intensive, even well-known OEMs, except for few, are reluctant in committing about e-MHDVs. OEMs are following the 'wait and watch' policy. Making the EV components in-house or purchasing them from the global market is an area that could be looked into. EV market is growing at a substantial rate across the globe and the Indian OEMs will play a very crucial role.

Learnings from China

Currently, China has swiftly shaped the world's largest EV market, and now accounts for half of World's electric vehicles and about 90% of e-buses and e-trucks. China is now looking forward to enter a new era of its EV development, in the context of both increasing global competition and nation's new pledge to achieve carbon neutrality by 2060, and for this China will be keeping an eye on some more holistic EV strategy in the future.

The financial structure and technological advancements in China are best in the entire world hence, India should also be looking for like-wise strategies where funding process and techno-advancements should grow. Focus on setting-up of battery manufacturing units in the country, as envisaged under the PLI scheme, will fast-track the EV transition in the HDV sector and will significantly cut down cost of batteries, as it accounts for the majority share in total cost of vehicles.

China introduced innovative EV pilot programs on an enormous scale, many cities showed their interests and prioritized deployment in public fleets. Further, there was support from the Chinese government in the form of investments in R&D and direct subsidies. The period from 2012 to 2017, witnessed speedy and massive growth of China's EV market. Post 2018, China started to move from subsidizing the industry to providing a combination of incentives and policy regulations to augment the potential of the market. This shift in the policy, collectively with increasing market openness and competition, showed China's improved confidence in its EV strategy and the maturing of its EV market (Jin, et al., 2021).

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7. VECV-Eicher in 16-40.2 tonnes segment and VECV-Volvo in > 49 tonne segment
8. A self-propelled wheeled vehicle, designed primarily to transport goods and heavy equipment.
9. Intermediate and Light Commercial Vehicle.
10. Truck (usually 10-wheeler) made-up of two sections joint together, a tractor and a trailer to carry heavy loads.
11. Key elements of the Stage 3 standard are:
    - Similar to the Stage 2 National Standard, the Stage 3 standard sets fuel consumption limits following a step function, using gross vehicle weight to segment each vehicle type.
    - The Stage 3 standard tightens vehicle fuel consumption limits for tractors, trucks, dump trucks, coaches, and city buses by an average of 12.5% to 15.9% compared to Stage 2 limits, and by an average of 21.7% to 27.2% compared to Stage 1 limits.
    - When comparing Stage 2 and 3 standards, the largest percent reduction comes from city buses with GVW 3.5-4.5 tonnes, tightened by 17.9%, and the smallest percent reduction comes from coach buses with GVW 14.5-16.5 tonnes, tightened by 10.7%.
12. A type of truck, that has all its axles attached to a single frame.
13. In TERI's transport model, medium-duty and heavy-duty vehicles are clubbed into one category 'HDVs'
14. https://www.iamconsortium.org/resources/model-resources/markal-india/
15. http://petroleum.nic.in/sites/default/files/autopol.pdf (page 252/294), last accessed on September 30, 2021
16. Sales and registration of in-stock China 5 LDVs are allowed in regions that have not yet adopted China 6 until January 1, 2021. By April 2020, Beijing, Shanghai, Tianjin, Chongqing, Hebei, Henan, Guangdong, Shandong, Hainan, Anhui, Zhejiang, and Jiangsu, as well as central cities of Shanxi, Shaanxi, Sichuan, and Neimenggu, had all implemented China 6.
17. The Indian OEMs have to report an annual fleet level fuel efficiency summary for monitoring purpose. Under CAFE Phase I, CO_2 emission target of 130 gm/km has been set by 2022-23. The overall aim is to improve fuel efficiency of on road vehicles by 35% by 2030.
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Annexure 1

Truck rentals on trunk routes for multi-axle truck carrying 18-19 tonne payload (full round trip) - August 2021

ODs	Rs (hike from July 2021)
Delhi - Mumbai – Delhi	1,16,500/- rental up to 1,18,000/- (+ 2500/- , +1.5%)
Delhi - Nagpur - Delhi	1,00,500/- up to 1,02,500/- (+2000/-, + 1.9%)
Delhi -Kolkata – Delhi	98,000/- up to 1,00,500/- (+2500/- , + 2.5%)
Delhi - Guwahati – Delhi	1,50,300/- up to 1,53,500/- (+ 3200/-, + 2.2%)
Delhi - Hyderabad – Delhi	1,32,800/- up to 1,35,300/- (+ 2,500/- , + 2.1%)
Delhi - Chennai – Delhi	1,44,000/- up to 1,46,800/- (+2,800/- , + 2%)
Delhi - Bengaluru – Delhi	1,29,000/- up to 1,31,600/- (+ 2,600/-,+ 1.9%)
Delhi - Ranchi – Delhi	1,00,500/- up to 1,02,200/- (+ 1,700/- , 1.6%)
Delhi - Raipur – Delhi	1,01,000/- up to 1,03,500/- (+ 2,500/- , + 2.1%)
Delhi - Kandla port – Delhi	1,47,500/- up to 1,50,000/- (+2,500/- , + 1.5%)
Delhi - Vijayawada – Delhi	1,32,500/- up to 1,34,500/- (+ 2,000/- , + 1.7%)

Source: IFTRT

Annexure 2

BAU Scenario – HDV Fuel Technology (% in new sales)

	>7.5 but ≤12 tonnes		>12 but ≤16.2 tonnes		>16.2 but <=25 tonnes		> 25 tonnes	
	Diesel/ L/C NG	Electric	Diesel/ L/C NG	Electric	Diesel/ L/C NG	Electric	Diesel/ L/C NG	Electric
1980-81	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
1990-91	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2000-01	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2010-11	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2020-21	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2030-31	98.00%	2.00%	99.50%	0.50%	99.50%	0.50%	99.50%	0.50%
2040-41	95.00%	5.00%	98.50%	1.50%	98.50%	1.50%	98.50%	1.50%
2050-51	92.00%	8.00%	97.00%	3.00%	97.00%	3.00%	97.00%	3.00%

Ambitious Scenario – HDV Fuel Technology (% in new sales)

	>7.5 but ≤12 tonnes		>12 but ≤16.2 tonnes		>16.2 but <=25 tonnes		> 25 tonnes	
	Diesel/ L/CNG	Electric	Diesel/ L/CNG	Electric	Diesel/ L/C NG	Electric	Diesel/ L/C NG	Electric
1980-81	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
1990-91	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2000-01	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2010-11	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2020-21	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%	100.00%	0.00%
2030-31	95.00%	5.00%	95.00%	5.00%	98.00%	2.00%	98.00%	2.00%
2040-41	70.00%	30.00%	70.00%	30.00%	90.00%	10.00%	90.00%	10.00%
2050-51	40.00%	60.00%	50.00%	50.00%	70.00%	30.00%	70.00%	30.00%