ECONOMIC ANALYSIS OF HFCV, BEV AND ICEV IN INDIAN CONTEXT

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Abstract : Governments across the globe are trying their best to be more and more carbon neutral. One known way to it is Hydrogen Economy, where clean power can be produced with zero emissions. Transportation sector being one of the major contributor in the greenhouse gases, it is impossible to cut noticeable carbon footprints without its being carbon neutral. So there is a sheer requirement of Automobiles to be carbon neutral which is leading the automobile sector to other clean alternative fuel like hydrogen. Hydrogen Fuel Cell Vehicles is the initiative taken by certain automobile manufacturers and governments of respective countries is supporting the initiative by giving subsidies and other incentives to the end user. India being a piece sensitive market for automobiles, this paper will help: manufacturers to price their product and provide schemes accordingly; government to decide subsidies so that HFCV can be competitive to other BEV and ICEV; people to analyze the life cycle cost of all three products without any hypothetical subsidy. Using a trend analysis model this paper analyses the future cost of fuels like petrol, diesel and electricity and the cost associated of each fuel in lifecycle of the respective vehicle. For calculation of hydrogen prices, a well to wheel model, which is constructed taking Indian scenario in mind, is used. HFCV being a new technology, its lifecycle cost is more than BEV and ICEV, if we don't take any manufacturer provided scheme and government provided subsidies into consideration. But if we will analyze other market, where free Hydrogen for certain amount of time is provided by manufacturers and there are government provided subsidies and incentives, Indian consumers would be very attracted toward this new segment of vehicles.

***IndexTerms* – Economic, Economic Analysis, Hydrogen, Hydrogen fuel cell vehicle, battery electric vehicle, India.**

1. INTRODUCTION

The fast rate of adoption of alternate fuel vehicles around the world over recent years has proved their reliability factor. Alongside with the increase in their number, the myths and the fear of unknown has decreased from the people's mind due to which they are now less hesitant to buy alternate Fuel Vehicle. In the recent years in India, electric vehicles have made their path clear by proving themselves equally competent both economically and environmentally. The increasing number of recharging stations has also helped reducing range anxiety of electric vehicle buyers and increasing the distance, that can be travelled by vehicle.

But the alternate fuel vehicles doesn't end here. Hydrogen Fuel Cell vehicles are proving themselves around the world, an alternative to electric vehicles. These vehicles are environmental friendly as they have zero tail pipe emissions and they can be truly carbon neutral if hydrogen is produced by green energy. Their refuelling time is an added advantage over the Electric vehicles. A hydrogen Fuel Cell vehicle can be refuelled in 3 to 5 minutes.

This paper focusses on the Life cycle cost of Hydrogen Fuel Cell vehicle in comparison with electric vehicles and conventional Internal Combustion engine vehicle with respect to Indian scenario. This analysis plays an important role as Indian consumers being very much price sensitive. Like other governments, Indian government has also focussed on their hydrogen missions. India can soon expect a hydrogen fuel cell vehicle in upcoming years. This paper will throw some light on the economic aspect of owning a hydrogen fuel cell vehicle in upcoming years in India.

2. REVIEW OF LITERATURES

2.1 ECONOMICS OF HYDROGEN

In the fast few decades, when global warming became an international concern, scientists and researchers started research on alternate fuels and their economic feasibility. Amos 1998 [1] calculated the cost of storing and transporting hydrogen and reviewed each possible aspect for the same. It further proposed that the cost of hydrogen depends on several factors or combination of factors such as production rate, storage capacity, storage time, delivery distance. It is widely used by many authors who provided a well-to-wheel cost of hydrogen to the end user. Franco Barbir 2005 [2] focussed on the economic aspect of producing hydrogen from electrolysis. An economic analysis describing 19 pathways of producing and delivering hydrogen was done by Simbeck and Cheng 2002 [3]. The data and the calculations for production, storage and delivery were backed up by Air Products and Chemicals, BOC and Praxair. It proposed that onsite hydrogen production becomes expensive because of lower production rates.

Morris 2003 [4] stated "A Hydrogen Economy Is Not A Renewable Energy Economy". It proposed that wind Electricity is 20 to 40 percent expensive than electricity from fossil fuel whereas wind generated hydrogen is approximately 200 percent expensive than hydrogen generated from fossil fuel sources Casten et.al 2000 [5] analysed different methods to use hydrogen as a fuel in automobile such as on-board reforming and off-boarding. They proposed central production of hydrogen would not be favourable as storage and transporting to a network of refuelling stations can be risky. They further proposed that hydrogen from local electrolysers would be expensive because of high cost of electricity in California. Berry 1996 [6] proposed that hydrogen generated from natural gas can do more emissions than an efficient gasoline or natural gas vehicle. One reason for this is fuel cell electric vehicles requires electricity intensive storage like liquefaction and compression. Turner 2004 [7] proposed that it would need 150 million tonnes of hydrogen to power whole transport sector of United States.

A well-to-wheel economic as well as environmental analysis on hydrogen as transportation fuel in context with Shanghai is done in Huang et.al 2006 [8]. It also considered the weight to weight energy efficiency of different processes into the account. Another well to wheel economic analysis for hydrogen technology is Balachandra and Reddy 2007 [9] in Indian Context. A central plant is considered which has a capacity of 150 tonnes of hydrogen per day with a load capacity of 90%. Hydrogen can be supplied from 72 pathways which costs as less as 84.54 INR/kg and high as 547.86 INR/kg. Gupta et.al [10], which analysed well to wheel energy ratio and greenhouse gas emission of hydrogen enriched compressed natural gas proposed that 20% hydrogen in CNG can reduce energy consumption by 7%, CO2 emissions by 6.2%, greenhouse gases by 11% and cost of fuel by 7% over CNG. Spath and Mann 2001 [11] calculated energy efficiencies, greenhouse gas emissions and global warming potential of a hydrogen production plant which uses natural gas as raw material to produce 57 million standard cubic foot per day of hydrogen. It stated that the energy content of natural gas is more than the energy content of hydrogen produced which makes the energy cycle negative in nature

2.2 HYDROGEN INFRASTRUCTURE

Many authors also attempted to solve the problem of planning and designing the hydrogen refuelling infrastructure. One of which, Greene et.al 2020 [12], discusses about the methods to plan hydrogen refuelling stations like p-median model and California Hydrogen Infrastructure Tool (CHIT). Jonathan et.al 2007 [13] calculated the cost of building hydrogen refuelling stations in Shanghai with the help of compendium of hydrogen refueling equipment costs (CHREC), hydrogen station cost model (HSCM) and Tongji hydrogen delivery cost model (THDCM). The study proposed that the on-site production of hydrogen by SMR was less expensive than delivery from a centralized plant since the price of natural gas was much lower at the station than the feedstock at the centralized plant. Further, it compared the costs incurred by the plant at Shanghai with one in California. From which it was proposed that the price of hydrogen produced by on-site electrolysis is much less in Shanghai than in California because of lower cost of electricity in Shanghai. Ogden 1997 [14] analysed the cost of hydrogen to end user and the cost of hydrogen infrastructure in California proposed that off-peak power from 6 pm to 10 pm can be available which can produce 440-660 million square cubic foot of hydrogen per day. There are several energy surplus nations who can produce electrolytic hydrogen from the excess available renewable energy

2.3 VEHICLE COMPARISONS

Buzoverov et.al [15] discusses the economic as well as environmental impact of various electric vehicles such as Battery Electric Vehicles (BEVs), Fuel Cell Vehicles (FCVs) and Aluminium Air Electrochemical Generator vehicles (AAECG). AAECG was considered the least environmental friendly among all because refining aluminium (A995) out of alumina is also an energy intensive process and emits comparatively huge amount of CO2.Gim 2015 [16] provides a treasure of Information regarding the economic comparison between hydrogen fuel cell vehicle (HFCV) and conventional internal combustion engine vehicle in respect to Korean scenario. This paper deals with the economic analysis of domestic fuel cell vehicles (Hyundai Tucson FCV) and conventional ICE vehicles (Hyundai Tucson) considering subsidy and hydrogen price in 2015 and 2025. It stated that the cost of fuel cell vehicle and hydrogen prices must be kept less for its being competitive with conventional ICE vehicles. Granovskii et.al 2005 [17] proposed natural gas can provide the same range as that of hydrogen with storage pressure two times less than that of hydrogen. It also stated that fuel cell vehicle remains uncompetitive because of high price of the vehicle and fuel. Richard Raustad 2017 [18] provides a life cycle cost analysis of several conventional internal combustion engine, plug-in hybrid and battery electric vehicles. It was stated in the paper that although the conventional internal combustion vehicles are having a cheap price tag they comes out to be most expensive in terms of 10 year ownership followed by plug-in hybrids and battery electric vehicles. Gilmore and Patwardhan 2016 [19] performs the cost of ownership analysis of the 4 door passenger cars in India on the basis of private cost and societal cost. It proposed that the lower societal and fuel cost of EVs are insufficient to compensate for its higher capital cost. It found out that CNG vehicles have the least ownership cost among all drive train vehicles as of their least private and societal cost.

DY Lee et.al 2018 [20] performed life-cycle analysis of diesel and hydrogen powered medium and heavy duty vehicles (2b to 8b gross vehicle weight category) in which the analysis was break down in two categories namely well to pump and pump to wheel analysis. Paper proposed that almost all of the CO2 emissions are produced from Well to pump part and that too in hydrogen production from steam methane reforming of natural gas for hydrogen fuel cell trucks whereas tail pipe emissions were eminent source of CO2 emissions for diesel powered trucks. Ajanovic and Haas 2018 [21] has compared conventional ICE vehicles, battery electric vehicles and fuel cell vehicles for three scenarios – pessimistic, average and optimistic. The pessimistic scenario was the worst case scenario where prices and emissions were exaggerated. The optimistic scenario was rather supported by least prices and emissions. It stated that using only coal for electricity generation or hydrogen production would do more emissions then convention ICE vehicles. Kaa rt.al 2017 [22] makes a comparison between battery electric vehicle and hydrogen fuel cell vehicle to analyse which technology will dominate the market. It made use of linear BMW model and certain factors such as technological superiority, compatibility and brand reputation & credibility. Battery electric vehicles scored more on all the factors than hydrogen fuel cell vehicles.

2.4 OTHER LITERATURES

Zorrilla 2018 [23] describes the trend analytics feature of Tableau and how important it is to choose correct trend line feature. It also compares 5 trend line models: Linear, Exponential, Logarithmic, Power and Polynomial, on a data source and explains which model parameter to give emphasis while selecting a perfect fit for your trend. Jena 2017 [24] proposes the methods to use the forecast feature of analytics in Tableau. The implementation of forecast feature was presented on ‘Sample Superstore’ dataset which is default available dataset in Tableau package.

Manoharan et.al [25] reviewed to inspect closely the feasibility of using hydrogen as a major fuel in transportation systems. All composites (Type IV) are primarily used, and sometimes metal lined composites (Type III) are used. The fill time of these tanks is competitive with fossil fuels when the hydrogen is pre-cooled. An alternative to traditional compressed H2 tanks that is still being researched is a tank with an internal skeleton, which is a complex design of struts in tension within the tank to resist the forces of the compressed gas.Goel et.al [26] 2014 studied the driving characteristic data of three cities in India – Delhi, Rajkot and Vishakhapatnam. The research proposed that daily average mileage has no direct relation with the city’s area or the population. The paper stated that the annual mileage of a car in Delhi is 12,200 km. Naveen et.al 2021 [27] performed a survey on Indian consumers to find out whether they would like to buy hydrogen fuel cell vehicle over a battery electric vehicle and conventional internal combustion engine vehicle. The result came out to be battery electric vehicle winning over the two other choices. The study proposed that the respondents were quite concerned about the price of alternate fuel vehicles. The price of hydrogen fuel cell vehicle was INR 4500000 in the survey, which was quite how as compared to respondent’s then owned car.

Gangloff et.al 2016 [28] assessed space available on different class of medium and heavy duty vehicles for hydrogen storage in type 4 tanks. They discussed about the importance og gravimetric capacity, length to radius diameter of tank, and the effect of storage pressure. They further proposed that a 700 bar cylinder can hold upto 1.7 times more gas than a 300 bar cylinder. Bidin et.al 2016 [29] studies the effect of sunlight on hydrogen production. It proposed that collimated sunlight has 53 percent more efficiency than conventional method of producing hydrogen by electrolysis.

Sierzchula et.al 2014 [30] studied the influence of financial incentives and socio-economic factors on the adoption of electric vehicles proposed that only financial incentives are not enough to boost electric vehicle purchase. There are other factors that contributes to the adoption of electric vehicles such as charging infrastructure in the region/country, is the vehicle manufactured by domestic manufacturer, number of electric vehicle models available for sale etc.

3. CALCULATIONS

3.1 ASSUMPTIONS

- Life of vehicle is assumed to be 10 years.
- No maintenance/service cost is included in the analysis.
- Each year vehicle would be driven 12,200 km.
- Degradation of mileage with time will not happen.
- Battery degradation factor is also not considered in the analysis as that won't affect the analysis.
- No subsidies or insurance being considered in the paper as none is mentioned by the government for HFCV. And subsidies on the BEV vary from state to state in India.
- The cost of hydrogen is calculated using electrolysis of water method of production of hydrogen.

3.2 ASSUMPTIONS

The vehicles chosen for analysis are conventional internal combustion engine (ICE), Battery Electric Vehicle (BEV) and Hydrogen Fuel Cell Vehicle (HFCV). The model year is selected as 2021. The prices considered in the report are ex-showroom prices of the top variants of each model.

Tata Nexon XZA+ DT(0)
Tata Nexon EV XZ+ LUX
Hyundai Nexo

The prices mentioned in the below table for Tata vehicles are taken from official Tata Motors website, and the expected price of Hyundai Nexo, which is not yet launched in India is also taken from the cardekho.com website. The range and mileage are obtained from Tata Motors and Hyundai's official sites.

Table 1. Vehicle Information for LCC Analysis

YEAR	MAKE	MODEL	PRICE lacs (INR)	TYPE	RANGE	KmpL/kmpLe
2021	Tata	Nexon	11.46	ICE	300 km	17 km/l
2021	Tata	Nexon EV	16.40	BEV	300 km	92.7 km/Le
2021	Hyundai	Nexo	65.00	HFCV	593 km	93.7 km/kg

kmpLe: kilometres per litre equivalent

3.3 DAILY MILEAGE

To evaluate the daily mileage, it is necessary to specify the number of kilometres a vehicle is driven per year. For this analysis, the data is taken from Assessment of Motor Vehicle Use Characteristic in Three Indian Cities by Goel et.al. [26]. The data belongs to the year 2014. According to the data provided, each personal car is driven 12200 km on an average.

3.4 CALCULATING ELECTRICITY, PETROL AND HYDROGEN PRICES

The most important thing that we needed to consider before calculating the fuel consumption is the price of each fuel over the years. For the fuel pieces we have considered various parameters from various sources.

3.4.1 ELECTRICITY COST

For the cost of electricity, we considered data from statista.com. The data available was from 2009 to 2019, on the basis of which, we estimated the upcoming 11 years from 2020 to 2030, which is stated in the table 2. For the prediction of the upcoming years (2020 to 2030), we used exponential trend line model, as it was providing the best quality results as compared to other models. The equation of the curve is: *1.9398e-48*exp(0.0553263*year)*. Pictorial depiction of the curve is in Figure 3 with dark maroon breaking lines

Table 2. Actual and Forecasted kWh Cost

ACTUAL AVERAGE PRICE		FORECASTED AVERAGE PRICE	
YEAR	PRICE (INR)	YEAR	PRICE (INR)
2009	3.4	2020	6.67
2010	3.55	2021	7.05
2011	3.98	2022	7.45
2012	4.55	2023	7.87
2013	5.03	2024	8.32
2014	5.19	2025	8.79
2015	5.21	2026	9.30
2016	5.43	2027	9.82
2017	5.48	2028	10.38

2018	5.6	2029	10.97
2019	6.09	2030	11.60

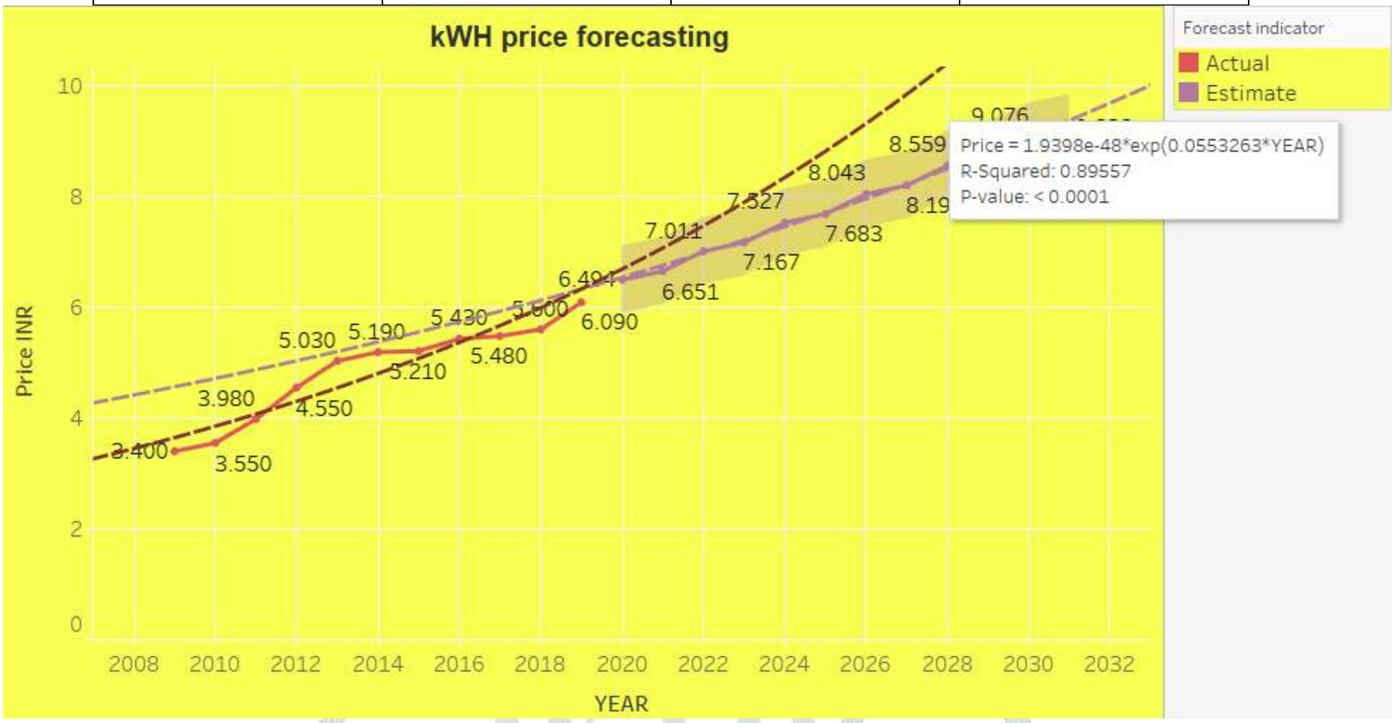

Figure 3. Trendline curve of kWh Price

3.4.2 PETROL PRICES

The estimation of Petrol prices (2018 to 2030) is done on the basis of data of Petrol Prices (2002 to 2017) available from Petroleum Planning and Analysis Cell site. For the prediction of the upcoming years (2018 to 2030), we used exponential trendline model, as it was providing the best quality results as compared to other models in Tableau Data Visualization Tool. The equation of the trend line curve can be seen in figure 4, i.e. *7.15449e-49*exp(0.0571139*Year)*.

Table 3. Actual and Forecasted Petrol Cost

ACTUAL AVERAGE PRICE		FORECASTED AVERAGE PRICE	
YEAR	PRICE (INR)	YEAR	PRICE (INR)
2002	29.22	2018	81.20
2003	31.65	2019	85.97
2004	35.78	2020	91.03
2005	40.24	2021	96.38
2006	45.68	2022	102.04
2007	43.02	2023	108.04
2008	47.23	2024	114.39
2009	42.65	2025	121.11
2010	51.56	2026	128.23
2011	63.92	2027	135.77
2012	68.83	2028	143.75
2013	69.13	2029	152.20
2014	69.38	2030	161.14
2015	61.78		
2016	62.74		
2017	68.06		

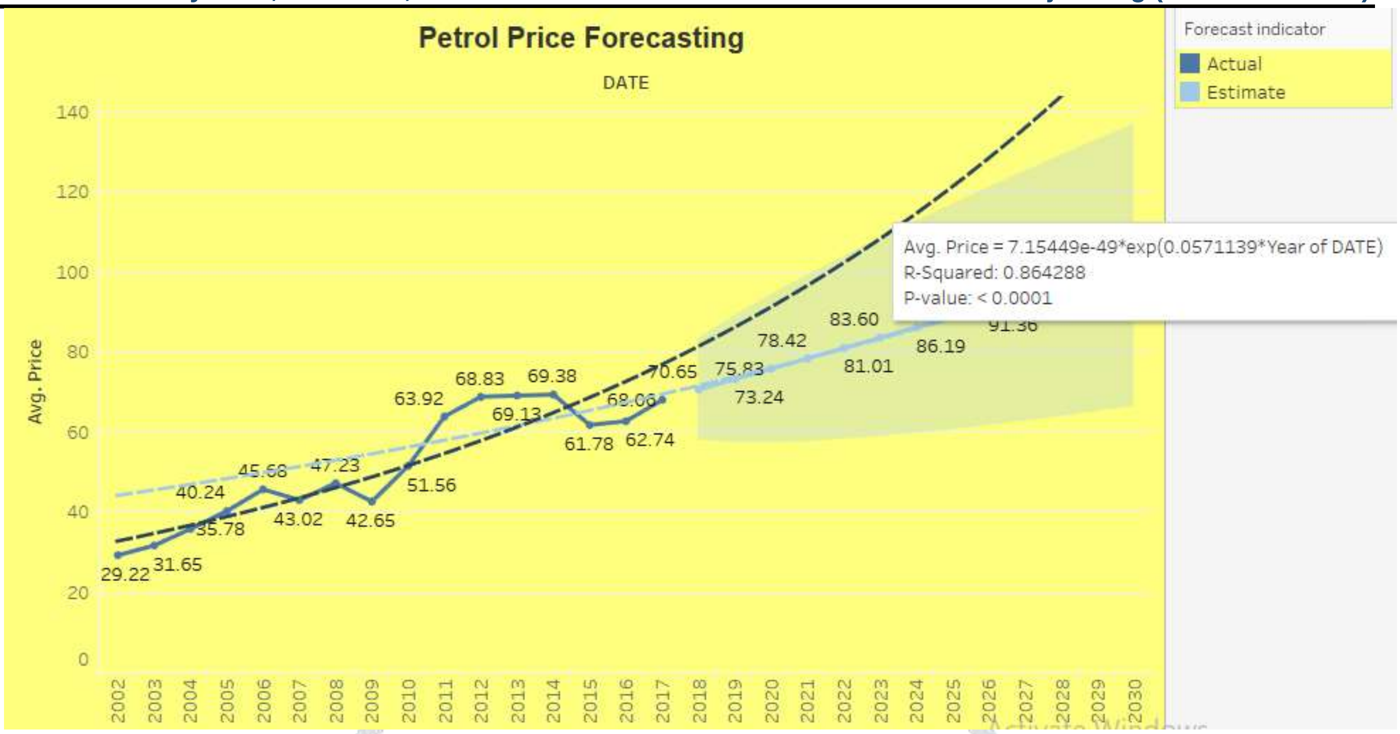

Figure 4. Trendline curve of Petrol Price

3.4.3 DIESEL PRICES

The estimation of Diesel prices (2018 to 2030) is done on the basis of data of Diesel Prices (2002 to 2017) available from Petroleum Planning and Analysis Cell site. For the prediction of the upcoming years (2018 to 2030), we used exponential trend line model, as it was providing the best quality results as compared to other models in Tableau Data Visualization Tool. The equation of the trend line curve can be seen in figure 5, i.e. 8.*5761e-62*exp(0.0717496*Year)*.

Table 4. Actual and Forecasted Diesel Cost

ACTUAL AVERAGE PRICE		FORECASTED AVERAGE PRICE	
YEAR	PRICE (INR)	YEAR	PRICE (INR)
2002	18.35	2018	65.33
2003	20.30	2019	70.19
2004	23.07	2020	75.40
2005	28.39	2021	81.01
2006	31.61	2022	87.04
2007	30.31	2023	93.51
2008	32.97	2024	100.47
2009	31.88	2025	107.95
2010	38.12	2026	115.98
2011	40.27	2027	124.60
2012	43.52	2028	133.87
2013	50.62	2029	143.83
2014	55.49	2030	154.53
2015	57.64		
2016	50.93		
2017	56.78		

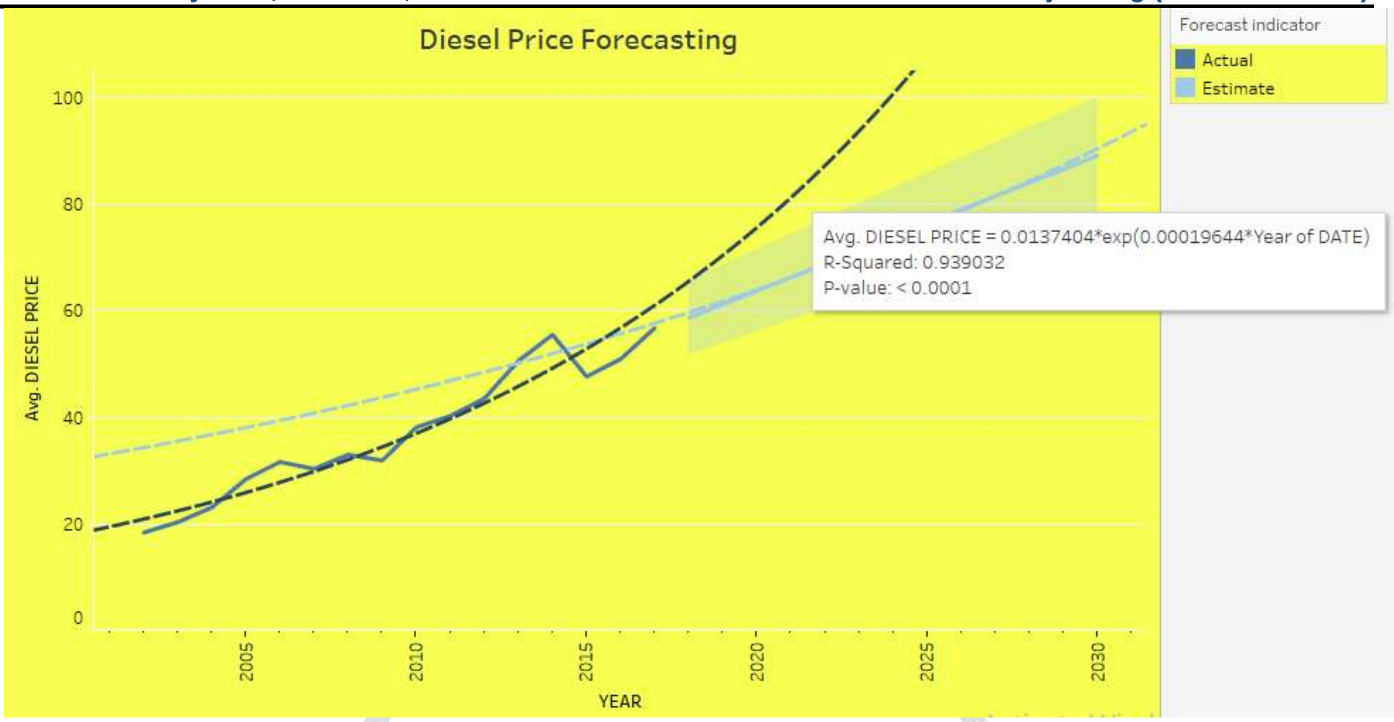

Figure 5. Trendline curve of Diesel Price

3.4.4 HYDROGEN PRICES

The prices of hydrogen are calculated from the model mentioned by Balachandra et.al [9]. The prices mentioned in table 5 are calculated by taking in mind the production is done by Electrolysis in a central plant having production capacity of 150 tonnes per day, stored in compressed form and transported by truck to refuelling stations. Each trip is considered to be of 300 km each side. All other costs are kept constant in the model except the kWh cost and diesel costs, which are taken according to our forecasted values. Following are the methods used to calculate:

TEC ~ Total Electricity Consumption
VNFC ~ Variable Non-Fuel O&M Cost
FOC ~ Fixed Operating Cost per year
CC ~ Capital Charges per year
HPR/H~ Hydrogen Production Rate per hour
CWC ~ Cooling Water Cost
AFU ~ Annual Fuel Usage
NT ~ Number of Trips
ALC ~ Annual Labour Cost
VOC ~ Variable Operating Cost
TNS ~ Total Number of Stations

$$\text{PRODUCTION COST} = \frac{\frac{\text{TEC}*\text{kWh cost}*\text{Days/year}}{1000000}+\text{VNFC}+\text{FOC}+\text{CC}}{\text{HPR/H}*24*\text{Days/year}}*1000000$$

Where,
TEC = 8218500 kWh/Day
VNFC = 205 Million INR/year
FOC = 617 Million INR/year
CC = 2468 Million INR/year
HPR/H = 6250 kg/hr
Days/year = 328

*The above values for production cost calculation are taken from Table 2 of “Hydrogen Energy For Indian Transport Sector: A Well-To-Wheel Techno-Economic and Environmental Feasibility Analysis” [9] except HPR/H which is taken from Table 1 of same paper.

$$\text{STORAGE COST} = \frac{(\text{TEC}*\text{kWh cost})+\text{VNFC}+\text{FOC}+\text{CWC}+\text{CC}}{\text{HPR/H}*24*\text{Days/year}}*1000000$$

Where,
TEC = 108640000 kWh/year
VNFC = 34.5 Million INR/year
FOC = 103.5 Million INR/year
CWC = 2.05 Million INR/year
CC = 414.2 Million INR/year
HPR/H = 6250 kg/hr
Days/year = 328

*The above values for storage cost calculation are taken from Table 3 of “Hydrogen Energy for Indian Transport Sector: A Well-To-Wheel Techno-Economic and Environmental Feasibility Analysis” [5] except HPR/H which is taken from Table 1 of same paper.

$$\text{TRANSPORTATION COST} = \frac{\frac{\text{AFU}*1.5*1000*\text{DIESEL COST}}{1000000}+\text{ALC}+\text{FOC}+\text{CC}+\text{VNFC}}{\text{HPR/H}*24*\text{Days/year}}*1000000$$

Where,
AFU = 41882.7 KL
ALC = 272.24 Million INR/year
VNFC = 36.56 Million INR/year
FOC = 109.69 Million INR/year
CC = 43.75 Million INR/year
HPR/H = 6,250 kg/hr
Days/year = 328

*The above values for transportation cost calculation are taken from Table 4 of "Hydrogen Energy for Indian Transport Sector: A Well-To-Wheel Techno-Economic and Environmental Feasibility Analysis" [9] except HPR/H which is taken from Table 1 of same paper.

REFUELLING STATION COST = $\frac{\text{CC+VNFC+(TEC*kWh COST)+VOC+FOC}}{\text{TNS*Days/year}}$

Where,
TEC = 1,20,075 kWh/year
VNFC = 1,04,695 INR/year
VOC = 4,64,950 INR/year
FOC = 6,28,170 INR/year
CC = 25,12,679 INR/year
HPR/H = 6250 kg/hr
Days/year = 328

*The above values for production cost calculation are taken from Table 6 of "Hydrogen Energy For Indian Transport Sector: A Well-To-Wheel Techno-Economic and Environmental Feasibility Analysis" [9] except HPR/H which is taken from Table 1 of same paper.

Table 5. Cost of Hydrogen in segments

YEAR	PRODUCTION (INR/kg)	STORAGE (INR/kg)	TRANSPORT (INR/kg)	REFUELLING (INR/kg)	TOTAL (INR/kg)
2021	453.14	26.83	120.87	33.70	634.54
2022	475.06	27.72	128.57	34.06	665.39
2023	498.07	28.64	136.83	34.43	697.97
2024	522.72	29.64	145.71	34.83	732.90
2025	548.47	30.67	155.27	35.25	769.66
2026	576.42	31.80	165.52	35.70	809.44
2027	604.91	32.95	176.53	36.16	850.54
2028	635.59	34.19	188.36	36.66	894.80
2029	667.92	35.49	201.08	37.18	941.67
2030	702.43	36.88	214.74	37.74	991.80

The annual cost of fuel per year is shown in the Table 6.

To calculate the annual cost of fuel for Tata Nexon, annual mileage (km), mileage (kmpl) from Table1 and petrol prices from Table 3 are considered. Firstly, the fuel consumed per year is calculated by "Annual Mileage (12,200 km) /mileage (17 kmpL)". To get annual cost, "(fuel consumed per year) * (petrol price of particular year)" is used.

AFC = $\frac{12{,}200*Petrol\ Price}{Mileage(\frac{km}{l})}$

To calculate the annual cost of fuel for Tata Nexon EV, annual mileage (km), mileage (kmpl) from Table1 and kWH prices from Table 2 are considered. Firstly, number of charges per year is calculated by "Annual mileage (12200 km)/Range per charge(300km)", which came out to be 40.67. To calculate annual cost, "40.67 * 30 * kWh price" is used. Here, 30 is the battery capacity of Tata Nexon EV in KWH.ss

AFC = $\frac{12{,}200*30*kWh\ price}{Range\ (km)}$

To calculate the annual cost of fuel for Hyundai Nexo, annual mileage (km), range (km) from Table 1 and hydrogen prices from Table 4 are considered. Firstly, number of refuelling per year is calculated by "Annual mileage (12200 km)/Range (593 km)", which came out to be 20.57. To calculate annual cost, "20.57 * 6.33 * hydrogen price" is used. Here, 6.33 is the fuel tank capacity of Hyundai Nexo in kg.

AFC = $\frac{12{,}200*6.33*hydrogen\ price}{Range\ (km)}$

Table 6. Fuel Cost /Year

YEAR	TATA NEXON		TATA NEXON EV		HYUNDAI NEXO	
	Petrol price	Annual Cost	kWH Price	Annual Cost	Hydrogen Price	Annual Cost
2021	96.38	69,166.82	7.05	8,601	634.54	82,622.25
2022	102.04	73,228.71	7.45	9,089	665.39	86,639.17
2023	108.04	77,534.59	7.87	9601.4	697.97	90,881.35
2024	114.39	82,091.65	8.32	10,150.4	732.90	95,429.52
2025	121.11	86,914.24	8.79	10,723.8	769.66	1,00,215.97
		3,88,936		48,165.6		4,55,788.26
2026	128.23	92,023.88	9.30	11,346	809.44	1,05,395.64
2027	135.77	97,434.94	9.82	11,980.4	850.54	1,10,747.20
2028	143.75	1,03,161.77	10.38	12,663.6	894.80	1,16,510.21
2029	152.20	1,09,225.88	10.97	13,383.4	941.67	1,22,613.06

2030	161.14	1,15,641.65	11.60	14,152	991.80	1,29,140.40
		8,02,347.12		1,11,690		10,40,194.77

Table 7. 5 year ownership cost

Vehicle	Vehicle Price	Fuel Cost	Total Cost
Tata Nexon	11,46,000	3,88,936	15,34,936
Tata Nexon EV	16,40,000	48,165.6	16,88,165.6
Hyundai Nexo	65,00,000	4,55,788	69,55,788

Table 8. 10 year ownership cost

Vehicle	Vehicle Price	Fuel Cost	Total Cost
Tata Nexon	11,46,000	8,02,347	19,48,347
Tata Nexon EV	16,40,000	1,11,690	17,51,690
Hyundai Nexo	65,00,000	10,40,195	75,40,195

4. RESULTS

Tata Nexon comes out to be the cheapest option when vehicle price is considered as compared to the other two cars. But when total cost of ownership (vehicle price along with fuel prices) is considered, figure 6 shows that Tata Nexon's and Tata Nexon EV's total ownership cost becomes pretty much same in seventh year of ownership (see 2027 in figure 6). This can equal up in fifth or sixth year if one consider the subsidies by the government and maintenance costs. Fuel prices would be a major concern for conventional ICE vehicle buyer, because the fuel price may see a hike in future above our predicted price as government has to keep up to Paris Agreement 2016 as mentioned by Gilmore and Patwardhan 2016 [19]. But at the end of ten years Tata Nexon EV appears to be the most economical option. Hyundai Nexo comes out to be the most expensive option without any subsidies or incentive from manufacturer. It seems from figure 6 that Nexo is a luxury vehicle competing with some compact SUV class.

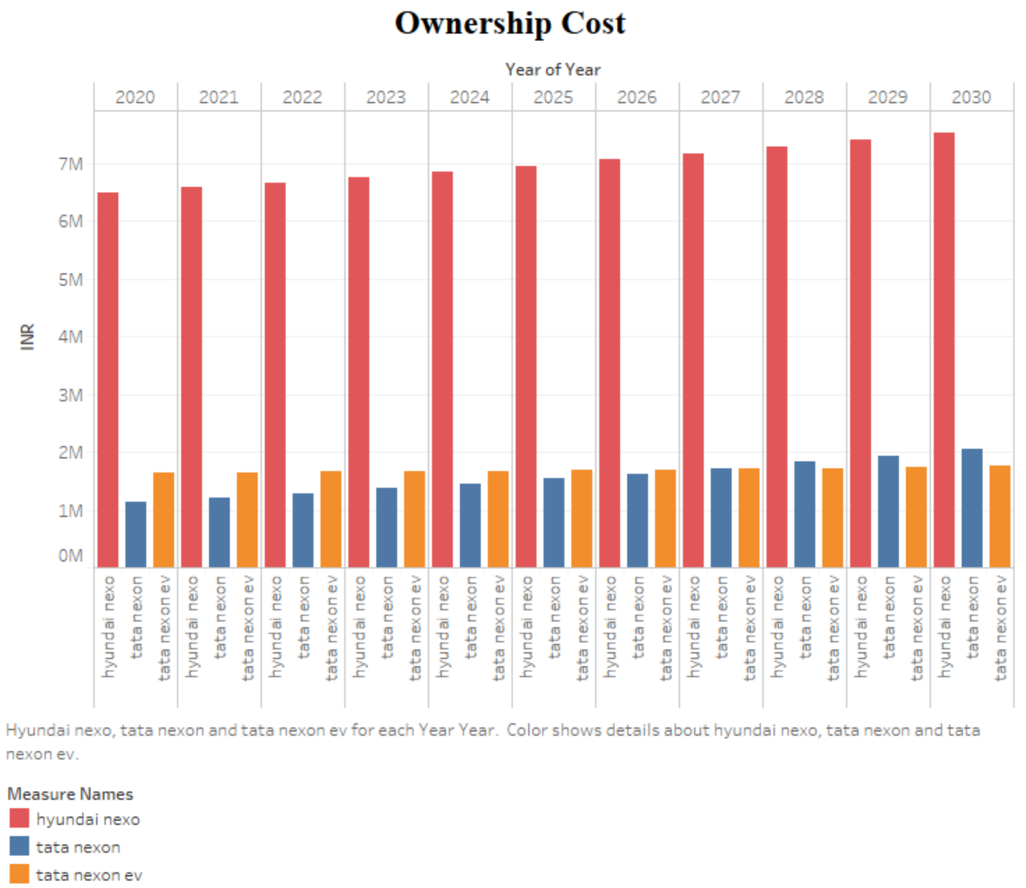

Figure 6. Ownership Costs of vehicles

5. CONCLUSION

Although the ownership cost of Tata Nexon EV comes out to be more than that of Tata Nexon in 5 years but after considering the subsidies by government, the total cost of ownership will equal up in fifth or sixth year instead of seventh. So, it is quite clear from the figure 6 that those who want to own a car for short time period (<5years) they must consider Tata Nexon a better choice from our analysis. But if a buyer wants to own a vehicle for 10 years Nexon EV comes out to be the best option.

Hyundai Nexo seems to be the out of league at the end of analysis as its ownership cost comes out to be approximately 4 folds than the two competitors. If Hyundai launches the Nexo at the estimated price in India, it would be out of reach of any middle class Indian. Government has to wave of import taxes on the Nexo along with providing a hefty subsidy to promote this vehicle. Along with all these financial helps, it requires a network of hydrogen refuelling stations. Right now there is only two refuelling stations in India – one at Indian Oil R&D Centre, Faridabad and the other at National Institute of Solar Energy, Gurugram. As per Sierzchula et.al 2014 [30], these factors can be opposing Hyundai Nexo in Indian Market – little presence of refuelling Infrastructure, foreign vehicle manufacturer etc.

At the estimated price, Hyundai Nexo will be competing with Jeep Wrangler, Jaguar XF, Audi A6, BMW 5 series, Mercedes Benz A-Class Limousine, Lexus ES, Mercedes Benz GLC class, BMW X3, Lexus NX, Volvo S90, Land Rover Range Rover Evoque, Volvo XC60. So it won't be a common man's piece of cake in India. Neither it is in other part of world.

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