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HOW CNG VEHICLES WILL COPE-UP WITH PENETRATION OF ELECTRIC VEHICLES IN INDIA

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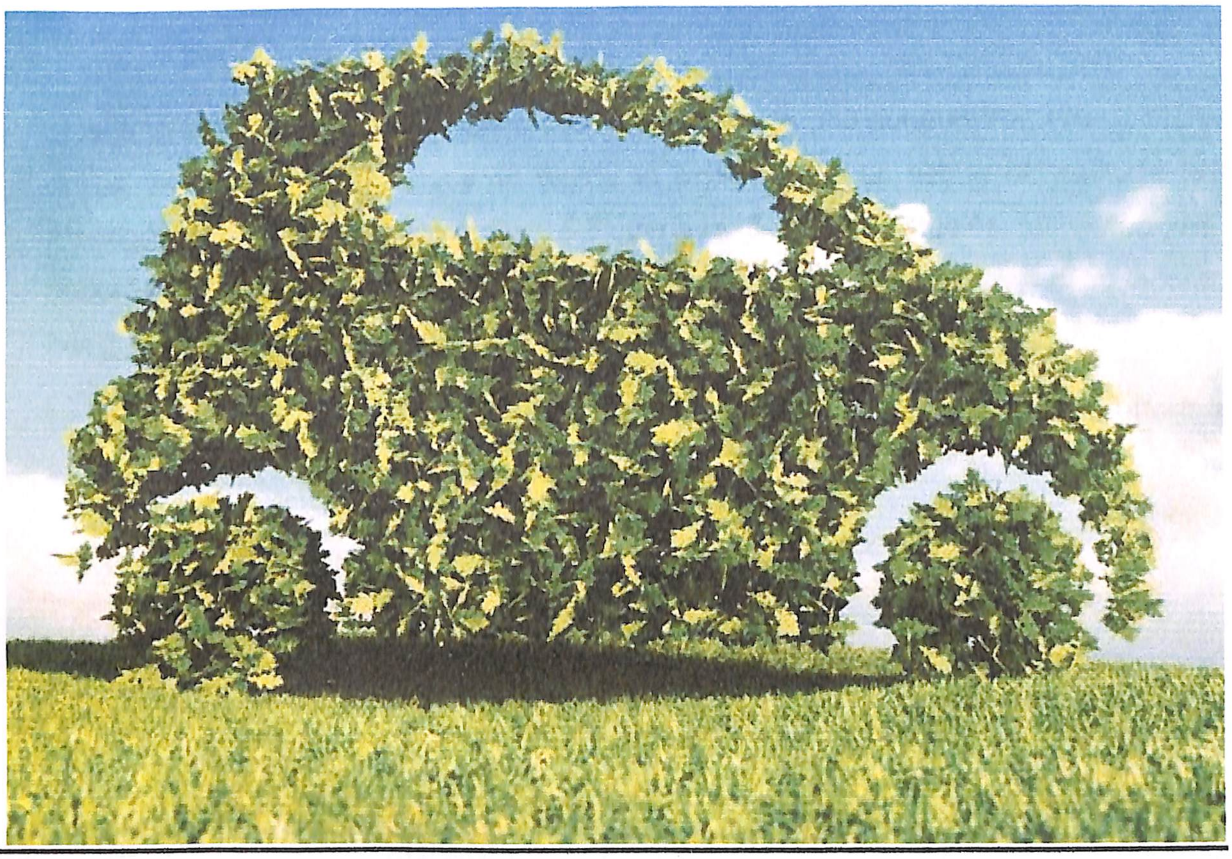
A DISSERTAION REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

MBA IN OIL & GAS MANAGEMENT COURSE

OF

CENTRE FOR CONTINUING EDUCATION
UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN



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Acknowledgement

This is to acknowledge with thanks the help, guidance and support that I have received during the Dissertation. I have no words to express a deep sense of gratitude to the management of UPES, University of Petroleum & Energy Studies for giving me an opportunity to pursue my Dissertation, and in Particular Ms Nimmi Banga, Coordinator for her guidance and support.

I must also thank Mr. Akshat Gupta, project guide for his valuable support, efforts and encouragement during the preparation of the dissertation.

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Declaration by the Guide

This is to certify that Ms. Nitya Sharma, a student of MBA in Oil & Gas Management, SAP ID 500065929 of UPES has successfully completed this dissertation report on "**How CNG Vehicles will cope-up with penetration of Electric Vehicles in India**" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analysed by her and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA.

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Table of Contents

Summary

In India all vehicles irrespective of the fuels they use have to meet the same emissions standards. This means the new OEM CNG vehicles are required to meet the same emissions standards as those meant for the conventional fuels and technologies of diesel and petrol. During the transitional phase the program implementation during 2000 – 05 the OEM vehicles had to meet Euro II standards like other vehicles. Vehicles that had undergone after market conversion had to meet Euro I standards -- one step behind the OEMs. Now the emissions standards for aftermarket conversion have been brought at par with the OEM standards.

The first generation CNG bus technology that rolled out in Delhi and Mumbai meeting Euro II standards is dominated by the conventional stoichiometric CNG engines using mechanical air-to fuel proportioning and mixing systems with electronic "trim" of the air-to-fuel ratio, based on the feedback from an exhaust oxygen sensor. They are also equipped with three-way catalytic converters (TWC).

The actual tests carried out on the Euro II compliant Indian buses by the Automotive Research Association of India as part of the TERI study found that even the first generation CNG bus technology meeting Euro II emissions standards had significant PM reduction and moderate Nox emissions advantage compared to the diesel counterparts. The PM levels from the Euro II CNG bus were found to be nearly 46 times lower than its diesel counterpart. This CNG technology choice seemed appropriate in terms of meeting the objective of particulate emissions reduction, as it could easily and readily make particulate emissions negligible. (*see Table 2 Comparative emissions of diesel and CNG buses in India).*

CHAPTER 1:

INTRODUCTION

Niti Aayog, which is leading the policymaking effort for accelerated penetration of EVs in the country, has reportedly proposed that only electric vehicles be sold after 2030. The government's plan to popularize electric vehicles (EVs) and phase out the sale of fossil fuel driven vehicles beginning 2023 can put at risk the planned investments of more than Rs 1.2 lakh crore in city gas distribution business, company executives said. Niti Aayog, which is leading the policymaking effort for accelerated penetration of EVs in the country, has reportedly proposed that only electric vehicles be sold after 2030. The EV push has created confusion among new licensees and may lead to companies missing work programme targets they had quoted to win licences and slow down investments in the sector, multiple executives at city gas firms said. "With such bleak future for the industry, banks will not lend for city gas projects," said another executive. Executives did not want to be named for the fear of annoying the government.

With a large number of Indian cities embarking on natural gas vehicle programme it is essential that the elements of these programmes are well defined for maximum environmental and public health gains. It is important that the lessons are drawn from the well established programmes in the region to chart the future course. The existing programs in Indian cities are of varying scale and scope and reflect the regional imperatives. Environmental imperatives are much stronger in India today, which in conjunction with the energy security concerns are propelling these programs.The front runner cities that have already established their first generation CNG programmes like Delhi and Mumbai along with the new ones are at the throes of planning the second generation expansion. This will require well thought out policy and criteria to maximize the environmental and public health benefits of these programmes and also make them economically effective. Therefore, it is important to consider the criteria on the basis of which the future expansion of CNG infrastructure and transport sector programmes will be planned in India.

Currently, it is estimated that the transportation sector uses up less than 2 per cent of the natural gas in the country.

CHAPTER 1:

As the natural gas grid further expands and more cities begin to get access to natural gas, the prospect of its application in the transportation sector also increases. The compressed natural gas vehicle (CNG) programme is expected to expand considerably in future.

According to the estimates of the Petroleum and Natural Gas Regulatory Board, currently, there are 7 lakh natural gas vehicles in the country. This is expected to increase to 58 lakh over the next 10 years. Delhi alone has more than 2 lakh vehicles. Around 30 cities have access to CNG and some of them have implemented the programme of varying scope. It is also expected that the pipeline network will increase to 15,000 Km and implementation of city gas distribution network will cover around 150 to 200 cities by 2014. This potential can be further exploited if thenatural gas distribution network is expanded and strengthened.

India's Electric Vehicle sales face challenges of affordability and charging:

Yet the world's fourth-largest auto market has vast potential for electric vehicles Hyundai Motor Co. launched India's first electric SUV this summer with a quirky TV commercial urging millennials to Drive Into the Future. A few months later, the automaker finds itself on a lonesome road. In a nation of about 15 crore drivers, only 130 Kona SUVs were sold to dealers through August. That slow pace is emblematic of the difficulties carmakers face in establishing an electric foothold in the fourth-biggest auto market, even with committed government support. The Kona sells for about $35,000 while the average Indian earns about $2,000 a year – and the best-selling gas guzzler costs $4,000. Yet Kona's sticker price only kicks off the conversation about why EVs aren't gaining traction in India – there's also a lack of charging infrastructure, a reluctance by banks to finance purchases and an unwillingness among government departments to use EVs as directed.

CHAPTER 1:

Barely more than 8,000 EVs were sold locally during the past six years, according to data compiled by Bloomberg. China sells more than that in two days, according to BloombergNEF projections.

Affordability:

The affordability of electric cars in India is just not there, said R.C. Bhargava, chairman of Maruti Suzuki India Ltd., maker of the sales leader Alto. I don't think the government or the car companies expect that in the next two to three years there will be any real buying of electric vehicles.The segment still isn't making meaningful strides more than four years after the government started promoting cleaner vehicles for one of the world's mostpolluted countries. In February, the Centre committed to spending $1.4 billion on subsidies, infrastructure and publicity. The potential of India's EV market can't be ignored. There are only 27 cars for every 1,000 Indians, compared with 570 for the same number of Germans, allowing global automakers an opportunity to challenge the dominance of Maruti - the unit of Japans Suzuki Motor Corp. that sells every other car on local roads. Maruti's not introducing its first EV until next year. Tata Motors Ltd. and Mahindra & Mahindra Ltd. build some base-level electric cars, yet they have a limited range or are exclusively for government use. The Kona gives Hyundai a first-mover advantage in a market where EVs may comprise 28 per cent of new vehicle sales by 2040, according to BNEF. Not only Hyundai sees opportunity in Asia's third-largest economy. MG Motor, the iconic British carmaker owned by Chinas SAIC Motor Corp., and Japan's Nissan Motor Co. see EVs as a way to expand in the country. Somebody has to take the leadership, and it will trickle down, said Rajeev Chaba, managing director of MG Motor India, which plans to launch an electric SUV by December. The process of scaling up will be slow, and MG Motors would be satisfied selling 100 cars a month initially. Right now, though, consumers pass over electric cars for bigger, longer-range and cheaper gas guzzlers, said Vinkesh Gulati, vice president of the Federation of Automobile Dealers Associations, which represents more than 80% of automobile dealers in India. More than half of the passenger vehicles sold in India last year cost

CHAPTER 1:

$8,000 or less, according to BNEF. Electric cars won't achieve price parity with gasoline-powered cars until the early 2030s, BNEF said. Consumers care about EVs, and the excitement is there, Gulati said. But that stops the moment we tell them the price.

Sparse charging infrastructure:

Yet even for those who can afford the Kona, plugging in is problematic. Nidhi Maheshwary, a 40-year-old finance professional working near New Delhi, wanted to buy an EV to show her children an example of environmental responsibility.

So when Hyundai launched the Kona, Maheshwary ordered one. Sounds easy, but it didn't turn out that way. Almost immediately, she got into a spat with neighbours about charging the SUV in her apartment buildings basement lot. The resident's society said it posed a fire risk - even though Hyundai engineers and the fire department said it was safe. So Maheshwary charges the car at her office while weighing potential recourse against those neighbours. Hyundai offers two small chargers with the Kona, although it can take as many as 19 hours to fill up the vehicle. India had an estimated 650 charging stations for cars and SUVs in 2018, according to BNEF. China, the largest market for EVs, has about 456,000 charging points, official data shows. India's inadequate charging infrastructure stems from locals chicken-and-egg approach to the issue. At a conference in New Delhi last month, government officials and EV-component makers debated whether to create an adequate charging infrastructure to promote sales or whether to wait until there are enough EVs on the roads before building it out. We are pretty sure that people are going to like our EV, but we would have our challenges like infrastructure, Chaba said. But we have our plans to handle that. Those include first requiring that the buyer can install a charger at home, he said. But there's another factor besides income that makes it difficult to pay for one of these cars. The unaffordability of EVs also stems from the unavailability of financing, said Pranavant P., a partner at Deloitte India focusing on the future of mobility. Until there's an established secondary market for EVs, banks and other institutions are hesitant to extend purchasing loans, he said. A majority of Indian vehicle sales are financed by lenders.

CHAPTER 1:

Government support:

The government, both federal and local, will have to offer help for EVs to be adopted in the mass market, said Puneet Anand, group head of marketing at Hyundai Motor India.

The budget in July included incentives such as reduced taxes, income tax benefits and import duty exemptions for certain EV parts. The first beneficiaries will be the ubiquitous scooters and motorcycles – with subsidies meaning to support sales of 1 million two-wheelers, compared with 55,000 electric cars. Yet the government still needs to practice what it's preaching. Energy Efficiency Services Ltd., a joint venture of state-run companies responsible for replacing state vehicles with EVs, awarded its first tender in September 2017 for 10,000 cars. But as of July, agencies had accepted only 1,000 of them. Now EESL is offering vehicles to taxi companies.

CHAPTER 2:

LITERATURE REVIEW

Environmental imperatives of CNG programmes in India: The use of natural gas in the transportation sector is primarily driven by the environmental and public health imperatives. Indian cities of Delhi and Mumbai had started implementing natural gas vehicle programmes during the nineties when even Euro I emissions standards were not in place and the sulfur content of diesel in India was as high as 5000 – 10,000 ppm. With fuel substitution, these cities were able to leapfrog to much cleaner emission levels.

The India's NGV programmes have primarily targeted the most polluting segments on the Indian roads that include diesel buses, three-wheelers, taxis and small commercial vehicles. This is somewhat different from the much older but very large programmes of Argentina and Pakistan where petrol driven light-duty cars were targeted largely for energy security reasons. Natural gas is abundantly available in Argentina, Bangladesh and Pakistan and it is easier for them to run their spark ignition petrol engines on natural gas as an energy security measure. Pakistan and Bangladesh however, have started to target diesel bus sector now for environmental reasons. The CNG programme targeted diesel vehicles in India mainly because diesel-related pollutants are either already very high or rapidly increasing in Indian cities. While more than half of Indian cities are reeling under critical level of particulate matter, the NOx levels have also begun to rise. There are serious public concerns over health implications of diesel related fine PM, and other air toxics. These fears are supported by the sprinkling of studies in India on health impacts as well as the epidemiological studies from other parts of the world that have shown statistically significant associations of ambient PM levels with a variety of health effects in sensitive populations, including premature mortality, hospital admissions, respiratory illness and changes in pulmonary function. Thus, Indian cities cannot continue to add the high emitters of PM and NOx, like conventional diesel vehicles. The level of roadside exposure to pollution from traffic has a significant effect on health and the severity of the public health impact. Rate of dieselization of the light duty vehicle sector is already quite high. In 2000 the share of diesel cars in the new car fleet was just about 4 per cent. This has already increased to 30 percent and is expected to be half by 2012.

CHAPTER 2:

In India, rigorous emissions inventories have not been carried out to understand the impact of dieselisation on ambient air. A collage of small evidences, however, bears out the impact on air quality. A collage of small evidences, however, bears out the impact on air quality. A World Bank supported study on source apportionment of PM2.5 (particulate matter less than 2.5 micron in size) in selected Indian cities released in 2004 shows that, depending on the season, the contribution of diesel fuel to the total PM2.5 ambient concentration can be as high as 61 percent in Kolkata, 23 per cent in Delhi and 25 per cent in Mumbai.

A 2004 study carried out by Mario Camarsa, then with the UK-based Enstrat International Limited, has assessed the impact of low-sulphur diesel fuel on diesel emissions in three Asian cities — Bangkok, Bangalore and Manila.iii This bears out the varying but growing trends in diesel emissions in these cities. In the Indian city of Bangalore, the Camarsa study found diesel engines to be a significant contributor of the total NOx emissions from vehicles — as much as 40 per cent and comparatively less significant contributor of PM10.iv

EVs IN THE INDIAN CONTEXT

Indians are famously value conscious. This is why consumers love diesel cars, despite their higher MRP and pollution relative to petrol counterparts. Even at today's low oil prices, running a diesel sedan can cost about Rs3.8 per kilometre versus petrol's Rs5.5. In contrast, CNG costs roughly Rs1.9/km, but it's not widely available. The cost of EVs depends on electricity price, which varies significantly. At Rs7/kWh (kilowatt hour) of power, they cost only about Rs1.1/km This saves consumers driving 5,000km per year over Rs20,000 annually, and taxis much more as they drive 10-15 times as much.

The catch is the upfront cost. EVs are expensive, primarily because of the battery. A single kWh of electricity is enough to go about 6km, so a 200km "full tank" range requires about 35 kWh of battery. Today's prices for lithium ion batteries are about $250/kWh globally, which comes to Rs5.7 lakh in battery costs, excluding import duties. Even with an eight-year lifespan and a 12% interest rate, justifying the battery costs on per kilometre savings alone means one would have to drive over 25,000km per year. Doable,

CHAPTER 2:

but not for everyone. However, when battery prices fall to $100/kWh, as projected a few years out, EVs can become a game changer.

Range turns out to be key: 5,000km per year is only about 15km per day on average, while an urban taxi may do 300km daily.

Higher range means not only more battery cost but weight as well. In an ideal world, we would have a smaller battery pack and simply recharge periodically. In practice, taxi and fleet vehicles can only charge overnight, and even private users may have limits on charging options.

Without fast-charging infrastructure—fast-charging an EV requires much more power than household 15 amp sockets, which can only offer about 3 kW of power, so 35 kWh takes almost 12 hours to charge—one inevitably has "range anxiety". Unlike the US, most Indians don't have a personal garage. Hence, widespread and company-agnostic public charging infrastructure becomes a key policy choice.

EVs SHOULD BE A WIN-WIN FOR STAKEHOLDERS

The power grid is also a key stakeholder in the ecosystem. Not just where but when does someone charge? The worst-case scenario is consumers coming home after work and plugging in at the same time, which also happens to be the grid's demand peak. One solution is charging consumers a variable rate based on time of day, but that isn't yet the norm for most users in India, and certainly not households.

Done right, EVs and the grid can have enormous synergy. Not only can EVs charge whenever there is "surplus" power, they have a battery useful for absorbing variable renewable energy. They can even offer backup power for the grid. This is one reason we should create a new electricity consumer category for EVs, one that includes aggressive time-of-day pricing (cheap charging when power is surplus). Otherwise, we risk commercial users attempting to charge EVs on subsidized residential power prices. Or worse, utilities disliking EVs if they hurt their viability, to the extent that they don't provide essential support (this already happens with renewables).

Not only are EVs efficient—with regenerative braking capturing energy otherwise wasted and also due to the inherent efficiency of motors, especially at low speeds—they pollute less.

CHAPTER 2:

We should value such environmental co-benefits, not just carbon reductions (which are roughly a wash, but avoided local air pollution. There are other distortions to consider. Over half of petrol's pump prices are for taxes. Petrol taxes are 1% of GDP (gross domestic product) and diesel, 2%. We could compensate cleaner vehicles through reduced registration charges, or even aim for mandating EVs for taxis and selected (urban) public transport vehicles. These are often diesel, and thus far worse polluters.

Fully switching to EVs means affecting some 2% of GDP. Of course, oil is predominantly imported, so moving to EVs should be a worthwhile trade-off. Plus, over time, more and more electricity will come from renewable sources.

There are other ways to spur EVs, including dedicated charging spots, and discounted or free parking. The long-run goal isn't just to make vehicles electric but to reduce personal driving. This means urban redesign for walking/biking, more shared services, and more and better public transport (convenient and fast enough that the rich will also choose it).

Instead of trying to pick technology winners, the government mainly needs to create the right frameworks and help overcome "network effect" problems, covering both the grid and charging infrastructure. Innovation is already happening in these areas.

CHAPTER 3:

RESEARCH DESIGN, METHODOLOGY & PLAN

Health benefits of the CNG programme in India: Specific studies have not been carried out to assess the health benefits of the CNG programmes in Indian cities. A World Bank study of 2004 had assessed the health benefits of the first generation air pollution action in five Indian cities that included Mumbai and Delhi which have the largest and the oldest CNG programmes in the country. The CNG programme is also the most important part of the first generation reforms in these cities. The World Bank study shows that the first generation measures in Delhi and Mumbai that also include one of the largest CNG programmes have helped to reduce the number of premature deaths annually – at least 3629 in Delhi and at least 5308 in Mumbai.

Climate benefits: The climate benefits of the CNG programmes in India are yet to be evaluated. It is however premised based on the global studies and experiences that in comparison to the conventional diesel, the CNG programme offers greater benefit of lowering CO_2 emissions given the lower carbon content of the fuel. Globally studies have established lower CO_2 potential of natural gas.

Paradigm shift in CNG technology:

Industry develops CNG hybrid buses: A large scale CNG programme in Indian cities has stimulated innovation. Bus industry has already developed prototype for CNG hybrid technology. Ashoke Leyland has developed a CNG plug-in-hybrid bus HYBUS. The company claims 20-30 per cent fuel savings compared to a conventional IC engine. However, fuel efficiency and emissions data for these vehicles are still not available to assess their performance. There is also no clear deployment strategy for these more expensive models. Some of these buses will be show cased during the upcoming Commonwealth Games scheduled to be held in Delhi during the October 2010.

CHAPTER 3:

CNG gate-way to Hydrogen future – hythane:

The pilot project on hythane programme (blending of hydrogen with natural gas) in Delhi demonstrates the future possibilities of making a transition and bridge the gap with new generation fuels and technology that are needed to combat pollution and climate change

This will enable future solutions. In a major initiative the Indian Oil Corporation Limited commissioned a H-CNG dispensing station at Dwarka in January 2010. This dispensing station will make H-CNG available or three-wheelers and cars. The project is funded jointly by the Ministry of New and Renewable Energy and the Ministry of Petroleum and Natural Gas with an investment of Rs. 5 crore.

CHAPTER 4:

ANALYSIS

There are currently more than 20 million vehicles in the world running on natural gas. This gas which is called CNG (Compressed Natural Gas), is same as the gas used to heat our houses. Natural is a resource that is widely available & is less polluting than petrol & diesel. Moreover, CNG is lighter than air. So, vehicles that use this gas are not subject to the ban on access to underground car parks.

It is important to note that indigenous capacity to produce natural gas vehicles has enabled large scale make over to gaseous fuel in India.

Concerns over after market conversion:

Since the launch of the CNG programme there have been concerns over the possible implications of allowing large scale conversion of old technologies especially diesel bus technologies. Global experiences have shown that poor quality conversion and diesel to CNG conversion can be particularly problematic and if not done well gaseous emissions can escalate. Different technical approaches are available in Indian cities to move to CNG – dedicated CNG vehicles built by OEMs, repowering or replacing old diesel engine with new spark ignition one, and, conversion of old diesel engine to run to spark ignition engines. Naturally the conversion of the old engines has been the cheapest option, OEMs being the most expensive (Rs lakh for conversion vs Rs 16 lakh for OEM standard bus in 2002). Amongst these three choices operators have opted for either OEM vehicles or conversion of old engines. Repowering has not happened.

CHAPTER 4:

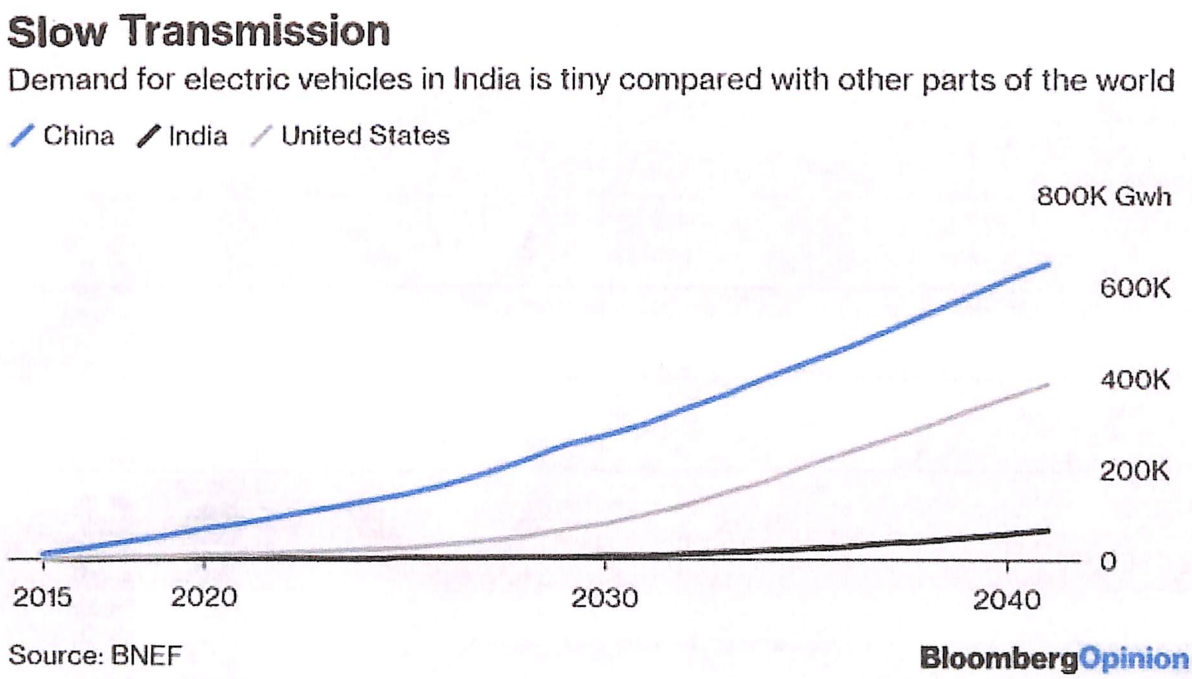
Conversion has however been very popular in smaller petrol vehicles like cars, and three-wheelers that also have spark ignition engines. This is very common globally and with good diesel engine conversion.

Locating CNG in the future roadmap:

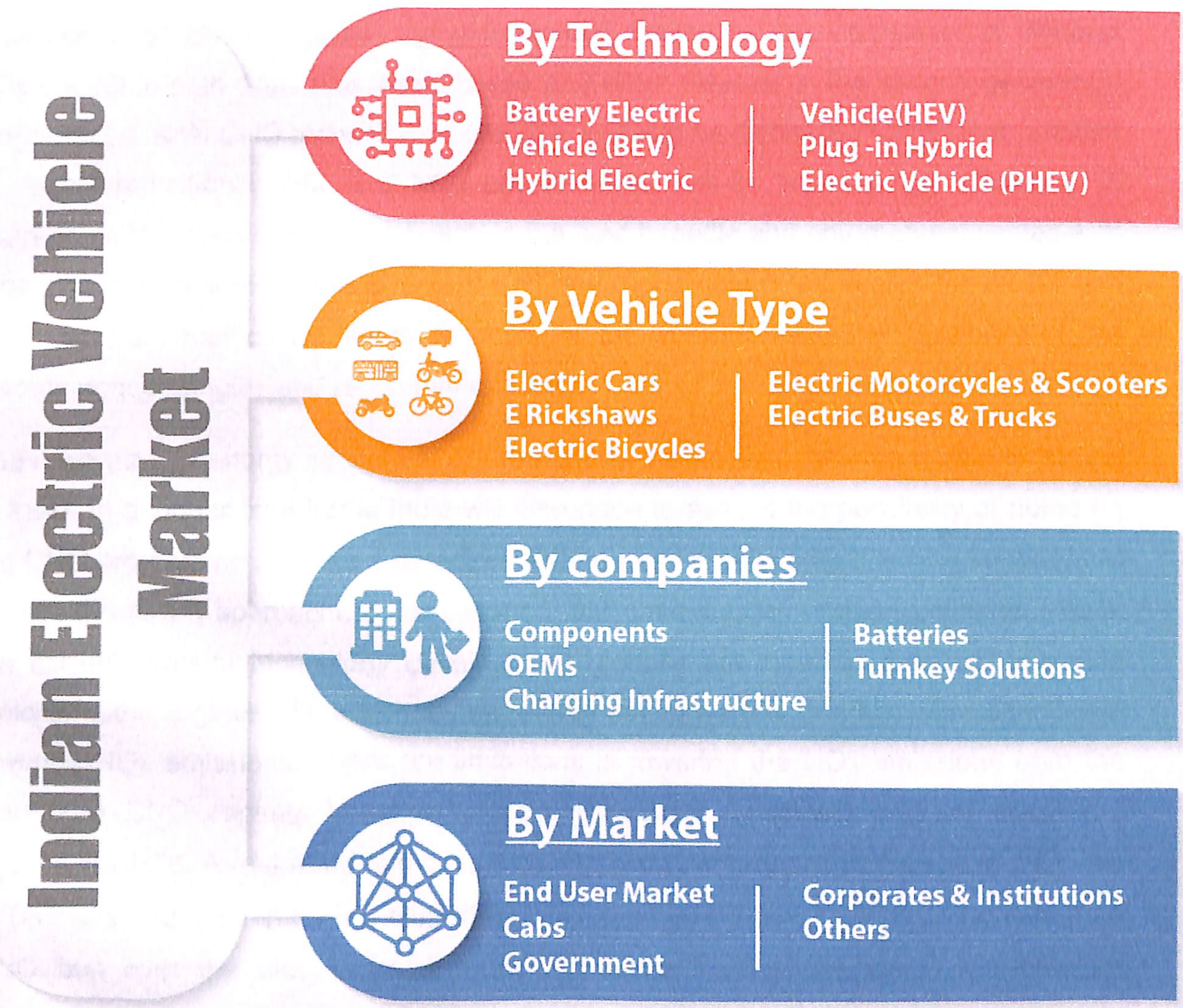
Fuel neutral approach is possible when diesel cleans up nationally: Fuel neutral approach is possible when equally clean alternatives are available across India. As of now there is no official roadmap that indicates the date of introducing clean diesel on a nation-wide scale. CNG therefore will continue to be preferred in cities that have access to natural gas. As there are no constraints of fuel quality in CNG these cities can adopt Euro IV technology that will also give them considerable emissions advantage. Currently, CNG is a preferred solution in high mileage city buses and para-transit that are also part of the mobility strategy in the cities. Cities are in any case discouraging small para transit like three-wheelers on diesel. Cars will not be part of any regulatory mandate and will be driven by the customer preferences, and fuel pricing. There are concerns over public health impacts of dieselization of the car sector across India. (See Annex 1: Cars: dieselized). The price differential between petrol and diesel is a loophole that is leading to dieselization. While the Union government earns nearly Rs 15.18/litre from every litre of petrol used by a petrol car as excise, it earns Rs 5.20/litre from a litre of diesel used by a diesel car. There is a growing demand for deregularisation of fuel prices and additional taxes on diesel cars to reduce the incentive for diesel cars in India. At the same time introduce clean diesel.

<u>CHAPTER 4</u>:

Demand for Electric Vehicle in India



CHAPTER 4:


Indian Electric Vehicle Market
By Technology
Battery Electric Vehicle (BEV)
Hybrid Electric Vehicle(HEV)
Plug -in Hybrid Electric Vehicle (PHEV)
By Vehicle Type
Electric Cars
E Rickshaws
Electric Bicycles
Electric Motorcycles & Scooters
Electric Buses & Trucks
By companies
Components
OEMs
Charging Infrastructure
Batteries
Turnkey Solutions
By Market
End User Market
Cabs
Government
Corporates & Institutions
Others

CHAPTER 5:

INTERPRETATION OF RESULTS

Indian cities will have to assess the enforcement challenges and economics of PM and NOx control in both CNG and diesel buses and other vehicles in the second generation programmes. New CNG technologies are also evolving as discussed earlier that promise significant reduction in PM, and NOx emissions as well as improve fuel efficiency. In future the CNG cities will have to weigh in the cost benefits and enforcement issues with regard to the technology improvement and emissions control strategies for diesel and CNG vehicles, fuel costs, life cycle costs of the vehicles, and the feasibility of the enforcement strategies and regulatory capacity.

The imperative of energy security of diverse energy basket will continue to remain strong in India. In a longer time frame India will also have to assess the possibility of riding on the CNG programme to make a paradigm shift to frontier solutions. It is now important to assess the future approaches. For instance, the emerging information indicates that at the current level of technology development globally the move is towards advanced stoichiometric engines with advanced three-way cat converters that are more effective in lowering NOx emissions. There are limitations in lowering the NOx emissions from the lean burn CNG engines below the levels achievable by diesel engines fitted with advanced CRTs. A real world bus emissions study was conducted in Europe in the cities of Brussels and Lausanne. It is clear that there is no advantage in NOX of the lean burn CNG bus over the diesel bus. But stoichiometric TWC CNG bus has substantial advantage over advanced diesel buses. The stoichiometric CNG bus has much lower NOx emission and also higher fuel efficiency.

CHAPTER 6:

CONCLUSION & SCOPE FOR FUTURE WORK

India has a lot to gain by converting its ICE vehicles to EVs at the earliest. Its oil-import bill would considerably reduce. ICE vehicles are a major contributor to pollution in cities and their replacement with EVs will definitely improve air quality. There is a considerable possibility that we can become leaders in small and public electric vehicles. India has over 170 million two-wheelers. If we assume that each of these vehicles uses a little more than half a litre of petrol per day or about 200 litres per year, the total amount of petrol used by such vehicles is about 34 billion litres. At ₹70 per litre, this would cost about ₹2.4 lakh crores. Even if we assume that 50% of this is the cost of imported crude (as tax and other may be 50%), one may save ₹1.2 lakh crores worth of imported oil. There is a real possibility of getting this done in the next five to seven years. This would however require innovations, a policy regime that encourages access to late technologies and a concerted effort by the Indian industry to achieve global competition through acquiring the necessary scale and using cutting edge technology.

The following conclusions can be drawn from the analytical part of present work investigation:

Combustion model has been prepared for heat of reaction and stoichiometry. Fuel Mole fractions at stoichiometric conditions for engine operation from lean to rich limit has been found analytically. Flammability limits of Gasoline, LPG and CNG fuels have been studied. Validation of the analytical model has been achieved within the domain of the present experimental investigation.

For stoichiometric condition, heat of combustion calculated from reaction of Gasoline, LPG and CNG is 44.687, 46.504 and 50.2 MJ/kg respectively. CNG having highest calorific value due to more percentage of methane.

Study and analysis of CNG/LPG conversion kit has been done to investigate working of major components for supplying gaseous fuel.

CHAPTER 6:

It is found that volume contained by second stage low pressure regulator is slightly higher than the volume of cylinder of engine. Mass flow rate and fluid velocity in all stages of LPR have been calculated. Also construction and working of low pressure regulator has been verified analytically.

The analytical investigation shows that, the DNS model explains the effects of partial fuel oxidation and reduced oxidation rate. It can be successfully incorporated into a simple one-step Arrhenius model by consideration of variable values of the heat of reaction and activation temperature.

SCOPE FOR FUTURE WORK :

As CNG operated engine is running hotter by 100°C compared to Gasoline operated engine, material of cylinder head, valve and valve seat insert must be changes for CNG compatibility. Cylinder head material should be upgraded with silicon copper high alloy material to retain hardness at elevated temperatures.

Cobalt base alloy should be used in valve seat inserts which remain intact even at elevated temperatures. Moreover, there is also a potential for improvement in design of mixture preparation system for CNG and LPG, which are still in the development stage. The development of gas flow controlled by micro-processor, which will regulate the gas flow in intake manifold vacuum, may produce a further reduction in emission levels and improve engine performance.

Engine parameters like fuel injection rate, exhaust gas recirculation rate, spark advance, etc. are controlled by electronic engine management system to keep emissions at low level and also to maintain an acceptable engine performance.

CHAPTER 6:

Making EVs Economically Viable:

The limiting factor of batteries on driving range may be addressed by developing an ecosystem of fast-charging or swapping of batteries. This can be achieved by creating requisite infrastructure, possibly even every kilometer, in dense areas. As a result an important question arises as to what kind of strategy can make EVs, especially small vehicles, economically viable. The general strategy should address two key variable affecting the costs of EVs: battery costs and any fiscal policies that either increase the costs of an ICE vehicle or decrease the costs of an EV. Broadly speaking, approaches exist to reduce battery costs – reducing the number of batteries that an electric vehicle needs and making batteries cheaper on a per kilowatt-hour basis. For the first approach, reducing the batteries needed for a given EV, there are two key pathways:

- Providing charging infrastructure: The limiting factor of batteries on driving range may be addressed by developing an ecosystem of fast-charging or swapping of batteries, by creating an infrastructure, maybe even every kilometre, in dense areas. A smaller battery will lower costs by reducing the total weight of the vehicle, resulting in high energy-efficiency and improved ability to upgrade as the technology evolves.

  Charging infrastructure can be rolled out on a city by city basis with select cities and regions leading the transition. This would be consistent with global experience where 33 percent of all EV sales take place in only 14 cities where charging infrastructure is widespread and convenient to use. Approaches for creating effective charging infrastructure are outlined below.
- Increasing efficiency of vehicles: Incentivising developments to increase vehicle efficiency, thereby reducing energy consumption, can enable to a vehicle to travel the same distance on a smaller battery pack. Energy efficiency can be enhanced by using more efficient electric motors [see Appendix II] using better tyres, enhancing the aero dynamics of the vehicles and reducing its weight. This would reduce battery size needed for a certain range. For the second approach, reducing the unit costs of each battery, India can explore several pathways:

CHAPTER 6:

1. Selecting appropriate battery chemistries. As batteries dominate costs of electric vehicles, the strategy would be to use battery chemistry with optimized cost and performance at Indian temperatures. India should encourage manufacturing of such battery cells in India. India is already making battery packs (cell to pack).
2. Exploring new battery chemistries: Focussing on materials like lithium, manganese, nickle, cobalt and graphite that are used in batteries and determine its costs. While it is important to secure mines which produce these materials, India must also obtain these battery materials through recycling of used batteries and should aim to become the capital of "urban mining" of used batteries. Beyond reducing battery costs, India can explore potential avenues of fiscal support for EVs to accelerate adoption. The standard approach in other countries to providing fiscal support to EVs has been direct subsidization. For example, EVs in USA, Europe and China have upto 40% "all-in" subsidies. Those subsidies include direct federal or state subsidy to buyers, mandates to manufacturers, utility subsidies or subsidy in the form of fee bates where vehicles are taxed based on their CO2 emissions, whereas EV receives support. As costs decline and the share of EVs in total vehicles increases, most nations plan to taper off such subsidies. For India, however, those paths are not viable; the elimination of direct subsidy will be the policy basis. Therefore India has to be creative to make electric vehicles and its infrastructure economically viable from the very beginning. Its policy and strategy have to be fundamentally set up to enable EVs to make business sense.

Direct financial demand-incentives / subsidies could be replaced by Tradable Auto-Emission Coupons or credits based on CO2 emissions per km as well as on a sliding scale for vehicle efficiency. This will encourage the market to build efficient vehicles with lower emissions per km. Thus, while vehicle manufacturers exceeding CO2 emissions targets would have to purchase coupons or credits, the manufacturers meeting the targets would be rewarded with coupons. Market will decide the prices of these coupons.

CHAPTER 6:

This will incentivize EVs and low-emission vehicles as well as energy-efficient vehicles at the expense of the vehicles with high emissions and lower-efficiency.

Accelerating the availability of necessary electricity network infrastructure as well as domestically produced technologically superior EVs, chargers and components will bring down costs and increase the options available for transportation electrification in India. This could bring total cost of ownership (TCO) of EVs to parity with ICEs by as early as 2025.

Focus on small and public vehicles to make early Impact:

While encouraging the sale of private EVs, India's focus, at least in the first few years, should be on small, public and rural transportation. It is possible for India to have a unique impact and scale early with two-wheelers and three-wheelers, including three-wheeler good vehicles. Special attention is needed to get these vehicles to become economically viable and flourish. Simultaneously, India needs to ensure that electric buses become viable. With the credits/coupons, buses would become economically viable very quickly with the rationalized customs duties. Cars used in the government and taxi fleets need to be available early. They should be economically viable with credits/coupons. India could use both charging and swapping to get these vehicles scale early.

Impact of EVs on Economic growth:

Shifting modes of mobility could launch new business opportunities. These would emerge in areas such as charging and swapping infrastructure, service, or integrated transport. In India, energy players have entered the mobility industry, while some traditional power companies are exploring possibilities in charging infrastructure, and infrastructure companies are seen entering the battery business. An important task that needs attention is transforming and up-scaling small and medium sub-system and auto-component industries. A large number of such mini-micro industries are auto-ancillary companies for diesel/petrol vehicles.

CHAPTER 6:

They provide large number of jobs. Many of them will not survive as EV replaces petrol/diesel vehicles. A careful plan to hand-hold such industries and help them during the transition to EV components manufacturing is required. Expansion of transport fleets based on IC engines negatively impact the economy considerably, apart from their negative health contributions. Crude oil price volatility adds uncertainty to an already burgeoning import bill, while also needing huge investments in oil refineries and related distribution infrastructure. There are several studies that suggest overall positive impact on GDP on introduction of EVs in fuel importing service dominated economies. On study has estimated that driving the shift to electric vehicles would lead to a 1% increase in EU GDP[6]. In another study, net private and social benefits are estimated between $300 and $400 per EV[7]. Coupled with generation of renewable power, the battery manufacturing industry in India can become bigger than the total amount spent on import of crude oil. This would provide a huge boost to the Indian economy. The revenue loss for governments from the taxes on the oil sector is expected to be replaced by higher taxrevenues in other economic sectors.

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