CONFLUENCE OF ENERGY AND MOBILITY

MAKING INDIA’S MOBILITY FUELS SUSTAINABLE AND ECONOMICALLY VIABLE
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Climate change and global warming are widely recognized as the most pressing environmental concerns which can have a debilitating effect on global public health and human life. While the Paris Agreement of 2016 aims at strengthening the global response by limiting temperature rise, the current rates of CO$_2$ emissions and lack of any major structural change across regions indicates that emissions will continue to increase and surpass COP21 targets. Concerns about atmospheric emissions have forced many countries to re-evaluate their emission sources and sustainability of their energy mix.

India has undertaken several initiatives to meet COP21 targets, but has its own set of unique challenges: heavy dependence on internal combustion engine (ICE) vehicles leading to high vehicular emissions, growing crude consumption leading to a hefty crude import bill, substantial dependence on a few countries for crude imports leading to high geo-political risk, significant carbon dependent energy mix and soaring urban pollution.

In this context, it becomes imperative to explore alternative solutions to sustain the growing mobility needs of India. There are multiple choices in the Indian mobility fuel basket and a comprehensive assessment is needed to evaluate them. In this paper, we review these alternatives from two major lenses: sustainability and affordability.

In our analysis, we look at the complete well to wheel lifecycle for different fuels on emissions and the total cost of ownership for different vehicle types.

Electric Vehicles (EVs) have emerged as a promising alternative powertrain worldwide. However, the economic viability based on the total cost of ownership will remain a critical factor in the consumers’ adoption of the vehicle. Our study also finds that while EVs rate well on CO$_2$ emissions, the story is not the same when emissions are accounted for other pollutants (NOx, SOx, and PM10) across the lifecycle. In India, EVs can be a key to shift the emissions away from urban centers to remote areas where thermal power plants are based. However, in the long term it is important to curb the total lifecycle emissions.

Natural Gas Vehicles (NGVs) offer an advantage on environmental emissions and on the cost compared to traditional ICE variants. However, their adoption has been restricted to a few areas due to insufficiency of the current natural gas current infrastructure in certain parts of India, the lack of adequate filling stations and below
par marketing efforts of natural gas as an economic and sustainable fuel choice specifically for private four wheelers. Irrespective, Natural Gas is an extremely promising fuel from an emissions and economics perspective.

Petrol and diesel are the two most commonly used fuels in India and their importance in the power mix cannot be undermined. Efforts to reduce Lead and Sulphur as well as the implementation of BSVI norms will help upgrade the fuel quality and reduce emissions. In order to reduce India’s emissions, equal importance must be given to make these two fuels more eco-friendly in the near-term including initiatives such as rapid roll out of BSVI, optimizing energy consumption in refining and ‘cleaner’ upstream operations.

Blending fuel with ethanol and methanol reduces vehicular emission and reduces the crude import bill for the country. However, the Government will also have to consider the high capex requirements and the inadequate ethanol storage capacity at depots before blends become a scalable option.

Looking at different alternatives in the Indian context, we believe that the path to alternative mobility solutions in India would be a complex one – like a mosaic – with different pieces congregated. Propagation of electrification, Natural Gas, ethanol blending along with controlling emissions from existing fuels (motor spirit and high-speed diesel) will be fundamental in reducing vehicular emissions and to leapfrog mobility advancements in India.

Any one alternative should not be considered as a single “silver bullet” to solve the mobility challenge. Every alternative is an option offering a range of possibilities at our disposal to solve the problem of environmental pollution and global warming.

This paper, hence, evaluates the various ‘vehicle-fuel’ options from a sustainability and economics perspective and presents a range of solutions across fuel types in the near and medium term. The paper also highlights the ‘call for action’ for public and private stakeholders to accelerate the path towards attainment of India’s climate change objectives from a vehicular emissions standpoint.
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1. RISING CONCERNS OVER GLOBAL WARMING AND CLIMATE CHANGE

The world is witnessing an unprecedented movement towards rise in temperatures and greenhouse gas concentrations. The global mean temperature in 2019 was observed to be 1.1 ± 0.1 °C (Exhibit 1) above the agreed baseline (1850-1900), making the year second warmest to date. In 2018, the Annual Greenhouse Gas Index was 1.43, which is an increase of more than 40% since 1990. Continuing CO₂, CH₄, NOx and SOx emissions from vehicles, factories, power stations, and use of fossil fuel energy sources can potentially increase global temperatures by another 2 to 6°C by the year 2100, a further jump from the already elevated levels.

In addition to the rising global temperatures, higher concentrations of CO₂ affect human life further. World Health Organization (WHO) expects 250,000 additional deaths per year between 2030 and 2050 due to heat-induced illnesses, exacerbation of cardiovascular diseases and respiratory diseases from air pollution. Apart from CO₂, various other pollutants have detrimental effects on human life. In 2017, the outdoor PM was responsible for 38.15 deaths for every 100,000 population and air pollution was responsible for 63.82 deaths for every 100,000 population. Nitrogen oxides harm human health by causing breathing problems, headaches, chronically reduced lung function.

EXHIBIT 1 | Global Mean Temperature has Been Rising Due to Increasing CO₂ Emissions

Source: NASA’s Goddard Institute for Space Studies
and is a major precursor to ground-level ozone which can damage vegetation.

As a result, concerns about rising levels of atmospheric emissions have forced countries to relook at their emission sources and sustainability of their energy mix. The initiation of the Paris Agreement of 2016 is a major step in strengthening global response to the climatic threat.

The agreement aims to limit global temperature rise to under 2 degrees Celsius above pre-industrial levels and bring it down further to 1.5 degrees through various emission control measures. However, at the current rates and lack of any major structural change, emissions are likely to continue to increase and surpass the COP21 targets.
2. INDIA HAS ITS UNIQUE SET OF CHALLENGES

India, the fourth-largest carbon emitter after China, United States and the European Union, is an important signatory to the COP21 agreement. It has made three bold commitments to the Paris Agreement: to generate 40 percent of total energy demand from non-fossil fuel (renewable) sources by 2022; to increase forest cover from the current 24 percent to 33 percent; and to reduce 3 billion tons of carbon by 2030. India’s progress towards the targets has been commendable and its initiatives such as an International Solar Alliance with France, creation of green energy corridors, implementation of National Smart Grid Mission, schemes such as PM-KUSUM, solar rooftop phase-2, and development of Ultra Renewable Energy Power Parks are contributing to meeting its 40% renewable energy target.

However, further issues need to be addressed. While India is operating in the same global context as other countries, it has its own set of unique challenges. Challenges such as high carbon dependence in the power mix, high growth in urbanization, and regional/geopolitical risks linked to crude sourcing further complicate matters on both climate and non-climate fronts.

Challenges on the climate side are:

2.1 Dependence on ICE Vehicles
While transportation accounts for about 11% of India’s carbon emissions and is a major source of pollution in cities, it is unlikely India will be able to change its dependence on Internal Combustion Engine (ICE) vehicles (Exhibit 2) for the foreseeable future. ICE vehicles contribute over 95% of the current vehicular stock in India, are well-rooted in its existing ecosystem and bring affordable convenience to millions of Indians. Even though the sector is innovating and getting a step closer to offering sustainable transport solutions via its BSVI compliant standards, fleet substitution can be a slow process. Hence, an interim solution to lower the carbon footprint of ICE vehicles is much needed while the process of fleet transition towards other fuels and electrification plays out gradually.
2.2 Rising pollution from increased urbanization

India has 21 of its cities among the 30 most polluted in the world. A 1% increase in urbanization leads to a 0.24% increase in CO\textsubscript{2} emissions in India, much higher than the 0.12% increase in China, and a falling emission rate in developed countries. Higher emissions in Indian cities is largely due to increasing distances between workplace and home, limited public transportation, carbon concentrated power mix and an increasing preference for private transportation. Emissions from industries, construction dust, burning of waste, and millions of poor households using fuels such as wood and cow-dung for cooking exacerbates the problem.

2.3 Carbon dependent power generation

India continues to be largely dependent on fossil fuels for power generation, even after taking dedicated measures to meet COP21 deadlines. With a high line loss rate and ~76% dependence on coal for the total power generation in the country, growing power needs lead to higher emissions. Indian government has put in significant efforts to increase renewable energy projects to 40% of installed capacity, yet the slow progress of renewable projects is a cause of concern. In addition, much needs to be done as renewables become an integral part of India’s power mix. Initiatives to increase overall grid stability, pushing states to comply with their RPO (Renewable Purchase Obligation) targets and introducing storage solutions are required to push this agenda.

In addition to climate related challenges, India also faces issues associated with high import bill and geopolitical risks.

2.4 High crude consumption and import bill

In India, two wheelers, three wheelers, cars and trucks together consume a third of its oil imports. Indian crude import bill has been constantly increasing and imported fuel dependence has risen from 77% in 2013-14 to 84% in 2018-19 to meet its growing energy demand. Coupled with stagnant domestic production, this has led to increasing crude import bills and current account deficit for the nation (Exhibit 4).

2.5 Geopolitical Risks

India’s dependency on imports for fuel makes it vulnerable to geopolitical risks such as pricing decisions, exchange rate fluctuation, trade restrictions, political instability, or natural disasters. Currently, India imports 42% of its crude oil from just 2 countries, Iraq and Saudi Arabia, thus adding concentration risk to the mix.

The Indian government has begun to actively address several of these issues. It has mandated a quick roll out of BSVI emission norms from April 2020 to limit vehicular CO\textsubscript{2}, NO\textsubscript{x}, SO\textsubscript{x}, and PM emissions. The government is also encouraging alternative powertrains (through schemes such as FAME I & II), which have low tailpipe
emissions and can help improve the air quality in cities. India also defined the Corporate Fuel Efficiency Norms (CAFE norms) in 2017, aimed at reducing average corporate CO₂ emissions from petrol, diesel, LPG, and CNG vehicles. The government has also laid down stricter norms for thermal power generation emissions, which need to be fulfilled by 2022 in line with the COP21 emission targets. Although these actions point in the right direction, we also need to develop a deeper understanding of lifecycle emissions for each fuel type to reduce the overall emission footprint. Another area of focus should be customer economics to enable faster adoption of cleaner fuels. Together, these will provide the ‘mosaic’ of solutions that are likely to work in India.

EXHIBIT 3 | Government Efforts Have Increased Energy Produced from Renewables but India is Still Significantly Dependent on Coal

EXHIBIT 4 | Indian Crude Oil Import Bill Has Been Rising

Source: Central Electric Authority, IEA, Energy technology perspectives

Source: Petroleum Planning and Analysis Cell, Ministry of Petroleum and Natural Gas
3. FOCUS OF THE STUDY

This paper analyses the current mobility landscape in India to identify the most optimal vehicle–fuel combination from environmental, emission and consumer perspectives. We have investigated the following questions:

- Across the entire mobility fuel and vehicle types landscapes, which is the most effective fuel-vehicle combination based on sustainability and affordability?

  - Sustainability involves lifecycle emissions for CO₂, NOx, SOx, PM10

  - Affordability entails evaluating the total cost of ownership for the end consumer

- How will adoption evolve for different fuel-vehicle types? What will be the areas of focus for different alternatives during the transition? What actions do the different stakeholders (government, power plants, fuel companies, OEMs, consumers) need to take in this transition?
A vehicle’s holistic impact can be understood through three lifecycle stages: production stage, operation stage, and disposal stage. In our analysis, we look at the complete well to wheel lifecycle for different fuels.

We cover the well to wheel emissions – which are emissions associated with the production of power source for the vehicle (such as battery manufacturing for electric vehicles, and upstream extraction, refining, transportation for ICE vehicles) and then tank to wheel emissions - the emissions associated with vehicle operations (e.g. tailpipe emissions) (Exhibit 5).

Emissions associated with the equipment lifecycle for the vehicle (vehicle manufacture, transporting, and distribution) and emissions associated with the repair, maintenance, or disposal of the vehicle are not covered in the study. The assumption is that manufacturing for both ICE and EV vehicles have similar emissions once we have accounted for the EV batteries separately. The environmental impact due to battery disposal has also not been considered as stringent regulations are already in place for its governance.

**EXHIBIT 5 | Scope and Boundaries of the Well to Wheel Emissions Analysis**

Source: Central Electric Authority, IEA, Energy technology perspectives

Note: Others include biofuel and waste energy
KEY RESULTS

4.1 Greenhouse gas emissions

- EVs outperform ICE on greenhouse gas emissions. EVs have zero tailpipe emissions with the entire emissions being generated from the well to tank phases (battery charging and battery manufacturing).

- Highest emission for the ICE vehicles comes from tailpipe followed by refining. Refining is the ‘dirtier’ process after tailpipe emission for ICE vehicles. Emissions associated with battery charging are the largest component for EVs due to the coal dependent power mix.

- For 4W, CNG has an advantage and EV are over EVs on comparable on a per km basis, with EVs being marginally better. CNG is a cleaner fuel than the traditional ICE variants (petrol and diesel) given it has lower tailpipe emissions and no associated ‘refining emissions’. (Exhibit 6 and 7)

EXHIBIT 6 | Well to wheel CO\textsubscript{2} emissions for different vehicles across fuel types

Note: Vehicle models are for 1. 2W Scooter: ICE – Activa 6G, EV– Ather 450; 2. 2W Bike: Bajaj Pulsar, Tork 6x 3. 3W: ICE-Bajaj Compact Diesel, ICE– Bajaj Re Compact CNG, EV– Mahindra Treo SFT; 4. 4W: ICE– Hyundai Aura Petrol, EV– Mahindra E-Verito; ICE– Hyundai Aura Diesel, ICE– Hyundai CNG; Cradle to Gate : Emissions associated with Battery Manufacturing

Source: BCG analysis; GHG Platform India

EXHIBIT 7 | Comparison across the different process from well to wheel for ICE and EV

TOTAL GHG EMISSIONS—ICE VS EV (CO\textsubscript{2} EQ. GM/KM) FOR A 2W SCOOTER

TOTAL GHG EMISSIONS—CNG VS EV (CO\textsubscript{2} EQ. GM/KM) FOR A 4W
4.2 NOx, SOx and PM10 emissions

- The environmental rationale for EVs weakens significantly once we look holistically at other emissions. While in all cases, EVs are better than ICEs for CO2 equivalent emissions, the story reverses if the emissions are accounted for other pollutants (NOx, SOx, and PM10).

- EVs perform poorly compared to ICE (vehicles) on NOx, SOx and PM10 across different vehicle types (Exhibit 8).

- Evaluating different fuels on a longer-term view\(^\text{10}\) (10 years) shows that
  - For CO2 emissions, EVs are better than any other ICE variants (MS, HSD, or CNG) across different vehicle types (2 Wheeler, 3 Wheeler, and 4 Wheeler).
  - On NOx, SOx, and PM10
    - For 2W – EV has lower emissions than ICE (MS, HSD).
    - For 3W and 4W, CNG emerges as a cleaner alternative than EV due to lower NOx, SOx emissions from the tailpipe compared to EV.

- For ICE vehicles, tailpipe and refining are the two biggest components for emissions.
  - While there has been an increasing focus on the tailpipe so far, it needs to now shift towards curbing emissions from other life-cycle stages such as refining and upstream operations.

- For EVs, emissions associated with the charging of batteries are crucial given a significant portion of that power is currently generated from thermal power plants. High SOx emissions from power plants impact the sustainability advantage which EVs offer otherwise.

  - Decarbonizing of power mix is a long-term answer. In the short term, stricter measures must be implemented to reduce SOx & NOx emissions from thermal power plants. Installation of FGDs and ash-handling systems are few techniques that can curb the emission at the power source in the near future.

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**EXHIBIT 8 | Well to wheel cumulative NOx, SOx and PM10 emissions for different vehicles across fuel types**

**Source:** BCG analysis; GHG Platform India
- India currently has one of the highest power transmission losses. This leads to increased emissions and higher cost - another disadvantage for EV adoption.

- Given ~80% of the emissions during the manufacturing of battery packs come from the upstream material (cell, module, and pack components), ‘cleaner’ localization of battery manufacturing will be critical to drive electrification.
5. TOTAL COST OF OWNERSHIP

Although emissions are a critical consideration for sustainability, the economic viability based on the total cost of ownership (TCO) is a critical factor in the consumer’s decision to adopt a vehicle. The government currently offers subsidies for the purchase of personal EV two wheelers and commercial three and four wheelers. This incentive can enable TCO parity and drive faster adoption. We looked at each cost and revenue line item to estimate TCO. Upfront purchase cost, salvage value at the end of vehicle life, incentives provided by the government, and operational cost based on the existing infrastructure are the key components of TCO for a consumer (Exhibit 10). We look at the total cost of ownership using two lenses: short term 5-year view and a lifecycle or 15 year view considering three starting points 2020, 2025, and 2030.

KEY RESULTS

5.1 Two Wheeler (2W)

Although the upfront purchase cost is higher for EV vehicles currently, savings associated with vehicle operations during the life of the vehicle make EV competitive. EV has a lower cost of ownership across different starting points with the subsidy provided by the government. Without subsidy, the TCO parity between EV and ICE will happen before 2025. Hence, initial incentives offered for the 2W after driving the initial adoption can be reviewed.
5.2 Three Wheeler (3W)

EV has a lower cost of ownership across different starting points with the subsidy provided by the government. Without subsidy, the TCO parity between EV and ICE will happen around 2025. Hence, incentives for 3Ws after 2025 can be reviewed. Over the lifecycle, EV vehicles have lower TCO than the existing ICE variants available. (Exhibit 11)

5.3 Four Wheeler (4W)

- **For 4W Personal:** EV has a higher cost of ownership across different starting points. Without subsidy, the TCO parity between EV and ICE will not happen before 2030, even for the lifecycle cost of ownership. High EV TCO is mainly driven by the high upfront purchase price of the 4W electric cars in India. (Exhibit 12).

- **For 4W fleet:** EV has a lower cost of ownership than the ICE Diesel variants across different starting points with the subsidy provided by the government. Even without subsidy, EV vehicles will have TCO parity with diesel fleet before 2025. CNG emerges as the lower-cost option, especially in the short term. EVs will achieve TCO parity with CNG post-2025. However, in the near future, CNG is the most feasible option based on the total cost of ownership for 4W fleet vehicles. (Exhibit 13).

- Based on the TCO, consumer adoption for EVs will be faster for 2W, followed by 3W, 4W fleet and then 4W personal.

- Available infrastructure (charging stations for EVs, filling stations for CNG) which directly impacts consumer convenience will be a key factor in the adoption of different powertrains.

- Subsidies will drive faster shift to electrification in the near term. However, over the lifecycle of the vehicle
(for 2W and 3W), the cost of ownership for EVs will be lower than the ICE counterparts, hence provision of incentives can be reviewed in future.

- In the case of 4W fleet, subsidies help make EVs more attractive than ICE vehicles, but the cost of ownership still remains higher as compared to CNG counterparts, mainly driven by the high cost of operations and maintenance. The case further worsens for personal cars, given that there are no subsidies.

**Battery Residual Value**
A key element in evaluating TCO of EV is the residual value derived from repurposing used batteries at the end of the battery life. EV batteries are still left with almost 70% of their capacity when they stop being suitable to power electric vehicles. They can be repackaged and reused for multiple other functions such as stationary storage applications. However, a market for used EV batteries is yet to reach any significant scale in India. Battery residual value will reduce the cost of ownership for EVs.

We looked at the TCO for 2W and 4W fleet to understand how TCO changes if we exclude the residual life of the battery.

- The lifecycle and the 5-year TCO increase with exclusion of the residual value of the battery.
- For 2W, even with increasing TCO, EVs remain cheaper than ICE vehicles on both 5-year (short) and lifecycle (long term) perspectives.
- In 4W, EVs continue to remain a better option over the ICE variant. CNG which was cheaper than the EV previously, continues to have a lower TCO than the EV vehicle.
Although, the TCO increases for EV with the exclusion of the battery residual value, the competitive placement against other variants remain the same. (Exhibit 14, 15)

Based on the both the perspectives: sustainability and economics, we see a significant evidence to explore and adopt various solutions in our mobility fuel mix.

EXHIBIT 14 | 5 Year and the Lifecycle Total Cost of Ownership For the 2W Scooter

EXHIBIT 15 | 5 Year and the Lifecycle Total Cost of Ownership for the 4W Fleet
WE NOW LOOK AT the different alternative powertrains: Electrification, Natural Gas, and Blending (in MS, HSD) and how they can help the transition towards a cleaner power mix. We review where they are today, what the key challenges are, and the required actions by different stakeholders to drive this transition towards a cleaner and economical mobility mix.

6.1 Electrification – Promising alternative but still a distant dream

Electric vehicles have emerged as a promising alternative powertrain worldwide with improving battery chemistry, falling battery pack prices, advances in renewable energy, urgent need to tackle climate change, and push for energy security. Sales of alternative energy vehicles continue to rise globally even when the global auto market is shrinking.

Electrification solves the key challenges we discussed previously. It has lower greenhouse gas emissions, offers a step-change in urban pollution, and reduces dependence on crude compared to ICE counterparts. However, EV in India has its own share of challenges.

Although India unveiled the ‘National Electric Mobility Mission Plan 2020’ in 2013, the EV market in India is still at a nascent stage. EV vehicles in India constitute just 5% of the total vehicle market. The EV cars in India have increased from 0.01% in 2012 to 0.10% in 2018.

Following are the key challenges for EV in India:

- Thermal power dependence: High SOx, NOx, PM 10 emissions from power plants given 76% of India’s power is generated through coal. The following steps need to be explored to address the emissions:
  - Electrostatic Precipitators (ESP) which is used for particulate deposit / ash removal
  - Flue Gas Desulphuriser (FGD) to reduce SOx emissions which is being implemented by some plants but needs further regulatory clarity on cost allowance
  - Selective Catalytic Reducer (SCR) to reduce NOx emissions
  - Coal washing to reduce ash / sulphur
- **Transmission losses**: India currently has one of the highest power transmission losses, a disadvantage for EV adoption. The following steps need to be explored to tackle commercial and technical losses:
  - Roll out of Automated Meter Reading by DISCOMs to avoid human intervention and lower corruption; Roll out of Smart Meters to enable remote disconnection (although implementation maybe a challenge)
  - Regular rotation of circle manpower / replacement of outsourcing contractors by DISCOMs

- **Battery disposal or recycle**: The market for used EV batteries is nascent. There needs to be significant coordination among OEMs, EV owners, utility companies, and battery manufacturers for secondary use of batteries. India also lacks relevant regulations and standards for guiding this. The government is now in the process of drafting rules called the ‘Battery Waste Management Rules 2020’ which will ensure that used batteries are sent only to registered recyclers and, provide structure to the market.

- **Poor Infrastructure**: Currently there a limited number of (<1000) charging stations in India which needs to be ramped up significantly through public private partnership.

- **Absence of a robust supply chain**: India is largely dependent on China for batteries. Efforts to localize battery manufacturing have not yet yielded results. Also, with the current technology dependent on availability on Lithium, whose reserves are concentrated in a few countries, battery manufacturing remains expensive. While a lot of players have shown interest, there still are only a few large EV battery manufacturing facilities in India.

- **Cost of ownership**: without subsidy, the cost of ownership for an EV remains higher than an ICE vehicle in a 5-year time frame given the higher upfront capital cost of EVs.

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### Following Actions May Be Considered by Stakeholders to Drive Electrification

<table>
<thead>
<tr>
<th>ESG Infrastructure, CNG economics</th>
<th>Government</th>
<th>Power companies</th>
<th>Auto OEMs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrification</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Localization using incentives in the initial period:*</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- Invest in localization of battery manufacturing with clean technology. Provide incentives to set-up large scale battery manufacturing plant in India</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- With sufficient infrastructure in place, for driving initial adoption consider the financial incentives: GST, Road Tax and Financing interest rates, toll charges and power tariffs for the charging stations</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- Incentivize the OEMs to producexEVs to enable adoption in the near term</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- Accelerate the development of charging ecosystem and speed up the supply chain readiness: public charging stations, vehicles from OEMs, battery packs, chargers etc.</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- Invest in the creation of a secondary market for EV batteries and devise regulations for battery disposal</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>- Drive local R&amp;D (improved battery technology, system integration and advanced supply chains) with incentives over a longer period</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>- Higher transmission losses makes EV inefficient. Work along with power distribution companies to reduce line loss rates to realize the full potential of EV</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
6.2. Natural Gas – A cleaner choice but limited by infrastructure

As discussed earlier, Natural Gas vehicles (NGV) provides an advantage over petrol and diesel vehicles on environmental emissions and cost. India produces around half of its natural gas requirement and the rest is imported under long-term contracts from the US, Canada, Russia, and Qatar. Currently, more than 30 lakh CNG vehicles run on Indian roads and have enabled substitution of nearly 3% of oil imports. Increasing CNG usage in the mobility fuel basket can positively address energy security and also bring significant savings in crude.

However, CNG adoption has remained restricted to a few areas due to:

**Lack of adequate filling stations:** CNG filling stations are limited in India with most of the CGD infrastructure concentrated in West and North India. There are around ~1800 CNG stations in India (compared to 60,000 liquid fuel filling stations) with 80% of them concentrated in Delhi, Mumbai, and Gujarat.

**Limited import terminals and limited CNG trunk pipeline:** Import terminals are currently located on the west coast of India. The trunk pipeline is also concentrated towards the west. There is limited infrastructure to supply CGD to the eastern states.

Hence, a dedicated and immediate effort is needed to improve the Natural Gas infrastructure to increase adoption of CNG vehicles.

Indian government has launched the Pradhan Mantri Urja Ganga Project (Exhibit 16), a pipeline project to increase CNG production and its availability in different parts of the country. It has unveiled a Natural gas infrastructure development plan to set up 10,000 CNG stations over the next 10 years to increase coverage to 52% of India’s area and 70% of the population. The Petroleum and Natural Gas Regulatory Board (PNGRB) has also announced plans to launch the 10th round of bidding for city gas distribution (CGB) to extend the CNG infrastructure. Natural gas has an important place among alternate energy solutions in India and there exists a significant scope to further leverage its potential in the country’s mobility fuel basket.

EXHIBIT 16| Strong Push by the Government to Increase the Share of Gas in the Energy Mix

Source: PNGRB, PNG statistics, GAIL
6.3 MS, HSD - Ubiquitous, scope to improve

Petrol and diesel are the two most commonly used fuels in India. The infrastructure for both is mature and multiple improvements over the years have helped upgrade the fuel quality and reduce emissions. Here are some of the key improvements in the past to curb tailpipe emissions and move towards cleaner mobility.

- **In gasoline:** Phasing out of lead (from 0.56 g/l to 0.005 g/l today), reduction in benzene content (to 1% vol. max), reduction of sulphur content (max 10ppm in BSVI), increase in RON\textsuperscript{11} (91 – regular, 95 – premium grade), limiting olefins (to 35%)

- **In diesel:** Reducing sulphur content (max 10ppm in BSVI), increasing cetane number (51) and limiting PAH\textsuperscript{12} content (max 8% by weight)

Strict implementation of BSVI norms will further aid this. Going forward, the focus needs to shift towards making refineries reduce emissions through targeted capex and also increasing the energy efficiency of Indian refineries, an area where India’s refineries have shown improvement but have a long way to go. The following should be explored in further detail:

- Improving emissions from refining (advanced techniques such as desulfurization of the flue gas, SNCR and low NO\textsubscript{x} additives to be explored to make refineries cleaner),

- There are additional initiatives that can increase refining energy efficiency such as:
  - Process improvement opportunities such as optimizing valve positions and reaction parameters to increase yield
  - Energy conservation opportunities such as deployment of reactive power management, proper sizing, improved insulation etc.
  - Other techniques such as reducing overall labor intensity, efficient shutdown and repair management and investments in R&D should be explored

- Faster fleet substitution (Scraping policy would be key in driving the fleet substitution and improving the vehicle mix)
6.3.1 Blending – Gaining traction, still insignificant in scale

Blending fuel with ethanol and methanol reduces vehicular emission as well as the import of crude. E10 and E20 blends can reduce vehicular emissions by 3.5% and 7.0% respectively\textsuperscript{13}. In 2019, ethanol-blending in petrol has risen to a record 6.2% in India, growing almost ten-folds from 0.67% in 2012-2013. The government has invested in ethanol production capacity to meet its target of 10% ethanol blending by 2022. This will reduce the country’s oil imports by 2 million tonnes annually and reduce the oil import bill by Rs. 7,000\textsuperscript{14} crore.

Indian vehicles post-2008 are compatible to use blends of up to 10%. In India, Ethanol and Methanol are the two potential candidates for the blending. Ethanol is mainly produced from sugarcane molasses through fermentation while Methanol is produced from syngas.

India is the 2\textsuperscript{nd} largest sugarcane cultivator after Brazil. Sugar production (30-35 MT) in the country exceeds sugar demand (~25 MT). This has resulted in growth stocks, providing an opportunity to utilize excess sugarcane for ethanol. A high potential exists in this first generation (1G) blending, driven by surplus domestic sugar production. The government is also exploring an alternate route of producing second generation (2G) ethanol from biomass and other wastes to bridge the supply gap in the ethanol blending program.

Although blending has a high potential in India, the option hasn’t been leveraged to its full extent due to the following challenges:

- Capex requirements are high for smaller-scale sugar mills resulting in less than 30% of the sugar mills putting up ethanol plants. Further, India makes very limited use of high-yield sources such as Molasses B for ethanol production
- Limited ethanol storage capacity at depots
- The cost of ethanol is dependent on the price of sugarcane, demand for sugar as well as the inter-state movement costs. Differing taxes across states for fuel movement is also a major problem for OMCs and ethanol suppliers.

Methanol-based blending can be a cost-competitive substitute; however, methanol production is limited in India. Nearly 90% of our domestic methanol consumption is serviced by imports. Coal-based methanol production can be an attractive option, given India has the fourth-largest coal reserves in the world. However, it would be critical to evaluate the coal-to-methanol value chain for both emissions and economics and its applicability in the Indian context.
Different stakeholders can consider the following actions to curb emissions associated with existing fuels (MS and HSD) and to promote blending:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Actions for consideration</th>
<th>Government</th>
<th>Oil companies</th>
<th>Auto OEMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol &amp; Diesel</td>
<td>• Effective BSVI implementation to curb tailpipe emissions</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increased focus on reducing pollution from refining. Implementation of advanced techniques such as desulfurization of flue gas, Selective Non-Catalytic Reduction (SNCR) system, low NOx additives and flare gas recovery system</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Release and ensure implementation of the scrappage policy: Infrastructure requirements, setting up vehicle scrappage facilities in the country &amp; streamlining the process for businesses interested in scrappage</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| | • Blending 
  - Notify the use of blends as a transportation fuel. Formulate regulations for OMCs on the usage of ethanol/methanol in blending (fuel specifications, safety standards, blending limits etc.) | ✓ ✓ ✓ | ✓ | |
| |  • Facilitate alliances (via technologies, JVs) with IOCs and leading Brazilian bioethanol manufacturers for: development of 2G ethanol (from non-sugarcane sources), improve yield/productivity of processes for 1G bioethanol | ✓ ✓ ✓ | ✓ | |
| |  • Develop fueling and safety standards (by Petroleum and Explosives Safety Organization and Oil Industry Safety Directorate) | ✓ ✓ ✓ | ✓ | |
| |  • Enhance support via means of financial grants for setting up ethanol plants (for ex: industry soft loans for distilleries) | ✓ ✓ ✓ | ✓ | |
| |  • Explore long-term offtake contracts between cooperative distilleries & OMCs; ensure assured availability to OMCs | ✓ ✓ ✓ | ✓ | |
| |  • Tax incentives for methanol and ethanol as a transportation fuel | ✓ ✓ ✓ | ✓ | |

Stakeholder responsible/involved
Hydrogen as a mobility fuel:
Globally, hydrogen is getting a lot of traction as an upcoming clean mobility fuel, specially hydrogen generated from renewable energy, called the “green hydrogen”. With the growth in renewables globally and significant reduction in cost, there are some reports that say that “green hydrogen” will become cost competitive to fossil fuels by 2030, however this will require a significant development in technology, cheap electricity and policy support. In terms of usage of hydrogen for Mobility, there are some projects running in Europe, Japan, Korea, China and Australia, however there is still a long way to go in terms of hydrogen being a mainstream fuel.

India and hydrogen for mobility:
India is well placed to create a market for Green-H\textsuperscript{2} – given our low cost of renewable energy along with innovations like RTC (Round-The-clock) RE. However, we are yet to see a significant push to promote Green-H\textsuperscript{2}. As an initial push, the Ministry of Road Transport and Highways recently issued a notification proposing to amend the Central Motor Vehicles Rules, 1989, and include standards for safety evaluation of vehicles that use hydrogen fuel cell technology. Also the Supreme Court has proposed the use of H\textsubscript{2} to tackle air pollution in New Delhi, NCR. Some initial pilots underway on using Hydrogen in mobility applications:

- IGL (Indraprastha Gas Ltd.) and IOCL (Indian Oil corporation) recently started a pilot of hydrogen-enriched CNG (HCNG) in Delhi, manufacturing hydrogen through compact reforming process. The project is running on 50 Cluster scheme buses as part of a pilot project for six months.

- IOCL is also looking at greater role of hydrogen for mobility. The company is seeking to purchase 15 fuel cell fitted buses for which a tender is out.

- Also, NTPC recently invited Global Expression of Interest (EoI) to provide 10 Hydrogen Fuel Cell (FC) based electric buses and an equal number of Hydrogen Fuel Cell based electric cars in Leh and Delhi.

However, in the long term, promoting hydrogen for mobility will require significant investment in distribution network and infrastructure which will need significant policy support.
**LNG as a mobility fuel:**
LNG has emerged as a solution globally for long-distance vehicles (trucks, buses, etc.), given the smaller tank size requirement as well as 50-200% faster filling for LNG as compared to CNG. The energy density per liter for LNG is ~2.5x greater than CNG, making it a preferred choice. The lower weight of cylinders means higher payload capacity. Moreover, LNG has the potential of reducing vehicular CO\textsubscript{2} emissions by almost 30% when compared to diesel vehicles, thus helping in fighting against climate change. However, LNG trucks are costlier than diesel counterparts. Limited availability of LNG is a major deterrent to its growth in the vehicle segment in India.

**India and LNG for mobility:**
India is looking to expand use of LNG for long haul. The country in the long run is planning 350 LNG fueling stations along its 6,000-km long golden quadrilateral highways. In a positive move to boost the LNG infrastructure, in June 2020, the Petroleum Natural Gas Regulatory Board (PNGRB) announced that any entity can set up an LNG station in any geographical area (GA), even if it is not the authorized entity for that GA, widening the ambit of companies that can set up LNG stations across the country.

Several key players have announced plans to invest in building the required infrastructure for expanding LNG for mobility in the country.

- Petronet LNG recently announced it is looking to partner with fuel and gas retailers on LNG stations along highways for long-haul trucks and buses. The company has tied up with state-controlled Gujarat Gas to open five such outlets on the Delhi-Mumbai highway in the next few months.

- Indraprastha Gas is separately setting up three more outlets on the same route. Petronet wants to set up 5 LNG stations in the fiscal year ending March 2021, and 300 by 2023. It eventually aims to have 1,000 LNG stations across India.

- Also, IOCL (Indian oil corporation limited) expressed its interest to start LNG retailing through its fuel pumps.

- India gas major GAIL is also looking to enter LNG fuel retailing business.

In terms of running a pilot, Petronet LNG has already launched its first commercially registered LNG-powered buses and LNG dispensing stations at its Dahej and Kochi Terminals. These buses are deployed for commuting the company’s employees between their residence and workplace. The company expect the business at pan India level could boost demand by 8mn-9mn t/yr in the next few years.
MOBILITY FUEL BASKETS ALL OVER THE WORLD ARE TRANSFORMING AND THIS transition is being triggered by the need to move towards a decarbonized world. There is a significant pressure on governments from all the players of the global ecosystem to move to a cleaner energy future.

In India too, adoption of alternative solution powertrains would not only address the alarmingly high emission levels, particularly in urban areas, but would also unlock savings in crude import bill adding to India’s energy security.

There are multiple alternatives to diversify beyond traditional MS and HSD across different vehicle types. Each alternative has its advantages but comes with its own implementation challenges. Whether the transition to a cleaner mobility mix is going to have more electrification, more CNG vehicles, higher blending, or more EVs on the road, depends upon the infrastructure, incentives and investments by different stakeholders – government, OEMs, and fuel/power companies.

Each of these alternatives will have a short and a long-term solution. In the short term, it is imperative to continue the ongoing initiatives: BSVI implementation, reducing emissions from refineries and thermal power plants and containing transmission losses. Natural gas and blends can also be quick wins in the short-term, given compliant vehicles are already available and some amount of infrastructure is in place. Incentives can also drive adoption of alternative sources in the short term.

The longer-term will require a holistic mobility strategy enveloping the various alternatives. It will involve

- Review of a range of solutions encompassing the auto, energy and manufacturing sectors to deliver sustainable and economic solutions across the value chain.

- Clear moves on the policy ranging from auto scrappage, battery disposal to renewable integration at scale.

- Review of emission intensive processes in refining and upstream for oil and gas and of NOx/SOx & ash emissions in thermal power plants.

- Deep investment into range of R&D topics considering the evolving scenario.

7. CONCLUSION: WHERE TO PRIORITIZE?
An important understanding emerging is that India will best respond to a diversified ‘mosaic’ approach, both in the short and the long term and we anticipate that various mobility powertrains will co-exist with further efficiencies being driven into each of them. This will be the most efficient way forward for India not just from the economic, energy security and consumer standpoints, but even from the perspective of environmental sustainability.

NOTES
2. The Annual Greenhouse Gas Index (AGGI) is a measure of the capacity of Earth’s atmosphere to trap heat as a result of the presence of long-lived greenhouse gases. The AGGI provides standardized information about how human activity has affected the climate system through greenhouse gas emissions. It is published by the National Oceanic and Atmospheric Administration Earth System Research Laboratory. https://www.globalchange.gov/browse/indicators/annual-greenhouse-gas-index
6. Central Electric Authority, CEA
7. PPAC, Petroleum Planning and Analysis Cell, Ministry of Petroleum and Natural Gas
8. Fuel basket includes Motor spirit, High-speed diesel, Natural Gas, Biofuels and Electric vehicles
9. 2wheelers scooters and bikes, 3wheelers autos, and 4wheelers personal and fleet cars
10. Decarbonizing of the current Indian power mix (gradual reduction from 76% thermal power generation to 50% thermal power generation by 2030), Reduction in line losses (improvement by 0.5% y-o-y) and Deterioration in mileage for both ICE and EV vehicles
11. Research Octane number
12. Polycyclic Aromatic Hydrocarbon
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(Sept, 2020)

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(June, 2020)

**Energy Transitions: Adapting to the New Normal of the Changing World**
(Dec, 2019)

**Creating Value with Digital Twins in Oil and Gas**
(Oct, 2019)

**Decentral energy and DISCOMs—can they co-exist**
(Aug, 2019)
NOTE TO THE READER

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