Comparison of Five Fuel Cell Electric Vehicles

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1 Introduction

Transport sector accounts for a major component of environmental pollution. Conservation of environment and resources through out the globe are grabbing the attention of the people. According to the International Energy Agency (IEA), 17% of CO_2 emissions are due to transportation, which also includes automobiles [1]. Conventional vehicles run on hydrocarbon fuels causing green house gas (GHG) emissions and environmental pollution. This leads to discover alternate fuel options for automobile and transportation sector [2]. For the last two centuries, water is used as a fuel, which is a combination of hydrogen and oxygen and can be easily separated by using water electrolysis technology [3].

Hydrogen can be a clean and environmental friendly fuel. It can be used in internal combustion engines directly or can be used by mixing with other fuels. Some amount of water is also generated, when H_2 is used in internal combustion engines (ICE) along with other emissions [2]. In the past few years, many researchers have shown interest on fuel cell electric vehicles (FCEVs). This is due to their inherent advantages of zero pollution, CO_2 emission free, and low noise. Conventional vehicles vent out huge amount of CO_2 in the atmosphere and are harmful to environment and human health. FCEV is zero emission vehicles and emits only water vapor as an exhaust. So, the use of FCEVs can be eco-friendly approach for automotive and transport sector. FCEV provides a solution for the issues related to oil dependence, GHG emission, and air pollution by using chemical energy of H_2 and FC technology in vehicles. FCEVs are better than the present conventional vehicles in terms of energy conversion efficiency, driving range, and carbon emission. Also FCEVs have the

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advantage in terms of refueling time compared to electric vehicles making them first choice for the vehicular applications [4].

This paper deals with different operating parameters of vehicles, which are beneficial to choose to get full advantage. To get better advantage, electrolyzer as well as FC vehicles should also be selected carefully in case of vehicular applications. Selection of electrolyzer is necessary to get maximum amount of hydrogen for the same amount of water compared to others, to cover more driving range. On the other hand, reduction in mileage or fuel economy indirectly affects the amount of CO_2 emission, life cycle fuel cost. In this paper, a comparative analysis of different FCEVs and gasoline vehicles is made, and necessary results are described briefly. It is also concluded that in terms of CO_2 emissions, FCEVs are always advantageous. However, every FCEV is not superior over gasoline vehicles in terms of cost. Hence, careful selection is needed.

2 Types of Commercially Available Vehicles for Automobile Sector

2.1 Conventional Vehicles

They have internal combustion engines (ICE) using gasoline as a fuel and are responsible for the CO_2 emissions.

2.2 Plug-in Hybrid Electric Vehicles

They also have an ICE that uses gasoline as a fuel and additionally have a battery to extend the range upto 20 miles, which have the advantage of 25% CO_2 reduction [5].

2.3 Battery-Operated Electric Vehicle

They have a large battery as a single power source, which vent out zero emissions and high efficiency. Short driving range and long charging times are the major disadvantages of battery-operated electric vehicle [5].

2.4 Fuel Cell Electric Vehicle (FCEV)

FCEVs are the vehicles that convert the chemical energy of H_2 into electrical energy to power the motor of the vehicle [6].

3 Hydrogen Fuel Cell Electric Vehicle

H_2 is used as a fuel, and fuel cell is used as an engine in FCEV. They have zero emission, large driving range, and less fueling time compared to the conventional vehicles [5]. FCEV comprises of mainly six components, namely fuel cell system, H_2 storage tank, air intake system, electric motor, power control unit, and power control unit. Stored H_2 from the storage tank and oxygen taken from the air by air intake system produces current. This current is controlled by the power control unit as per need. According to the operating conditions, control unit can either supply power to the motor or charge the battery or both. The main function of battery is just storage of excess electricity which can be used whenever needed. The generated current rotates the motor for the mechanical work in terms of the rotation of wheels [4]. Table 1 shows the specifications of five FCEVs. Fuel cell works as an energy converter, while the conventional batteries are an energy source. Therefore, the FC always requires an external feeding source [2]. Figure 1 shows the basic diagram of the system.

Proton electrolyte membrane (PEM) fuel cell using H_2 as a fuel have low start up time, low temperature, small size, high power density, and require negligible maintenance work making them prime for transport and automotive applications [2]. Presently, so many FCEV models are available in the market as Hyundai Tucson fuel cell, Mercedes B-Class fuel cell, Honda FCX Clarity, and Toyota Mirai. These vehicles have almost same features of power levels and hydrogen storage system (storage tank of 700 bars with fiber-wrapped composite) with battery [12].

In case of battery electric vehicles, the weight of energy storage system (ESS) increases with the driving range of the vehicle thus limiting the driving range. Fuel saving of a vehicle with 100 kg weight reduction is almost 0.3−0.5 L/100 km which is almost 6−10% of the total fuel for a fuel economy of 5 L/100 km. In other words, increase in 100 kg mass accounts to 0.3−0.5 L/100 km (7.5−12.5 g CO_2/km) increased fuel consumption for a passenger car of 1500 kg [13].

Battery electric vehicles are cost effective compared to FCEV up to 100 km travel where as beyond 100 km, FCEV are the cheapest [12]. The major components of these vehicles are the fuel cell, convertors, H_2 storage tank, electric motor, batteries, or super capacitors.

Table 1 Specifications of five fuel cell passenger vehicles [7–11]

S. no	Vehicle model	Fuel cell type	Fuel type	Fuel cell stack power (kW)	Motor type & power	H_2 storage capacity (kg)	Pressure (MPa)	Maximum driving range per tank (km)	CO_2 emission (g/km)
1	Tucson fuel cell	PEM	Compressed gaseous hydrogen	100	Induction	5.6	70	424	0
2	Honda Clarity	Proton electrolyte fuel cell	Compressed gaseous hydrogen	103	Synchronous electric motor	5.46	70	585.6	0
3	Toyota Mirai	Solid polymer electrolyte fuel cell	Compressed gaseous hydrogen	114	AC synchronous electric generator	5.0	70	499.2	0
4	Mercedes Benz	PEM	Compressed gaseous hydrogen	100	NA	3.7	70	385	0
5	Hyundai ix35 fuel cell	NA	Compressed gaseous hydrogen	100	Induction motor	5.63	70	594	0

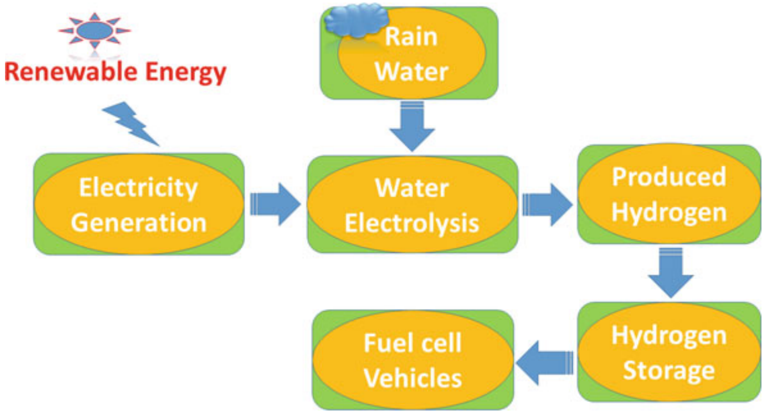

Fig. 1 Basic diagram of the system

4 On Board Storage of H_2 Fuel in Vehicles

The average fuel consumption of new cars is in the range of 8.5−12.75 km/L (20 to 30 miles per gallon). Current conventional gasoline vehicles have storage capacity of 30–45 L (10–16 gallons) of space. Since hydrogen has twice the efficiency of gasoline vehicles, they would store between 5 and 8 kg of hydrogen, which is equivalent to between 200 and 400 L, which is a sizable reduction in the space needed for fuel. Liquid H_2 storage tanks are light in weight; they can also be used for onboard storage, but storage at extremely low temperature is a difficult task [14].

5 CO_2 Emission Savings by Using H_2 as a Fuel in FCEV

Transport sector plays an important role in the CO_2 emission and global warming. So, it is necessary to move toward the green transportation to reduce green house gas emission due to automobiles. Hydrogen is a clean energy carrier which is abundantly available in the atmosphere. H_2 when used as a fuel in the FC generates zero CO_2 emissions and only water vapor is generated as exhaust. The quality of H_2 as a clean fuel which makes it a better option for the current transportation and automotive field. According to [6, 13], the European CO_2 emission target upto 2015 is 130 g/km in gasoline vehicles. By considering CO_2 emission per km, one can find the total CO_2 emission from the vehicles, and it can be compared with H_2 fuel cell vehicles which have zero emission during operating range. One can see a significant amount of CO_2 emission can be reduced by using H_2 as a fuel.

6 Life Cycle Fuel Cost of Gasoline Vehicles and FCEV

Life cycle fuel cost is the cost of fuel, consumed by a vehicle during its whole lifetime. Levelized cost of dispensed hydrogen (LCODH) from solar or wind energy is 2.34–4.68 US$/kg$H_2$ or 2–4 €/kgH_2 [15]. The lifetime of both FCEV and gasoline vehicles is assumed to be 15 years on the basis of 40 km/day driving distance, overall driving distance will be 219,000 km or 137,188 miles in 15 years. The average price of gasoline in Canada in April 2015 is considered as US$1.08/L or €0.92/L [16]. In Europe, Govt. has already defined compulsory fuel efficiency standards of 5.6 L/100 km for petrol and 4.9 L/100 km for diesel in 2015, and 4.1 L/100 km for petrol and 3.6 L/100 km for diesel by 2021 [17].

7 CO_2 Emissions and Fuel Economy Targets for Automobiles

CO_2 emission is a major concern worldwide. Policies for the reduction of CO_2 are made by different countries by imposing some specific targets of CO_2 emission per km. In Europe, one fifth of total emission is by road transport of which cars contribute to 75% [13].

In Europe, 130 g CO_2/km for year 2015 and 95 g CO_2/km for year 2020 is targeted by European Commission in 2009 [6, 13, 18, 19]. But the difference between certified and actual CO_2 emission in 2016 for passenger cars is 25–35 g CO_2/km which is almost 25% higher than the established target [6]. For light commercial vehicles, the target is 175 g/km for the year 2017 and 147 g/km by 2020 [13]. Table 2 shows CO_2 emission targets set by different countries.

According to [20], greenhouse gas emissions from a conventional gasoline vehicle can be calculated by multiplying total fuel consumption with CO_2 emission factor

Table 2 CO_2 emission standards of different countries [13]

S. no	Country	CO_2 target (g/km)	Year
1	European Union (Passenger cars)	95	2021
2	European Union (Light commercial vehicles)	147	2020
3	United States & Canada	97	2025
4	Japan	122	2020
5	China	117	2020
6	India	113	2021
7	South Korea	97	2020
8	Brazil	138	2017
9	Mexico	145	2016

(8887 g CO_2/gallon). United States Environmental Protection Agency (USEPA, 2011) and Intergovernmental Panel on Climate Change (IPCC, 2006) also used the same process. USEPA in 2011 also used another method for calculation of CO_2 emission per mile by applying the fuel economy/mileage data or miles per gallon (mpg), using (1), (2) and, (3).

$$\text{CO}_2 \text{ emissions per mile} = \frac{\text{CO}_2 \text{ per gallon}}{\text{MPG}} \tag{1}$$

$$\text{CO}_2 \text{ emissions per vehicle} = \frac{\text{CO}_2 \text{ per gallon}}{\text{MPG}} \times \text{Miles per vehicle} \tag{2}$$

$$\begin{aligned} \text{Total emissions} = {} & \text{Number of vehicles} \times \text{Distance travelled} \\ & \times \text{Emission per vehicle distance travelled} \end{aligned} \tag{3}$$

Europe already defined compulsory fuel efficiency standards for new cars, fuel economy of 5.6 L/100 km for petrol or 4.9 L/100 km for diesel in 2015, and 4.1 L/100 km for petrol or 3.6 L/100 km for diesel by 2021. US also proposed for passenger vehicles fuel economy of 54.5 mpg, or 5.2 L/100 km by 2025, which can correspond to 50% improvement in fuel economy [17]. According to [13], failure of a manufacturer to follow the preset standards will be penalized in the range of US$5.85–US$111.15 or €5–€95 on per gram extra CO_2 emission per vehicle sold. Incorporation of some alternative green fuel vehicles can also be an approach for the reduction of preset CO_2 emission targets.

8 Methodology

For estimation of CO_2 emission savings by means of FCEV, amount of hydrogen produced from any source is required. Water electrolysis technology is considered in the present study for the production of hydrogen. Specifications of some typical electrolyzers are given in Table 3 [21–25]. Ten million liters (10,000 m^3) of water is assumed for the production of H_2 through electrolysis. The produced H_2 can be used onsite or transported to different distances. The whole calculation has been done by considering driving distances in 'km' and fuel economy/driving range/mileage is in 'km/L'. So, the fuel economy and driving distances are converted from miles per gallon (MPG) to kilometer per liters (km/L) and 'miles' to 'km' for the whole calculation. The whole methodology is divided in the following steps [26]:

Step1: Electrolysis efficiency and amount of H_2 produced is calculated using [26–29]. Isothermal compression efficiency of hydrogen is considered to be 95% [26–31].

Step2: By using Table 1, driving range/fuel economy/mileage of vehicles is calculated, and results are given in Table 5.

Table 3 Specifications of electrolyzers [21–25]

S. no	Model	H_2 pro. rate (Nm^3/h)	Water cons (L/Nm^3 H_2)	Energy cons (kWh/Nm^3 H_2)	H_2 purity (%)	Pressure (Bar)
1	E1	300	0.9	4.4	99.9	0.02
2	E2	250	1	4.5	99.5	16
3	E3	170.6	0.84	5.3	99.5	*5/12/20
4	E4	45	2	5.2	99.9	10
5	E5	150	1	5.9	> 99%	10

a* cons. denotes consumption, b *pro. denotes production

Step3: For an average distance of 40 km/day, amount of hydrogen required for each vehicle is calculated (considering their driving range/fuel economy/mileage). Then, by utilizing the quantity of H_2 produced (per day) from different electrolyzers as a fuel in each type of FCEVs, number of FCEV that can be operated (per day) is calculated.

Step4: For the purpose of comparison with calculated number of FCEVs, by considering the permissible CO_2 emission target of 130 g/km in the equivalent gasoline vehicles (upto 2015) [6, 13], the total per day CO_2 emission for an average distance of 40 km/day is calculated.

Step5: Finally, total annual CO_2 emission saving is estimated using (1), (2), (3). Further the calculations of CO_2 emissions involve following steps:

(1) For the calculation of CO_2 emission, first we use (1) and find the value of CO_2 emission per mile or km. For this, driving range/fuel economy/MPG (km/L) is calculated by considering the hydrogen tank storage capacity and driving range per tank from Table 1, and CO_2 emission factor 8887 g CO_2/gallon of gasoline is considered [20].

(2) CO_2 emission per vehicle for a driving distance of 40 km/day is calculated using (2) by multiplying per day driving distance to CO_2 emission per mile or km.

(3) Now finally, the total emissions can be found using (3). For this, number of vehicles are considered from Table 6, driving distance is 40 km/day, and the CO_2 emission (130 g CO_2/km) occurs during the driving distance is considered.

So from (1), if the fuel economy is given, then amount of CO_2 emission can be found. In the same way, if amount of CO_2 emission is given, then also it is possible to find out fuel economy of a vehicle. Figure 2 explained the strategy of calculation in the form of flowchart.

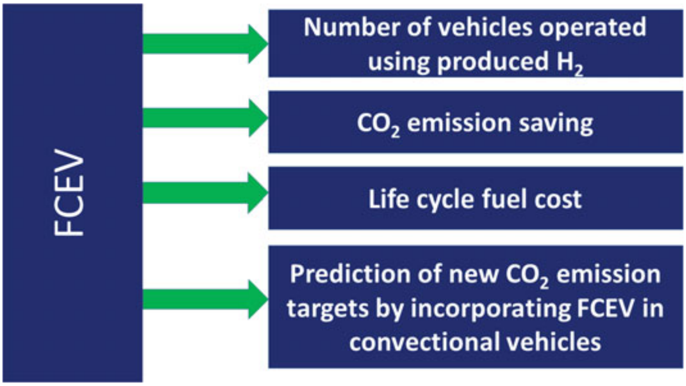

Fig. 2 Flowchart for calculations

Table 4 Different parameters of electrolyzers

S. no	Model	Amount of water required for per kg H_2 (L)	Efficiency of electrolysis (%)	Amount of H_2 produced at source (kg/day)
1	**E1**	10.01	68.1	9,98,667
2	**E2**	11.13	66.6	8,98,800
3	**E3**	9.346	56.54	10,70,000
4	**E4**	22.25	57.62	4,49,400
5	**E5**	11.13	50.79	8,98,800

9 Results and Discussions

9.1 Electrolysis of Water

In electrolysis, DC current is passed through the electrolyzers for the production of hydrogen and oxygen. For the electrolysis of water, five commercial electrolyzers are considered, and their hydrogen production (onsite) and efficiency is calculated as per the given specifications in Table 3, and the results are given in Table 4. It was found that the electrolyzer E1 has maximum electrolysis efficiency or lowest power consumption which is 68.1%. But amount of H_2 produced is maximum by E3 which is 10,70,000 kg/day because lowest water required for per kg of H_2 production.

9.2 Number of Vehicles Operated Using Produced Hydrogen

Hydrogen produced from water electrolysis is in its purest form and can be utilized in FC vehicles. By using Table 1, driving range/fuel economy (km/kg) of the vehicles

Table 5 Driving range calculated for different FCEVs

S. no	Vehicle model	Maximum driving range per tank (km)	Driving range (km/kg)
1	Tucson fuel cell	424	75.71
2	Honda Clarity	585.6	107.25
3	Toyota Mirai	499.2	99.84
4	Mercedes Benz	385	104.05
5	Hyundai ix35 fuel cell	594	105.51

Table 6 Number of vehicles operated using onsite produced hydrogen

S. no	Model	Amount of hydrogen produced at source (kg/day)	Tucson Fuel Cell	Honda Clarity	Toyota Mirai	Mercedes Benz	Hyundai ix35 Fuel cell
1	E1	9,98,667	18,90,226	26,77,675	24,92,673	25,97,782	26,34,233
2	E2	8,98,800	17,01,204	24,09,908	25,13,045	23,38,004	23,70,810
3	E3	10,70,000	20,25,243	28,68,938	26,70,720	27,83,338	28,22,393
4	E4	4,49,400	8,50,602	12,04,954	11,21,702	11,69,002	11,85,405
5	E5	8,98,800	17,01,204	24,09,908	25,13,045	23,38,004	23,70,810

is calculated and results are given in Table 5. For an average distance of 40 km/day, amount of hydrogen required is calculated. Then by using produced H_2, number of vehicles that can be run are calculated. The results obtained for number of vehicles operated by using onsite produced H_2 are given in Table 6.

9.3 Estimation of CO_2 Emission Savings

By considering number of FCEVs that can be run using produced hydrogen, one can estimate CO_2 emission savings. FCEVs are zero emission vehicles, so by the comparison, CO_2 emitted by the same number of gasoline vehicles is equal to CO_2 saving by FCEVs. For this, amount of CO_2 emitted by a gasoline vehicle for the distance of 40 km (25 miles) by considering 130 g CO_2/km [6, 13, 18, 19] is calculated. Then, per day and annual CO_2 emission reduction by the total number of vehicles is calculated, and results are given in Table 7.

Table 7 Overall CO_2 emission savings per day and annual CO_2 emission savings for different vehicles for onsite hydrogen production

S. no	Model	Tucson fuel cell		Honda Clarity		Toyota Mirai		Mercedes Benz		Hyundai ix35 fuel cell	
		CO_2 in ton/day	Annual CO_2 reduction (Lac ton)	CO_2 in ton/day	Annual CO_2 reduction (Lac ton)	CO_2 in ton/day	Annual CO_2 reduction (Lac ton)	CO_2 in ton/day	Annual CO_2 reduction (Lac ton)	CO_2 in ton/day	Annual CO_2 reduction (Lac ton)
1	E1	9,829	35.90	13,924	50.82	12,962	47.31	13,509	49.31	13,698	50.0
2	E2	8,846	32.30	12,532	45.74	11,666	42.58	12,158	44.38	12,328	45.0
3	E3	10,531	38.44	14,919	54.45	13,888	50.69	14,473	52.83	14,676	53.57
4	E4	4,423	16.14	6,266	22.87	5,833	21.29	6,079	22.19	6,164	22.5
5	E5	8,846	32.30	12,532	45.74	11,666	42.58	12,158	44.38	12,328	45.0

Table 8 Fifteen years life cycle fuel cost comparison of FCEV and gasoline vehicles

S. no	Vehicle	Fuel cost (US$)	Per day driving distance (km)	Fuel economy (km/kg) or (km/L)	Lifetime driving distance (km)	Amount of fuel L or Kg	Lifetime cost (US$)
1	Diesel	1.08/ L	40	20.41	2,19,000	10,730	11,588
2	Petrol	1.08/L	40	17.85	2,19,000	12,269	13,250
3	Tucson	4.68/ kg	40	75.71	2,19,000	2,893	13,537
4	Honda	4.68/kg	40	107.25	2,19,000	2,042	9,556
5	Toyota Mirai	4.68/kg	40	99.84	2,19,000	2,194	10,268
6	Mercedes	4.68/kg	40	104.05	2,19,000	2,105	9,850
7	Hyundai	4.68/kg	40	105.51	2,19,000	2,076	9,714

9.4 Life Cycle Fuel Cost of Gasoline Vehicles and FCEV

H_2 dispensed cost US$4.68/kg$H_2$ is considered for the calculation. The average price of gasoline in Canada in April 2015 is considered as US$1.08/L [20]. The fuel economy (km/L) for petrol and diesel vehicles is calculated considering 5.6 L/100 km for petrol and 4.9 L/100 km for diesel [15], and fuel economy of hydrogen vehicles (km/kg) is taken from Table 5. Considering a lifetime period of fifteen years, the fuel cost of gasoline and FCEVs is calculated. Table 8 shows fifteen years life cycle fuel cost comparison of FCEV and gasoline vehicles. It can be seen that FCEV TUCSON has the highest life cycle fuel cost among the FCEV and gasoline vehicles considered here.

9.5 Estimation of New CO_2 Emission Targets

Different countries fixed their future CO_2 emission targets from vehicles. To achieve such targets, either one should improve the fuel economy or incorporate some percentage of alternative vehicles in number of gasoline vehicles.

So, for the same number of vehicles, the new reduced CO_2 emission target can be set. This study has concern about both the issues. In this study, FCEVs are considered for incorporation. Fuel economy targets of European cars are 17.85 km/L of petrol or 20.41 km/L of diesel in 2015 and 24.39 km/L of petrol and 27.77 km/L of diesel for the year 2021 [18]. The percentage reductions in the consumption of petrol and diesel per km from 2015 to 2021 for petrol and diesel vehicles are 26.82% and 26.50%, respectively. In terms of CO_2 emission, the target is 131.71 g/km for petrol vehicles or 115.09 g/km for diesel vehicles in 2015, and by 2021, the corresponding values are 96.39 g/km, 84.66 g/km for petrol and diesel vehicles respectively.

Table 9 CO_2 emission target reduction when 25%, 50%, or 75% FCEVs are incorporated in conventional vehicles

S. no	Country	CO_2 Target (g/km)			
		Preset targets	New target with 25% FCEV	New target with 50% FCEV	New target with 75% FCEV
1	European (Passenger Cars)	95	71.25	47.50	23.75
2	European (Light commercial vehicles)	147	110.25	73.20	36.75
3	U.S. & Canada	97	72.75	48.5	24.25
4	Japan	122	91.5	61	30.5
5	China	117	87.75	58.5	29.25
6	India	113	84.75	56.5	28.25
7	South Korea	97	72.75	48.5	24.25
8	Brazil	138	103.5	69	34.5
9	Mexico	145	108.75	72.5	36.25

Another method of CO_2 emissions reduction is using some percentage of H_2 in conventional vehicles. In this study, incorporation of 25%, 50%, and 75% H_2 in conventional vehicles is considered. New CO_2 emission from these vehicles are predicted, and the results are given in Table 9. Also the fuel economy for these vehicles is also calculated. On the basis of given CO_2 emission targets of different countries, fuel economy to achieve such targets is calculated and is given in Table 10.

10 Conclusions

To reduce CO_2 emissions, hydrogen can be a better option compared to the conventional fuels in automobiles and for transportation sector. In this study, it is considered that CO_2 emission from each vehicle are 130 g/km. Among the five electrolyzers used for hydrogen production, E1 has the highest electrolysis efficiency or lowest power consumption. But amount of H_2 produced is maximum by E3 because minimum water is required for per kg of H_2 production. Hence, more vehicles can be run by using H_2 produced by E3, and thus, large amount of CO_2 emission can be reduced. It can be concluded that choice of electrolyzer is also essential, and the electrolyzer which uses minimum amount of water for the production of hydrogen be the first choice. For the maximum reduction of CO_2 emission, the electrolyzer with the lowest water consumption for per kg of hydrogen generation shall be considered.

The life cycle total fuel cost of the vehicles is in the order of tucson > petrol > diesel > toyota > mercedes > hyundai > honda. The cost for Tucson FC vehicle is

Table 10 Fuel economy of conventional vehicles required to achieve same CO_2 emission targets

S. no	Country	Preset fuel economy targets (km/L)	Fuel economy required for gasoline vehicles to achieve (km/L)		
			Targets same as 25% of vehicles are FCEV	Targets same as 50% of vehicles are FCEV	Targets same as 75% of vehicles are FCEV
1	European (Passenger cars)	24.75	33	49.5	98.99
2	European (Light commercial vehicles)	15.99	21.32	32.12	63.97
3	U.S. & Canada	24.24	32.32	48.48	96.95
4	Japan	19.27	25.69	38.54	77.08
5	China	20.09	26.79	40.19	80.38
6	India	20.81	27.74	41.61	83.22
7	South Korea	24.24	32.32	48.48	96.95
8	Brazil	17.04	22.72	34.07	68.15
9	Mexico	16.21	21.62	32.43	64.86

US$13,597, and for Honda FC vehicle, it is US$9556 for fifteen years of life time with a driving range of 40 km per day. If the fuel economy/driving range/mileage of the vehicle is low, then it can also happen that the life cycle fuel cost of FCEV would become higher than gasoline vehicle due to higher price of hydrogen compared to petrol or diesel. Obviously, it will reduce the CO_2 emission, but it will not be cost effective compared to gasoline vehicles. We can also see from Table 8 that for some FCEV the overall life cycle fuel cost of FCEV will be higher than diesel/petrol vehicles.

Two methods of CO_2 emission reduction are there. First one is by incorporating some percentage of alternative green fuel vehicles in conventional vehicles, and second one is improving the fuel economy of gasoline vehicles. By adding 25%, 50%, or 75% FCEV in conventional vehicles, the CO_2 emission targets of different countries can be reduced by 25%, 50%, and 75%, respectively. If the FCEV are not added, then to achieve such targets improvement in fuel economy by 133%, 200%, and 400% is essential.

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