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Automotive fuel: Racing towards a multipolar world

February 2019

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Foreword

Peter Drucker referred to the automotive industry as 'The industry of industries' - such has been the diversity, enormity and impact of the industry on our everyday lives. But this pervasiveness has its flipside too - the industry gets impacted by factors not just confined to automotive science and technology but also other economic, technological and environmental forces that are seemingly unrelated to the industry.

With rising environmental concerns and increasing oil import bills, alternatives to Internal Combustion Engines (ICE) are being evaluated for past several years. Electric vehicles (EVs) with zero tailpipe emissions, comparable performance and increasing affordability promise to be the panacea to several of the concerns identified above.

While Battery Electric Vehicles (BEVs) are the early leaders in EV technology, is this leadership position sustainable? We have attempted to synthesise emerging arguments in favour of and against the various alternative fuel options and provide a view on what type of fuel would drive EVs in the future - whether BEVs are the apt and the only solution that would pervade all forms of mobility, is there a case for hybrids and can fuel cells be a realistic long-term solution to the challenges associated with BEVs and hybrids? We have also attempted to evaluate if the evolution of EVs in India will be in line with global trends or will players in the EV ecosystem have to adapt their offerings to suit the expectations of Indian customers.

The report draws upon findings from 'KPMG's Global Automotive Executive Survey', which has distilled views from senior automotive industry stakeholders across the globe. We capture their perspective towards likely evolution of alternative fuel technologies, country specific compulsions that will determine adoption of one technology over another and necessary conditions for consumers to embrace EVs.

Through this report, a glass-half empty person might guard herself from the vulnerabilities of disruption and a glass-half full person might see opportunities for growth. The paper puts forth our thoughts on the automotive fuel debate and we look forward to hearing your views and exchanging ideas on the same.

Thank you
Vinodkumar Ramachandran
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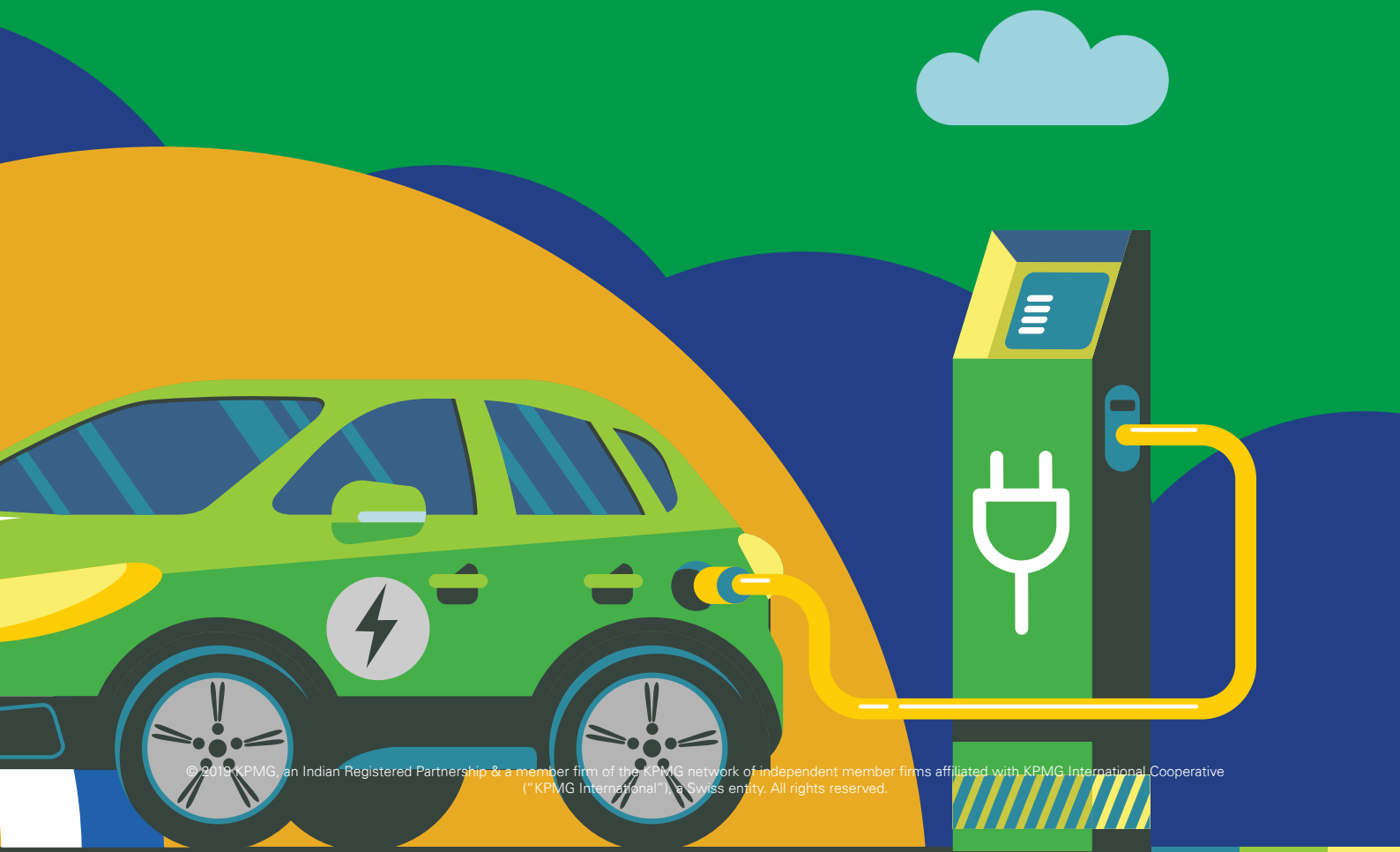


01. An age of disruption:

Market forces and government initiatives expected to bring about changes in energy sources for vehicles

70 per cent of the oil consumption is used for transportation. Oil Companies are now beginning to seriously evaluate the impact of electric cars on their future and are finding ways to participate in the electric revolution. Similarly, traditional automotive majors have realised that they may not be the ones shaping or controlling the future of the automotive industry as waves of creative destruction have brought in not just new tech startups from the Silicon Valley but also technology giants, as contenders who are likely to shape the future of the industry.

Massive investments are being made into this rapidly evolving space by both incumbents as well as challengers, to develop the automotive fuel of the future. Most importantly, companies have taken divergent routes to achieve the ultimate objective of developing a cleaner fuel – some have taken the Battery Electric Vehicle (BEV) route that uses Lithium Ion cell based batteries, some are experimenting with Fuel Cells and the incumbents are working with Hybrids and greener Internal Combustion Engines (ICE).

Governments too, are playing a critical role by introducing new policies that can set the rules of the game not just for mobility but also for the energy ecosystem. The Paris agreement, signed by 195 nations, as a commitment to control greenhouse emissions within permissible limits, is a landmark deal that will accelerate the shift away from fossil fuel powered vehicles. Truly, the stakes are now very high for all players in the ecosystem.

With increasing competitive pressures to define which energy option powers the cars of the future, it is important to note the factors that drive the choice of automotive fuel.

Reduction in aggregate emissions:

The transportation sector is one of the biggest contributors (23 per cent) to GHG emissions and needs to play a crucial part in optimizing the emissions trajectory and in meeting the targets outlined in the Paris agreement. This means reducing aggregate emissions across the energy value chain, including production and transmission of automotive fuel and not just the generation of exhaust gases during vehicular movement.

Achieving country specific economic mandates:

Country specific objectives may influence the government's efforts to transition to a particular choice of automotive fuel. For example, India has a pressing need to reduce its import dependence and control rapidly rising levels of pollution in urban areas. 80 per cent of the fuel in our country is imported and 10 of the world's 20 most polluted cities are in India. In this context, a shift to clean energy based automotive fuel that reduces the need for imported petroleum, is imperative.

Meeting consumer expectations:

Consumers would consider shifting from an established technology, only if the proposition is strong enough i.e. the cost differential is within an acceptable range, performance, safety and reliability are at par, and convenience and comfort, are not compromised.

The choice of an alternative fuel should, therefore, be a fine-balancing act after taking a holistic view of all the above major factors.

02. The electric vehicle revolution:

The shift from ICE vehicles is led by battery and hybrid electric cars

Across the world, governments have set aggressive targets for adoption of BEVs and PHEVs (Plug-in Hybrid Electric Vehicles). BEVs are powered entirely by electricity and hence, have zero tailpipe emissions. An electric car emits significantly less CO2 for an equivalent distance to be driven than that of an ICE car. This is true even if the grid from where it sources electricity is entirely powered by oil.

For every 100km travelled in a petrol car...

...it takes 26 megajoules to get petrol out of the ground and transport it to the car...

...and the car itself uses 142 megajoules to move itself around.

For the same distance in an electric car, using electricity generated in an oilfired power plant

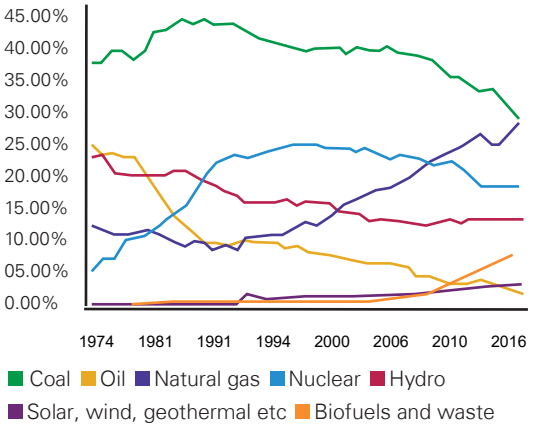
...it takes 74 megajoules to generate and transport the electricity to the car...

...which then uses just 38 megajoules to move itself and its passengers.

Source: Well-to-wheels analysis for European Commission, JRC, 2015

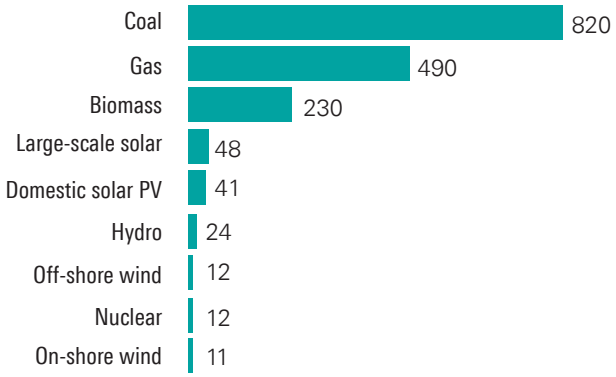
The energy sources of the grid are also going through a transformation. Coal, which causes a high level of pollution, as a source of energy is on the decline and other more environmental friendly sources, such as solar and wind energy, have started gaining prominence.

OECD gross electricity production by source, 1974 - 2016



Source: Electricity information, OECD, 2017

Life cycle emissions from electricity generation, gCO2/KWh



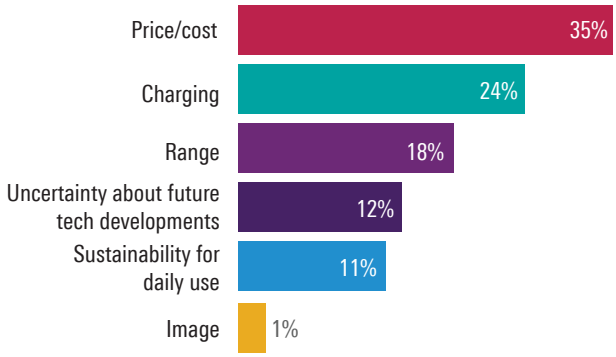
Source: Median estimates of life cycle carbon intensity of selected electricity sources, IPCC, 2014

Adoption of BEVs and PHEVs have increased steadily over the last few years, with sales of new electric vehicles surpassing a million units in the year 2017. 65 per cent of these vehicles were pure EVs (BEVs) while the rest were PHEVs.

Yet, BEVs have to address certain barriers to become a sustainable, long-term solution:

- **Consumer preference:** Up-front cost, charging experience (availability of stations as well as time taken to charge) and range offered per charge have to become more user friendly
- **Supply constraints:** The supply side concerns of Li-Ion batteries, land-fill challenges and advanced technology required for battery manufacturing have to be addressed
- **Electricity source:** The energy sources to the grid themselves need to undergo further transformation towards cleaner, renewable sources of power, for the shift in technology to be sustainable and clean.

The one thing that really keeps me away from considering a fully electric car is:

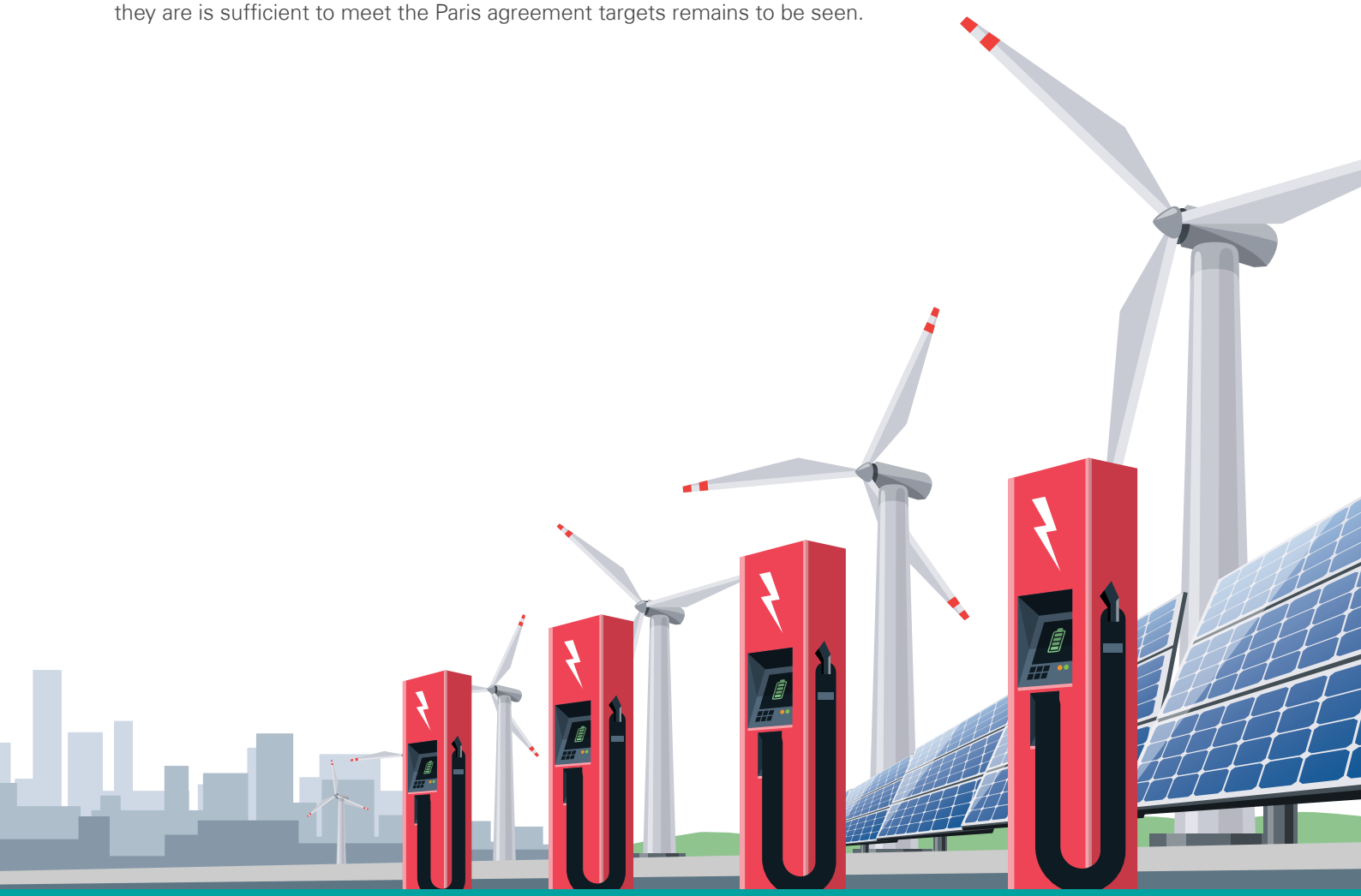


Source: Global automotive executive survey, KPMG, 2018

Automotive OEMs, technology companies and energy companies have been working on the above areas and innovations in this space are integral for success of the private sector going forward.

PHEVs come in as a via-media solution because they are not completely reliant on charging infrastructure and use a smaller battery.

While BEVs and PHEVs are definitely a step in the right direction towards reduction in tailpipe emissions whether they are is sufficient to meet the Paris agreement targets remains to be seen.



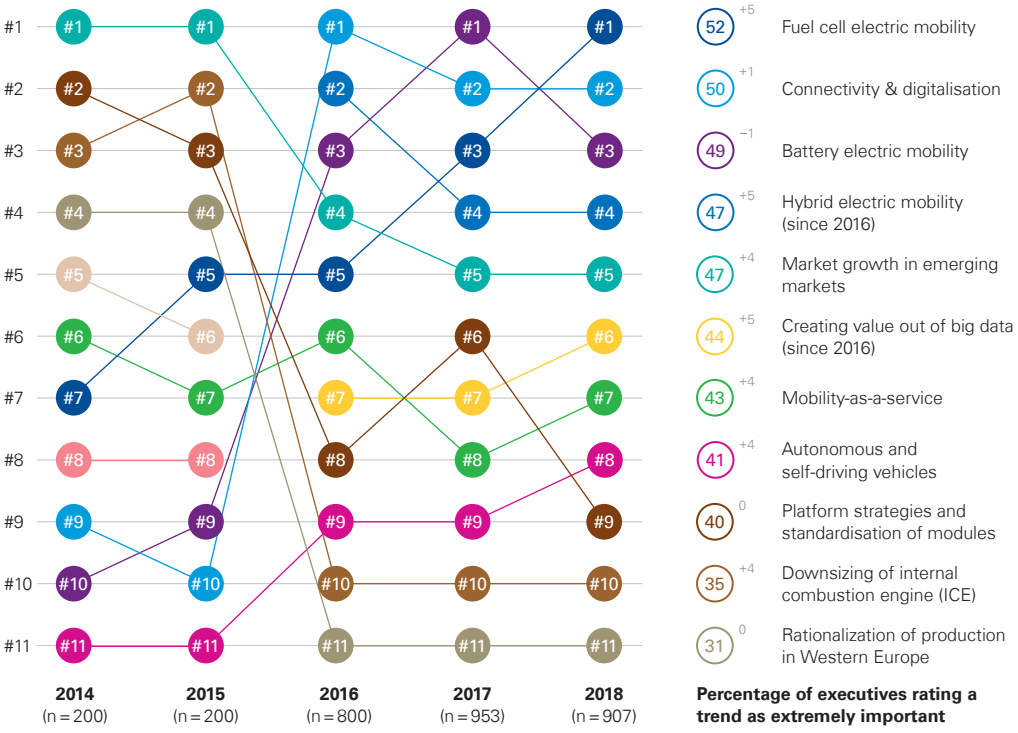
03. Fuel Cell Electric Vehicles (FCEVs):

Hydrogen's promise as the fuel of the future

Hydrogen council's[1] pitch to the automotive companies appears to have started earning mileage. The 'Global Automotive Executive Survey' (conducted by KPMG) found that the top-most key trend in automotive in 2018 was that of fuel cell electric mobility (refer fig.), having grown in importance from its #5 ranking in 2016. The hitherto subdued topic has gained prominence as the so-called hydrogen-ization is gaining traction.

EXECUTIVE

Global automotive executive key trends until 2025



Note: Executives (n = 907); figures and deviations from the previous year 2017 (n = 953) in percent

Source: Global automotive executive survey, KPMG, 2018

1) The Hydrogen Council is a global partnership of companies from energy and transport sectors with the aim of promoting hydrogen's role in energy transition

However, as of today, fuel cell electric vehicles trail BEVs in terms of global adoption, as a result of several factors including technology nascence, a relatively higher up-front cost and underdeveloped charging infrastructure.

Advantages of FCEVs and barriers in their adoption:

Convenience – Refuelling time of few minutes comparable to current gasoline/diesel cars

Low weight – Higher energy density w.r.t batteries

makes FCEVs suitable for heavy tonnage vehicles

Higher range – Higher range compared to BEVs (already more than 500 kms)

Abundant supply – Hydrogen is the most abundant element in universe

Cost – Fuel cell technology is still far from market maturity, resulting in high cost of FCEVs (~2-3 times BEVs)

Infrastructure – High investments required for H2 distribution infrastructure, cost of H2 refuelling station ranges from USD2-4 million

H2 production – H2 production from renewable sources (e.g. electrolysis of water) not established yet; entialing in higher costs

04. Towards a multipolar world:

Automobiles are likely to be powered by a mix of energy sources

While the automotive fuel debate has primarily revolved around BEVs and conventional vehicles; it is not long before when FCEVs would join the debate.

Different technologies have different strengths:

A comparative analysis between these technologies highlights how these fare in comparison to the conventional vehicles on range of parameters from cost to customer convenience to supply side risks.

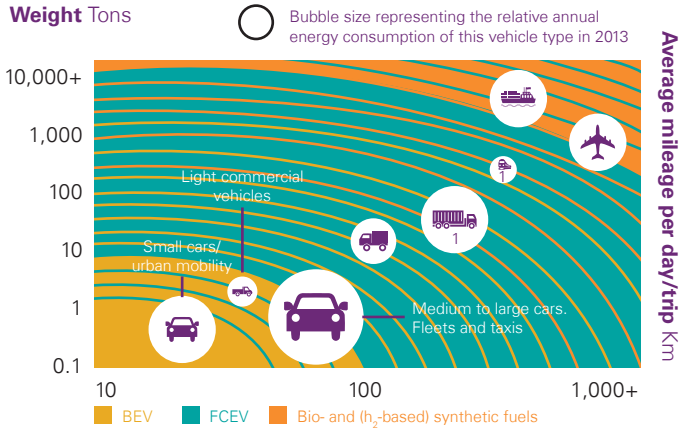
Parameter	Alternative			Traditional
	FCEV	BEV	PHEV	ICE
Purchase price of car	> 3x	~ 1.2-1.8 x*	~ 1.2-1.8 x*	Lower benchmark (x)
Maximum range	>500 kms	300-400 kms	Comparable to ICE	> 1000 kms
Re-fuelling time	Few minutes	Few hours (as per charger type)	Few minutes/ hours for charging	Few minutes
Fuel efficiency (pump to wheels)	~40%	> 80%	~20-40%	~20%
Fueling infrastructure	H2 stations similar to gas stations	Chargers (home and public)	Chargers/gas stations	Gas stations
Technology maturity	Farthest from market maturity	More mature than FCEVs	More mature than FCEVs & BEVs	Established
Supply side risks	Nil (abundance of hydrogen)	Limited reserves of Li and Co	Limited reserves of Li /Co, fossil fuels	Limited reserves of fossil fuels
Emissions at wheel	Zero emissions	Zero emissions	Lower emissions compared to ICE	Highest emissions

Most favourable option Least favourable option

Note: 1) Price differential is a function of the model and availability of subsidies. It may be noted here that the technology is evolving for all. As per Hydrogen Council, the total cost of ownership of different technologies is likely to converge by 2025 for medium to passenger cars.

Different technologies for different segments:

At this stage of evolution of technology, no single technology appears to satisfy all key criteria and meet the needs of different consumer segments. The adoption of the technology would be faster in that segment where the technology proposition best meets the specific requirements of the average consumer in that segment. As a result, the automotive industry is expected to transition from a single powertrain technology to a mix of powertrain technologies where ICE, BEV, PHEV and FCEV have a complementary role to play in their specific areas of application.



Source: How hydrogen empowers the energy transition, Hydrogen Council, 2017

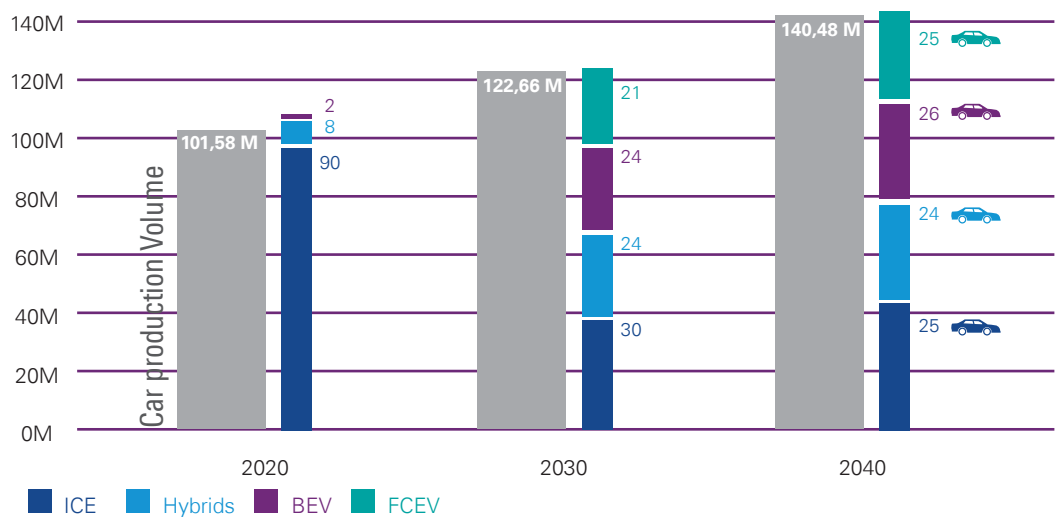
BEVs are expected to be the superior technology in distribution and in city-centric use cases. So they could take the pre-dominant position for consumer segments requiring short, city-centric commutes. BEVs might not be able to satisfy 'high average mileage customer's' needs for battery recharging times. Besides, BEVs consume payload due to battery weight that which would be a deterrent in the eyes of commercial, long distance operators.

FCEVs have a strong advantage in the heavy duty transport segments requiring long range and high payloads, due to their lower weight and comparable (with conventional vehicles) refueling time. A commercial long distance carrier might find this proposition attractive but a city-based commuter may not.

PHEVs can alleviate some of the concerns raised by BEVs, particularly w.r.t. range and charging times and hence can act as a stopgap arrangement till the time zero emission technologies reach the stage of mass adoption.

As per KPMG's automotive executive survey, different powertrain technologies are expected to converge, leading to an almost equal distribution of ICEs, PHEVs, BEVs and FCEVs by 2040. The reasons are compelling as seen above.

What is your opinion on the share between ICE, PHEV, BEV and FCEV in 2020, 2030 and 2040?



Source: Global automotive executive survey, KPMG, 2018

The roll-out and implementation of alternative technologies is expected to progress at varying speeds across different countries, depending on a multitude of factors including raw material access, technological maturity, economic wealth along with regulatory and industrial policies. The end state is likely to be a multipolar world with almost equal split of all four technologies, as reflected by the executive survey.

The India story: India to follow similar path towards multiple technologies:

India, being a signatory to the Paris agreement, needs to reduce its GHG emissions. Also, it has a country specific mandate of reducing its oil import bill and securing fuel supply. Moving from ICE to EVs can help the government meet both these objectives. While a definitive policy and roadmap is still in the works, the government has made it amply clear on several occasions that electrification is the way forward. Amongst BEVs and FCEVs, BEV technology is far ahead in market maturity and is expected to be the obvious choice in a value conscious market like India to kick-start the shift towards cleaner fuel. The efforts are already underway – technology startups are launching products, OEMs are working on their EV strategies, charging infrastructure is being developed and the government is finalising incentive plans for encouraging adoption. All this is expected to increase the penetration of BEVs in due course of time.

However, supply side constraints might prove an obstacle in BEV becoming the only technology to have pervaded all forms of mobility as India produces close to four million passenger cars and roughly about 30 million mobility products (as on 2018). These numbers could double in the next 10 years considering their current pace of growth. India does not have reserves of some of the most important raw materials such as lithium, cobalt and nickel which are required for battery manufacturing. Cell manufacturing itself is concentrated outside India. Hence, we will continue to be dependent on imports which could compromise economic mandates and constrain the adoption of BEVs. Also, if charging duration and payload issues are not addressed, then commercial and long-distance transport would be difficult.

Reserves of Li-ion battery raw materials in selected countries

	DRC	South Africa	China	India	Russia	Bolivia	Brazil	Chile	Cuba	Canada	United States	Australia
Graphite			■	■	□		■			□		
Copper	□		■		■					□	■	■
Aluminium			□	□	□		■				□	■
Manganese		■	■	■			■					■
Nickel		□	□		■		■		■	□	□	■
Cobalt	■	□	□		□		□		■	□	□	■
Lithium			■			■	□	■			□	■

□ Low proportion as a per cent of global known reserves

■ Significant proportion as a per cent of global known reserves

Source: India's energy storage mission, NITI Aayog and RMI, 2017

This is where FCEV can come in as a complementing technology in the second phase of electrification in India. By this time, it is likely that some of the teething concerns in FCEVs such as costs would have been addressed, the technology would have reached a certain level of maturity and would have been market tested in other parts of the globe. Hence for larger vehicles, India might swerve towards FCEVs, partly perforce due to supply constraints of Li-Ion and partly driven by economic and market forces.

As an interesting precedence for India, China – the market leader in BEVs, is now focusing on development of FCEV technology and has set a target for over one million FCEVs and 1,000 H2 refueling stations in service by 2030 without mitigating its drive to establish BEVs.

The result: India's EV portfolio, as it matures, is likely to reflect that of the global automotive industry.

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05. Driving the change:

Government impetus will herald the transition to alternative energy options

The mobility ecosystem requires a confluence of multiple interdependent structural changes to come together in congruence with each other. Each player in the ecosystem has a limited span of control – A BEV manufacturer tends to focus on technology development in the area of electric motors, batteries etc. At best, some can diversify into setting up the charging ecosystem themselves. For an FCEV system to be established at scale, the change involves the transportation sector evolving in tandem with the energy sector.

New roles in the mobility ecosystem

Role	BEV ecosystem	FCEV ecosystem
Energy production	• Electricity supply • Grid management	• Hydrogen production • Supply to refueling stations
Energy storage	• Battery cell manufacturing • Battery pack assembly • Integration in vehicle	• Fuel cell manufacturing • Integration of fuel stack in vehicle
Infrastructure	• Charging infrastructure setup and maintenance	• H2 refueling infrastructure setup and maintenance
Mobility services	• Battery leasing/swapping • Battery management	–

Under the circumstances, it is imperative that a larger, more powerful player, outside the realms of the market forces and sectoral confinements takes the initiative to drive the change forward. The government's role in this transformation is therefore extremely critical.

As we have seen with the case of EVs, policy environment has been a key driver in leading EV countries like China, Norway, the Netherlands etc. to incentivize:

- Automotive OEMs and battery manufacturers to make the investments required for the successful deployment of EVs
- Vehicle owners, by addressing the barriers to adoption faced by them, mainly through subsidies for up-front cost difference and infrastructure creation for range anxiety

The Japanese government is partnering with major auto OEMs and energy and gas companies to expand hydrogen station infrastructure; with the government sharing 50 per cent of total cost. The Chinese government, which has provided manufacturing incentives to EV companies, as well as purchase subsidies to consumers, has propelled EV adoption in the country, to the extent that China has the largest EV market globally, with c.90 per cent of global sales. There are many such examples where government's clear policies have created early clusters of development.

Therefore for rapid advancements to happen on adoption of cleaner fuels, government has to take the initiative to establish clear policy framework for the benefit of all players.

In summary.

The automotive fuel debate is far from over and the government and industry will work closer than ever to usher the next big change in automobiles and attain climate change goals.

The automotive industry is at an important state of evolution and the choice of fuel is expected to have a significant impact on each of its players, as well as the government and the economy. The industry needs to play its part in fulfilling the climate-change goals and enable the shift to a cleaner, low-carbon future.

The automotive fuel debate is not likely to remain as it has been historically, a one-sided one, where a single technology meets all the requisite criteria on performance, economics and environment. Rather, multiple technologies would complement each other and co-exist to meet the needs of different consumer segments.

Hence, the government's role has become even more critical as the choice to make will not only be between competing technologies or companies but between competing ecosystems.

About ETAuto

ETAuto is the automotive vertical of The Economic Times. It offers in-depth news, views, analysis and global trends in the automotive industry. Its coverage encompasses the entire events and segments of business including components, OEMs, policy, aftermarket, auto technology etc.

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